WORKING POSTURES IN DENTAL PRACTITIONERS AND DENTAL STUDENTS: RELATIONSHIPS BETWEEN POSTURE SEATING, AND MUSCLE ACTIVITY

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ABSTRACT

The principal aim of this project is to examine posture and muscle activity when using an ergonomically designed saddle seat compared with a conventional seat during common dental procedures with the dental students and practising dentists. The study was conducted with practising dentists across the West Midlands and the dental students in the School of Dentistry – University of Birmingham. The study is mainly divided into a questionnaire survey of practising dentists, a questionnaire survey of dental student posture in the dental schools across the U.K, postural analysis, and a daily symptom survey of practising dentists and dental students, and finally the EMG analysis of practising dentists and dental students working posture. This thesis has established the relationship between posture, seating and muscle activity and indicates that use of an ergonomic aid (dental operator stool) may improve posture, decrease pain and muscle activity and may decrease the development of musculoskeletal disorders among dental students and dentists.

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PREAMBLE

Many dentists develop back and upper limb pain during their working life and develop compromised postures, which leads to the development of musculoskeletal disorders where the active working life of dentists may be reduced. Many dental stools currently on the market allow the dentists to slump and encourage an unhealthy working posture. Ergonomically designed seats are now available that encourage a good sitting posture where the pelvis is encouraged to rotate forwards allowing the back to maintain a natural curve. The recording of muscle activity from surface electrodes will provide an objective measure of the postural demands required to undertake dental work and the differences if any from the two seats. The incidence of musculoskeletal disorders in the dental population has been widely reported, with the lower back and neck more susceptible to pain. Various studies have identified that around a third of dentists and dental hygienists were affected by musculoskeletal disorders, and musculoskeletal disorders have also been cited as a major reason for premature retirement in dentists. It could be hypothesized that the physical nature of work and stressful working postures carry a higher predisposition to the development of a musculoskeletal disorder. The static posture required by the dental practitioner may be a contributory factor to these musculoskeletal disorders together with the precise nature of work in a confined space. Various researchers have investigated dental practitioners who were working in seated, and standing positions and have reported that the severity of symptoms were higher when dental practice was undertaken in a seated position. However there is little research in the field as to the effectiveness of the equipment in achieving this outcome and hence the study was undertaken.

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GLOSSARY I

EMG	Electromyography
ATP	Adenosine Tri Phosphate
MN	Motor Neuron
AP	Action Potential
RMP	Resting Membrane Potential
MUAP	Motor Unit Action Potential
MVC	Maximum Voluntary Contraction
APDF	Amplitude Distribution Probability Function
MPF	Mean Power Frequency
TAMP	Time Averaged Myoelectrical Potential
ECRL	Extensor Carpi Radialis Longus Muscle (Wrist Extensor)
SENIAM	Surface Electromyography for the Non-Invasive Assessment of Muscles
ISEK	International Society of Electrophysiology and Kinesiology
CM	Centre of Mass
BRIEF	Baseline Risk Identification of Ergonomic Factors
EASY	Ergonomic Assessment Survey
OWAS	Ovako Working Posture Analysis System
MHOR	Manual Handling Operations Regulations
PLIBEL	Method of identification of musculoskeletal stress factors which may have injurious effects
AET	Arbeitswissenschaftliche Erhebungsverfahren zur Tatigkeitsanalyse
QEC	Quick Exposure Check

GLOSSARY II

BSD	Bambach Seat Dentista
CSD	Conventional Seat Dentists
BSS	Bambach Seat Students
CSS	Conventional Seat Students
BS	Bambach Seat
CS	Conventional Seat
RULA	Rapid Upper Limb Assessment
VDU	Visual Display Unit
VDT	Visual Display Terminal
PT	Preset Tilt Down System
SPSS	Statistics Package for the Social Sciences
ANOVA	Analysis of Variance
SD	Standard Deviation
BSD	Bambach Seat Dentists
CSD	Conventional Seat Dentists
ADA	American Dental Association
NSW	New South Wales
DSS	Daily Symptom Survey
WEH	Work Environment and Health
HSE	Health and Safety Executive
TE	Tooth Extraction
UK	United Kingdom
JRC	Junior Restorative Course

Chapter 1

Introduction to Posture in Dentistry

1.1 Posture

The term posture is described as a biomechanical alignment of the body, which orients the body to the environment, while the term postural orientation is defined as the ability to maintain an appropriate relationship between the body segments and between the body and the environment for a task (Horak and Macpherson, 1996). Movement begins and ends in a posture and for most of the time the motor system is concerned about maintaining the body in a stable posture, rather than moving the body. Maintaining this stable posture is an active process because the centre of gravity is high. Proprioceptive feedback is essential in the maintenance of posture. This chapter explains the control of posture in general, the importance of lumbar spine in the control of posture in sitting, and aspects of good and bad sitting postures in light of dentistry.

1.1.1 Various Definitions of Posture

- Position the body assumes in preparation for the next movement (Roaf, 1977).
- Position of the limbs or the carriage of the body as a whole (Stedman's Medical Dictionary, 2000)
- The healthy posture is defined as a

> ''Skeletal alignment refined as a relative arrangement of the parts of the body in a state of balance that protects the supporting structures of the body against injury or progressive deformity.''
>
> (The Posture Committee of the American Academy of Orthopaedic Surgery - 1947, cited in Cailliet, 1981, p. 23)

1.1.2 Orthopaedic Aspects of Posture

The skeletal system provides a framework to the body for the maintenance of posture, the nervous and muscular system are involved in maintaining the skeletal system in position. Hence it is necessary to discuss the orthopaedic aspects in order to provide a good understanding of posture.

The vertebral column plays an important role in the maintenance of posture and is discussed in detail. The spine consists of 33 vertebrae and is divided into four areas the Cervical (7 vertebrae), Thoracic (12 vertebrae), Lumbar (5 vertebrae), Sacral (5 fused vertebrae) and Coccyx (4 fused vertebrae). When the vertebral column of the adult is viewed from the side, four distinct anterior and posterior curves are evident (Fig 1-1). The two curves (thoracic and sacral) that are convex posteriorly are called primary curves (Kyphotic Curves), while the two other curves (cervical and lumbar) that show the reversal of posterior convexity are called secondary curves (Lordotic Curves). The curves are interdependent, i.e. changes in the position of any one segment may result in changes in the position of adjacent superior or inferior segments. A change in pelvic position (Anterior / Posterior Pelvic Tilt) may result in increased lordosis or kyphosis of the lumbar spine (Norkin and Levangie, 2005).

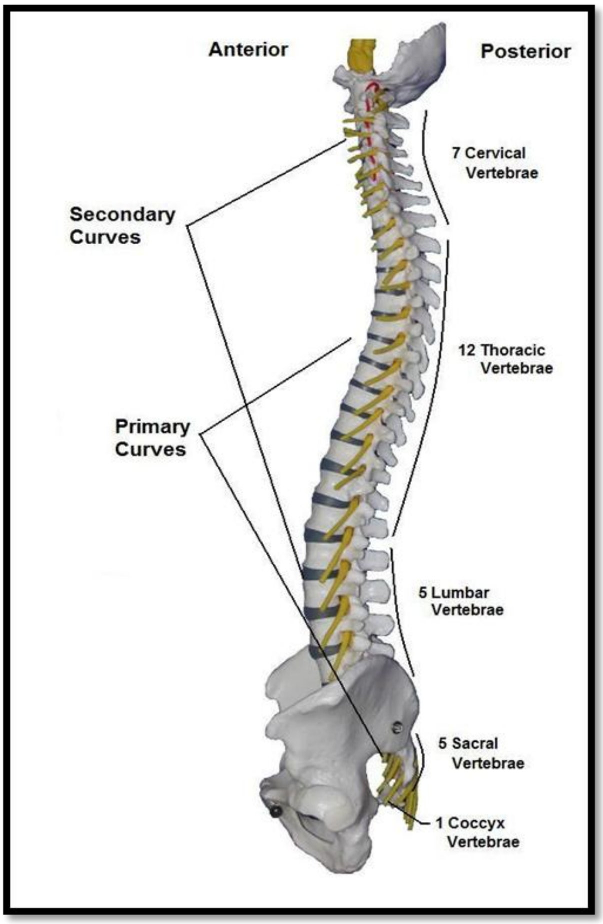


Fig.1-1. Primary and Secondary Curves of the Vertebral Column

1.1.3 Applied Anatomy of Lumbar Vertebrae

The lumbar vertebra has a large body, which allows the lumbar spine to support the weight of the upper body. Each lumbar vertebra is divided into:

Anterior element, consisting of the vertebral body (Fig 1-2): This sustains the compression loads applied to the vertebral column, including body weight and compression loads imparted by contraction of the back muscles. The vertebral bodies are larger in the lumbar spine when compared with the cervical spine, which helps them to sustain the load applied.

Middle element, consisting of the pedicles (Fig 1-2). The pedicles are thick and short, directed backwards and laterally.

Posterior elements consisting of the laminae, articular facets, spinous process, transverse process, mamillary and accessory processes (Williams, 2004) (Fig 1-2 and 1-3). They regulate the passive and active forces applied to the vertebral column and control its movement. The articular facets are oriented somewhat parasagittally, which is thought to contribute the large range of anteroposterior bending possible between lumbar vertebrae.

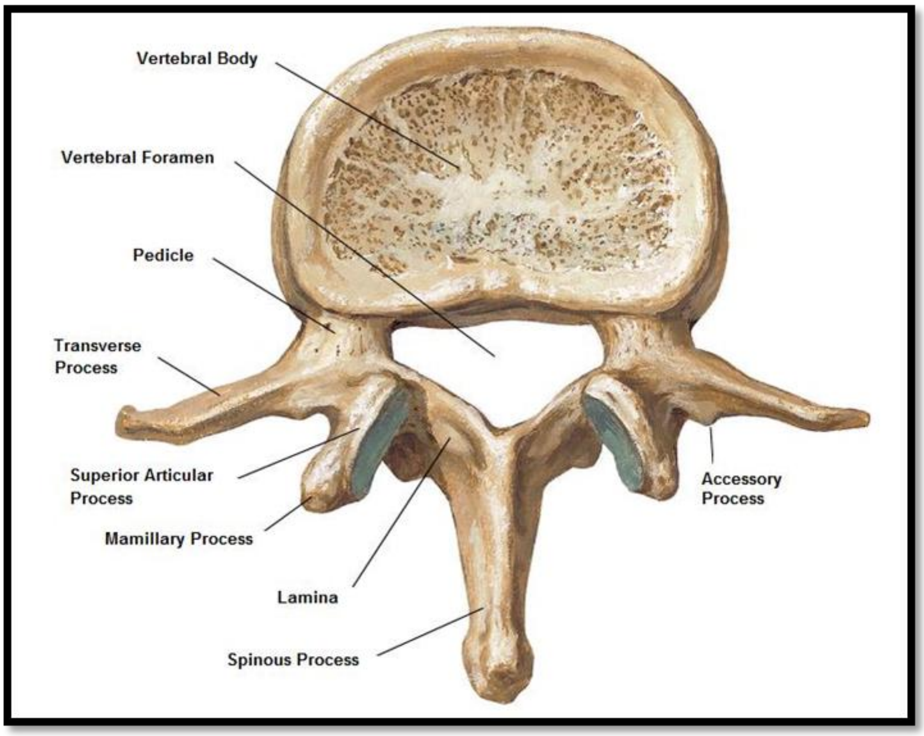
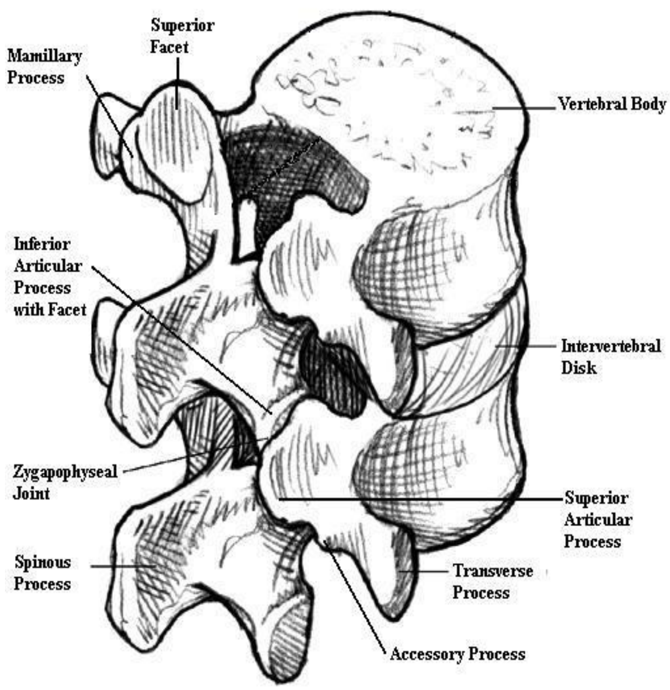


Fig. 1-2. A Typical Lumbar Vertebrae – Superior View

(Adapted from Netter, 2002)

- The articular processes provide a locking mechanism that resists forward sliding and twisting of the vertebral bodies.

- The spinous processes, transverse processes, mamillary processes, and accessory processes (Fig. 1-3) provide areas for muscle attachments and constitute levers that enhance the action of the attached muscles.
- The laminae transmit the forces from the spinous processes and inferior articular processes to the pedicles, thus they are susceptible to injuries such as Pars Interarticularis fractures (Pars Interarticularis being a thin slice of bone on the vertebra located between the inferior and superior articular processes of the facet joint).
- The pedicles, which are the connection between the posterior and anterior elements, transfer the controlling forces from the posterior to the anterior elements (Williams, 2004).



Adapted from Oliver and Middleditch (2005) & Williams (2004)

Fig. 1-3. Lumbar Vertebrae (Postero Superior View)

1.1.4 Intervertebral Discs and its Nutrition

The intervertebral disc is a pad of fibro-cartilage located between the bodies of adjacent vertebrae. The discs are the major compressive carrier of the spine, which act as shock absorbers that absorb the forces acting on the spine. Without these discs, the spine would be an inflexible solid mass of bone. The intervertebral disc is made up of two basic components of annulus fibrosus (outer part) and nucleus pulposus (inner part) (Figures 1-4 & 1-5). The annulus fibrosus consists of concentric layers (lamellae) of collagen fibres enclosing the nucleus pulposus and a proteoglycan gel, which binds the collagen fibres and lamellae. The nucleus pulposus is a semi-fluid gel comprising 40% to 60% of the disc (Oliver and Middleditch, 2005). Apart from the outermost annular fibres the disc is avascular. The nutrition of the disc depends on the diffusion of the nutrients such as glucose, sulphate and oxygen. These nutrients reach the disc through the blood vessels surrounding the periphery of the annular fibrosus (annular route), and from the capillary plexus beneath the end plates (end plate route) (Figures 1- 4 & 1-5). The nucleus receives most of its nutrition from the end plate route.

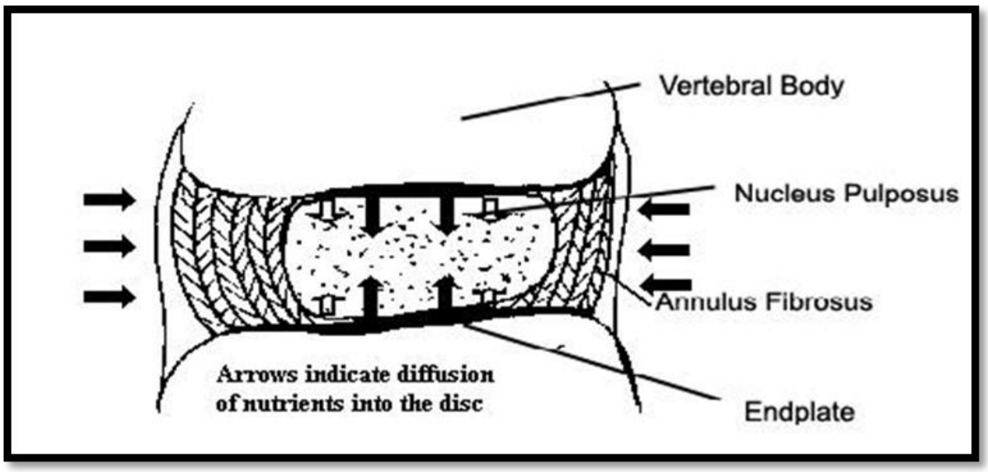


Fig. 1-4. Nutrition of the Intervertebral Disc (Adapted from Oliver and Middleditch; 2005)

1.1.5 Effect of Posture on Disc Nutrition

The Posture of the spine was found to have different effects on fluid flow due to higher loads in some postures (Oliver and Middleditch, 2005). Erect posture favoured diffusion into the anterior half of the disc. The fully flexed lumbar posture favoured diffusion into the posterior annulus, by thinning it and increasing the surface area, thereby decreasing the path from the nucleus to the periphery. However, this flexed posture may reduce the supply through the endplate route because flexion increases the distance from the end plates to the midplane of the posterior nucleus. During normal daily activities the loads experienced by the intervertebral disc result in fluid loss, pressure loss, and creep deformation. During periods of rest (when spinal loading is decreased), fluids are re-imbibed into the disc, causing a restoration of volume and intradiscal fluid pressure (Oliver and Middleditch, 2005).

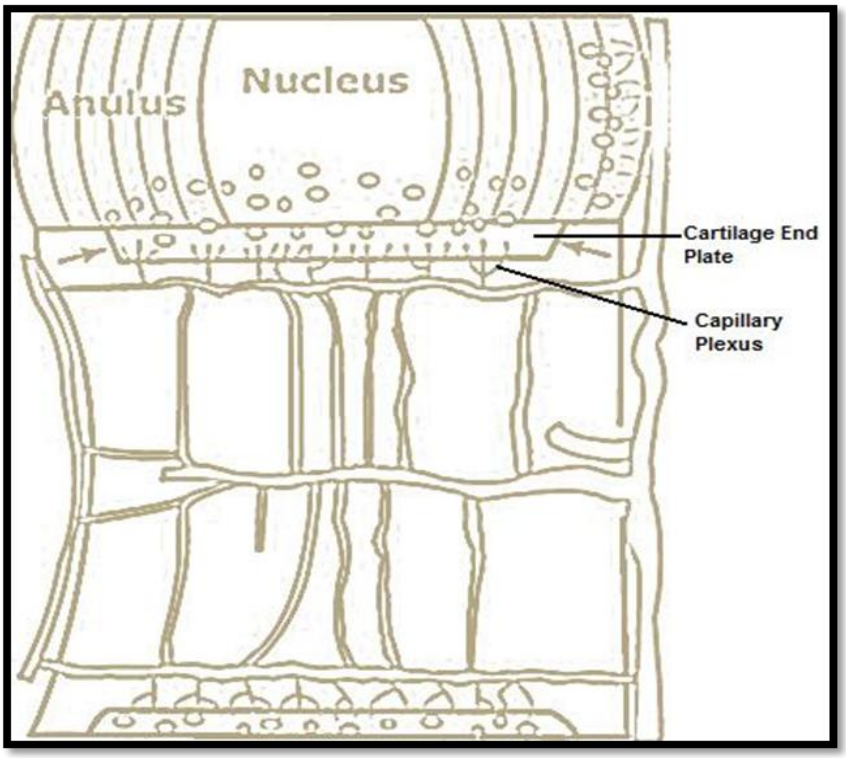


Fig. 1-5. Blood Supply of the Intervertebral Disc (Adapted from Oliver and Middleditch; 2005)

1.1.6 Effects of Posture on Intradiscal Pressure

There is an intrinsic pressure of about 0.7 kg/cm^2 within the intervertebral disc of the resting / unloaded spine (Nachemson, 1966). The intrinsic stability of the disc is provided by this pressure. This resting pressure rises when the disc is subjected to external loading, such as from body weight. This loading of the spine will vary depending on the factors such as position of the body due to the effects of force of gravity and muscular contraction.

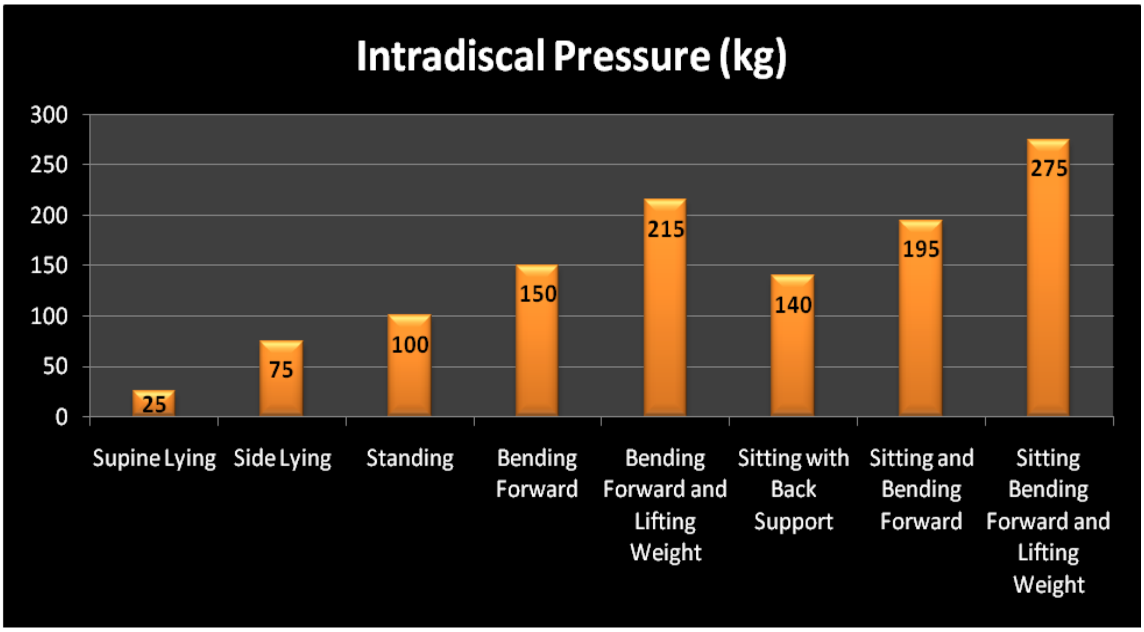


Fig. 1-6. Relative change in intradiscal pressure (loading) in the third lumbar disc

(Adapted from Oliver and Middleditch; 2005)

The effect of various body positions on disc pressures in the 2nd to 4th lumbar discs (Fig. 1-6) were measured by Nachemson and Morris (1964) and Nachemson (1966). Three positions were tested, namely, standing, sitting and reclining. It was found that seated and bending postures apply more pressure to the disc than standing and recumbent positions. The pressure in the sitting position varied between 100 - 180 kg, standing between 80 – 150 kg and lying between 35 – 85 kg. The load of the disc was indicated to be directly related to the body weight above the level of the disc measured, and was approximately three times that of the body weight above it. The reason for this increased pressure is due to the activity of the vertebral portion of the psoas major muscle, which has a stabilising influence on the lumbar spine, and at the same time, a compressive effect. Alternatively, the increase in pressure may be due to the position of spine in sitting. When a person is seated on a flat surface the lumbar spine is usually in some degree of flexion. This increases the pressure, and additionally, the load is transferred from the zygapophyseal joints on to the discs. Nachemson (1976) found that when the person is sitting and leaning forward to 20°, the load on to the disc increased by 40 – 60 kg. It was also found that the psoas activity was decreased in this position, but the activity of the erector spinae was increased considerably to prevent the trunk from falling forward, and thereby increasing the compression on the discs (Keagy et al 1966). Further increases or decreases in the intradiscal pressure can be brought about by an alteration in either the lumbar lordosis or the seat or backrest inclination (Refer to Section 1.1.8).

1.1.7 The Effects of Posture and Disc Height on Stress distribution in Lumbar Spine

Different postures change the sagittal-plane curvature of the lumbar spine and alter the angle at which adjacent vertebrae are pressed together. The vertical spacing of the adjacent lumbar vertebrae is smaller when compared to their length and width. This is the reason for large changes in stress with small angles of flexion and extension. The effects of posture become exaggerated when the disc thickness is reduced either by sustained loading (Creep), for example, in slumped sitting positions or by pathological changes. Studies by Adams and Hutton (1980) have shown that, following 3 hours of compressive creep loading at 1kN, just 2° of extension of a motion segment is sufficient for the apophyseal joints to resist 16% of a applied compressive force of 1kN, whereas just 2° of flexion is sufficient to unload the apophyseal joints. This may be the reason that Adams et al (1994) suggest use of moderate flexion in heavy lifting activities, this being explained below.

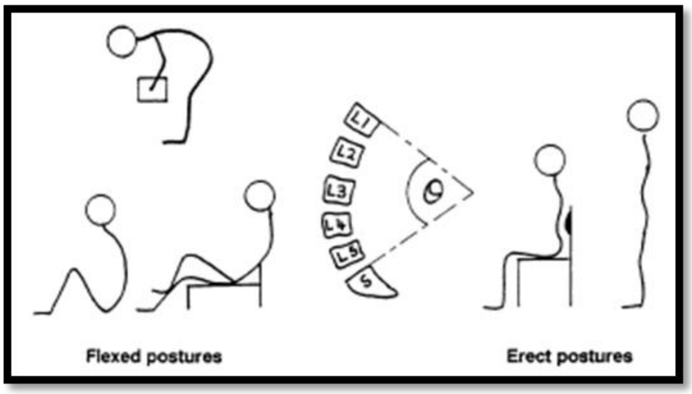


Fig. 1-7. Flexed and Erect Postures (Adapted from Adams et al 2000)

Small angles of flexion and extension also have a large effect on the tension acting on the intervertebral ligaments, particularly those, that lie farthest from the centre of rotation in the disc. Ligament tension acts to increase compressive forces on the intervertebral discs. If a motion segment is subjected to a compressive force of 3kN to simulate moderate manual work, the pressure within the nucleus pulposus increases by 6% in moderate flexion and 30% in full flexion (Adams et al 1994), when compared with neutral (unloaded) posture. Generally flexed postures are not recommended for lifting as flexion may considerably increase intradiscal pressure (Nachemson, 1966) In a study by Adams et al (1994) the effect of posture on compressive strength was measured on cadavers. Nineteen lumbar spines aged from 19–74 were collected at necropsy from subjects who had no history of spinal injury. Lumbar motion segments consisting of two vertebrae and the intervening disc and ligaments were compressed while positioned in various angles of flexion and extension. The first experiment measured the load sharing between the disc, apophyseal joint surfaces, and the intervertebral ligaments. The results showed that the extension caused load bearing on apophyseal joints, and that damage could occur at a compressive load as low as 500 N. Flexion angles greater than 75 % of the full range of flexion generated high tensile forces in the posterior ligaments and caused a substantial increase in intradiscal pressure, indicating the optimal range for resisting compression on the discs as 0-75% of flexion. In the second experiment the distribution of compressive stress within the disc at the endpoints of this range were compared. The results showed that, at 0% of flexion, high stress concentrations occurred at the posterior annulus of many discs, whereas an even distribution of stress was usually found at 75% flexion. They concluded that a position of moderate flexion is to be preferred when the lumbar spine is subjected to high compressive forces e.g. in heavy lifting activities.

Changes in posture and disc height combine to influence the distribution of compressive stresses within the intervertebral discs themselves. In degenerated discs, which are decompressed and dehydrated, stress distributions are hypersensitive to small changes in flexion and extension. Studies have shown that just 2° of extension can significantly increase concentrations of compressive stress within the posterior annulus (Adams et al, 1994; Adams et al 2000). Moderate lumbar flexion tends to equalise compressive stress across the entire disc and this may be the reason for weight lifters using a moderately flexed flat back posture. In a study by Adams et al (2000) in which the cadaveric lumbar motion segments were mechanically tested, 38 cadaveric lumbar motion segments (mean age, 51 years) were subjected to complex mechanical loading to simulate typical activities in vivo while the distribution of compressive stress in the disc matrix was measured using a pressure transducer. Stress profiles (a method of applying compressive load on cadavers to study the mechanical properties of various tissues) repeated after a controlled compressive overload injury had reduced motion segment height by approximately 1%. Moderate repetitive loading, appropriate for the simulation of light manual labour, was applied to the damaged specimens for approximately 4 hours. The discs were sectioned and photographed after this. The results showed that endplate damage reduced pressure in the adjacent nucleus pulposus by 25% to 27% and generated peaks of compressive stress in the annulus, usually posterior to the nucleus. Discs aged 50 to 70 years were affected the most. Repetitive loading further decompressed the nucleus and intensified stress concentrations in the annulus, especially in simulated lordotic postures. The results suggest that minor damage to a vertebral body endplate may lead to progressive structural changes in the adjacent intervertebral discs (disc degeneration).

Variations in the disc height can also affect the tensile stresses in the lumbar spine and compressive stresses on the apophyseal joints. A diurnal loss of disc height of 2mm will reduce tension in all the collagenous tissues which hold them together and the slack will have a greater effect on the short collagen fibres of the annulus than on long fibres of the intervertebral ligaments. As a result, creep loading causes the annulus to resist a lower proportion of any bending movement applied to the spine, and the ligaments to resist more (Adams et al 1994).

1.1.8 The Importance of Lumbar Posture in Sitting

There is no ideal posture for sitting or one posture which should be sustained. Healthy sitting posture, therefore, is best thought of as an active, not a static phenomenon. In the resting position, between movements, healthy sitting posture can be thought of as occurring when unnecessary (static) muscle activity, ligamentous tension, intradiscal pressure, and zygapophyseal joint forces are minimized, and when the body weight is distributed evenly through the ischial tuberosities and thighs to the seat and through the torso via the backrest (Oliver and Middleditch, 2005).

A primary function of the lumbar spine is to transfer weight from the upper body in static and dynamic conditions. This is possible due to the large size of the vertebral body in this region. The compressive load sustained on the lumbar spine is altered by changes in the lumbar curvature or arrangement of body segments. Changes in the location of body segments alter the body's centre of gravity and forces acting on the lumbar spine. In normal standing the line of gravity, an imaginary line, passes through the lumbar vertebrae and no net torque exists. Any deviation in this line results in torque production and muscle contraction may create additional compression on vertebrae. If the line shifts anteriorly the lumbar paravertebral muscles contract to maintain the erect posture.

In a seated posture an anterior tilt of pelvis will change the inclination of the first sacral segment. This will result in increased lumbar lordosis and increase the shearing forces acting on the lumbar vertebrae and also increase the likelihood of anterior displacement of the fifth lumbar vertebrae on the first sacral segment. Lumbar lordosis also increases the compression forces on the posterior structures, which could damage the spinous process, zygapophyseal joints and posterior ligament. In order to avoid this, the abdominal muscles will contract to exert an upward pull on the pelvis, which posteriorly tilts the pelvis, but this can create a compressive force on the structures of the lumbar region. The annulus fibrosus, joint capsules, and orientation of the facets also will provide stability (The role of abdominal muscles is explained in Section 1.18).

In a posterior tilted seated posture the inclination of the first sacral segment moves to neutral or towards kyphosis. This will result in a flattening of the lumbar lordosis and may lead to kyphosis (slumping of the spine). Lumbar kyphosis also increases the compression forces on the anterior structures, which increases the intradiscal pressure (Nachemson, 1966) and may affect the nutrition of the discs. The body weight is supported by the passive structures, the ligaments and posterior joint capsules, since the line of gravity is posterior to the ischial tuberosities.

In the seated posture, the spine, pelvis, the legs and feet mainly support the body. The orientations of the lumbar and sacral vertebrae are very important since, it is these vertebrae and their respective discs and muscles that will take most of the spinal load in sitting. When standing, the spine is in its natural curved position, which enables the body's centre of gravity to pass through the trunk and feet, so requiring only minimal muscular activity to maintain the posture. Corlett and Eklund (1984) identified that only intermittent muscle activity is required when standing to restore momentary displacements of posture. They identified that when standing the line of gravity (a vertical line through the body's centre of gravity) passes through the trunk and feet, so minimal activity of the postural muscles are needed to hold the trunk erect. They have observed this phenomenon by using force platform measurements and correlated the results with the electromyography (EMG) activity of the muscles observed. They found reduced muscular activity in the trunk during standing. This may be because of the lumbar lordosis in standing, which brings the lumbar vertebrae together, and the centre of gravity of the trunk, arms and head is in line. Sitting disrupts this arrangement of vertebrae; sitting with a 90º angle between the trunk and the thighs causes the pelvis to rotate backwards, which reduces the lumbar lordosis (posterior pelvic tilt) (Grandjean, 1973). This increases the tension in the muscles and ligaments in the lumbar region to compensate for the movement of centre of gravity towards the anterior of the body, which, in turn, increases the load placed on the spine and intervertebral discs.

A chair design should aim at reducing the spinal load and should be concerned in the angle of seat inclination, since this may influence the amount of pelvic tilt. Since the spine naturally rests in its normal 'S' shape, it is important to maintain this position in sitting as it reduces the pressure on the intervertebral discs and static loads on the spinal extensors. Studies on intervertebral disc pressures when adopting various seat angles and posture have suggested that intradiscal pressure is gradually lowered to around 100 to 120 kg when the seat angle is increased to above 110º to 120° (Oborne, 1987) When the seat angle is increased the pelvis moves into anterior tilted position and the intradiscal pressure is lowered, as this position is comparable to standing (Fig 1-6).

Keegan and Radke (1964) studied the spinal shape during different postures using X-rays, suggesting that the normal, relaxed spine shape is produced when a person is lying on his/her side with the thighs and legs moderately flexed. They compared this position with 10 seated positions and their data suggest that a sitting posture, which produces a normal lumbar shape, is the position in which the trunk-thigh angle is 115° and the lumbar position of the spine is supported. They also suggest that erect sitting produces more spinal distortion. The compressive weight from the upper trunk increases the compression in the lower lumbar vertebrae and causes discomfort and sometimes pain is experienced when sitting in chairs with 90-degree backrest angle (Keegan and Radke, 1964).

1.1.9 Seat Inclination and Lumbar Spine

The spinal posture is also influenced by the seat inclination in sitting. A seat, which is inclined backwards, encourages the lumbar spine to flex. In order to sit upright on a 5° backward-sloping seat, the lumbar spine will be flexed to 35°. When a person works at a desk, sitting on this type of seat, the body is tilted away from the work surface, and to position him/herself to work effectively (s)he compensates by increasing the flexion of the lumbar spine (slumped sitting). With increasing forward inclination of the seat, the lumbar spine moves into more extension. With a 5° forward slope, the individual can sit upright with only 25° of lumbar flexion and can be further reduced to 15° with seat inclination of 15° (Mandal, 1984). This moves the person towards the work surface, which was clearly identified by Mandal (1984) in a study of redesigned school furniture. In the study, 5000 school pupils were observed seated on newly designed furniture, in which the newly designed seat allowed forward tilt of pelvis, and the reading desk designed much higher than the conventional desk. Photographs were taken during a 4-hour examination at 24-minute intervals. The photos identified good sitting posture among students using new furniture when compared with the students using conventional school furniture, which has low desk and chair height and encourages poor posture; the good seating position identified was anterior tilt of pelvis which encourages lumbar lordosis and prevents slumped posture.

1.1.10 Relationship between Posture and Muscle Fibres

The muscles of the human body mainly consist of skeletal muscle fibres, which are responsible both for movement and postural control. The muscle fibres are important in maintaining posture. For example, when standing for long periods it is the postural muscles that maintain the upright position due to their slow oxidative physiology allowing maximum endurance. An example would be the neck muscles, which essentially work/contract all day long just to hold the head up either in sitting or standing. Therefore it is important to know the relationship between posture and different types of muscle fibre, which are discussed below.

The skeletal muscle tissue is striated (fibres contain alternating light and dark bands (striations) that are perpendicular to the long axes of the fibres) (Williams, 2004). There are different types of skeletal muscle fibres, which contract with different velocities, depending on their ability to split Adenosine Triphosphate (ATP). Faster contracting fibres have greater ability to split ATP. In addition, skeletal muscle fibres vary with respect to the metabolic processes they use to generate ATP. They also differ in terms of the onset of fatigue. On the basis of various structural and functional characteristics, skeletal muscle fibres are classified into three types (Williams, 2004; Guyton and Hall, 2005), the different types of skeletal muscle fibres and their role in mobility and control of posture being explained below:

Type I Fibres: These fibres, called slow twitch or slow oxidative fibres, contain large amounts of myoglobin, many mitochondria and many blood capillaries. These fibres are red, split ATP at a slow rate, have a slow contraction velocity, are resistant to fatigue and have a high capacity to generate ATP by oxidative metabolic processes. These fibres are found in large numbers in the postural muscles, for example, the multifidus and longissimus muscles (Guyton and Hall, 2005). The lumbar paravertebral muscles, which maintain the back posture in sitting, primarily consist of these fibres (Mannion, 1999).

Type II A Fibres: These fibres are called fast twitch or fast oxidative fibres. They contain large amounts of myoglobin, many mitochondria and many blood capillaries. These fibres are red, have a very high capacity for generating ATP by oxidative metabolic processes, split ATP at a very rapid rate, have a fast contraction velocity and are resistant to fatigue. They are not usually found in humans (Williams, 2004).

Type II B Fibres: These fibres are called fast twitch or fast glycolytic fibres, contain a low content of myoglobin, relatively few mitochondria, relatively few blood capillaries and large amounts of glycogen. These fibres are white, and are designed to generate ATP by anaerobic metabolic processes. They are not able to supply skeletal muscle fibres continuously with sufficient ATP, they fatigue easily, split ATP at a fast rate and have a fast contraction velocity (Guyton and Hall, 2005). These fibres are found in large numbers in the muscles of the upper limbs and lower limbs e.g. quadriceps. These muscles are responsible for speed, they contract at high velocities and fatigue easily. These fibres are also found in small numbers in the lumbar muscles due to the effect of posture and back pain and are discussed later. Mannion (1999) showed that normal subjects had type I fibres and people with back problems had type II b fibres predominantly in the lumbar paravertebral muscles, which is responsible for fatigue and back pain. The splenius capitis muscles help to maintain the head in the neutral position and consist predominantly of Type II B fibres.

1.1.11 Static Muscle activity and Myalgia (Muscular Pain)

The link between static muscle activity and neck myalgia was investigated by Eriksen (2004). According to Eriksen (2004), neck myalgia may be evoked by static low-level contractions in the trapezius muscle, combined with sympathetic vasoconstriction due to psychological stress or prolonged neck flexion at work. This static and ischaemic muscle activity increases the nitric oxide /oxygen concentration ratio in the muscle fibres. This may increase the reversible inhibition of mitochondrial cytochrome oxidase by nitric oxide and depletes adenosine triphosphate (ATP). This, in turn, elicits the production of lactic acid, which in turn activates the nociceptive fibres in the connective tissue, resulting in myalgic pain and tenderness. High oestrogen levels, which increases the expression of nitric oxide synthase in the muscle, aggravates the situation. During episodes of sustained inhibition of cytochrome oxidase by nitric oxide, peroxynitrite may be produced, which causes irreversible inactivation of several enzymes in the mitochondrial electron-carrier chain, thus an increasing part of the enzymatic capacity for cellular respiration is inactivated. Even if the process occurs within a small portion of muscle fibres, it may contribute to frequent exacerbations of pain. Adrenergic antagonists and nitric oxide synthase inhibitors could reduce these symptoms. However the most effective intervention is to avoid prolonged neck flexion i.e. to avoid static muscle activity at work.

1.1.12 Muscle Activity and Stress Distributions in the lumbar spine

Muscles of the back and abdomen act to protect the spine from excessive bending and torsion, but the resulting muscle tension can subject the spine to high compressive forces. Skin surface EMG and electromagnetic devices have been used to monitor lumbar flexion and extension during daily activities. If lumbar curvature in standing is considered 0%, and toe touching position as 100%, then it is apparent that many common postural habits position the lumbar spine in moderate flexion (Dolan, Adams and Hutton, 1998). For example crossing the legs in sitting increases the lumbar flexion from 35% to 53%, and squatting down on heels results in 70 to 75% flexion (Andersson et al 1979). Standing upright increases lumbar lordosis approx 2° per lumbar level compared to the curvature of an unloaded cadaver spine (Dolan, Adams, Hutton; 1998), and sitting upright and unsupported flexes each lumbar level by an average of 4 – 10° (Dolan et al 1998; Andersson et al 1979).

A study by Hedman and Fernie (1997) has investigated the relationship between seated postures and the mechanical responses in component tissues of the lumbar intervertebral joints. Twelve fresh lumbar spine specimens were selected. To decrease variation between the specimens, only adult male spines were selected. Mean age of the specimens was 55.25 years (range, 31-68 years). These spines were subjected to constant loading conditions while in flexed and extended seated postures. Time-dependent forces were measured in the anterior column at the L4 and L5 superior endplates and in the four facets of the L3-L4 and L4-L5 motion segments. Component forces changed under static loading in both postures. There were significant differences between the mechanical responses of the two postures. Although the vertical creep displacement was greater in the extended seated posture (3.22 mm *versus* 2.11 mm), the escalation of forces was more severe in the flexed posture. The results suggest a mechanism of force balancing in lordotic postures under static loads, whereas flexed postures produce large increases to the tensile forces in the region of the posterior annulus. These studies were performed on cadaver specimens on simulated postural conditions, but the actual forces on the vertebrae may vary in normal physiological conditions and this may be considered to be a principal drawback of cadaver studies.

A study by Black, McClure and Polansky (1996) has evaluated the changes in head, cervical, lumbar, and pelvic postures in different sitting positions and also determined if there is a relation between lumbar posture and cervical posture during sitting. A sample of 30 asymptomatic volunteers was studied (23 females and 7 males). Mean age was 28 years, with a range of 22 to 45 years. A biomechanical model was developed that allowed detailed, quantitative description of head, neck, lumbar, and pelvic postures. This model enabled a distinction to be made between upper and lower cervical motions. Various spinal angles were measured in 30 healthy subjects in four sitting positions using a three-dimensional digitising system. With the exception of head orientation, analysis of variance revealed significant differences in spinal angles between different sitting positions. Head orientation appeared to be maintained by compensatory adjustments in both the upper and lower cervical spine and changes in lumbar posture were associated with compensatory changes in overall cervical position. As the lumbar spine moved toward extension, the cervical spine flexed and as the lumbar spine flexed the cervical spine extended.

Beach et al (2005) has investigated the effects of prolonged sitting on the passive flexion stiffness of the lumbar spine. Twelve university students with no recent back pain were studied. The quantified changes in the shapes of the passive flexion moment-angle curves - slopes, breakpoints and maximum lumbar flexion angle were studied. While sitting, average lumbar flexion/extension angles, the distribution of lumbar flexion/extension postures, average EMG amplitude, the number and average length of EMG gaps, and trunk extensor muscle rest levels were measured. Participants performed deskwork for 2 hours while sitting on the seat pan of an office chair. Moment-angle relationships for the lumbar spine were derived by pulling participants through their maximum possible range of lumbar flexion on a customized frictionless table. The results indicated that lumbar spine stiffness increased in men after only 1 hour of sitting, whereas the responses of women were variable over the 2-hour trial. Men appeared to compensate for this increase in stiffness by assuming less lumbar flexion in the second hour of sitting. The results indicate that individuals who sit for extended periods can be at an increased risk of injury if full flexion movements are attempted after sitting and may contribute to low back pain in sitting.

Radebold et al (2001) studied postural control of the lumbar spine in patients with low back pain. They measured balance performance in unstable sitting and trunk muscle response to quick force release in 16 patients with chronic low back pain and 14 matched healthy subjects. An unstable sitting test was performed by attaching different sized contours to the bottom of a seat. Subjects performed trials with eyes open and closed while the displacements of the centre of pressure were measured with force plates under the seat. Responses from 12 major trunk muscles were measured using surface EMG. Subjects performed isometric trunk exertions in semi-seated position when the resisted force was suddenly released with an electromagnet. The results indicated that patients with chronic low back pain demonstrated poorer postural control of the lumbar spine and recorded longer trunk muscle response times compared to healthy volunteers, suggesting a common underlying pathology in the lumbar spine.

1.1.13 Effect of Pelvic and Limb positions on Lumbar Spine

The position of the head, shoulders and trunk is usually altered according the task to be done, especially in relation to visual acuity. During work, such as writing and reading, the arms are moved forwards in front of the body. This immediately increases the neck and shoulder muscle activity (Erector Spinae Cervicalis, Upper Trapezius, Erector Spinae Thoracalis, Levator Scapulae and Sternocleidomastoid). In particular, increased activity is found in the upper thoracic and neck extensors caused by abduction of arm with a flexed elbow (Schuldt et al 1986), which tends to occur when working at a table, which is too high. This can lead to fatigue and pain of the neck and shoulder muscles identified above, because the capacity for sustained muscle load is very limited on type II b fibre type muscles (E.g. Upper Trapezius) (Bjorksten and Jonsson, 1977).

Schuldt et al (1986) analysed the effect of changing the sitting posture on the level of neck and shoulder muscular activity. Ten healthy experienced female workers aged 21 to 55 yrs (mean = 38.9 yrs) from an electronics plant were chosen for the study. The subjects were not randomly selected. An ordinary office chair with height adjustable back rest was used. The task was to keep a soldering pen at a certain dot on a card for 5 seconds. Using surface electrodes, the level of electromyographic activity was recorded from neck and shoulder muscles in the following eight standardized work postures (Table 1-1).

	A	B	C	D	E	F	G	H
Cervical Spine	Flexed	Flexed	Straight Vertical	Flexed	Vertical	Flexed	Straight Inclined Forward	Flexed
Thoraco Lumbar Spine	Flexed	Flexed	Straight Vertical	Straight Vertical	Inclined Backwards	Inclined Backwards	Straight Inclined Forward	Straight Vertical
FT	0	35	35	35	75	75	35	35
Arm Position	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Abducted

Table 1-1. Table of work postures investigated in the study (A to H)
FT = Angle of attachment frame to the table

The results showed that slumped posture (Posture A) produces a higher level of activity in neck and shoulder muscles than erect posture, but a lower level of neck muscle activity was found in subjects who sat with a slightly inclined thoraco-lumbar spine with the cervical spine vertical (Posture E), when performing light assembly work (Schuldt et al 1986). However, this position has a risk of hyper-flexion in the lower cervical spine. Shuldt et al (1986) have suggested that the backward inclination of the thoraco-lumbar spine should be no more than 10-15° and the cervical spine vertical to reduce the static muscular load low. This position may reduce the frequency of musculoskeletal pain during sitting work.

The position of the lumbar spine is also affected by the pelvic tilt, together with the position of hips and knees. When moving from a standing to an unsupported sitting position, the hips move into flexion, tension in the hamstrings and gluteals rotate the pelvis backwards, causing the lumbar spine to flex. An X-Ray study by Schoberth (1962) found that in a traditional sitting posture i.e. with the thighs at 90° to the trunk, flexion occurred 60° at the hip and 30° at the lumbar spine, 80 to 90% of the flexion occurred at the L4 and 5 level. To maintain this position in unsupported sitting active back muscle work is required. This is always not possible and there is an increased tendency to slump because of the position of lumbar spine. Balance between the abdominal and back muscles is achieved better when the hip is in its neutral position i.e. 45°of flexion, and the lumbar spine assumes its neutral position, which is easier to maintain.

The hamstrings act over both the hip and knee joints and the amount of knee extension may affect the position of the hips and the lumbar spine. If the knee is flexed to 70° or less the lumbar mechanism is extremely sensitive to any change in hip flexion (Brunswic, 1984). Intradiscal pressure increases as the lumbar lordosis decreases and this may occur when knees extend in sitting or the arm moves forwards to reach an object.

1.1.14 Unsupported Sitting Postures

Schoberth (1962) described three basic unsupported sitting postures. He described these postures based on the centre of gravity of the trunk and the amount of weight transmitted through the legs to the floor. He explains these postures under the following condition: flat sitting without backrest, thighs horizontal to floor, legs vertical and feet flat on the floor. The following are the detailed description of these unsupported sitting postures (Harrison et al 1999).

Anterior Sitting Posture (Fig. 1-8) (Flat Sitting without Backrest)

In this position the centre of gravity of the trunk is anterior to the ischial tuberosities and the feet transmit more than 25% of the body weight to the floor. The amount of lumbar lordosis depends on activation of the erector spinae and degree of hip flexion. The stability is improved as the person leans forward in this position as this will increase the supporting surface, which is provided by the upper posterior thighs and increased body weight placed on the legs (Harrison et al 1999).

Muscle Activity: As the line of gravity passes anterior to ischial tuberosities there is increased activity of the erector spinae and hip extensors to maintain the posture and prevent the trunk from falling forwards (Figure 1-8 1b) (Cotton, 1904; Akerblom, 1948; Schoberth 1962; Andersson et al., 1974a; Preuss et al 2005). In extreme spinal flexion, the erector spinae will relax and only the hip extensors are needed to maintain this posture (Figure 1-8 1a) (Akerblom, 1948; Floyd and Silver 1955; Floyd and Roberts, 1958; Carlsoo, 1972). If there is an external support the muscle activity of the erector spinae and hip extensors can be completely relieved, and the anterior sitting posture can become the most stable unsupported sitting posture. Examples of such support are supporting the hands and forearms on the thighs, the anterior trunk supported by the edge of the table, or the hands supported on a table (Meyer, 1873). The line of gravity passes further anterior to the cervical spine, causing increased stress of the posterior neck muscles.

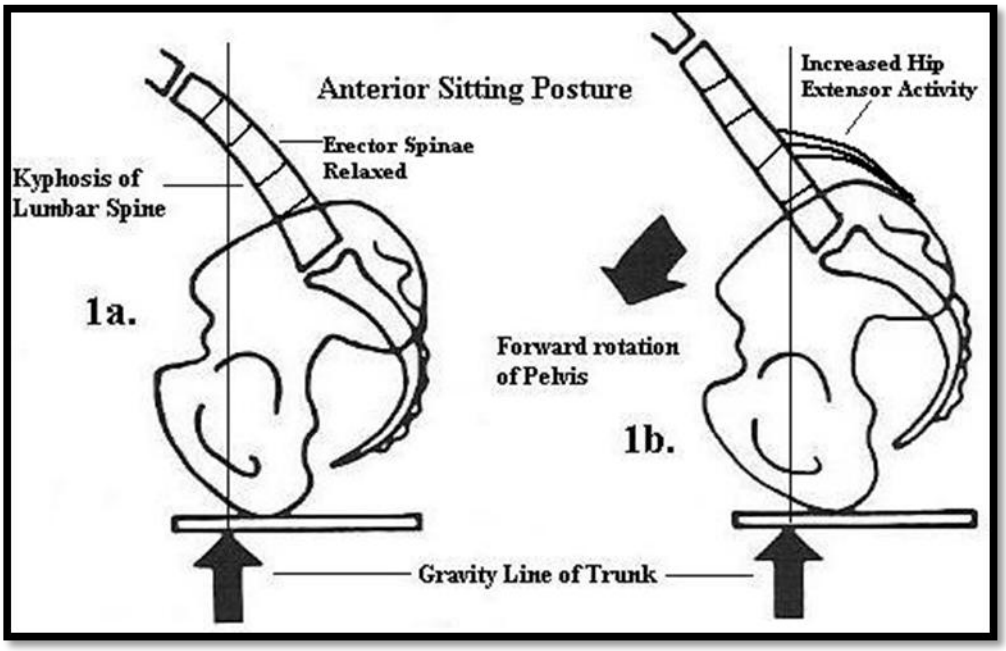


Fig. 1-8. Anterior Sitting Posture (Adapted from Zacharkow 1988)

1a. Anterior sitting posture with little or no pelvic rotation, but with kyphosis of the lumbar spine

1b. Anterior sitting posture with forward rotation of the pelvis and no kyphosis

Relaxed middle sitting position (Fig. 1-9)**:** In this position, the centre of gravity of the trunk is above the ischial tuberosities, and the feet transmit about 25% of the body weight to the floor, the same as previous position. In this posture the lumbar spine is straight or in slight kyphosis. However, with contraction of erector spinae, more upright middle position may result with lumbar spine straight or lordotic. The lordosis will shift the trunk's line of gravity anteriorly (Harrison et al 1999).

Muscle Activity: It is a position of unstable equilibrium. This is because the ischial tuberosities have narrowed curved surface, which provide only a linear support (Helbig 1978; Meyer, 1873). Sitting with lordosis in this position cannot be held for a prolonged period in many individuals because of the continuous static work of the erector spinae muscles (Preuss et al 2005).

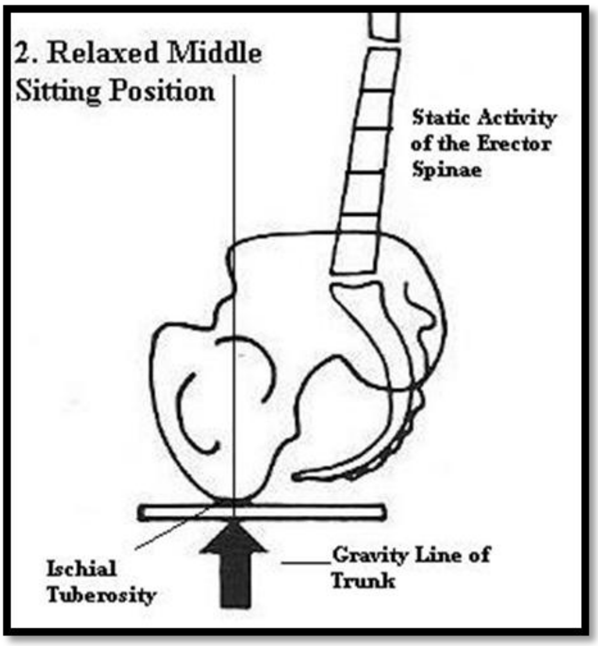
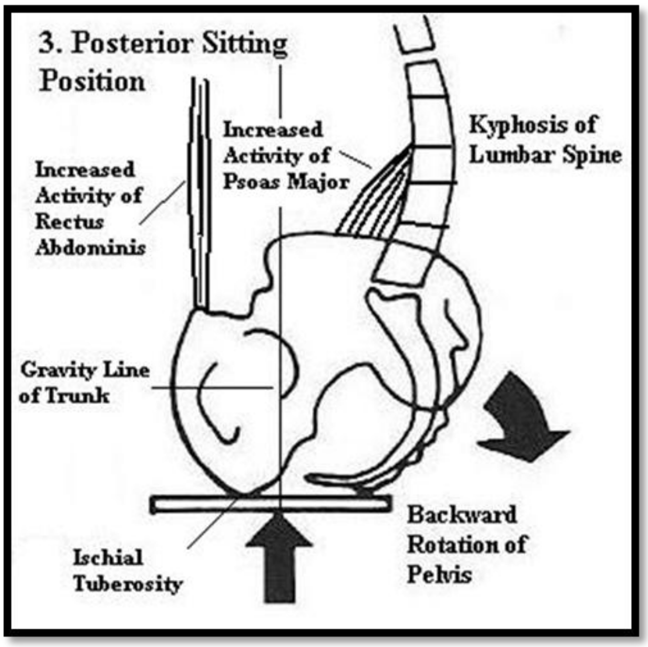


Fig. 1-9. Relaxed Middle Sitting Position

(Adapted from Zacharkow 1988)

Posterior sitting position with a backward rotation of the pelvis and kyphosis of the lumbar spine (Fig.1-10)**:** In this position, the centre of gravity is above or behind the ischial tuberosities and less than 25% of the body weight to the floor is taken by the feet. This position is obtained from the middle position and results in lumbar kyphosis. Stability will be improved as the coccyx, sacrum and posterior buttocks come in contact with the seating surface. This posture becomes very unstable as there is minimal weight bearing on the legs.

Muscle Activity: This position generally relaxes the back muscles (Schoberth, 1962; Carlsoo, 1972; Anderson et al 1974a). The psoas major becomes the main antigravity muscle as the line of gravity passes behind the ischial tuberosities. To maintain this posture requires increased activity of the rectus abdominis and neck extensors (Asatekin, 1975; Cotton, 1904). In the slumped sitting posture, the line of gravity passes further anterior to the head when compared to lordotic upright sitting posture, this places an increased demand on the posterior neck musculature to keep the head erect and the gaze horizontal (Jones et al 1961; Gray et al 1966; Bunch and Keagy, 1976). The slump and thoracolumbar kyphosis causes the head to thrust forward, resulting in increased activity of the upper trapezius and other posterior neck musculature (Gray et al., 1966). A 50% increase in muscle tension at the back and neck has been reported when going from an erect to slumped posture (Gray et al., 1966).



(Adapted from Zacharkow 1988)

Fig. 1-10. Posterior sitting position with a backward rotation of the pelvis and kyphosis of the lumbar spine

1.1.15 The Shape of Lumbar spine and the Supporting Structures in different Sitting Postures

The shape of the lumbar spine is similar in the most frequently used anterior and posterior sitting positions (section 1.1.14). The lumbar spine is in kyphosis and the erector spinae muscles are relaxed. Due to this the lumbar spine is mainly supported by passive structures especially the posterior ligaments (Akerblom, 1948; Floyd and Silver, 1955; Carlsoo, 1972). The factors affecting lordosis are detailed below.

Factors affecting a lordotic sitting posture

Decreased Hip Mobility

This is one of the important factors influencing the sitting posture (Le Floch and Guillaumat, 1982). Decreased hip mobility will make the lordotic sitting posture impossible. This may be due to one or more of the following

Tight hamstrings: When these muscles are tight they pull the pelvis into posterior pelvic tilt and in order to maintain the trunk upright, marked flexion of the lumbar spine is needed (Floyd and Roberts, 1958; Stokes and Abery, 1980; Brunswic, 1984a,b). The effect of tight hamstrings may also depend upon the angles of hip flexion and knee extension assumed by the individual on a specific seat. Brunswic (1984a,b) has found a rough relationship between the angles of hip flexion and knee extension and the percentage of lumbar flexion. The angles were measured by using a hydrogoniometer with the subjects seated on an experimental rig which has a adjustable footrest platform and a variable seat. It was found that an increase in hip flexion or knee extension increased the percentage of lumbar flexion in a ratio of 1:2.

Degenerative Changes: Hip mobility may also be limited by degenerative changes in the joint, restricting hip flexion or abduction. The individual will then be forced to flex the lumbar spine to maintain an upright posture (Rosemeyer, 1973). Along with these changes, the degenerative changes of the disc may contribute to the flexed posture by reducing the intervertebral space. Ageing may reduce the water content of the disc and joints and may contribute to degeneration of the joints combined with poor posture.

Decreased Back Extension Mobility

As a result of prolonged slumped sitting posture some individuals may have lost the ability to extend their spine sufficiently. Structural changes in the spine may also prevent the lumbar spine from being able to achieve a lordotic sitting posture. A study by Milne and Lauder (1974) found that lumbar lordosis was absent in a large proportion of men and women who are aged over 60 years.

1.1.16 Exercise and Lumbar Lordosis

Improper movement patterns may result from exercises that reinforce thoracolumbar flexion with hip flexion. For example toe touches, sit-ups (Zacharkow, 1984). Sit-ups[1] can stretch and straighten the upper rectus muscle and overstretch the back extensors (Anderson, 1951).

Toe touching may induce hypermobility in spinal flexion, especially when tight hamstrings restrict the hip movement. This movement pattern can be seen in the anterior sitting posture a student adopts sitting in front of a desk (Fig. 1-8) (Cotton, 1904). Goldthwait (1909), Mosher (1914, 1919), Schurmeier (1927), and Schuldt (1986) have stressed that, in anterior sitting, the trunk should be kept straight and not slumped and the flexion should occur at hips and not in the spine. The lumbar spine may slump in anterior sitting when the person is supporting the desk in front of him with his upper limbs.

1.1.17 Role of abdominal muscles in different Postures

Ainscough-Potts et al (2005) studied the response to alterations in seated stability, in transverse abdominis and internal oblique abdominis. The thickness of the right transverse abdominal muscles was measured using ultrasound imaging in different postures. In this respect, the thickness of muscle corresponds to amount of contraction of muscles. Thirty healthy subjects (22males and 8 females) aged 18 and 50 years were studied in

[1] Sit-ups are performed in lying with your knees bent to around 90 degrees and feet flat on the floor; raise your torso, shoulders, and head 6-12 inches; tense your abdominal muscles and hold this position for a few seconds; return slowly to the floor and repeat. Hold your hands at your sides, across the chest, or cross behind your neck (Stamford; 1997)

- supine lying,
- relaxed sitting on a chair with both feet on the ground,
- relaxed sitting on a gym ball with both feet on the ground and
- sitting on a gym ball lifting the left foot off the floor.

Measurements were taken at the end of both inspiration and expiration. The results indicated that muscle thickness, expressed as a percentage of the actual muscle thickness in supine lying, did not differ between relaxed sitting on a chair and sitting on a gym ball for either muscle (P= 0.0122–0.054) where Bonferroni corrected P-value for significance = 0.002. Raising the foot off the floor produced a significant increase in thickness for transverse abdominis and internal oblique, when compared with the other seated postures (P<0.001) (Ainscough-Potts et al 2005). It was also found that both muscles were thicker at the end of expiration (P<0.001). These findings suggested that both deep abdominal muscles respond in the same way to postural changes. It also demonstrated that these muscles are automatically targeted by significantly decreasing the base of support (unstable sitting posture), but sitting on a gym ball is not sufficient to increase their activity.

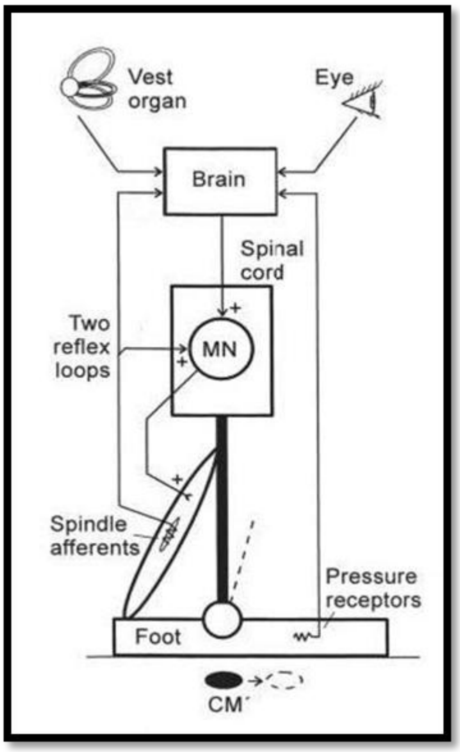
1.2 Control of Posture

Posture may be considered as an actively stabilized definite orientation of the body and its segments in space in relation to each other (Kandel et al 2000). Postural control involves controlling the body's position in space for the purpose of stability and orientation.

These postural control systems minimize deflections of the body from desirable orientation and are able to stabilize the body in different postures. These systems use multimodal sensory inputs, namely the somatosensory, visual and vestibular systems to maintain a desirable posture with a family of adjustments. They are also necessary for all motor tasks and need to be integrated with voluntary movements (Fig 1-11).

The requirements for postural control are:

1. Head & body support against gravity
2. Maintain Centre of Mass (CM) within the base of support and stabilize body during movement
3. Anticipate goal-directed responses and integrate with voluntary movement



(Adapted from Kandel et al 2000)

Fig. 1-11. Sensory Inputs for Postural Control System

MN – Motor Neuron, CM – Centre Of Mass

1.2.1 Proprioceptive Control of Posture

The proprioceptors are the important receptors which provide information to the brain about the positions and movements of limbs, the forces generated by muscles, and orientation of the body in space.

The proprioceptors are divided into:

- Muscle Proprioceptors: Muscle Spindle and Golgi tendon organs
- Joint Receptors
- Vestibular Apparatus

Muscle proprioceptors

The muscle spindles respond to muscle length and rate of change of length; and Golgi tendon organs signal muscle tension or force. Both of these are stretch receptors. The spindles are parallel with the main contractile elements in the muscle so that their stretching is the measure of degree of stretch of the muscle, whereas the tendon organs are situated in the tendons in series with the contractile elements. The load, hence the stretch, is proportional to the tension exerted by the muscle (Allum et al 1998). Brumagne et al (2000) showed that patients with low back pain have a less refined position sense than healthy individuals, possibly because of altered paraspinal muscle spindle afference and central processing of this sensory input. The lumbosacral position sense was determined before, during and after lumbar paraspinal muscle vibration in 23 young patients with low back pain and in 21 controls. Sacral tilt position was electronically recorded by an electrogoniometer that was attached to the skin over the sacrum at spinous process S2. Before testing, the range of motion of pelvic-sacral tilting was measured. During testing, the participants were instructed to maintain a criterion position for 5 seconds and then tilt the pelvis completely forward. Then, starting from this position (anterior pelvic tilt), they had to reproduce the criterion position. The participants were instructed to move only the pelvis and lower back during this task. After completion of each trial, the same sequence of events was repeated five times. No feedback on accuracy was provided to the person. The criterion positions were pseudorandomly chosen by the examiner. Position sense was estimated by calculating the mean absolute error, constant error, and variable error between six criterion and reproduction sacral tilt angles. Their findings indicated that precise muscle spindle input of the paraspinal muscles is essential for accurate positioning of the pelvis and lumbosacral spine in a sitting posture.

Joint receptors

They are found in ligaments and capsules of joints and convey information to the brain about limb position and movements. They are many types, varying in structure, and are as follows:

- Pacinian corpuscle and Golgi-like endings are found with large axons (Group I),
- Ruffini endings (Group II), and also small nerve fibres with unencapsulated endings.

Some of these receptors show complete adaptation and are more sensitive to rate of change of movement, whereas some receptors show incomplete adaptation and are able to signal the position of the limb (Carpenter 2003; Allum et al 1998). McLain & Raiszadeh (1995) histologically analysed the thoracic and lumbar facet joints to determine the density and distribution of encapsulated nerve endings. The encapsulated nerve endings are believed to be primarily mechanosensitive and may provide proprioceptive and protective information to the central nervous system regarding joint function and position. McLain & Raiszadeh (1995) found that a consistent, but small population of these receptors has been found in cervical facets in their previous study, but the innervation of the thoracic and lumbar levels are found to be less consistent. This would be expected as cervical position is an essential function where as thoracic and lumbar spine is not as critical functionally

The Vestibular Apparatus

The vestibular apparatus forms a part of the labyrinth of the inner ear. The apparatus consists of a system of tubes lined with ciliated sensory cells and in communication with the surrounding water; the cells are stimulated by the flow of fluid through the tubes. The vestibular part of the labyrinth is divided functionally into two components, the semicircular canals (3 on each side of the head) and the otolith organs (two on each side – utricule and saccule). The semicircular canals (horizontal, anterior, posterior) are responsible for detecting angular velocities and the Otolith organs (Utricule & Saccule) are responsible for detecting linear acceleration and angular position relative to gravity (Allum et al 1998).

1.2.2 Vestibular Control of Posture

To control the posture the effective direction of gravity is more important than the real direction, for example whether a person falls when standing in a bus which starts to accelerate is not due to the projection of the centre of gravity vertically relative to the critical area, but it is the projection in the direction of the vector formed by the gravity and the horizontal linear acceleration acting together and this is determined by the utricle and saccule (Carpenter, 2003). The utricle and saccule gives two types of postural reactions, and these should be distinguished between static or tonic postural responses by the otolith organs and the dynamic or phasic ones driven by the semicircular canals.

The otolith organs produce less powerful postural responses than the canals, but they are the only source of information about the position of the head in space because the canal only detects signals about changes of position. Their main function is to keep the head upright despite changes in position of body, through changes in the tone of neck muscles (head-righting reflexes). If the head is forcibly tilted in different directions compensatory static vestibulo-ocular reflexes help to maintain the normal attitude of eyes with respect to the outside world (Carpenter, 2003; Allum et al 1998).

1.2.3 Visual Control of Posture

The receptors in the retina provide information about head position in order to maintain posture. The visual and vestibular information share common pathways to transmit information to the brain and control the position of the head in space.

Static Visual Responses: Our visual world is made up of horizontal and vertical visual elements and their orientation mean that we can use our eyes to estimate head position. Experiments have demonstrated that this tonic visual information is used in making postural judgements and responses (Carpenter, 2003). When the subjects are seated on a tilting chair inside a dummy room, which can be tilted in various angles, it is found that their sense of upright direction generally lies between the true and the apparent upright of the room (Carpenter, 2003). This sort of information is not available in more natural surroundings and the ability to manage such surroundings is a learnt behaviour.

Lanzetta et al (2004) examined trunk stability in unstable sitting in two different functional activities. Twenty subjects were recruited, 10 healthy subjects and 10 patients with multiple sclerosis. The subjects were given two tasks seated on an unstable support surface. They were instructed to keep the trunk as stable as possible in the tasks in which they needed to track an object with the head or grasp an object. Angular displacement and mean absolute angular velocity in the anteroposterior (Sagittal) and mediolateral planes (Frontal) of the support surface were measured. It was found that both the patients and healthy subjects had more difficulty with frontal plane stability than with sagittal plane stability and patients were unstable more when compared with healthy subjects during head movements in the frontal plane. Conversely, arm movements produced larger angular displacement in the sagittal plane. This may be important because dentists work in unstable sitting postures and this may affect their frontal plane stability, which is important for treating patients.

1.2.4 Postural Adjustments (Fig. 1-12)

The postural adjustments are achieved by means of two major mechanisms:

Feedback control: reactive. Signals from sensors are compared with the desired state and output is adjusted. The response lags behind the stimulus, and is sometimes too late, especially because muscles react slowly. Feedback is responsible for most moment-to-moment control (Kandel et al 2000). The feedback controls are activated by sensory events following loss of desirable posture (Compensatory postural adjustments).

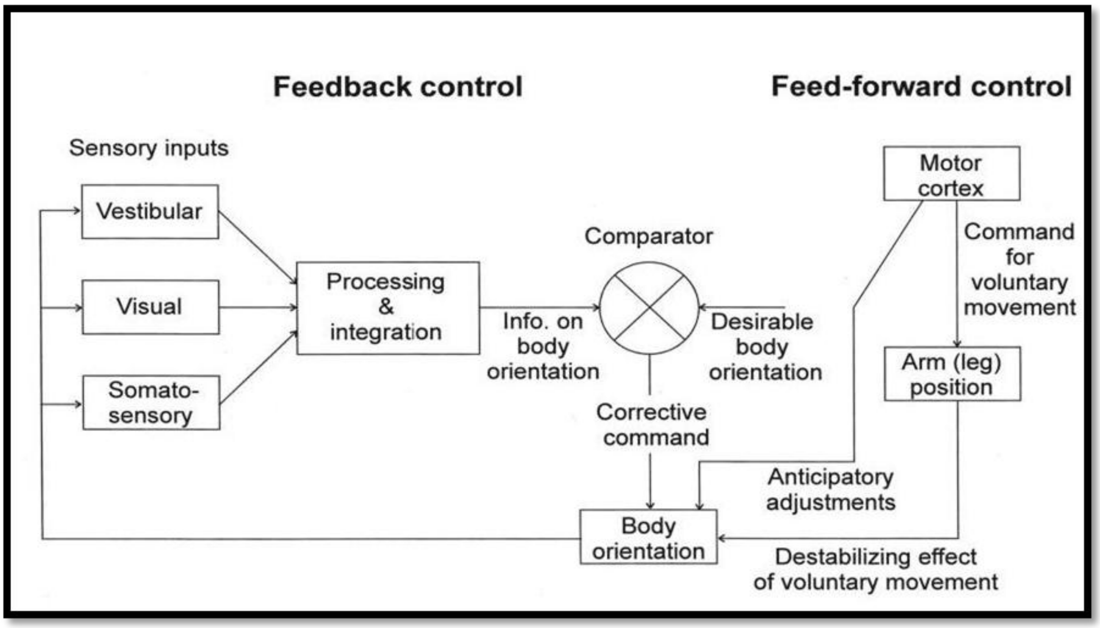


Fig. 1-12. Principles of Postural Control (Adapted from Kandel et al 2000)

Feed-forward control: predictive. The response anticipates the stimulus. Feed forward is essential for rapid action. With experience, feed-forward mechanisms can be strengthened; the system learns to become sensitive to the velocity of change and gets a jumpstart on reflexes. Example: catching a ball. (Kandel et al 2000). The feed-forward mechanisms are anticipatory in nature and predict disturbances and produce pre-programmed responses that maintain stability (Anticipatory postural adjustments) (Kandel et al 2000).

Some of the compensatory postural adjustments are innate, while others have to be acquired by motor learning. Anticipatory postural adjustments must be learned, and then they operate automatically and postural control is adaptive. The shape of postural adjustment depends on behavioural context. All levels of the CNS are involved in postural control. Integrity of the brainstem centres is necessary for generation of compensatory postural adjustments. Integrity of highest levels of the CNS including the motor areas of the cerebral cortex is necessary for anticipatory postural adjustments. Adaptive postural control requires an intact cerebellum.

1.2.5 The Anatomy of Control of Posture

The maintenance of erect posture and the orientation of body and head are controlled by a basic premotor interneuronal system in the spinal cord. This premotor system was found to be controlled by several brainstem supraspinal control areas through descending pathways of the spinal cord that target the medially located axial and proximal muscle motoneurons and their basic premotor motoneurons (Holstege, 1998). Posture also depends on the position of the visual field and has a relationship between the premotor interneurons of the axial and proximal muscle that control the extrinsic eye muscles. The motor cortex also plays a limited role in control of posture through the corticospinal tract, since this pathway is mainly responsible for execution of distal limb movements and speech (Holstege, 1998).

1.2.6 Postural Control in Different Functional Tasks

All tasks require postural control, however, the requirements may vary according to the task involved i.e. the orientation and stability may vary with the task and the environment. The task of sitting in a chair and reading requires keeping the head and gaze stable on the reading material, the arms and hands to hold the book and to keep it in relation to head and eyes (Shumway-Cook and Woollacott, 2001). This posture requires minimal effort to maintain as the body is supported in a large base of support, (thighs and buttock) and when the same task is performed in standing more effort is required to maintain the posture, as there is a small base of support (feet and area between feet). When a person is standing on a moving bus the individual needs to continuously maintain the stability of the body constantly threatened by the movement of the bus. The task here is unpredictable and changing. The visual system, vestibular system and the motor system play an important role in the control of posture in these circumstances.

1.3 History of Dentist Working Posture

At the beginning of the 16th century both the patient and the practitioner were standing during treatment, which has been clearly shown in figure 1-13. The figure shows a standing patient treated by a 16th century practitioner in Europe. The first sixty years of the 20th century the practice of dentistry in the United States remained basically the same i.e. in standing.

Dental students were taught by men and women who themselves were taught in the late 19th or early 20th centuries. After this period many advances were made in science and technology following the Second World War. In the 1950's, after the war, although the older generation of instructors still set the curriculum, a new generation of dentists came with new ideas, materials and concepts.

Fig. 1-13. Patient being treated in Europe by 16th century practitioner (Reproduced from Glenner, 2000)

During the 1950's there were developments in techniques of dental practice and new equipment was developed; the early 1960's were the years of transition in the practice of general dentistry (Rundcrantz el al 1990). From the beginning of the 20th century to 1960, dentistry was comparable to present day. The dental surgery design during this period would appear to resemble a surgery today, there being a chair, cabinet and (after the 1920's) an X-ray machine. Although with changes in design, colour and materials the basic equipment remains the same today.

In the first half of this century, a dentist was a person who for the most part, was expected to perform most of the duties. But in the latter part of this century, with the advent of specialties, changes were occurring in all aspects of the dental profession (Four-Handed Dentistry). These continue to occur to the present day, affecting the way that dentistry is practiced. In the early 1960's some dentists continued to work standing-up but many dentists felt more comfortable working in a sitting position and increasingly used the dental stool (Glenner, 2000). The dentists began to realize that it was healthier for them to work sitting down, rather than standing up, with the patient in a reclining position (Rundcrantz et al 1990).

Some dentists tipped their conventional patient chair backward to work (Fig. 1-14), while others, primarily dentists starting out who were going into new surgeries, purchased the newly introduced dental chairs - some were motorised conventional chairs with motorised backs, while others were chairs which filled the contour of the body. Other dentists purchased contour seat adapters to convert their conventional chairs (Glenner, 2000). These chairs allow better access to the patient's mouth as they allowed the patient to recline.

In the early 1960's, dentists who were working sitting down began to realize that their units and cabinets were too high and difficult to reach. Although a few lower units came on the market, it was some time before new delivery systems and cabinetry became available. The dentists found it awkward to work, stretching for instruments and materials. Some dentists began to practice four-handed, seated dentistry (working with a chair-side assistant), but again, it was also some time before this became the standard.

Fig. 1-14. Early 1960's - This dentist is shown working sitting down in an office set up for stand-up dentistry. (Reproduced from Glenner, 2000)

1.4 Four-Handed Dentistry

Four-Handed Dentistry is an operating technique that was conceptualized by many researchers during the early 1960's and formalized through clinical studies at the University of Alabama, School of Dentistry. Applying time and motion study techniques used by industrial engineers to increase efficiency and productivity in repetitive task environments, the university studied dental procedures of hundreds of practicing dentists and dental students in order to define the criteria for Four-Handed Dentistry (**http://www.hspinc.com/whatis.htm**). Figures 1-15 and 1-16 show current practice of four-handed dentistry and that of the 1960’s.

Four Handed dentistry has been defined as follows:

“Four-handed dentistry is a team concept where highly skilled individuals work together in an ergonomically designed environment to improve productivity of the dental team, improve the quality of care for dental patients while protecting the physical well-being of the operating team” (Finkbeiner, 2000; Page 2).

The concept of four handed dentistry specified: (Finkbeiner, 2000)

1. Positioning: Correct interaction of the dentist and the dental assistant
2. Organization: Procedure and work flow in order
3. Equipment: Criteria for the selection of equipment

Applying the criteria for selection of equipment and the concept of positioning and organising the procedure allowed more effective and efficient dentistry. This research proved that the approach increased productivity, reduced stress and fatigue, and improved the quality of dental care, which was achievable by all dentists.

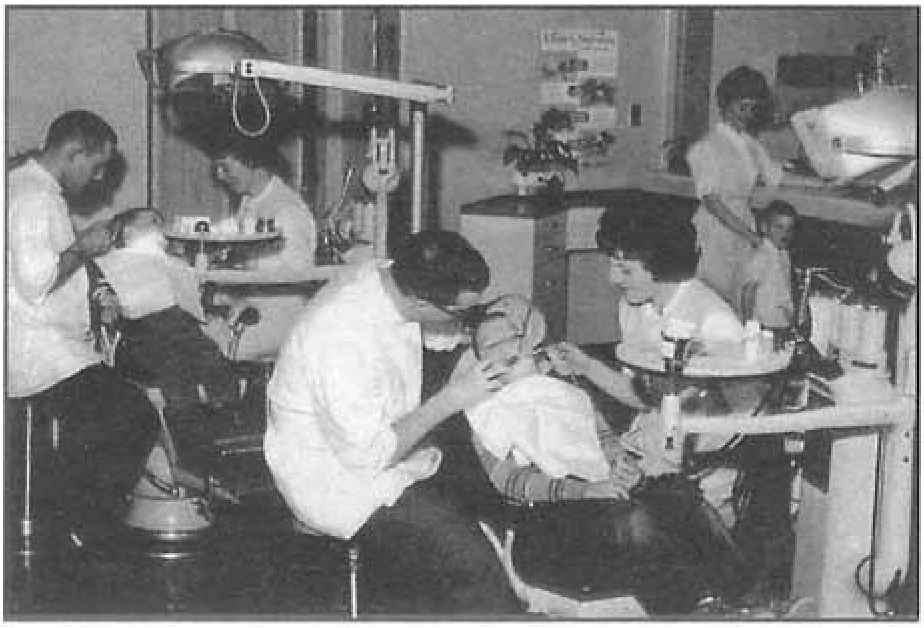


Fig. 1-15. Four-handed, seated dentistry (Pediatric Dental Clinic of Indiana University School of Dentistry 1962) (Reproduced from Glenner, 2000)

Fig. 1-16. Four-Handed, seated dentistry (Dental Clinic of University of Birmingham School of Dentistry 2005)

Myth: The Dentist or hygienist and the assistant, utilizing two hands each (which equals four hands), are performing Four-Handed Dentistry.

Fact: Unless the assistant has been properly trained to create team synergy, unless organization and standardization is employed and maintained in clinics, and unless ergonomically designed equipment is used, the dental team is in fact only performing traditional sit-down dentistry.

1.5 Sitting Positions of the Dental Operator in Relation to the Mouth

The dental operator has to position himself around the patient in relation to the treatment areas of the mouth. These are usually identified in relation to a 12-hour clock (Fig 1-17)

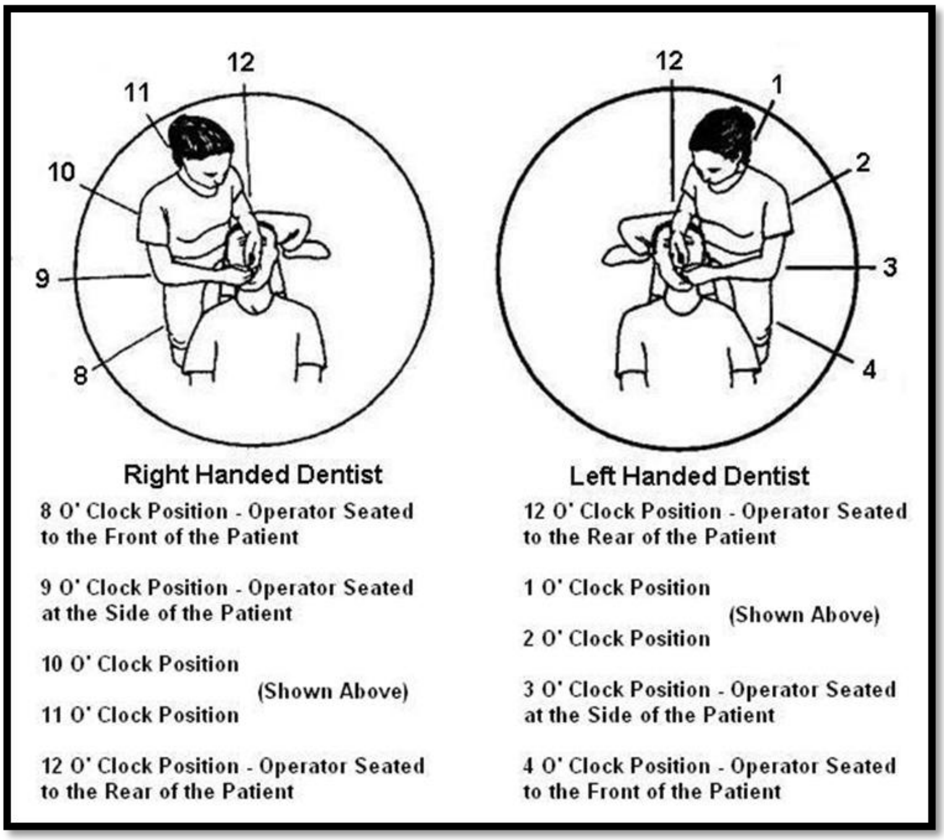


Fig. 1-17. Sitting Positions of the Dental Operator (Clock Positions)

(Fundamentals of Dental Assisting, Sweet Haven Publishing 2006)

1.6 Sitting Posture

Grandjean (1973) describes sitting as 'a natural human posture' because sitting relieves the person of the need to maintain an upright posture and reduces the static muscular workload required to maintain the joints of the foot, knee, hip and spine and so reduces energy consumption. Seating also helps the person to be more stable and might help when performing tasks that require fine or precise upper limb movements, and it produces a better posture for foot control operations. This may be the reason for the major change in dental working posture from standing to sitting. However, sitting in a slumped posture may contribute to the development of musculoskeletal disorders e.g. Low Back Pain. Earlier studies failed to explain that the spine needs to be maintained in an optimal posture and reduced muscular load in order to maintain the spinal posture.

Although there are many physiological advantages in sitting, mobility might be severely restricted. Prolonged sitting might lead to complications, For example Grandjean (1973) stated that a sitting posture causes abdominal muscles to slacken and slump the spine, in addition to impairing the function of some internal organs. Pottier, Dubreuil and Mond (1969) have demonstrated that prolonged sitting (> 60 minutes) produced swelling in the lower legs of all sitters, which is caused by increased hydrostatic pressure in the veins and by compression of thighs resulting in an obstruction of venous return. Volume changes of the foot were recorded continuously by constant water level plethysmograph on 32 subjects, during 78 experiments from 1-2 hours. Volume variations due to sitting posture and temperature were studied in a group of five male and five female subjects, aged 17 to 38. Volume variations resulting from compression of the underside of the thigh were studied in 11 female and 11 male subjects aged 17 to 35. The results indicated a 2 to 3 % increase in foot volume after an hour. Pottier et al. (1969) have suggested the following recommendations for people who work for long hours in a sitting posture:

- Use of frequent and short rest pauses, or working for short periods in the standing position and
- Use seats with vertical height adjustment in order to avoid compression on the thighs.

People who sit for long periods are also at risk of back injury due to the following reasons:

- Slouched sitting produces ligamentous strain in the back and stretching of back muscles and this posture maintained over a time period may result in fatigue and back pain (McGill & Brown, 1992; Gunning, Callaghan, and McGill, 2001) (Refer to Section 1.1.7)
- This slouched sitting posture increases the disc pressure considerably and may result in back pain (Grandjean, 1988) (Refer to Section 1.1.5 and 1.1.6)
- Long term use of slouched posture (Flattening of lumbar spine) during sitting may result in disc herniation (Bogduk, 2005)

Pynt et al (2001) recommended lumbar lordosed seated posture, regularly interspersed with movement (Lordosis to Kyphosis) as the optimal sitting posture, which is necessary to maintain lumbar postural health, and in preventing back pain.

Pheasant (1991) suggested that the action of sitting down on a seat of average height involves the flexion of the knees and hips (about 90° each) and in most people the comfortable limit of hip joint flexion is about 60° between the trunk and hips, beyond which the passive tension of the hamstring muscles increases, pulling the pelvis backwards to about 30°. The tension in the hamstring muscles alters when the angle of knee flexion and hip flexion varies in sitting. The weight of the body is taken by the ischial tuberosities and the top of the sacrum lies near horizontal. If the trunk needs to be vertical there should be compensatory flexion or flattening of the lumbar spine by an amount equal to the backward rotation of pelvis (Posterior Pelvic Tilt) (Refer to Section 1.1.12).

1.6.1 Various Sitting Postures:

Right Angled / Cubist Sitting Posture

In this posture the hips, trunk, knees, and ankles are maintained at right angles. This static form of sitting was recommended from the Victorian era as the traditional ideal posture (Graf, Guggenbuhl, & Krueger, 1995). Seating research between 1948 and 1962 mainly investigated the anatomical and physiological effects of this sitting position. Slowly this has proved to be a posturally unhealthy concept since it leads to the adoption of a flexed posture (Andersson et al 1979; Bridger, Von Eisenhart-Rothe, & Henneberg, 1989; Keegan, 1953 Schoberth, 1962; Twomey & Taylor, 1987). Recent radiological studies have shown that, in the right angled sitting position, without lumbar support, lumbar lordosis is flattened by 50% compared with standing (Lord, Small, Dinsay, & Watkins, 1997). The reason for this is that sitting with 90° hip flexion creates tension in the hamstring and gluteal muscles, which in turn causes backward rotation of the pelvis, resulting in a lessening of the sacral horizontal angle and a flattening of the lumbar lordosis (Fig. 1-18) (Adams & Hutton, 1980; Andersson et al 1979; Bridger, Von Eisenhart-Rothe, & Henneberg 1989; Keegan, 1953; Schoberth, 1962; Twomey & Taylor 1987).

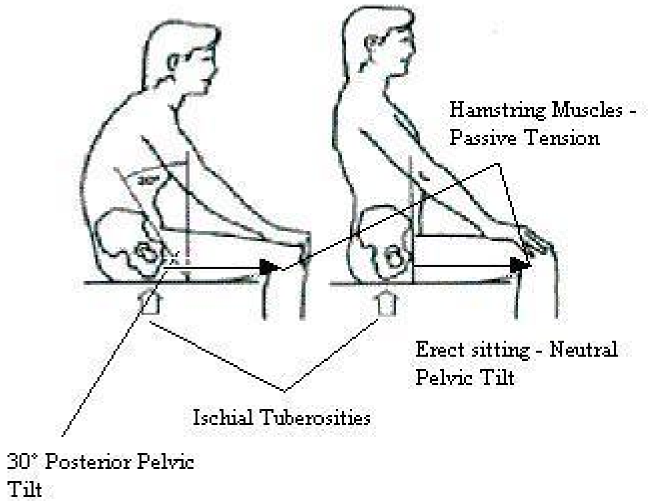


Fig. 1-18. The orientation of pelvis in the sitting position (Adapted from Pheasant; 1991)

In the 90 degrees sitting position the lumbar lordosis (Fig 1-19) can only be maintained by the continuous activity (static muscle activity) of the erector spinae muscles which increase compressive loading on the intervertebral discs (Andersson et al 1974a). Through the rapid onset of muscle fatigue it is also difficult to maintain this position for a prolonged time (Floyd and Roberts, 1958). When fatigue occurs, the user slides his/her buttocks forward and adopts the posterior / slumped sitting posture, which is a posture with less back muscle activity (Andersson et al, 1975; Dolan, Adams, & Hutton, 1988) (Refer to Section 1.1.8). However, in this position there is activation of the neck extensor muscles in order to maintain the cervical spine in neutral (Black, McClure, & Polansky, 1996), which is an unhealthy posture for the cervical spine. This explains why a slumped posture is often assumed in a chair with a vertical backrest meeting a horizontal seat.

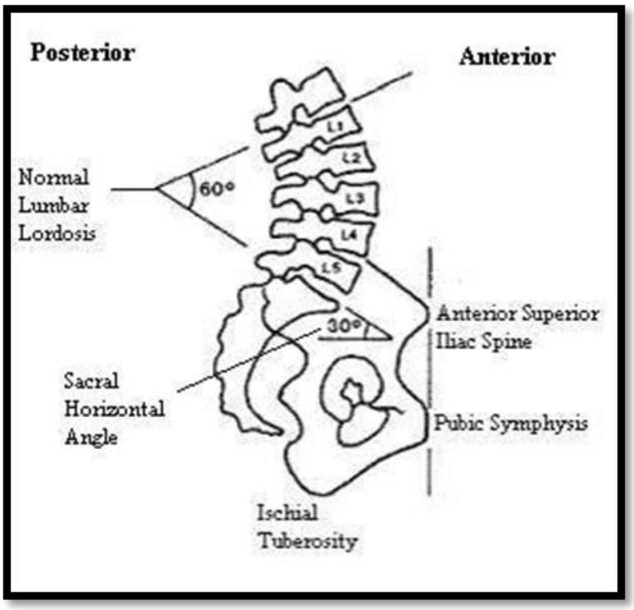


Fig. 1-19. The Lumbar Lordosis Based on Andersson et al (1979)

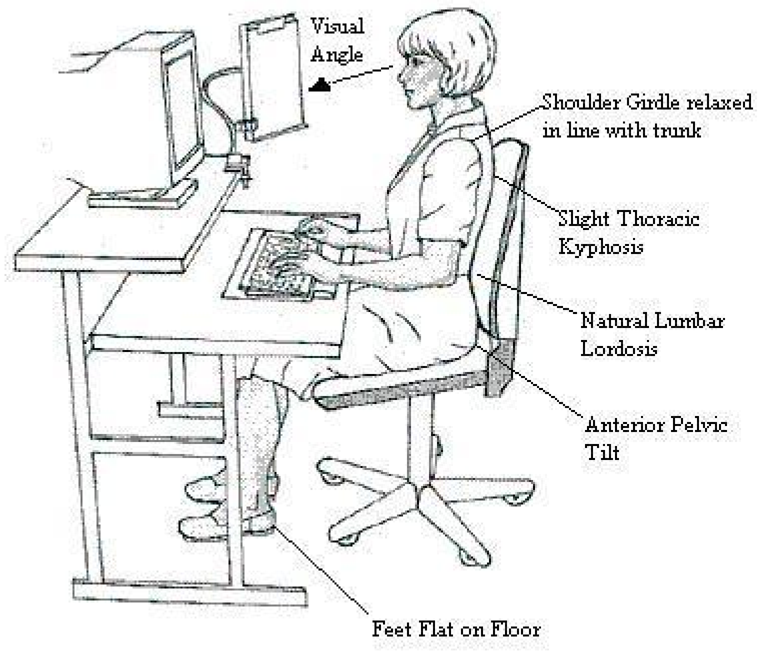
1.6.2 Good Sitting Posture – Office Workers

Sitting has become the predominant daily posture for a large proportion of Western society. Today, professional-level office workers spend about 70 % of their time sitting in their offices (Herman Miller, 2002). As the use of computers is increasing, jobs are evolving from multidimensional to unidimensional, often requiring workers to sit for long periods (sedentary work). Labour-saving devices reduce the need for people to work and encourage sitting. Sitting is also a main posture for professional drivers such as heavy vehicle drivers, taxi and bus drivers. Sitting fundamentally changes the posture and the demands and constraints placed on the musculoskeletal system. It changes the natural spinal curve from a three-curve structure to a single curve, which profoundly alters the biomechanical forces and physiological homeostasis of the spine.

The requirements for a good sitting posture for a VDT (Visual Display Terminal) workstation are listed below (See Fig 1-20). The aim is to provide good spine and pelvis posture while still being able to easily access work tools and maintain good visual angles and distances Silverstein (1997):

- Spine and pelvis – 110–130° (Anterior Pelvic Tilt)
- Lumbar spine – retain some natural lordosis
- Thoracic spine – a slight kyphosis
- Head and neck – erect and close to the centre of gravity
- Visual angle – 10–30° below horizontal
- Shoulder Girdle – relaxed in line with the trunk
- Elbows – 90–100°
- Wrists – straight with wrists extended up to 20 ° and forearms supported where possible
- Hip – 100 – 120°
- Knees – 60–120°
- Feet – flat on the floor or on footrest.

The above-mentioned parameters are recommended for a good sitting posture for task-related sitting (Silverstein, 1997). Fig.1-20 shows an example for task related sitting posture with above-mentioned parameters.



Adapted from Silverstein (1997)

Fig. 1-20. Task-related sitting posture while working at a computer

1.6.3 Suggestions for Maintaining Good Posture by Various Authors

- Adams et al (1994) suggest that a position of moderate flexion is to be preferred when the lumbar spine is subjected to high compressive forces e.g. in heavy lifting activities because this position evenly distributes the compressive forces on the disc.
- A seat angle of 110 – 120° is suggested as this reduces the intervertebral pressure (Oborne, 1987).
- Since the spine naturally rests in its normal ‘S’ shape chair design should be concentrated as to maintain this position in sitting as it reduces the pressure on the intervertebral discs and static loads on the spinal extensors (Oborne 1987).

- Mandal (1984) suggested a 15° of forward slope of seat to the horizontal, as this moves the person towards the work surface and reduces muscle work in the upper limbs.
- Shuldt et al (1986) suggested that the backward inclination of the thoraco-lumbar spine should be no more than 10-15° and the cervical spine vertical to reduce the static muscular load low and this position may reduce the frequency of musculoskeletal pain during sitting work.
- Goldthwait (1909), Mosher (1914, 1919), and Schurmeier (1927) have stressed that in anterior sitting the trunk should be kept straight and not slumped and the flexion should occur at hips and not in the spine.

1.6.4 Benefits of Good Posture

The following are the benefits of good posture

- Decreases ligamentous strain and prevents overstretching of back muscles, which causes muscle imbalance.
- Decreases intradiscal pressures and reduces stress on the thoracic and cervical spine and shoulder girdle.
- Efficiency in muscle work and reduction in fatigue because muscles are at mechanical advantage. There is recruitment of postural muscles, which support the spine, and the extremities are free to work.
- There is increase in range of motion in extremities due to erect posture.

Chapter 2

Dental Ergonomic Questionnaire

Questionnaire Study of Dentists

2.0 Overview

The first part of the chapter introduces the ergonomic questionnaire studies with dentists, the introduction to the questionnaire, development of the questionnaire, with the final part of the chapter presenting the results.

2.1 Questionnaire studies with Dentists and Other Workers

Bassett (1983) conducted a survey in Toronto area to determine back pain among dentists. A questionnaire was given to two different sample groups on two different occasions. Two hundred questionnaires were distributed at a meeting of University of Toronto part-time dental clinical staff and a total of 167 valid forms were returned. Seven hundred questionnaires were distributed to dentists attending a provincial convention and a total of 298 valid forms were returned. A total of 465 (52 %) out of 900 were returned. Differences were determined between the samples and between the back pain sufferers and non-sufferers. Of the 465 dentists 62.2 % (288) had suffered back/neck pain at sometime in their lives and 36.3 % were currently suffering from such a problem. Back pain was found to be greatest among dentists aged 30 to 50 years, which is similar to the general population (Oksuz, 2006). In a concurrent survey it was noted that 220 dental hygienists, whose average age was 15 yrs younger than that of dentists, had an identical incidence of back pain (62.2 %). Twenty percent reported that their back problem led them to modify their practice of clinical dentistry. The most common modifications of dentists and dental hygienists included: reducing working hours, postural changes, and adoption of sit-down technique and changing dental stools. Seventy percent of back pain sufferers had sought some medical help, while 242 (84 %)

out of 288 sufferers (62.2 %) felt that some form of treatment would alleviate their problem.

Shugars et al (1987) investigated the nature of pain among dentists, the amount of disability resulting from these problems and the effectiveness of treatments used by this population to seek relief from musculoskeletal pain. A pilot study with 50 members was performed before the main study. A questionnaire was sent to 2000 members of the American Dental Association who were chosen for the main study. The response rate was 59.5% (n=1253), with 96% being males, and the average age being 45 yrs. The respondents had practised, on average for 18 yrs for 37 hours / week. Of the respondents, 59.5% (n=746) had experienced musculoskeletal pain during the previous year, similar to the study by Bassett (1983). The results indicated that low back pain is most commonly reported, followed by pain in the neck and shoulder and then upper back and legs. A pain scale was used (0-10; where 0 indicating no pain and 10 severe pain) in the questionnaire. Back pain was reported to be 4.6 on average on the pain scale, which was the highest intensity when compared to other regions. Sixty percent of the respondents reported musculoskeletal pain and the treatment intervention was reported only to be effective for 1 out of 5 dentists, which included exercise, heat, and medication etc. They suggested that a future intervention should concentrate on the prevention of musculoskeletal disorders, investigate practicing characteristics with the presence of pain, document working positions and identify the causes of pain.

Milerad and Ekenwall (1990) evaluated the occurrence of musculoskeletal symptoms and investigated whether Raynaud's phenomenon occurs excessively in dentists. One hundred dentists were randomly selected from the dentist register in Stockholm (Birth date: 1932 to 1952; 10 yrs clinical experience) and 100 pharmacists in the same age span were also selected from Stockholm. The dentists and pharmacists were interviewed by telephone by a physician using a questionnaire. Questions about work situation were included for dentists in addition to the pharmacists group.

The work related questions for dentists were:

- Years in clinical dentistry
- Work hours per day
- Minutes per day with high speed drills, other drills or ultrasound devices
- Sitting / Standing work position

The general questions include

- Handedness
- Vibration exposure during leisure time
- Smoking habits
- Diseases other than musculoskeletal disorders
- Symptom related questions – Neck; shoulder; upper arm; forearm and hands at any time before interview
- Neck and Shoulder – Nordic Questionnaire

The results indicated low exposure of vibration in both groups. Hypertension was the most common diagnosis made (6 dentists; 7 pharmacists). Mean employment time (19 years for dentists and 20.3 years for pharmacists). Eighty five dentists worked sitting, 11 dentists worked both in sitting and standing, and 3 only standing. Dentists had a higher frequency of cervical symptoms than pharmacists. Age related increase in symptoms was noted in females. (48% had symptoms in the 35 to 44 yrs group and 73% had symptoms in the 45 to 55 yrs group). Dentists with neck symptoms also had shoulder and arm symptoms more often than pharmacists with neck symptoms. Twenty dentists and 10 pharmacists had neck symptoms in the last 12 months and both had symptoms for more than 30 days.

The study by Milerad and Ekenwall (1990) also reported, in relation to

Raynaud's Phenomenon: Dentists reported more than pharmacists. Six dentists and 1 pharmacist had symptoms in the dominant hand. This was considered to be due to presence of vibration during dental procedures.

Neurological symptoms: There was a high risk in dentists compared to pharmacists. Symptoms were localised in the dominant hand in both dentists and pharmacists. Median and ulnar nerves were commonly affected in both dentists (27) and pharmacists (7).

It was concluded that dentists have a higher than expected risk for musculoskeletal symptoms in the neck and upper extremities and the reason for this is the working posture.

Rundcrantz and colleagues (1990) studied the frequency of pain, ache and discomfort in the musculoskeletal system among dentists in Sweden, including headache, cervical and shoulder symptoms in order to find a possible correlation between these symptoms and different kinds of working positions. The investigation consisted of the standardized Nordic questionnaire for the survey of musculoskeletal symptoms in different parts of the body during the previous 12 months and previous seven days and specific questions about working posture of the dentist. A pain scale was also included (0-10; where 0 indicating no pain and 10 severe pain). The first questionnaire was distributed to 395 dentists and 90.9 % (n=359) responded to the questionnaire. Of the 359 dentists 193 (54 %) were women and 166 (46 %) were men. The age varied between 25 to 65 years. Mean age was 43.3 for females and 45 for males. Mean work experience was reported as 17 years. The dentists worked an average for 35.5 hours per week. Women worked on average of 32 hours and men for 39.5 hours. Of the 193 female dentists, 46 (23%) and male dentists 8 (5%) worked less than 30 hours per week.

Working Posture: Three hundred and thirty eight dentists (95%) worked in a sitting position, 11 (3%) worked standing and 7 (2%), used both positions. The dentists who worked standing were generally older. The most frequently used clock related positions reported were found to be 9 and 10 ‘O’ clock positions (Chapter 1; Section 1.28). Nine dentists (5%) had the patient sitting, 44 (12%) had the patient half lying and most of them 290 (85.8%) had the patient lying. Seventy four percent of dentists placed the patient in such a position that a direct view was possible, 196 (55%) used a mouth mirror in positions where a direct view was difficult to obtain, and 62 (18%) used a direct view in these situations, and a total of 96 (27%) of these indicated pain and discomfort in the musculoskeletal system.

Pain and Discomfort: 259 (72%) had had symptoms in the previous 12 months, 74% had pain in the head, neck and shoulders. This was more pronounced in females, of whom 46% suffered from headaches, 61 % from pain in neck and 62 % had pain in the shoulders. The results indicated that dentists who positioned the patient carefully so that a direct view was gained had a significantly lower frequency of headaches. It is clear from the results that those dentists who frequently used a mouth mirror did not have any discomfort in the upper locomotor system.

Rundcrantz and co-workers (1991) performed a prospective study to follow-up the pain and discomfort among dentists in the cross-sectional study carried out in 1987 and studied the influence of ergonomic factors on the course of symptoms. The investigation consisted partly of the standardized Nordic questionnaire for the survey of musculoskeletal symptoms in different parts of the body during the previous 12 months and previous 7 days and partly of specific questions about working posture of the dentist. A pain scale was also included.

The first questionnaires were distributed in November 1987 to 395 dentists and the response rate was 90.9% (359) dentists. At follow up in 1990 identical questionnaires were sent to those 359 dentists, finding that 12 dentists were retired, three dentists had died and, of the remaining 344 dentists, 315 responded (92 %). Forty eight dentists did not take part in the follow up study, of which 11 were without pain and discomfort in 1987 and the others reported symptoms. Of the 311 dentists, 56 worked less than 30 hours per week in 1990 (48 women and 8 men), compared with 46 dentists who worked less than 30 hours per week in 1987 (41 women and 5 men). Two hundred and seventy

(87%) of the 311 dentists were found to not suffer from any other long-standing disease in 1987 or in 1990. However, of the 311 dentists, 262 (84%) had symptoms in different parts of the locomotor system in the previous 12 months. The occurrence of pain and discomfort had increased in most parts of the body except in lower back. The differences were significant only in shoulders and the symptoms were more pronounced in female dentists. Of the 225 dentists who reported pain in neck and shoulders in 1987, 112 (75 women and 37 men) also had low back pain. Seventy dentists had the same symptoms in 1990. In summary, the results considered that pain and discomfort in the locomotor system among dentists had a protracted cause and a high incidence and the reported symptoms appeared to have a moderate impact on working ability, this being similar to the study reported by Milerad and Ekenwall (1990).

Mandel (1993) performed a National Survey of 1,218 ADA (American Dental Association) members and reported on occupational risks in dentistry. The survey indicated that 60 to 80% of adults experienced musculoskeletal pain, in particular, back pain, at some point in their lives. After colds, it was found to be the second leading cause of absence from work. The results of the survey indicated that 60 % of 1253 dentists reported having some type of musculoskeletal pain during one year. The study by Rundcrantz et al (1990) indicated a higher incidence of pain and discomfort in the neck; shoulder and low back among dentists than other occupational groups. The survey reported that dental hygienists and dentists complain equally (62%) about Low Back Pain, even though the hygienists were, on average 15 years younger.

Marshall et al (1997) described the prevalence and distribution of symptoms of musculoskeletal disorders in New South Wales dentists and found that there was a relationship between these symptoms and work practices (Type of Dentistry; Position used to practice; and Duration of Practice). A questionnaire was sent to 442 members of the Australian Dental Association and included questions on headaches, pain, numbness, pins and needles or weakness. The response rate was 80% (n=355), with 14% of respondents being females and 93% being right handed. The average work period taken before a 10 minute rest period was 172 (+/- 101) minutes. The practice positions used were 87% sitting (n=306), 10.5% standing (n=37) (Older People), while 65% (n=230) used 4 handed dentistry. Eighty two percent reported musculoskeletal symptoms in general, with four handed dentists group reporting more pain. Central back pain (n=140) and headache 52% (n=192) were reported generally among all the groups.

Dentists were predominantly reported to be right handed and used a sitting posture to practice. They adopted a clock related practice position between 9 and 12 (Chapter 1; Section 1.28). Headaches were reported in the younger age groups and only 18% were symptom free among the whole group. Increased pain was reported in four-handed dentists. This was associated with a reduction of movement, and with greater use of the dental assistant. Distal neurological symptoms (Pins and Needles / Numbness) in the upper limb were reported to be common in the dominant hand but shoulder pain did not vary with the dentists. Pain and headache were the most commonly reported symptoms, but neurological symptoms in hands were also prevalent.

Finsen et al (1998) carried out a questionnaire study to identify work tasks and working conditions of dentists. One hundred and fifteen members of the Danish Dental Society were selected (mean age 45 yrs; 41% female and 59% male). The study was performed to identify common work tasks, pauses and working positions (3 and 9 ‘O’ clock positions). The Nordic Standardized questionnaire on disorders was also included. The response rate for the questionnaire was 86%, with the results indicating that work time was less in females, and musculoskeletal problems (neck and shoulder region) were present in two-thirds of the dentists, with more pain among dentists who worked for long hours.

Akesson et al (1999) explored the variation of musculoskeletal disorders in the neck, upper extremities, and hips over a 5-year period in different groups of Swedish female dental personnel. The subjects were 30 dentists, 30 dental assistants, 30 dental hygienists and a control group of 30 female medical nurses. There was a five-year follow-up with 29 dentists, 29 dental assistants, 30 dental hygienists and 27 medical nurses. In year 5 a clinical diagnostic examination of each subject was carried out.

The Nordic questionnaire for neck and shoulder was used at Year 0 and Year 5 and included pain ratings by the Borg 10-Scale category ratio, and the Functional Disturbances Scale – 0 – 4 (disorders and their influence on work and leisure). Seventy-eight percent (n=57) reported pain at Year 0 and in Year 5, 68% (n=50) reported symptoms from at least one anatomical region in the past week and 92% (n=68) reported symptoms over the past 12 months. Physical examination included a standard protocol with emphasis on neck, shoulder and hip. Findings were recorded in 64 (89%)

respondents and diagnosis was given in 35 (49%). The results indicated higher prevalence of musculoskeletal symptoms in dentists compared with medical nurses but the dental hygienists left the occupation in large numbers due to increase of symptoms while the dentists continued with their job despite an increase in musculoskeletal symptoms. The musculoskeletal disorders reported among the Swedish dentists were comparable to that of the Australian dentists.

Ratson and Kanner (2000) determined the prevalence of musculoskeletal symptoms among Israeli dentists and explored the relationship of work posture, bio-demographic factors, and workload factors with those symptoms. Sixty male dentists were randomly selected from yellow pages of Jerusalem (both self employed and salaried) with at least 4 years experience, and working at least 18 hours per week and with at least five patients per working day. Mean age was 46 (SD 8.66 - 32-67). Thirty dentists reported that they worked 80% of time sitting, 13 reported alternate sitting and standing (< 40% sitting and < 90% standing). In addition, nine dentists working in alternating (both sitting and standing) positions were recruited. Two Groups were selected, Group 1 using a sitting position and Group 2 used alternating position.

The investigation by Ratson and Kanner (2000) consisted of the Standardised Nordic Questionnaire for analysis of musculoskeletal symptoms in 9 anatomical regions and, for the survey, low back symptoms during the past 12 months and specifically in the past 7 days, plus questions regarding practice, bio-demographic variables and work loads. Results indicated that the mean years of experience as 19.24 (SD 5.7), and only a minority of dentists using (22% of sample) altering positions (both sitting and standing). Musculoskeletal symptoms reported in the previous 12 months were predominantly in the lower back (55%) and neck (38.3%) and in the previous 7 days were the neck (28.3%) and shoulders (15%). No statistical significance was found in reported symptoms in the previous 7 days. Only the low back region in the previous 12 months showed statistical significance between the two groups. The severity of symptoms among dentists in the sitting position was higher than among dentists who used altering position. There was a statistical difference between age, time load and human load between two groups. The altering position group had higher mean scores on all three variables. The three main practice areas among the study population were general practice (36%), Maxillo Facial Surgery (27%) and Oral Rehabilitation (25%). Dentists who worked in a sitting position were found to have more severe low back pain than those who alternated between sitting and standing. They suggested that altering position should be recommended for dentists.

Burke and Freeman (1997) assessed the reasons for premature retirement among practising dentists. The details of the reasons for premature retirement due to illness were requested from organisations operating in the private medical sickness insurance industry. Data from the Dentists Provident Society was provided from 1981 to 1992 and were categorised as Musculoskeletal, Cardiovascular, Respiratory, Digestive, Tumours, Neurotic Symptoms, Accidents and Diseases of skin, eyes and ears, and the nervous system. A total of 393 / 401 (8 Disregarded) consecutive cases were used for analysis. The most frequent medical causes of premature retirement were reported to be musculoskeletal, cardiovascular and neurotic symptoms. Further analysis of musculoskeletal diseases (n=116) indicated that cervical spondylosis (n=23:19.8%), arthritis of the spine (n=17:14.6 %) and arthritis of the hands (n=17:14.6%) were the most common cases of premature retirement in this group. The age of retirement was 50 years or more in 91% of cases.

Fifty-five percent of cases (n=227) examined were in the 50-59 age group at the time of premature retirement and 24.9% were in the >60 age group (n=98) and the remaining 20% were not reported. Comparing these groups it was interpreted that the main cause of premature retirement was due to high prevalence of musculoskeletal disease and suggests that physical rather than emotional stress was the most frequent cause of premature retirement in this group. The importance of correct working posture was considered to be important.

All the above studies using questionnaires show similar results i.e. the musculoskeletal symptoms were reported to be $\pm$ 60% among the dentists and back pain was found to be most commonly reported by dentists, followed by pain in the neck and shoulder. The summary of the findings are reported in table 2-1.

Author and Country	Study Population	Key Findings
Bassett (1983) - Canada Questionnaire survey of dentists.	200 questionnaires at a meeting at University of Toronto. 700 questionnaires at a provincial convention in Toronto. (Response rate: 52%)	62.2% had back/neck pain some time in their lives and 38.8% were currently suffering from such a problem. Back pain was greatest among dentists aged 30 to 50 years. Dental hygienists concurrently surveyed had a similar incidence of back pain.
Shugars et al (1987) - U.S.A Questionnaire survey of dentists.	2000 questionnaires to members of American Dental Association. (Response rate: 59.5%)	59.5% had musculoskeletal pain during the previous year. Low back pain in most commonly reported, followed by neck, shoulder, upper back and legs.
Milerad & Ekenwall (1990) - Sweden Investigated Raynaud's phenomenon in dentists by telephone interviews.	100 dentists randomly selected from dentist register in Stockholm and 100 pharmacists from Stockholm.	Dentists had higher frequency of cervical symptoms compared to pharmacists. Dentists with neck symptoms also had shoulder and arm symptoms. Dentists reported Raynaud's phenomenon in the ratio of six dentists to one pharmacist. Dentists have a higher than expected risk for developing musculoskeletal disorders.
Rundcrantz et al (1990) - Sweden Investigated bodily pain among dentists using Nordic questionnaire.	395 dentists. (Response rate: 90.9%)	95% worked in sitting posture. 72% had had symptoms in the past year. 74% had pain in the head, neck and shoulders.
Rundcrantz et al (1991) - Sweden Studied the influence of ergonomic factors on the course of symptoms using Nordic questionnaire.	Follow up study from 1987 – 359 dentists. (Response rate: 92%)	84% had had symptoms in the past year. The occurrence of pain increased in most parts of the body except lower back. This high incidence of musculoskeletal symptoms appears to have moderate impact on working ability.
Mandel (1993) – U.S.A Questionnaire survey of dentists.	1218 questionnaires to members of American Dental Association. (Response rate: 59.5%)	60% to 80% experience musculoskeletal pain at some point in their lives. 60% of dentists reported musculoskeletal symptoms in the past year.

Marshall et al (1997) - Australia Questionnaire survey of dentists	442 questionnaires to members of Australian Dental Association (Response rate: 80%)	82% of dentists reported musculoskeletal symptoms. Head ache was commonly reported followed by back pain.
Finsen et al (1998) - Denmark Questionnaire survey of dentists using Nordic questionnaire.	115 questionnaires to members of Danish Dental Society (Response rate: 86%)	Musculoskeletal disorders were reported among two-thirds of dentists, with more pain reported among dentists who work for long hours.
Akesson (1999) – Sweden Questionnaire survey (5 year follow-up) of Swedish female dental personnel using Nordic questionnaire.	30 female dentists, 30 female dental hygienists and a control group of 30 female medical nurses.	78% reported pain in year 0 and 68% reported pain in year 5 from at least one anatomical region, and 92% reported symptoms over the past 12 months. Physical examination recorded findings in 89% and diagnosis was given to 35%. Musculoskeletal symptoms were prevalent among dentists compared to nurses.
Ratson & Kanner (2000) - Israel Questionnaire survey of dentists using Nordic questionnaire.	60 male dentists randomly selected from yellow pages of Jerusalem.	55% reported lower back pain and 38.3% reported neck pain in the past 12 months. 28.3% reported neck pain and 15% reported shoulder pain in the past week. Severity of symptoms was higher among dentists working in the sitting position compared to dentists using altering position (sitting and standing).
Burke & Freeman (1999) – U.K Investigated the premature retirement among dentists due to illness.	Data from Dentists Provident Society from 1981 to 1992. 393 consecutive cases was used for analysis	The most frequent medical causes of premature retirement were reported to be musculoskeletal (29.5%), cardiovascular (21.1%) and neurotic symptoms (16.5%). 82.7% of cases examined were in the >50 yrs age group

Table. 2-1. Summary of key findings from the questionnaire studies in dentistry.

Amick and colleagues (2003) investigated the musculoskeletal symptoms among the employees from a state department of revenue services. They examined the effect of an office ergonomics intervention in reducing musculoskeletal symptom growth over the work day and pain levels throughout the day. These workers worked in sedentary computer-intensive jobs (requiring at least 4 hours per day working at an office computer and at least 6 hours per day sitting in an office chair). Individuals agreeing to participate were assigned to one of three study groups: a group receiving a highly adjustable chair with office ergonomics training, a training-only group and a control group receiving training at the end of the study. The intervention consisted of a highly adjustable chair and a one-time office ergonomic training workshop with a series of educational follow-ups conducted concurrently with the chair distribution.

Data collection occurred 2 months and 1 month before the intervention and 2, 6, and 12 months post intervention. During each round, a short daily symptom survey (DSS) was completed at the beginning, middle, and end of the workday for 5 days during a workweek. Respondents rated their level of pain or discomfort on a scale from 0 (none) to 10 (extremely severe) for each of nine body areas (neck, shoulders, upper back, elbows, lower arms/wrists/hands, lower back, buttocks/thighs, knees, and lower legs/ankles/feet). The primary outcome variable was the sum of the ratings, which could range from 0 (no pain in any body area) to 90 (extremely severe pain in all body areas). Pain scores were not calculated if any of the body area scores were missing. A longer work environment and health questionnaire (WEH) was completed just once subsequent to the week of DSS completion. Thirty different covariates and potential confounders were measured in this.

The workers who received a chair and office ergonomics training experienced reduced development of pain and discomfort over the work day compared with workers who received only training, or compared with a control group. No significant reduction in symptom development over the workday for the training- only group compared with the control group was observed. Amick et al (2003) concluded that the office ergonomic intervention of a highly adjustable chair, coupled with ergonomic training, should increase ergonomic knowledge and skills, reduce musculoskeletal loads and strains, and allow users to maximize health and productivity.

Karasek et al (1998) investigated the Job Content Questionnaire, designed to measure scales assessing psychological and physical demands. They included the psychosocial scales such as decision latitude, psychological demands, and social support on their questionnaire, in order to predict stress-related risk associated with a job. Physical demands of the job and job insecurity were also investigated in the questionnaire. The decision latitude scale investigates the psychological strain occurring due to high psychological demands and helps predict strain development and learning over time which is important in most of the jobs. The decision latitude scale further investigates skill discretion and decision authority. The skill discretion is measured by a set of questions that assess the level of skill and creativity, which is considered important in dentistry. The decision authority assesses the possibilities for workers to make decisions about their work, which may also be considered important in dentistry. Physical demands are investigated in the Job Content Questionnaire as the physical demands of a job combined with mental demands are considered an important factor in the development of a work related musculoskeletal disorder. This is an important factor to be investigated in dentistry as the musculoskeletal disorder has been found as the primary reason for premature retirement in dentists (Burke and Freeman, 1997). Since the skill discretion, decision authority and physical demands of work are important in investigating the psychosocial demands of dental work these questions were included in the questionnaire study.

Dickinson et al (1992) undertook a study using the Nordic Musculoskeletal Questionnaire in the U.K. The questionnaire included a body chart with nine body areas shaded and defined (neck, shoulders, upper back, lower back, elbows, wrists/hands, thighs, knees and ankles) (Dickinson et al, 1992 and Kaewboonchoo et al, 1998). The questions requested a ‘yes’ or ‘no’ response for each body area concerning the annual prevalence, any disability during the last year and weekly prevalence. The questionnaires were distributed to six Health and Safety Executive (HSE) professional staff, data entry clerks, 10 HSE administrative clerks and 481 checkout staff at 10 supermarkets. Comments were obtained from the HSE professional staff, data entry clerks and HSE administrative clerks and several questions were changed to improve understandability and repeatability of the questionnaire. The findings were found to be consistent with respect to repeatability of the questionnaire; the need for 80% response rate for the questionnaire was emphasized. The nine body areas included in the Nordic Musculoskeletal Questionnaire were considered to be the common areas affected by a musculoskeletal disorder, and are relevant for dentists and included in the questionnaire.

2.2 The Questionnaire Study

The questionnaire study was undertaken with the dental students at University of Birmingham - School of Dentistry and dentists working in the community in the West Midlands.

2.2.1 The Questionnaire (Appendix I)

The questionnaire was based on the work of Amick et al (2003), Karasek et al (1998) and various other studies on ergonomics detailed in section 6.2. The questionnaire included questions on demographic data of the dentist, dental practice, hours of work, general health, pain, questions on dental procedures used, operator seat features and some psychological questions related to the general attitude and motivation towards work.

2.2.2 Introduction and Development of the Questionnaire (Appendix I)

Questions on Demographic Data

Year of Graduation (Question 1): To calculate the years of Experience

Age and Sex (Questions 2 and 3): To compare the age and sex related changes in reported musculoskeletal symptoms.

Practice related questions (Questions 4 to 10): The questions related to area and types of practice are included. This is to ascertain whether there is difference between the dentists practicing in the city, suburban and rural areas in the musculoskeletal symptoms reported. Also to ascertain whether the dentists working single handed report increased pain more than dentists working in a partnership/group. Questions on speciality of practice were included to determine if there is a correlation with incidence of back pain.

Questions on general dental work and health

Hours of Work (Question 11): To ascertain the number of hours spent by the dentist treating patients, sitting on operators stool and sitting on another chair at their work place (Amick et al. 2003). These questions may be related to the amount of pain reported by dentists.

Rest Breaks (Questions 12 to 14): Frequency of rest breaks during the past week, on a typical working day, and frequency of rest given to hands on a working day are included (Amick et al. 2003). These questions can be related to amount and area of pain reported.

General Health (Questions 15 to 17): General health, health problems and use of glasses or contact lenses were included. These questions investigate the general health condition of the dentist.

Magnifying Loupes (Question 18): To ascertain if dentists using magnifying loupes report less pain compared to other dentists.

Training in Operating Position (Question 19): To ascertain if the dentists had any training on operating position during their undergraduate or postgraduate degree course. This will be compared to the results of the questionnaire sent to Dental Schools (Chapter 4).

Questions on Dental Procedures used (Questions 20 and 21)

This part investigated findings on frequency of certain dental procedures used, and the force used by wrist and hands for those procedures. These questions relate to the area and amount of pain reported.

Questions on Operator Stool

Use of Operator Stool (Question 22): The questions on how they are seated and how their body is supported on their operator stool, Questions on how comfortable their arms, legs, feet and neck rests when they are seated on their operator stool (Amick et al. 2003). These questions determine level of comfort when working on their operator stool.

Height and Weight of the Dentist (Question 23): This question may be helpful to ascertain whether their operator stool is suitable for their body type.

Type of the Operator Stool (Question24): The type of operator stool (Flat or Saddle shaped seat) will help to compare and relate the musculoskeletal symptoms reported by dentists. To identify whether the dentists in the conventional seat group use Bambach seats or a saddle seat that is not the Bambach.

Age of Operator Stool (Question 25): This question is included to determine how long the dentists have been using their operator stool.

Adjustable Features of the Operator Stool (Question 26): The questions on height, seat angle, back support and arm support are included to ascertain any relation to their working posture (Amick et al. 2003).

Training on using Operator stool (Questions 27 and 28): These questions investigate whether the dentists know how to adjust their operator stool, this being an important factor in determining whether dentists adjust their operator stool according to the requirements for each patient and to the height of dental chair.

Questions on Pain

The questions relating to pain and the regions affected were based on the Nordic Musculoskeletal Questionnaire (Dickinson et al 1992; Johansson, 1994; Kaewboonchoo et al. 1998 and Karasek et al. 1998).

Pain reported in the previous four weeks (Question 29): This question determines whether the dentists had any pain in the last four weeks.

Areas of Pain (Question 30): This question provides information on the regions of the body commonly affected in dentists.

Pain and Dental Work (Question 31): This question ascertains whether perceived pain among dentists has affected their dental work.

Amount of Pain (Question 32): To ascertain the amount of perceived pain reported by dentists using a visual analog scale.

Medications during the past 4 weeks (Question 33): This question is to identify whether the dentists have taken any medications for pain in the past four weeks.

Consultation for pain (Question 34): This question is to identify if the dentists have consulted a general practitioner, a physiotherapist or any other practitioner regarding their pain.

Psychological Questions (Questions 35 and 36)

These questions were based on Karasek et al (1998) which identify how difficult is for the dentist to perform certain daily activities and to identify whether they agree or disagree with statements relating to their attitude towards work and pain.

2.2.3 Pilot Study

The questionnaire was sent to 30 students studying for the Masters in General Dental Practice at the University of Birmingham - School of Dentistry in order to obtain comments and feedback on the questionnaire. The students were asked to complete the questionnaire and a separate feedback sheet was included with the questionnaire. The feedback sheet included the following questions

- How long it took to complete the questionnaire
- Generally how do you feel about the questionnaire
- Comments about specific questions on the questionnaire.

Specific Comments from the Masters students on the questionnaire included were

- Clear instructions needed for some questions
- Some questions are not straightforward and relevant
- Some questions to be worded better
- Too many styles of questions

In general, the dentists found the questionnaire interesting and relevant but considered it had too many questions as it took a long time to complete. The dentists were not able to interpret the meaning of some questions and found some questions not relevant for the questionnaire. These comments were considered and the questionnaire was modified accordingly. Some questions exploring the psychosocial aspects of dental work were deleted from the questionnaire to make the questionnaire more concise. The Questionnaire used in the pilot study was ten pages long, which was shortened to 6 pages prior to distribution to the participating dentists.

2.2.4 Methodology of Questionnaire Study of Dentists

Subjects:

The subjects were 200 dentists practising in the community (100 dentists using the Bambach saddle seat (BSD) and 100 dentists using a conventional seat (CSD)). The dentists using the conventional seat were randomly selected from Electronic Yellow Pages and the BSD were randomly selected by the manufacturer from their list of dentists who had purchased a Bambach Seat. The manufacturer initially wrote to the selected dentists informing them of the study and asking them to contact them if they did not want to be part of the study. At no time did the research team have access to the manufacturer's database.

Procedure:

The pack containing the questionnaire, covering letter and pre-paid reply envelope was sent to 100 CSD from the School of Health Sciences – University of Birmingham. The manufacturer also sent the same pack to 100 BSD with a covering letter from the project team.

Response Rate: The initial response rate was 21% (n=21) for the BSD and 16% (n=16) for the CSD. Due to the poor response rate a follow up letter was sent to the dentists who had not responded. After the letter was sent a final response rate of 61% (n=61) for the BSD and 60% (n=60) for the CSD was achieved.

2.2.5 Results of the Questionnaire study of Dentists:

Questions on Demographic Data

Year of Graduation: The years of experience of BSD ranged from 3 years to 36 years with an average of 17.6 Years (± SD 8.46). The experience of CSD ranged from 2 to 45 years with an average of 24.6 years (± SD 9.44).

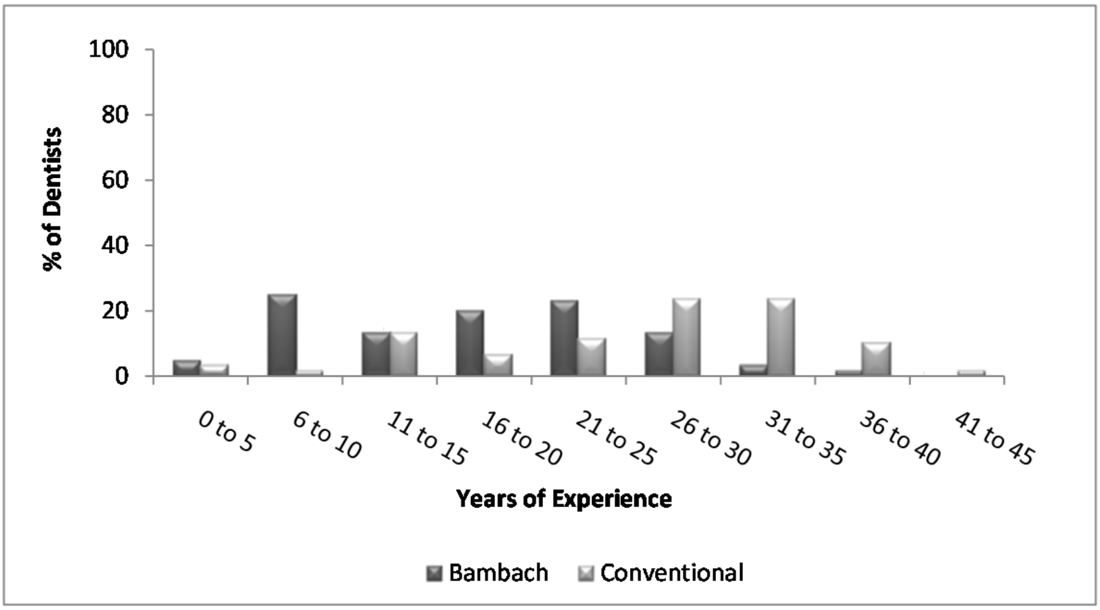


Fig. 2-1. Years of Experience of Dentists

Age and Sex:

The age of BSD ranged from 26 to 56 years with an average of 38.2 (± SD 8.28) years, whereas for CSD the age ranged from 25 to 68 years with an average of 46.2 years (± SD 9.61).

The BSD group had 67.2% (n=41) male dentists and 32.8% (20) female dentists; the CSD group had 88.3% (n=53) male dentists and 11.7% (n=7) female dentists.

Job Status in Dental Practice

Figure 2-4 indicates the percentage of BSD and CSD practising as practice owners, associates, assistants and as salaried reported in the questionnaire

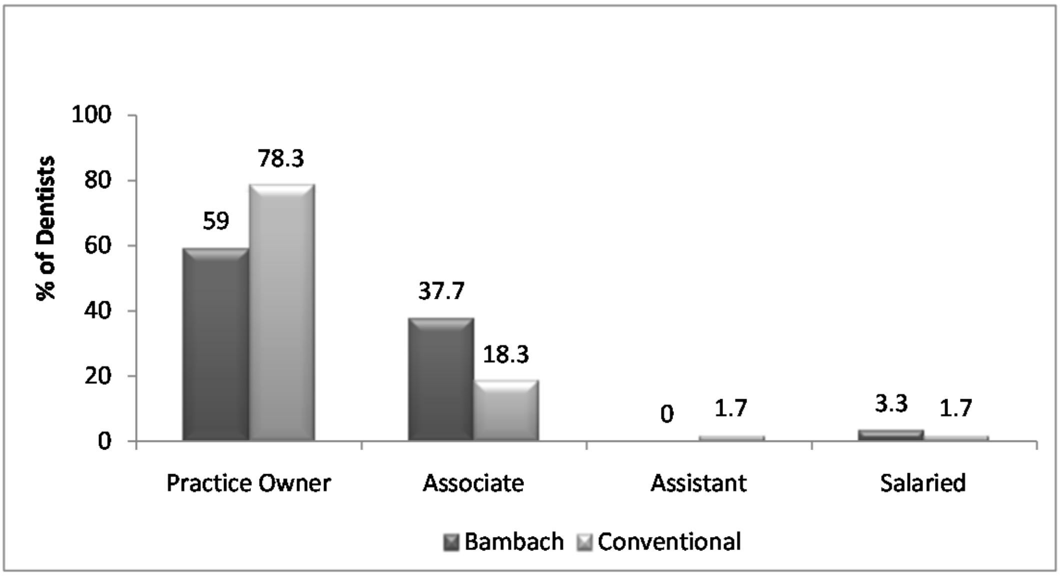


Fig. 2-2. Job Status of Dentists in the Dental Practice

Type of Dental Practice

Figure 2-5 indicates the percentage of BSD and CSD working single handed or in a partnership / group.

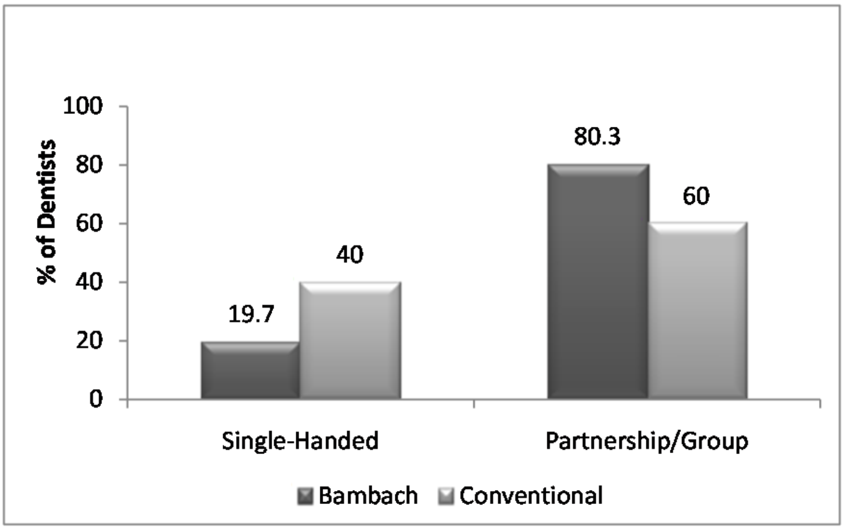


Fig. 2-3. Percentage of Single-Handed and Partnership Dentists

Hours of Work Treating Patients

On average the dentists work around 7-8 hours on each workday, with a slight variation with CSD where they worked for longer hours compared to BSD (figure 2-4).

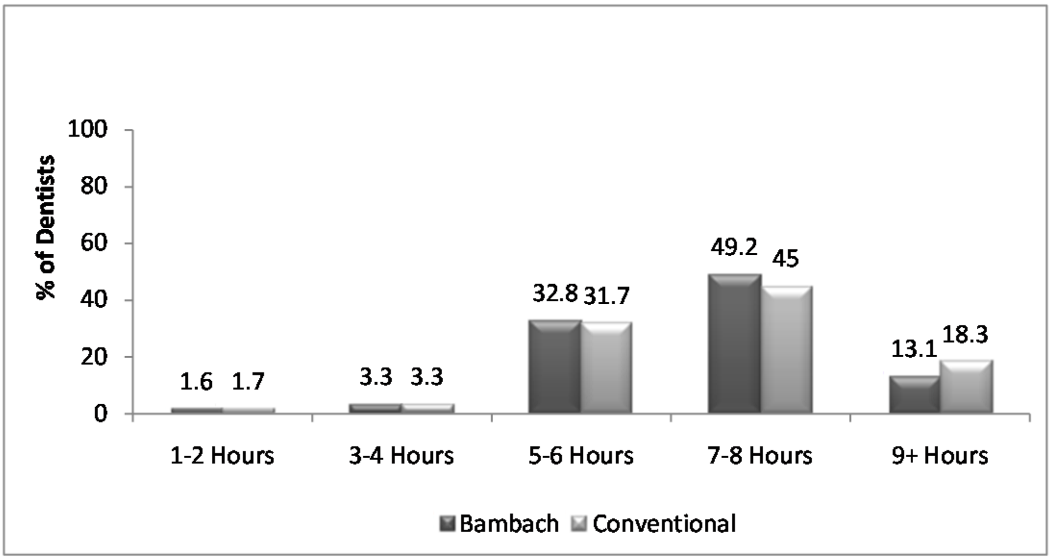


Fig. 2-4. Hours of work spent treating patients in the dental surgery.

Questions on general dental work and health

Rest Breaks: Frequency of rest breaks during the past week, on a typical working day is presented on figure 2-5.

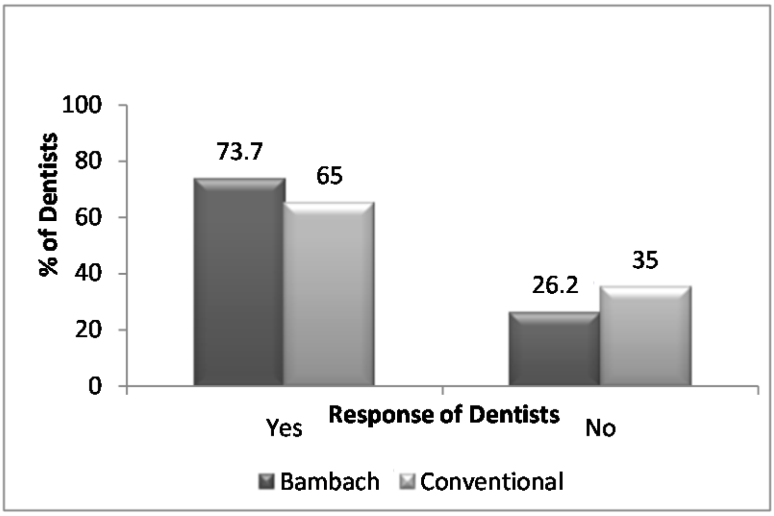


Fig. 2-5. Rest Breaks during Dental Work

Frequency of rest given to hands: The data indicates that 65.6% (n=40) of BSD and 61.7% (n=37) of CSD never rest their hand during a typical workday (Fig 2-6).

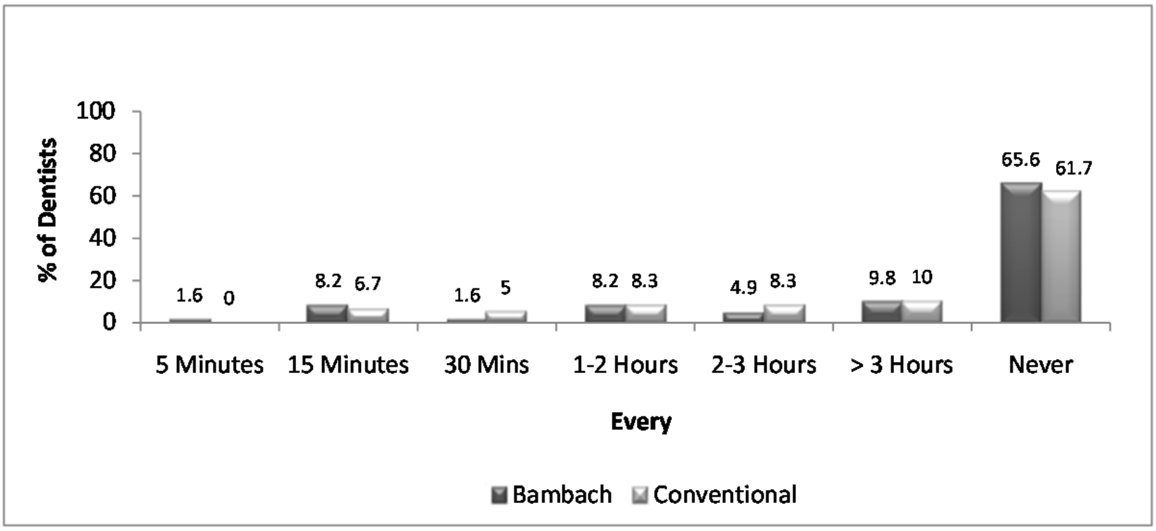


Fig. 2-6. Frequency of rest given to hands in a typical workday

General Health: The general health condition reported by dentists is presented in figure 2-7.

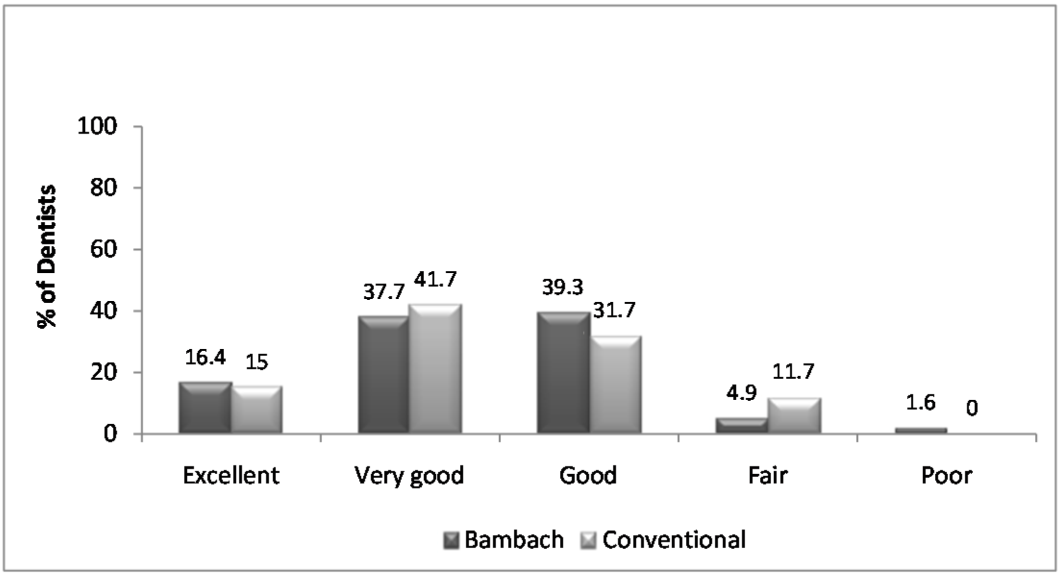


Fig. 2-7. General Health condition of Dentists

Health Problems: The health problems reported were broadly classified into musculoskeletal and medical problems and reported on Fig. 2-8. 24.6% (n=15) of BSD and 25% (n=15) of CSD reported musculoskeletal problems during the four weeks prior to completion of the questionnaire. Only 6.56% (n=4) of BSD and 11.7% (n=7) of CSD reported medical problems, suggesting that musculoskeletal problems are reported by dentists more frequently than medical problems, although the majority of dentists have no musculoskeletal or medical problems.

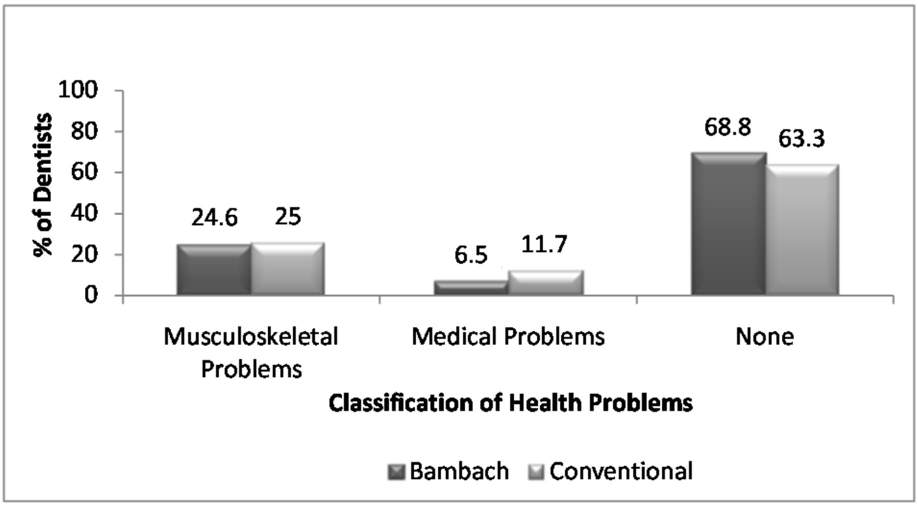


Fig. 2-8. Health Problems reported by Dentists

Magnifying Loupes: The data indicates that 34.4% (n=21) of BSD and 43.3% (n=26) of CSD regularly use magnifying loupes during dental work.

The results indicate that the dentists' work for long hours, with 2/3rd of dentists never resting their hands and 1/3rd of the dentists never taking rest breaks from dental work. Musculoskeletal disorders are reported as a major health problem among dentists.

Training in Use of Correct Operating Position:

BSD: The BSD indicated that 29.5% (n=18) had undergraduate training, 24.6% (n=15) had post-graduate training, 13.1% (n=8) had training both in the undergraduate and post-graduate level, and 32.8% (n=20) had no training.

CSD: The CSD indicated that 20% (n=12) had undergraduate training, 18.3% (n=11) had post-graduate training, 8.3% (n=5) had training both in the undergraduate and post-graduate level, and 53.3% (n=32) had no training. The results indicate that a greater number of BSD had training when compared to CSD. The result suggests that even though dentists have purchased a particular type of operator stool, training in the correct use of the operator's stool may be necessary. They might have no opportunity for training if the stool used was the one available at practice and not new for their use.

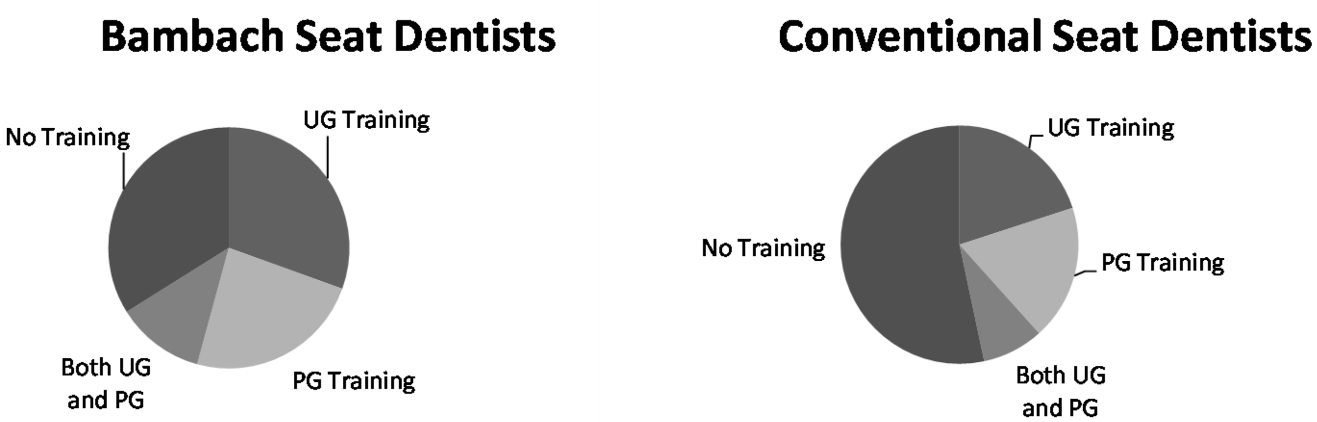


Fig. 2-9. Training in correct operating position

Questions on Dental Procedures used

Frequency of Dental Procedures used:

The frequencies of various dental procedures used by dentists in their workplace reported in the questionnaire were included in this session.

Dental Examination: The frequency of dental examination used is presented in figure 2-10.

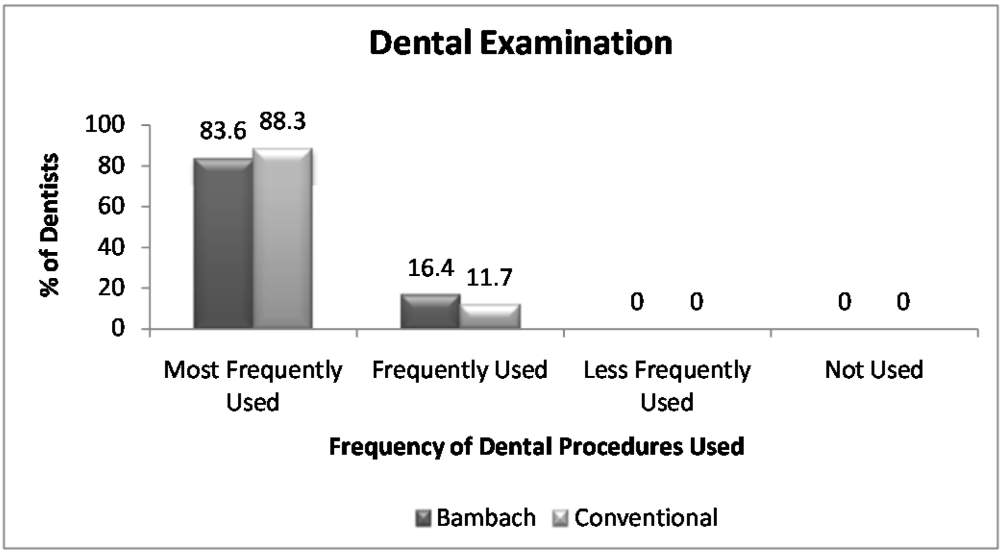


Fig. 2-10. Frequency of Dental Examination

Scaling and Polishing: The frequency of scaling and polishing used is presented in figure 2-11.

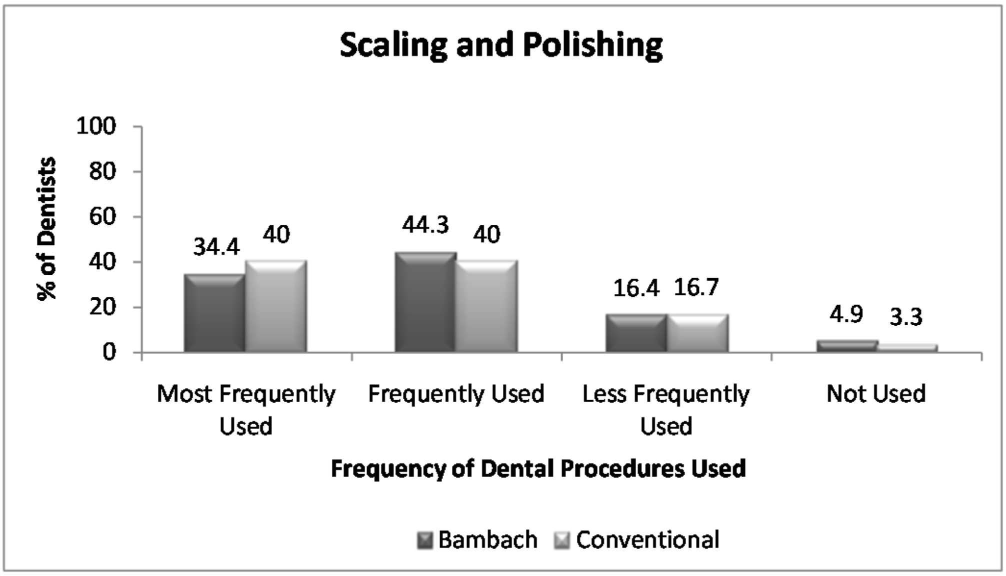


Fig. 2-11. Frequency of Scaling and Polishing

Direct Placement Restorations: The frequency of direct placement restorations used is presented in figure 2-12.

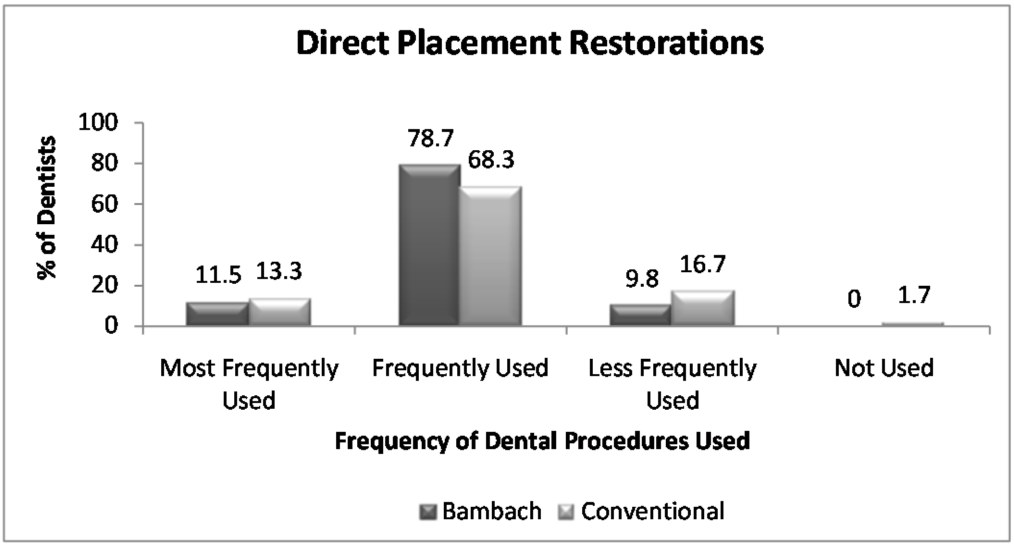


Fig. 2-12. Frequency of Direct Placement Restorations

Orthodontics: The frequency of orthodontics used is presented in figure 2-13.

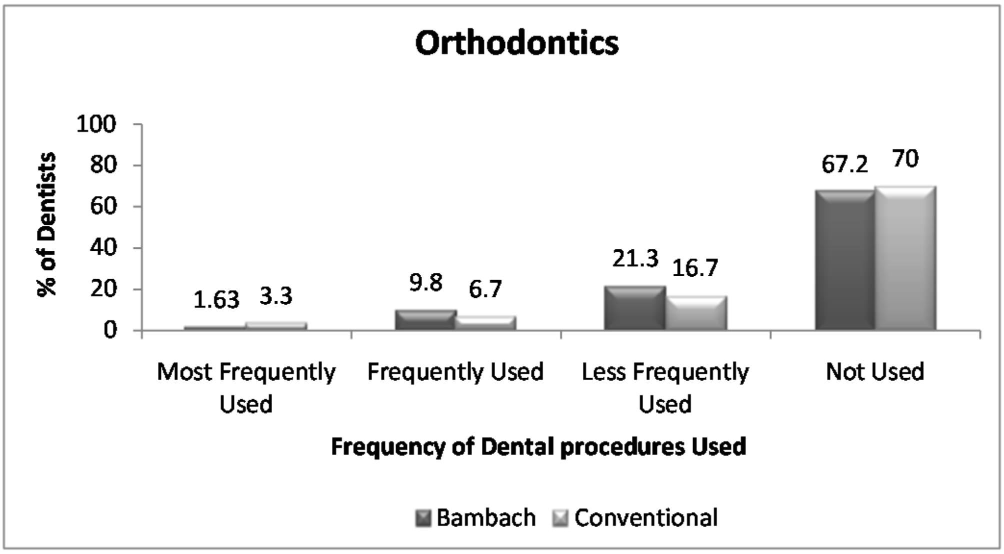


Fig. 2-13. Frequency of Orthodontics

Crown and Bridge Work: The frequency of crown and bridge work used is presented in figure 2-14.

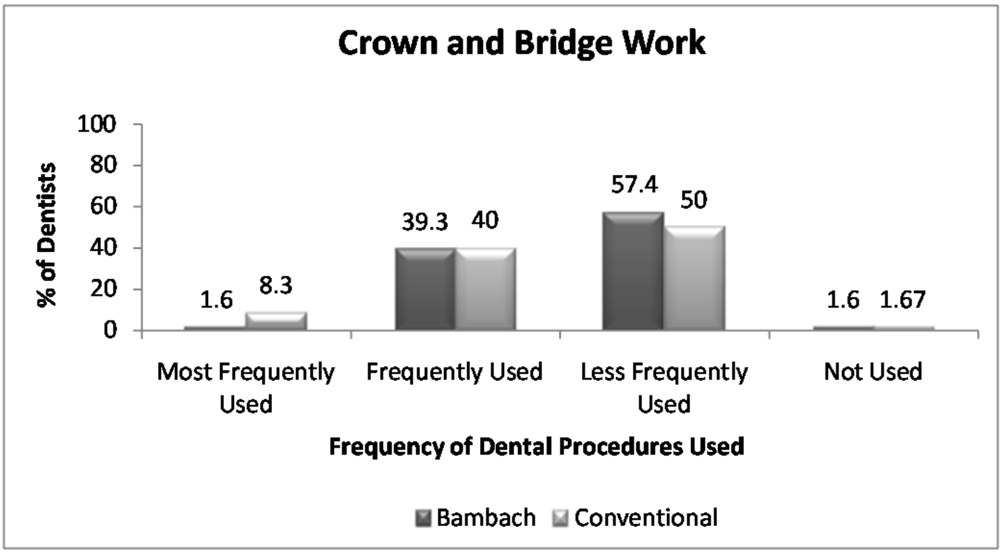


Fig. 2-14. Frequency of Crown and Bridge Work

2.2.5.3.1.6 Removable Prosthodontics: The frequency of removable prosthodontics used is presented in figure 2-15.

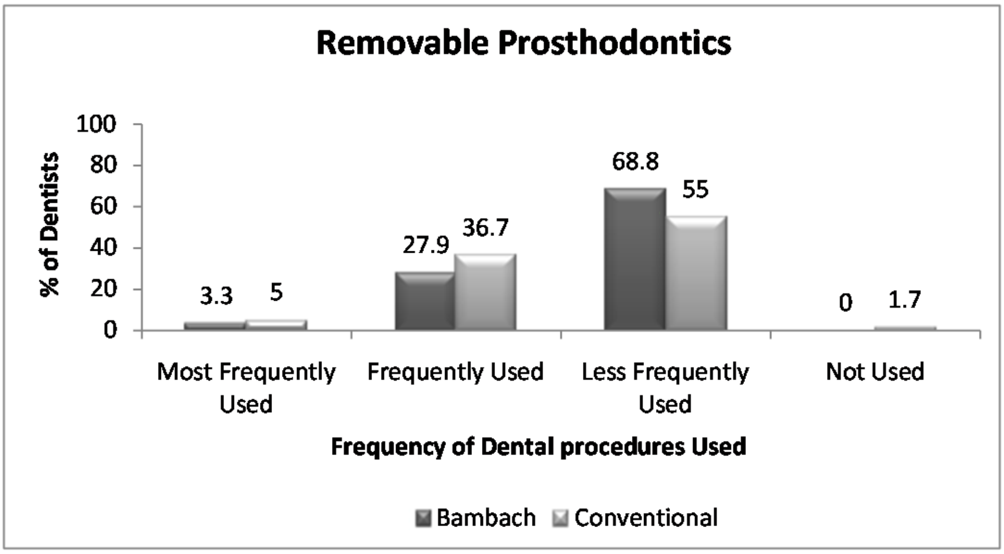


Fig. 2-15. Frequency of Removable Prosthodontics

Endodontics: The frequency of endodontics used is presented in figure 2-16.

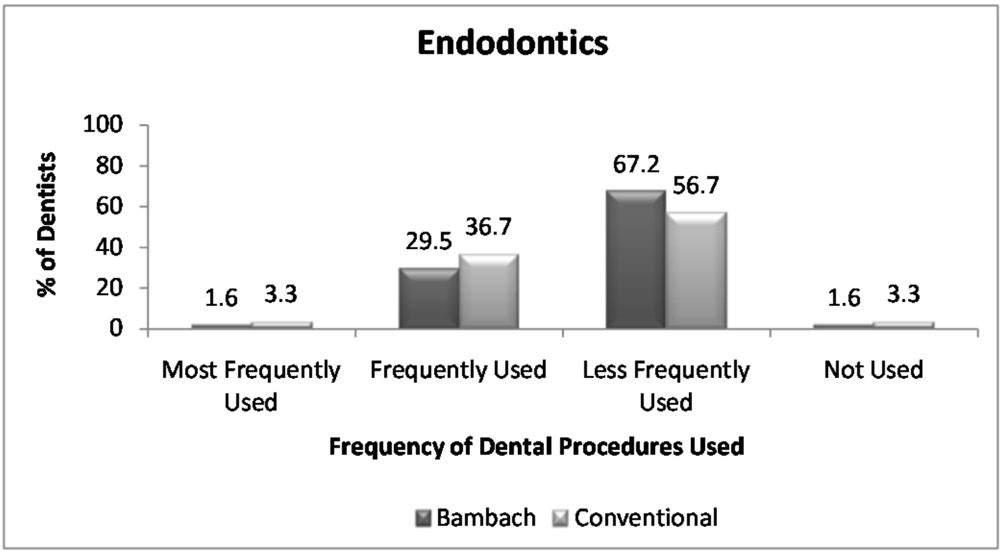


Fig. 2-16. Frequency of Endodontics

Tooth Extraction: The frequency of tooth extraction used is presented in figure 2-17.

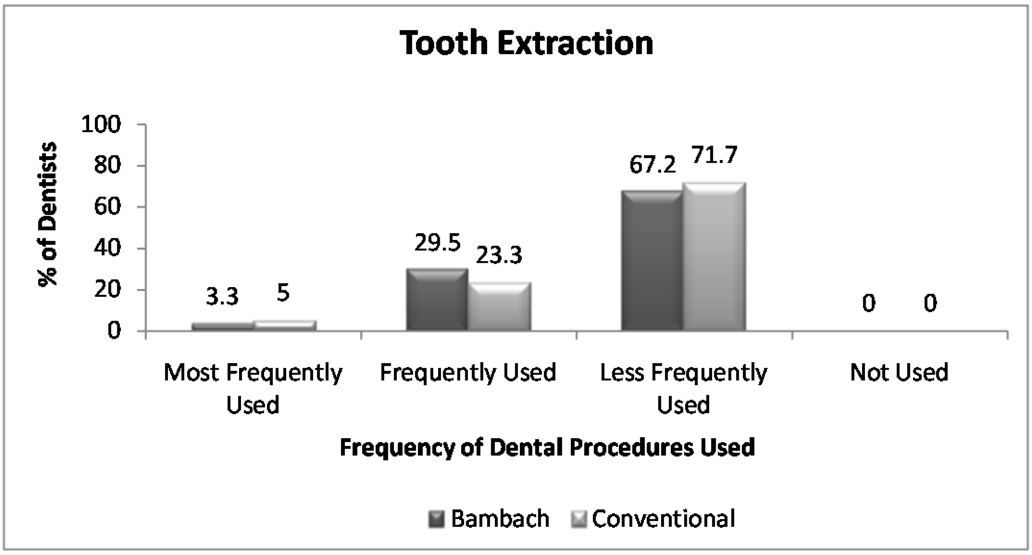


Fig. 2-17. Frequency of Tooth Extraction

The results indicate that both the groups of dentists reported similar results, and dental examination was reported to be the most frequently used procedure, tooth extraction was reported to be less frequently used, and orthodontics was not used by 2/3rd of dentists.

Force used by Wrists and Hands

The force used by wrists and hands during dental procedures used by dentists in their workplace reported in the questionnaire were included in this section. The force used by dentists was recorded on a scale of 1 to 7 for each procedure, where 1 being no force using wrists and hands and 7 being extremely high forces using wrists and hands. The results are presented in figures 2-18 to 2-25.

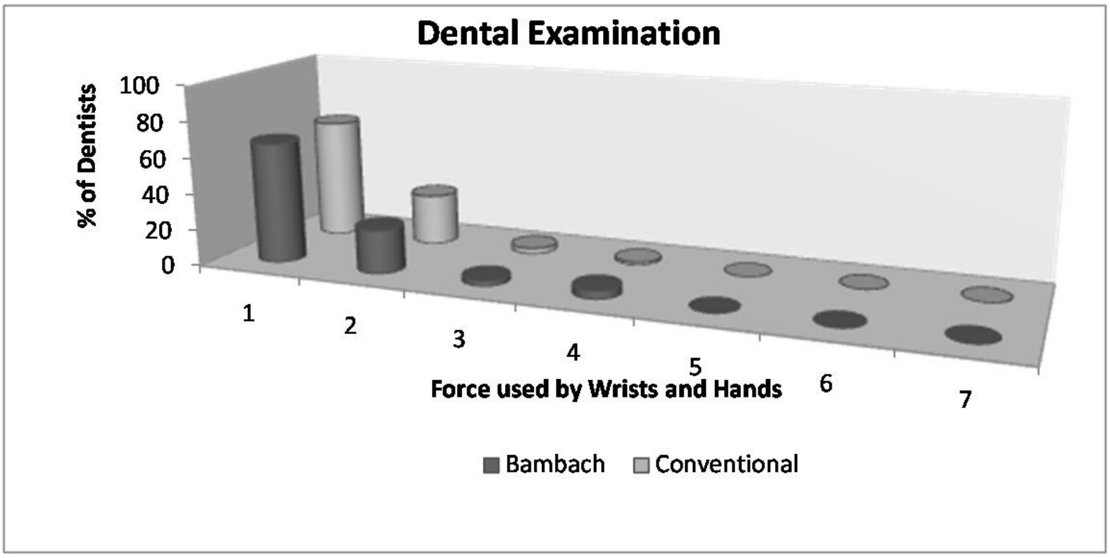


Fig. 2-18. Force used for Dental Examination

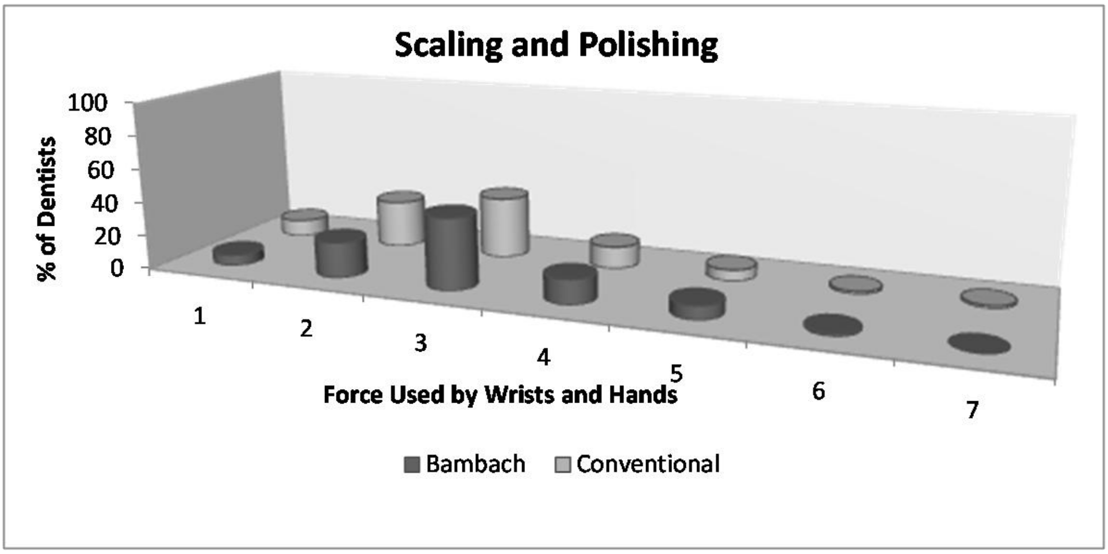


Fig. 2-19. Force used for Scaling and Polishing

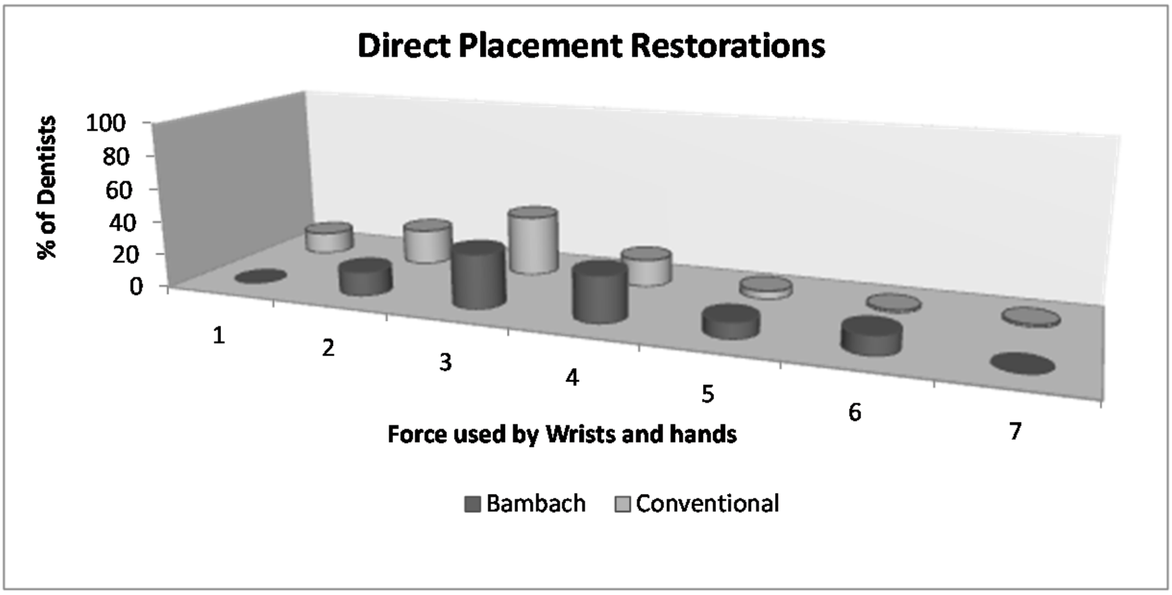


Fig. 2-20. Force used for Direct Placement Restorations

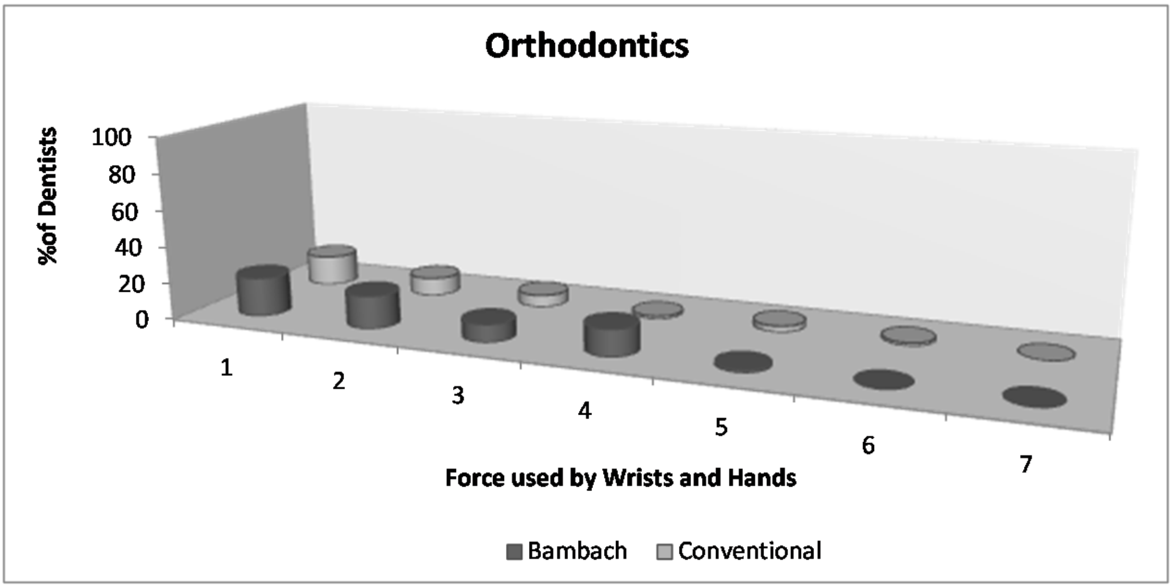


Fig. 2-21. Force used for Orthodontics

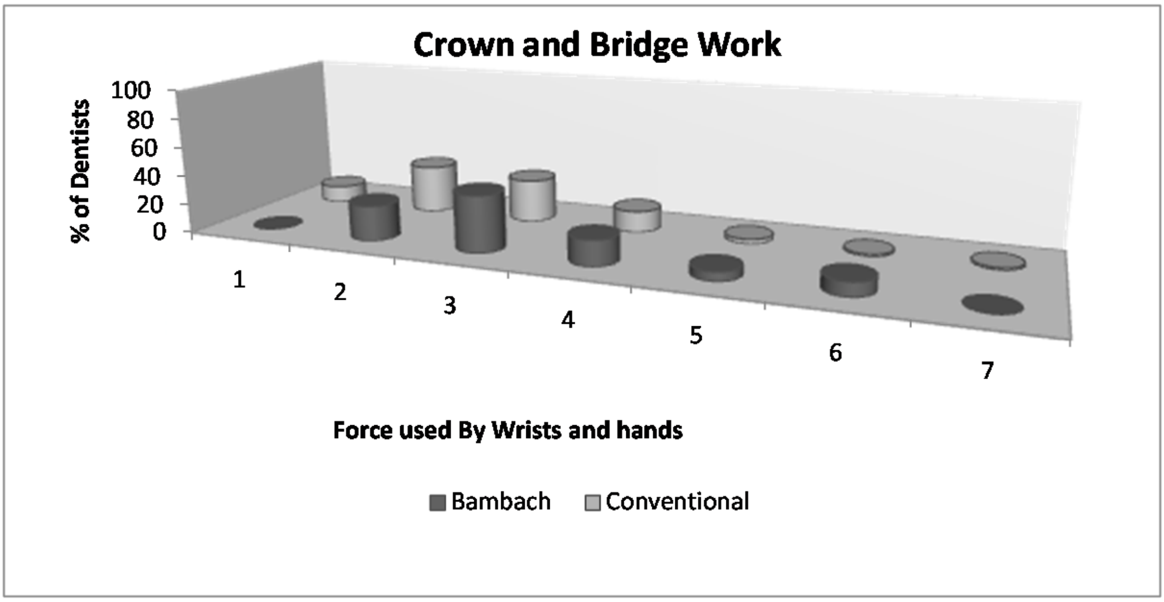


Fig. 2-22. Force used for Crown and Bridge Work

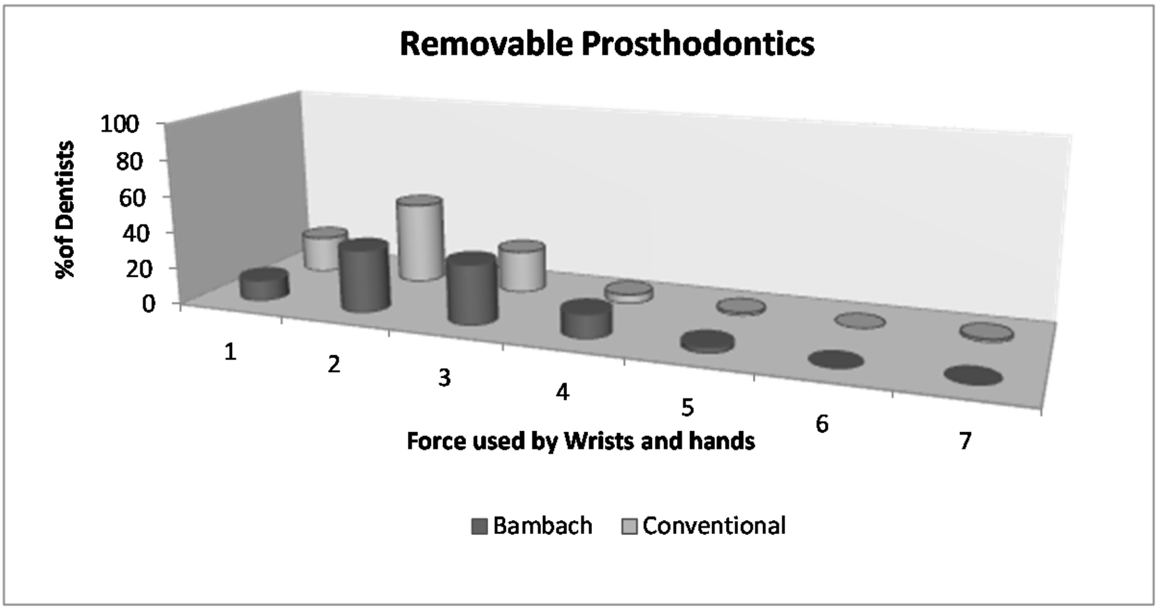


Fig. 2-23. Force used for Removable Prosthodontics

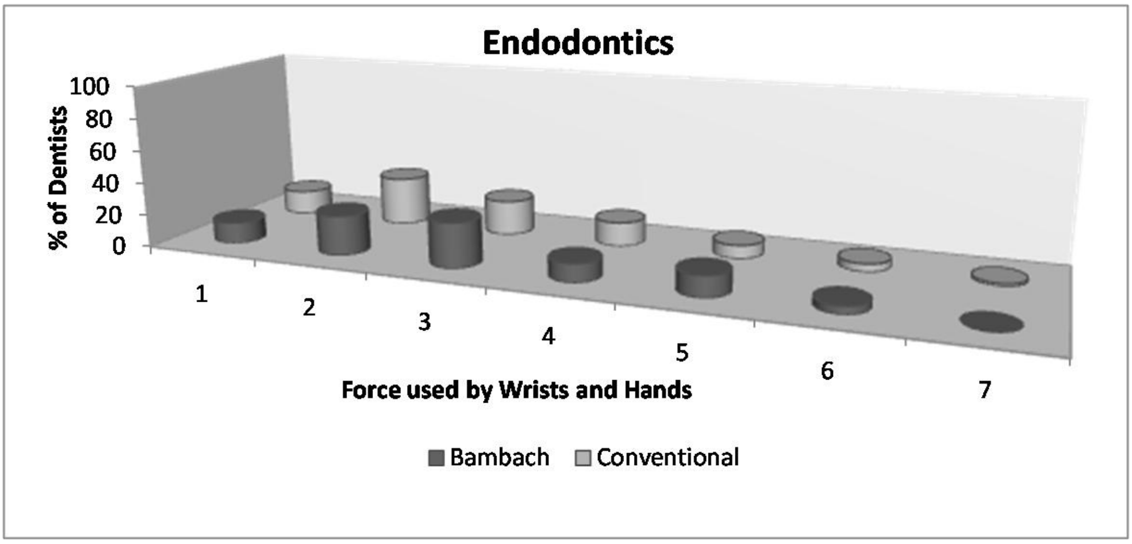


Fig. 2-24. Force used for Endodontics

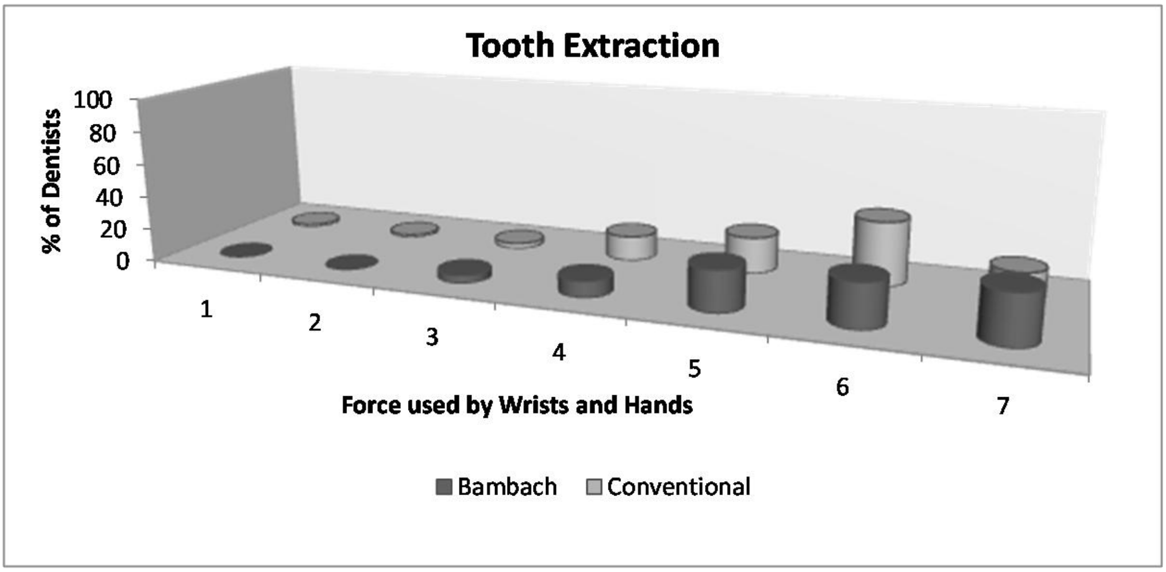


Fig. 2-25. Force used for Tooth Extraction

The results indicate that dental examination is the procedure that utilises least force with wrists and hands, with tooth extraction utilising extreme force, and direct placement restorations and orthodontics using medium force.

Questions on the Operator Stool

This part includes questions on the use and adjustable features of the operator stool, age and type of operator stool, training on adjusting the operator stool, and satisfaction with their operator stool[1].

Use of Operator Stool:

Lumbar Spine Supported

The results are presented in figure 2-26, and indicate that more CSD agree with the statement that their lumbar spine is supported.

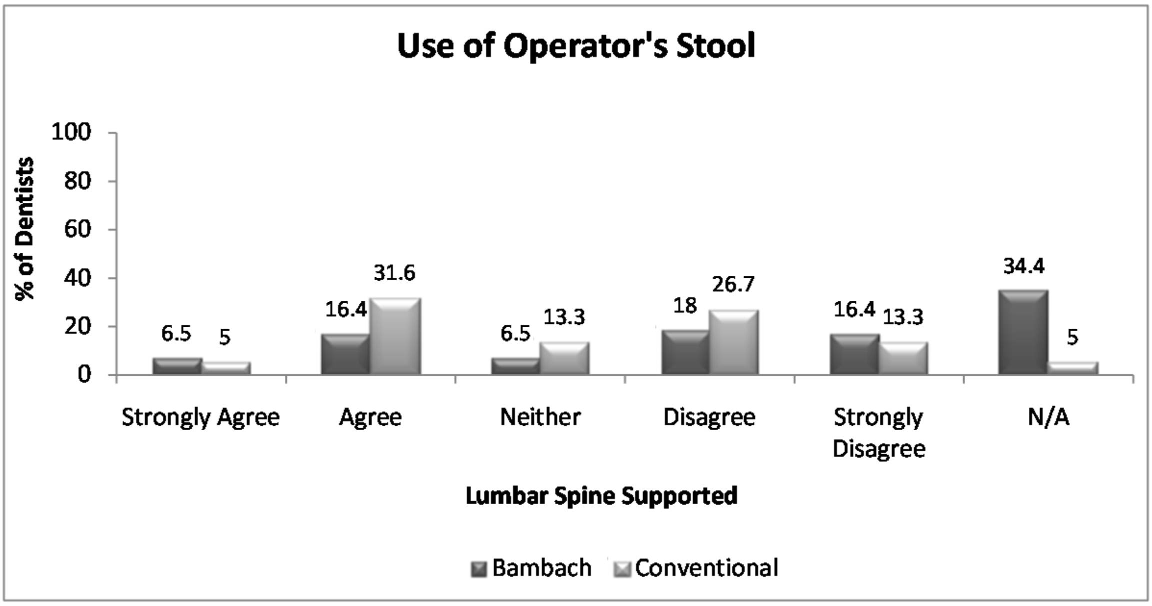


Fig. 2-26. Lumbar Spine is supported against the Seat Back

Comfortable Bottom Support

The results are presented in figure 2-27, and indicate very few variations between the BSD and CSD

[1] Note: The Bambach Saddle seat does not come with a backrest as a standard feature but can be purchased separately.

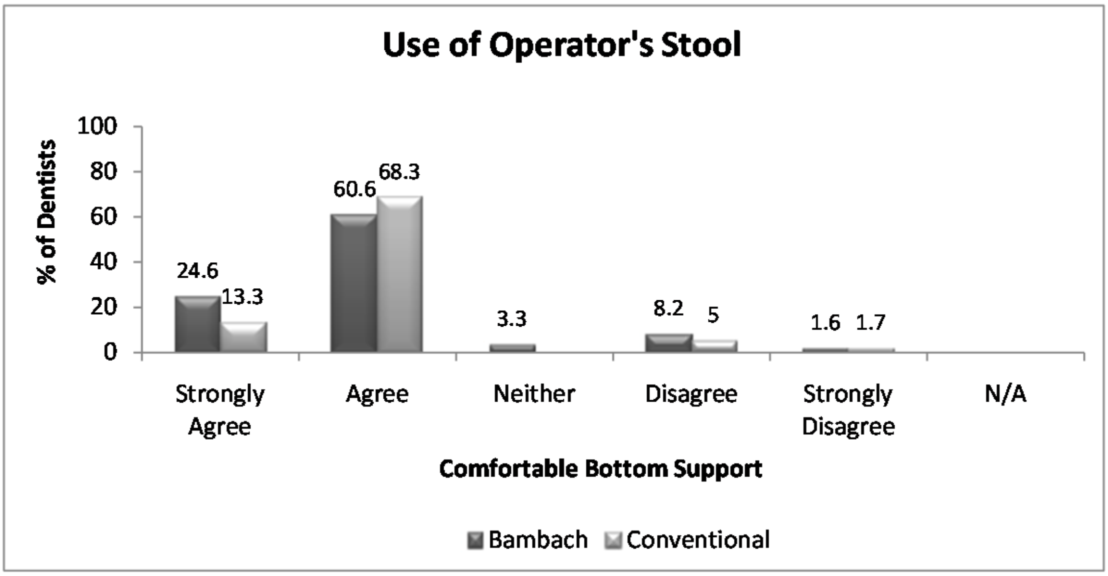


Fig. 2-27. Operator Stool provides Comfortable Bottom Support

Arms Rest Comfortably

The results are presented in figure 2-28, and indicate that more BSD agree that their arms rest comfortably while using the Bambach saddle seat.

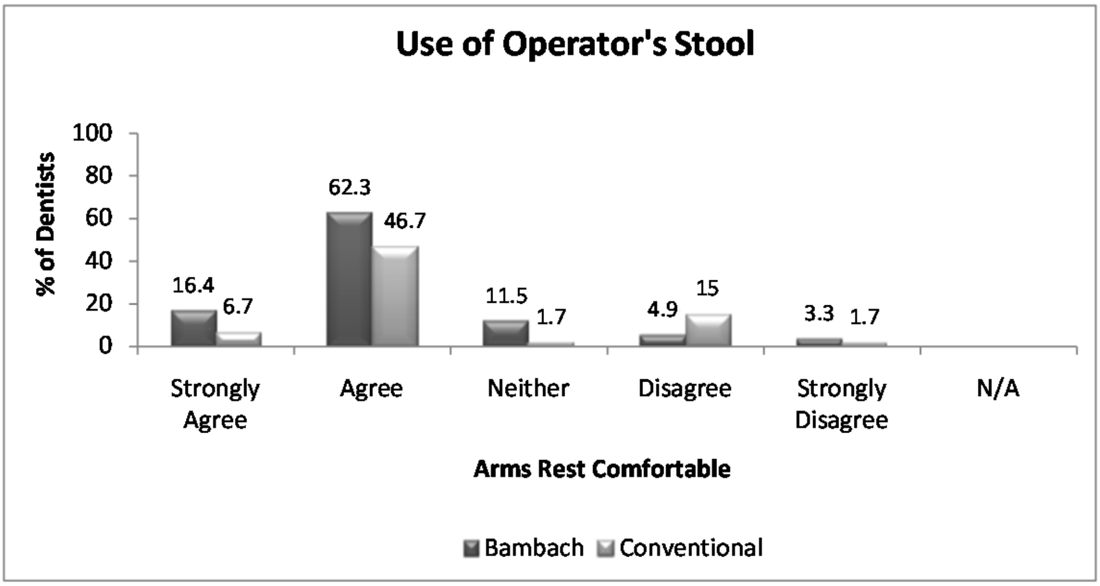


Fig. 2-28. Arms rest comfortably at my sides

Legs and Feet Comfortably

The results are presented in figure 2-29, and indicate that more BSD agree that their legs and feet feel comfortable while using the BS.

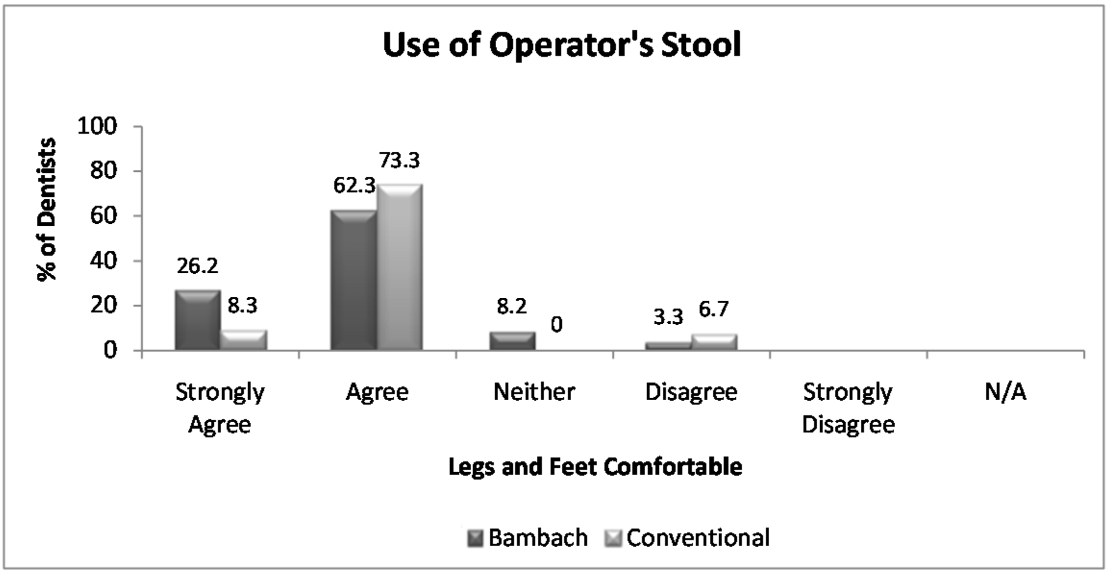


Fig. 2-29. Legs and feet are in a comfortable position

Neck is in a Comfortable Position

The results are presented in figure 2-30, and indicate that more BSD agree that their neck is in a comfortable position while using the BS.

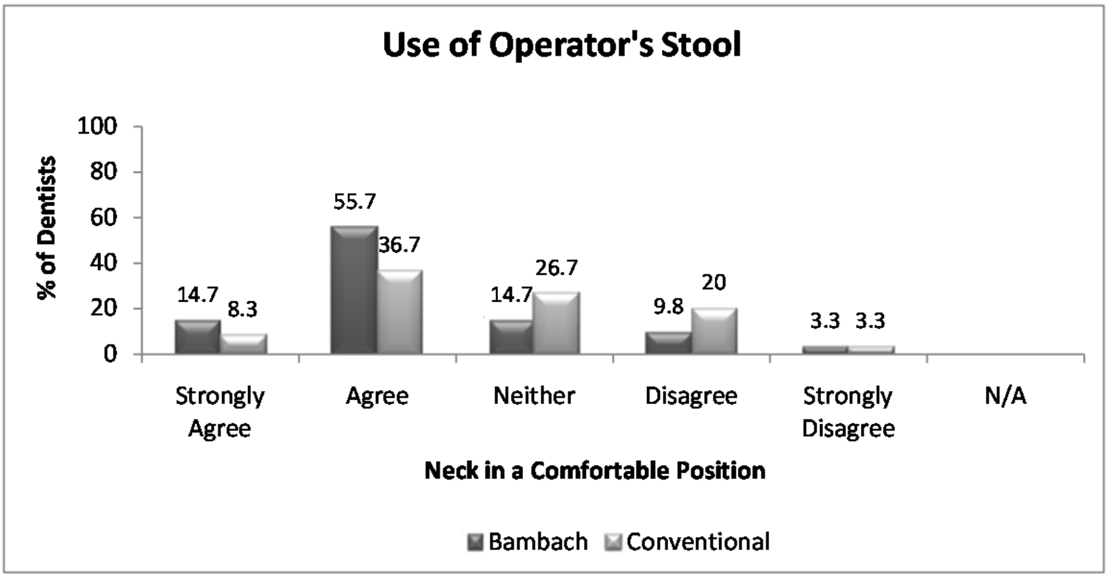


Fig. 2-30. Neck is in a comfortable position when seated

Overall, Operator Stool Comfortable

The results are presented in figure 2-31, and indicate that more BSD agree that BS is comfortable.

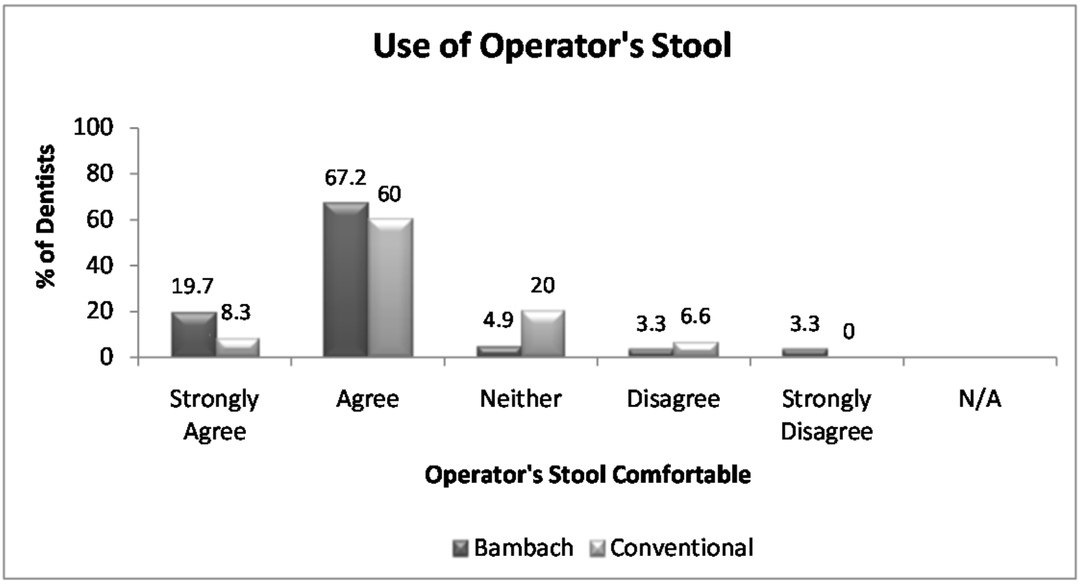


Fig. 2-31. Overall, the Operator Stool is Comfortable

Satisfaction in using Operator Stool

The results are presented in figure 2-32, and indicate that more BSD agree that they are satisfied using the BS.

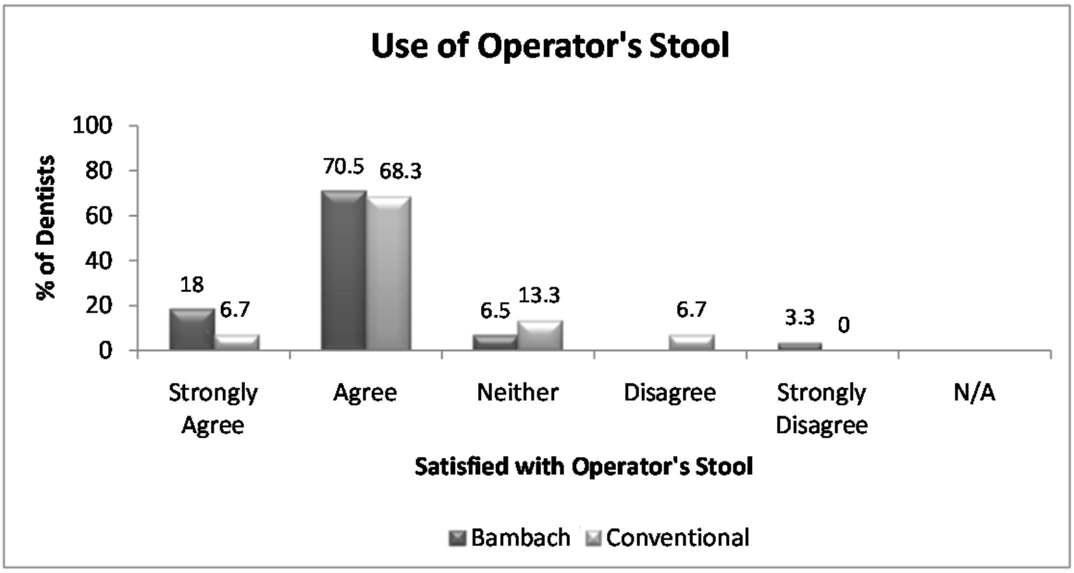


Fig. 2-32. Satisfied with Operator's Stool.

Adjustable Features of the Operator Stool: The questions on height, seat angle, back support and arm support are included to see any relation to their working posture.

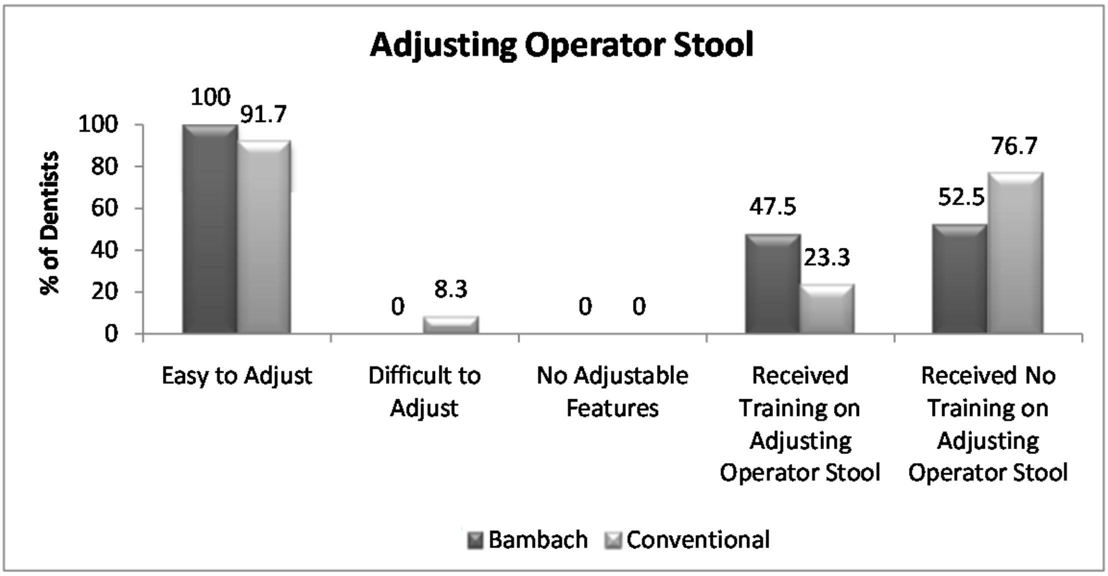


Fig. 2-33. Questions on Adjusting Operator Stool

The results indicate that most of the dentists using the BS agree that their seat is comfortable, rests various regions of the body in a comfortable position and easy to adjust.

Questions on Pain

This part includes questions on pain in the last 4 weeks, areas of pain, amount of pain (Visual Analog Scale, 0-10), medication for pain, consultation for pain, and exercise for pain and whether the pain has affected their dental work

Pain reported in the four weeks prior to completion of questionnaire:

The results indicate that 50.8% (n=31) of BSD and 60% (n=36) of CSD reported pain in the four weeks prior to completion of the questionnaire.

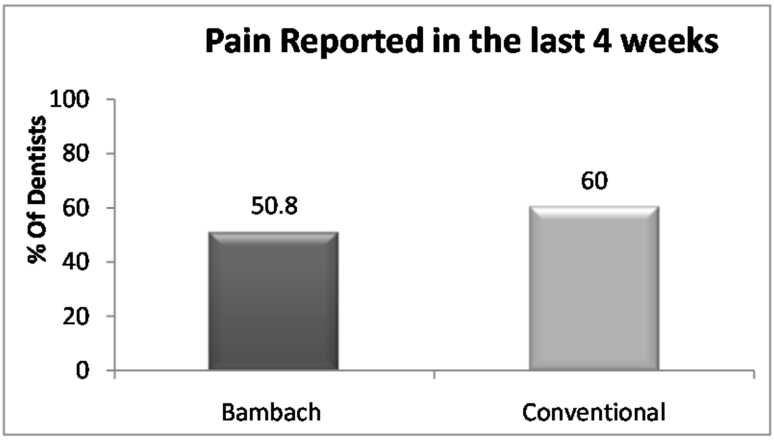


Fig. 2-34. Pain reported by the dentists in the past 4 weeks

Areas of Pain: The areas affected by pain are presented in figure 2-35, indicating that lower back is the most commonly reported area of pain.

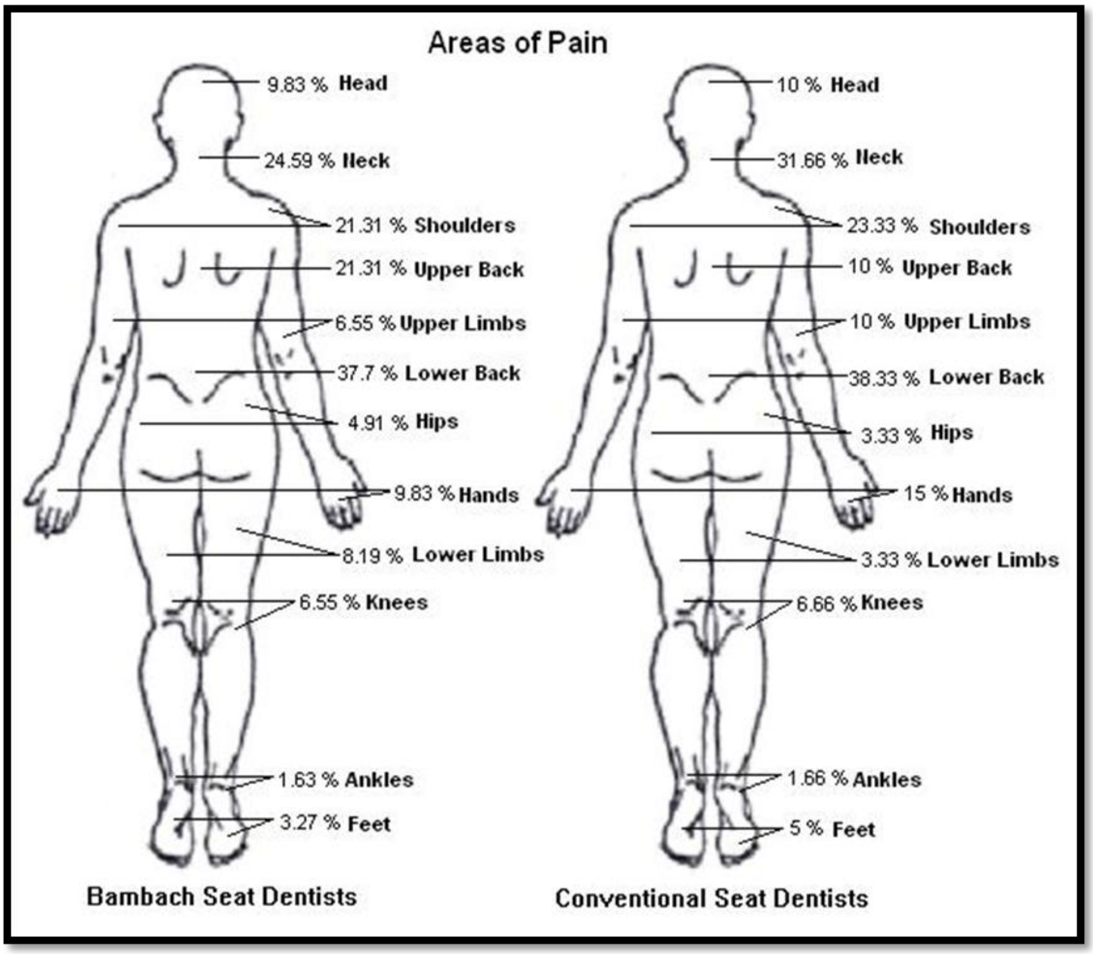


Fig. 2-35. Areas of Pain reported by the Dentists in the past 4 weeks

Pain and Dental Work: The results are presented in figure 2-36, where a large number of dentists have reported that their pain has not affected their dental work.

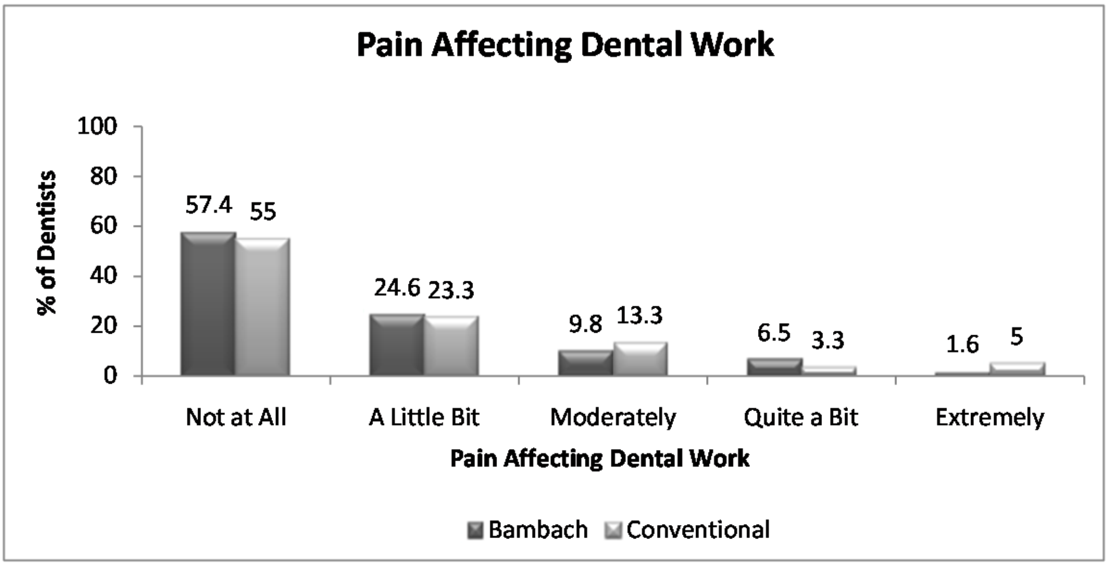


Fig. 2-36. Effect of pain on Dental Work

Amount of Pain: The results about the general intensity of pain are presented in figure 2-37.

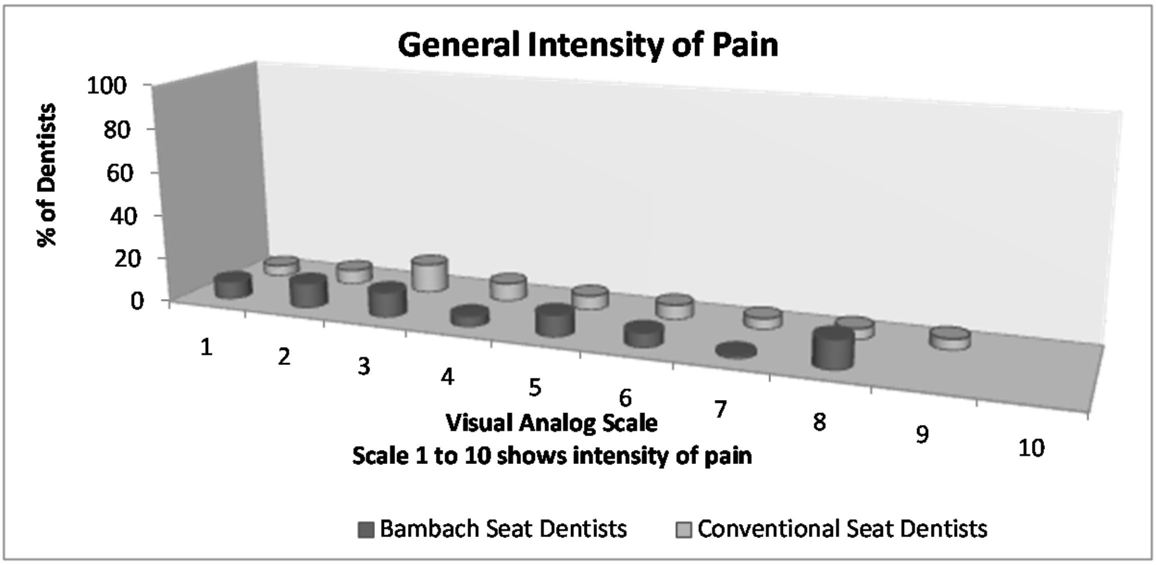


Fig. 2-37. General Intensity of Pain reported by Dentists

Medications during the four weeks prior to the completion of the questionnaire: The results are presented in figure 2-38, and indicate little variability between CSD and BSD.

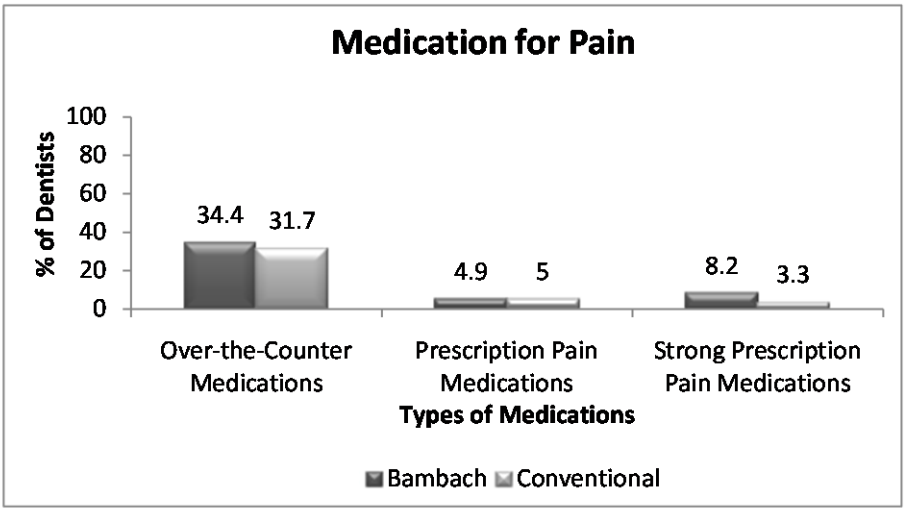


Fig. 2-38. Medication taken for Pain

Consultation for pain: The results are presented in figure 2-39, and indicate that larger numbers of BSD had consulted a health professional regarding their pain.

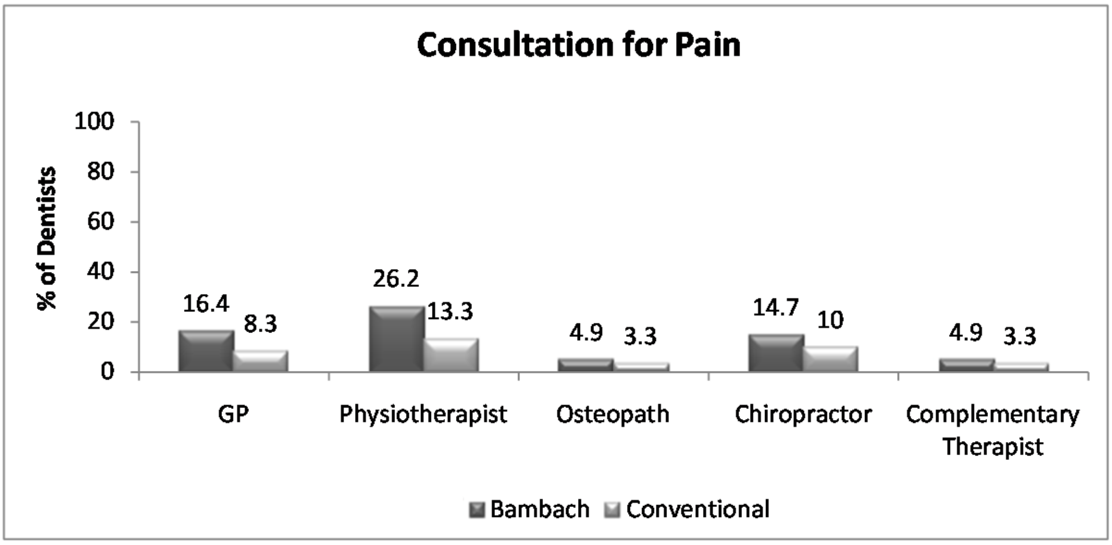


Fig. 2-39. Consultation for Pain

Analysis of Pain reported by Dentists:

Pain reported by Single-Handed and Partnership / Group Dentists: The results are presented in figure 2-40, indicate more pain is reported among dentists working in partnership (or) group.

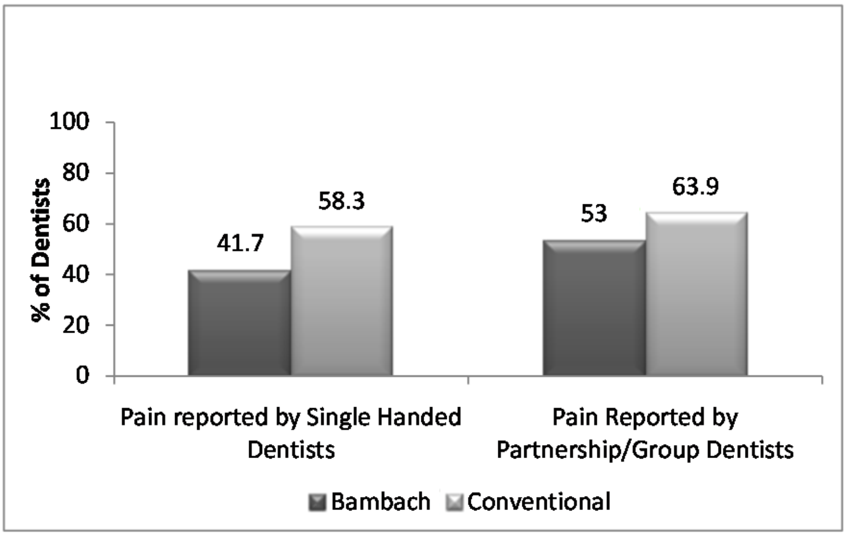


Fig. 2-40. Percentage of dentists reporting pain in the Single Handed and Partnership / Group dentists

Relationship between pain reported and hours of work: The results are presented in figure 2-41, and indicate that fewer number of BSD report pain as the hours they work increases; whereas more number of CSD report pain as the hours they work increases. Statistical association was measured using Pearson Chi-Square where the results indicate significant association between the hours of work and pain, $\chi^2 = 30.06$; df = 2; p = 0.000. The strength of association was measured using Phi Coefficient ($\Phi = 0.310$; p = 0.000), and Cramér's V (Cramér's V = 0.310; p = 0.000) indicating significant strength of association between hours of work and pain.

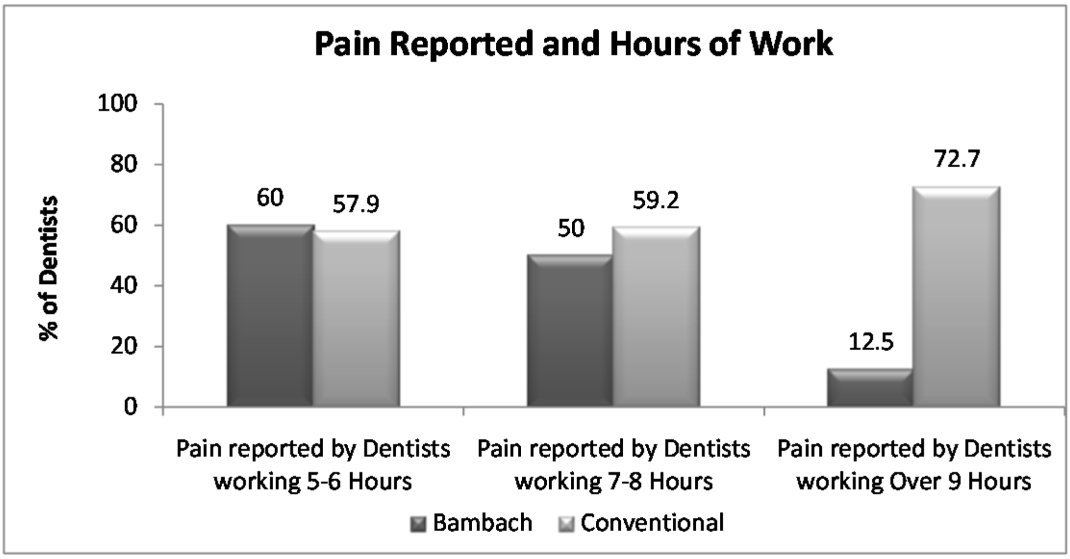


Fig. 2-41. Relationship between Pain Reported and Hours of Work

Relationship between pain reported by male and female dentists: The results are presented in figure 2-42. Statistical association was measured using Pearson Chi-Square where the results indicate no significant association between the gender and pain, χ^2 = 1.59; df = 1; p = 0.206. The strength of association was measured using Phi Coefficient (Φ = 0.083; p = 0.206), and Cramér’s V (Cramér’s V = 0.083; p = 0.206) also indicate no significant strength of association between gender and pain.

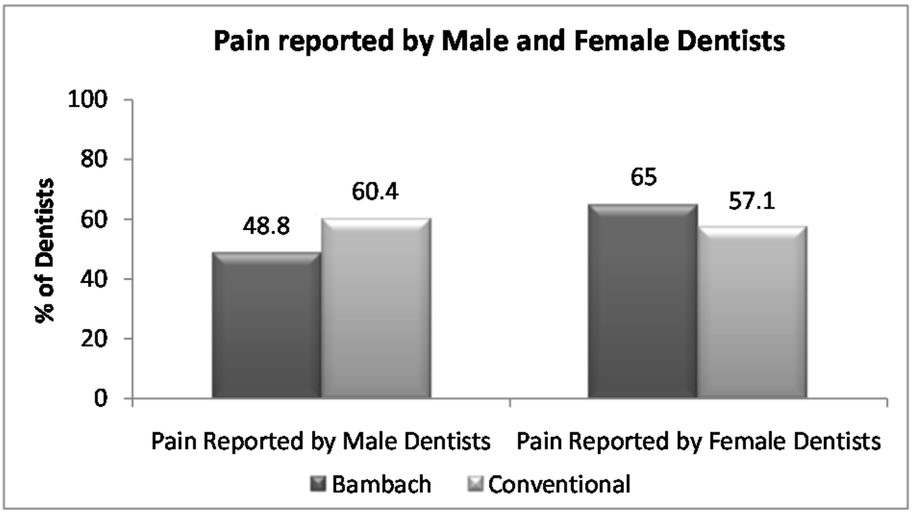


Fig. 2-42. Pain reported by male and female dentists.

Relationship between age and pain reported by dentists: The results are presented in figure 2-43. The results indicate that in the BSD the pain reported by younger and older dentists are similar, whereas in the CSD the percentage of pain reported by younger dentists is more when compared to older dentists. However, when the statistical association was measured using Pearson Chi-Square, the results indicate no significant association between the age and pain, $\chi^2 = 0.731$; df = 1; p = 0.393. The strength of association was measured using Phi Coefficient ($\Phi = -.056$; p = 0.393), and Cramér's V (Cramér's V = 0.056; p = 0.393) also indicate no significant strength of association between age and pain.

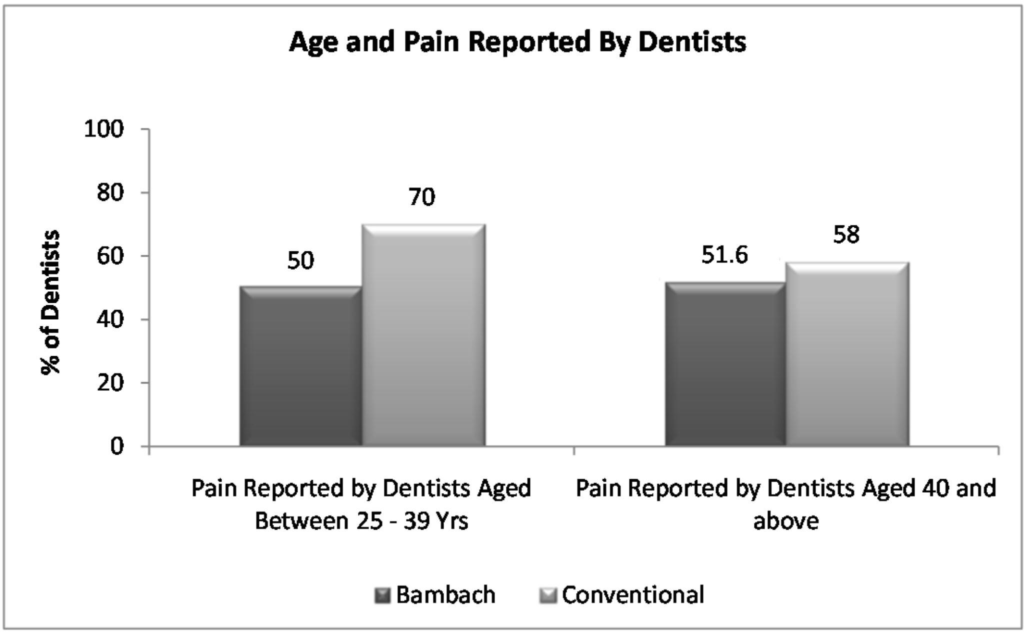


Fig. 2-43. Relationship between Age and Pain Reported by Dentists

Relationship between dentists reporting back pain and the agreement about back support while seated: A high number of dentists who reported back pain in the questionnaire indicated that their back was not supported while seated and were seated on a CS (Fig. 2-44). Statistical association measured using Pearson Chi-Square indicated significant association between the dentists reporting back pain and their agreement about back support, $\chi^2 = 8.76$; df = 1; p = 0.003. The strength of association measured using Phi Coefficient ($\Phi = 0.241$; p = 0.003), and Cramér's V (Cramér's V = 0.241; p = 0.003) also indicated significant strength of association between dentists' agreement about lower back pain and back support.

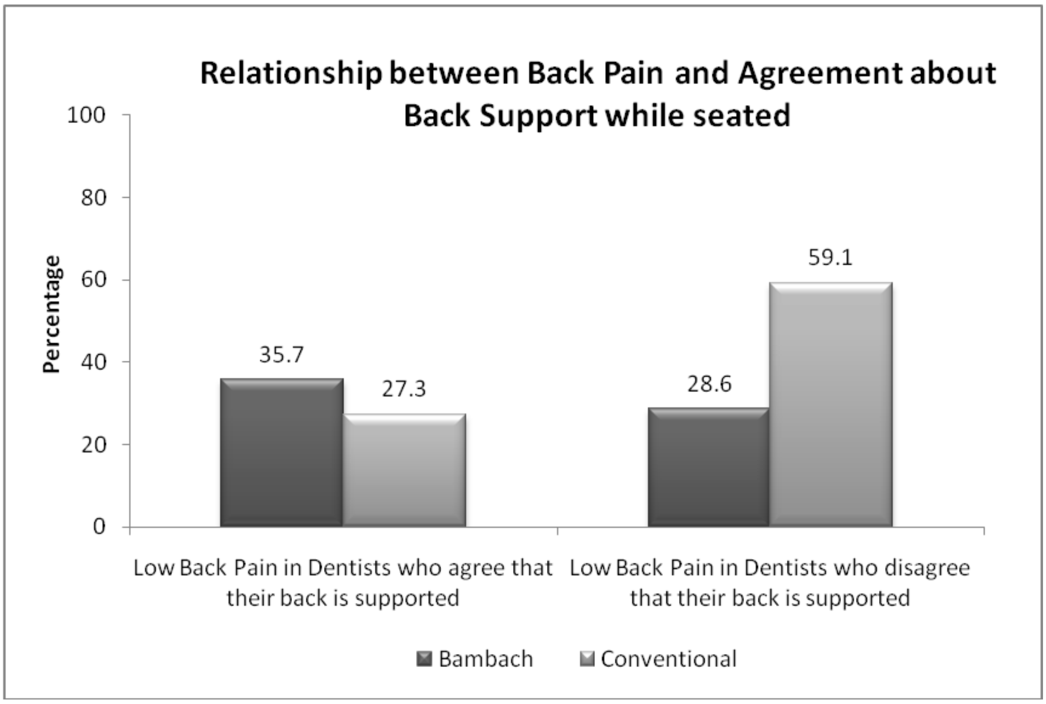


Fig. 2-44. Relationship between Back pain and Back Support

Relationship between dentists reporting neck pain and the agreement about neck comfort when seated: A high number of dentists who reported neck pain in the questionnaire indicated that their neck was not supported while seated and were seated on a CS (Fig. 2-45). However a higher number of CSD who agree that their neck is supported while seated also reported neck pain. Statistical association measured using Pearson Chi-Square indicated significant association between the dentists reporting neck pain and their agreement about neck resting comfortably, $\chi^2 = 4.25$; df = 1; p = 0.039. The strength of association measured using Phi Coefficient ($\Phi = 0.215$; p = 0.039), and Cramér's V (Cramér's V = 0.215; p = 0.039) also indicated significant strength of association between dentists' agreement about neck pain and neck comfort.

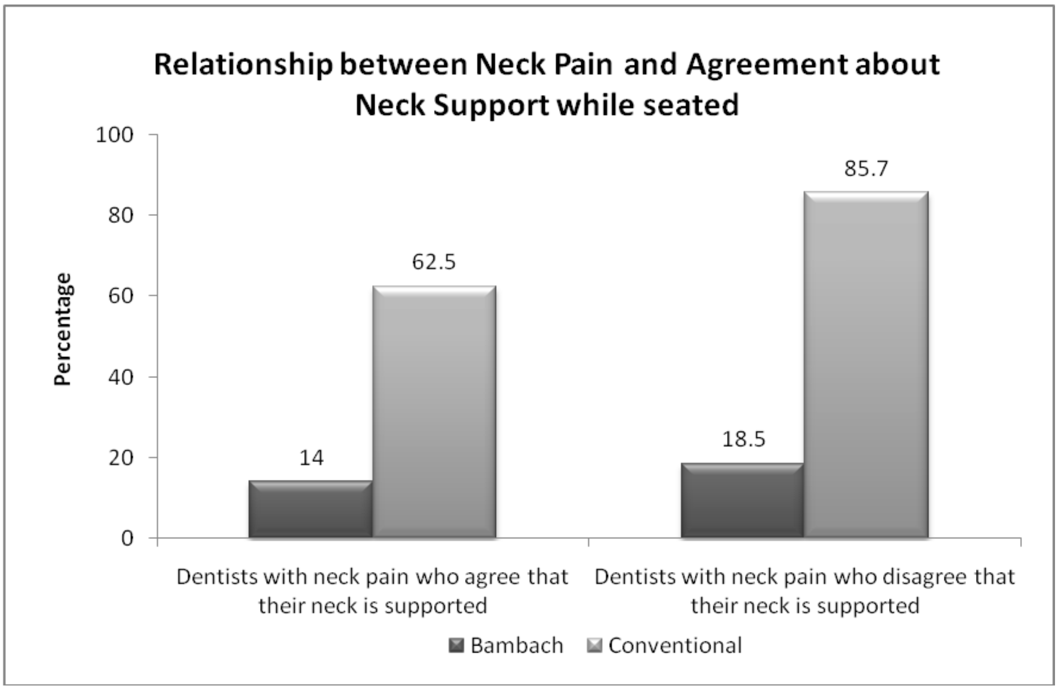


Fig. 2-45. Relationship between Neck pain and Neck Resting Comfortably

Relationship between taking rest breaks and the bodily pain reported by dentists: The results indicated that higher number of dentists who do not take regular rest breaks reported bodily pain and were seated on a CS (Fig. 2-46). Statistical association measured using Pearson Chi-Square indicated significant association between the dentists reporting bodily pain and taking rest breaks, $\chi^2 = 7.68$; df = 1; p = 0.006. The strength of association measured using Phi Coefficient ($\Phi = -.181$; p = 0.006), and Cramér's V (Cramér's V = 0.181; p = 0.006) also indicated significant strength of association between dentists' reporting bodily pain and taking rest breaks.

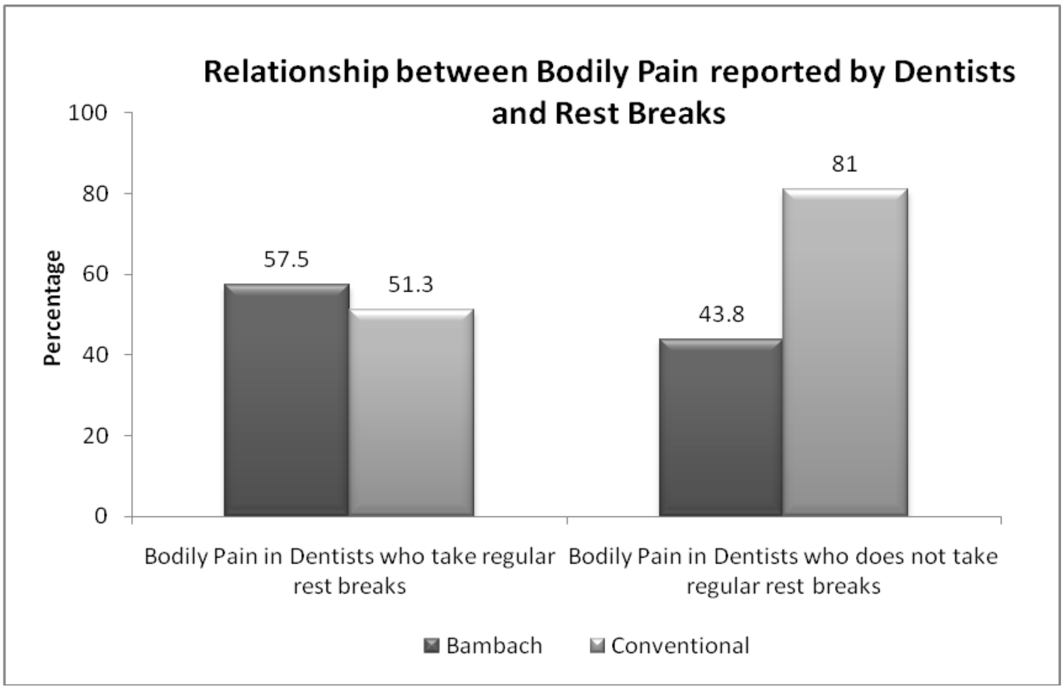


Fig. 2-46. Relationship between Bodily pain and Rest Breaks

Psychological Questions

The questions identify how difficult is for the dentist to perform certain daily activities and to identify whether they agree or disagree on certain activities.

Difficulty in working the required number of hours

The results are presented in figure 2-47.

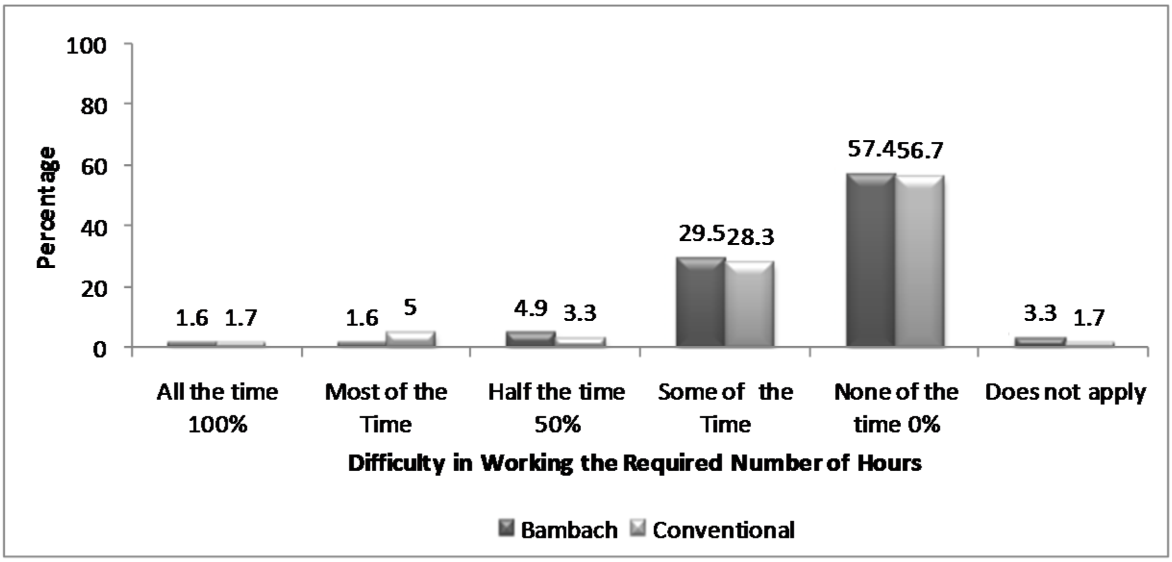


Fig. 2-47. Difficulty in working the required number of hours

Difficulty in get going easily at the beginning of the day

The results are presented in figure 2-48.

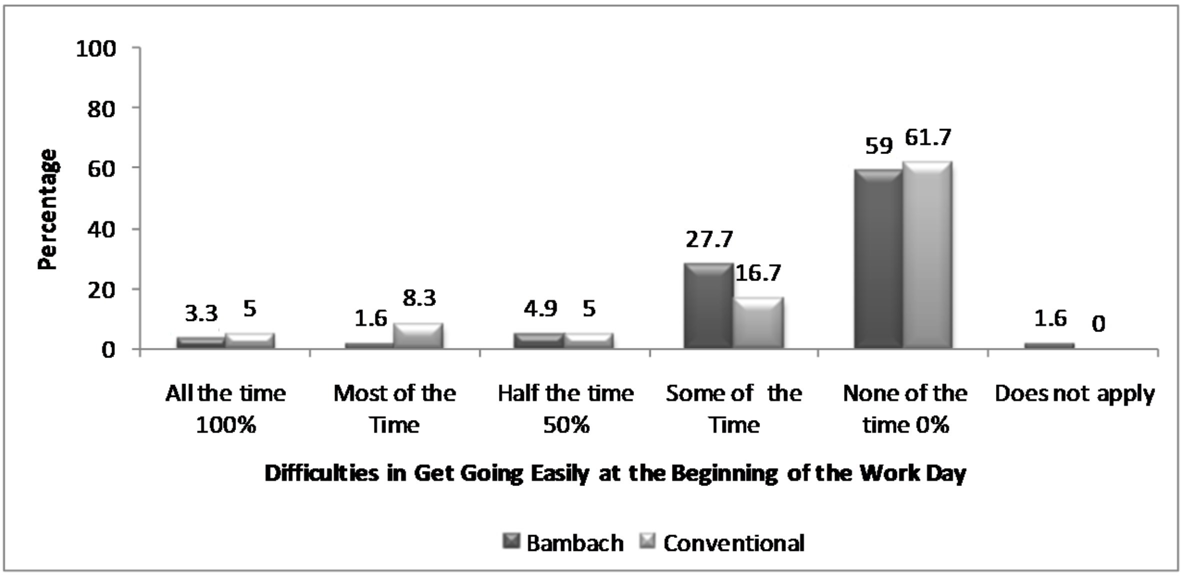


Fig. 2-48. Difficulties in get going easily at the beginning of the day

Difficulty in starting job immediately at arrival for work

The results are presented in figure 2-49.

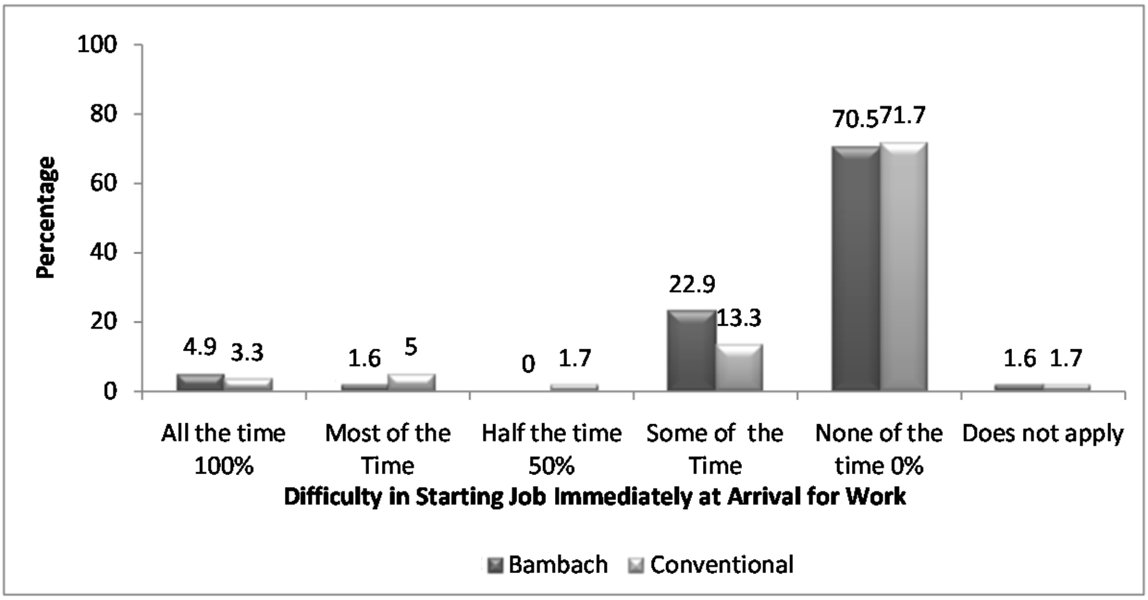


Fig. 2-49. Difficulty in starting job immediately at arrival for work

Difficulty in doing work without taking extra breaks or rests

The results are presented in figure 2-50.

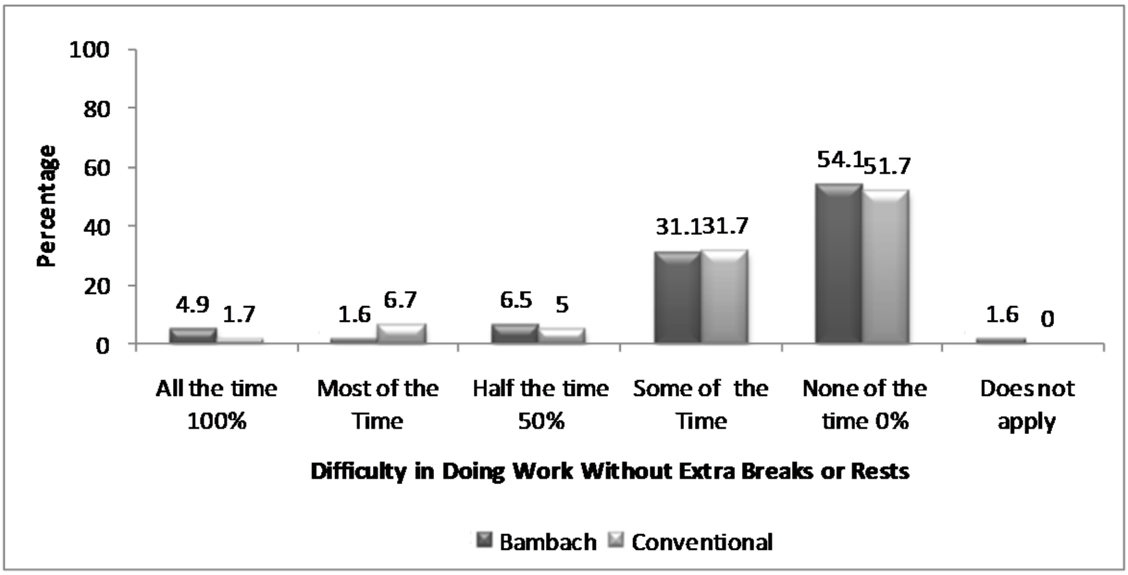


Fig. 2-50. Difficulty in doing work without taking extra breaks or rests

Difficulty to stick to a routine or schedule

The results are presented in figure 2-51.

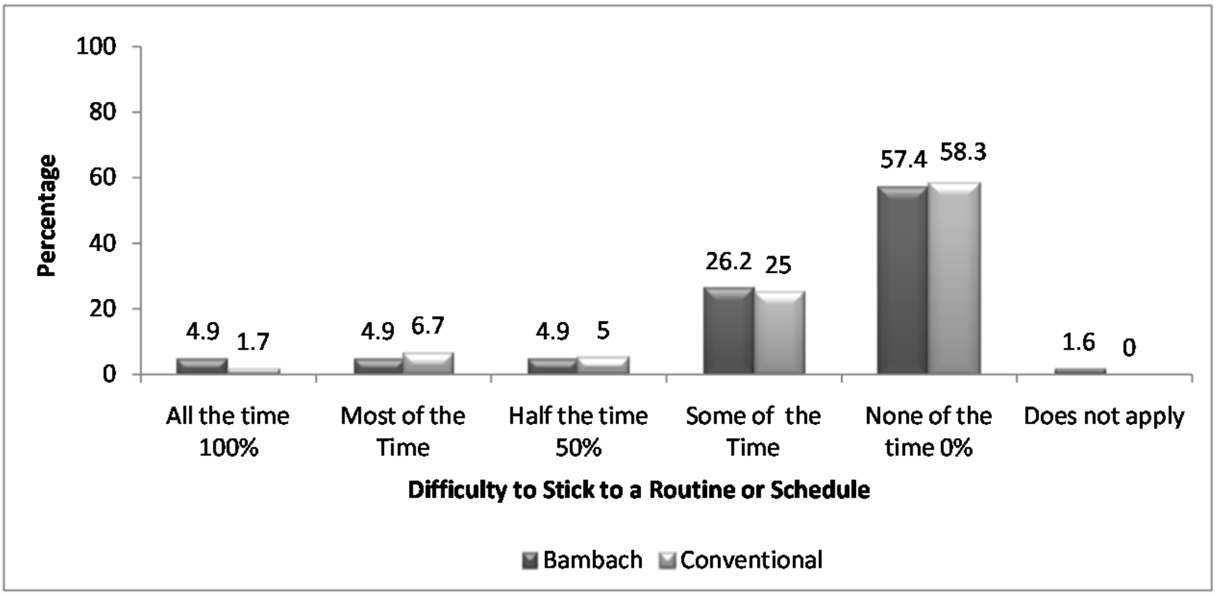


Fig. 2-51. Difficulty to stick to a routine or schedule

Difficulty to handle the workload

The results are presented in figure 2-52.

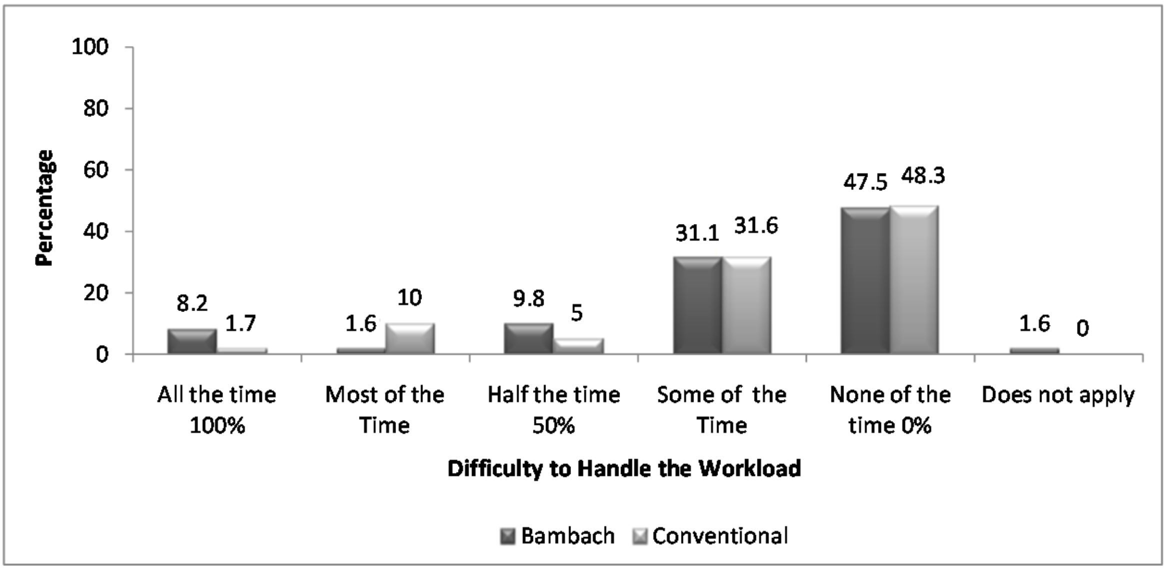


Fig. 2-52. Difficulty to handle the workload

Difficulty to work fast enough

The results are presented in figure 2-53.

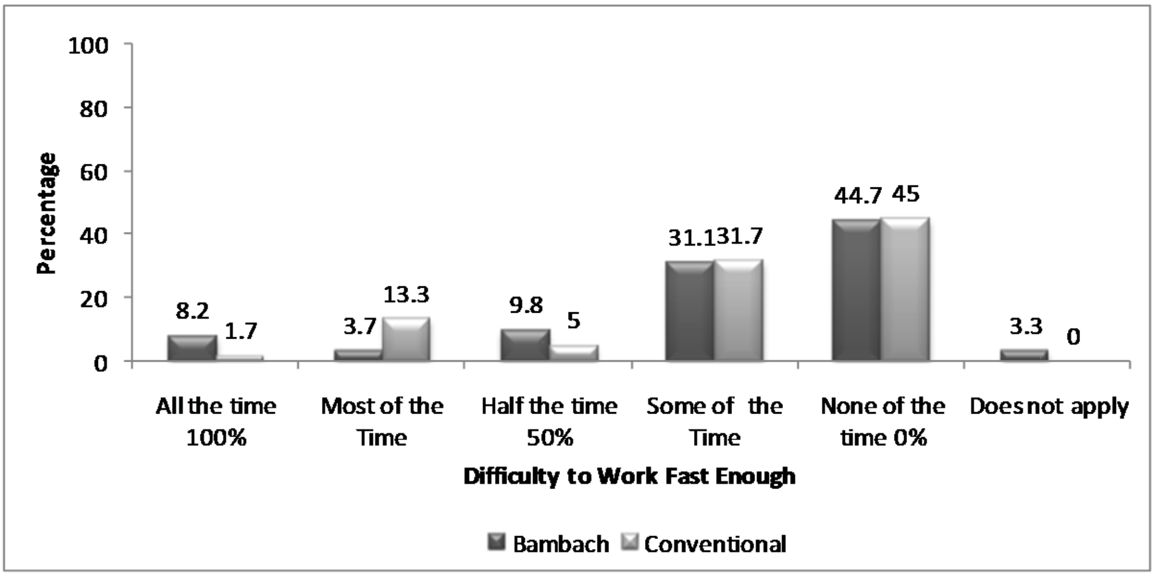


Fig. 2-53. Difficulty to work fast enough

Difficulty in finishing work on time

The results are presented in figure 2-54.

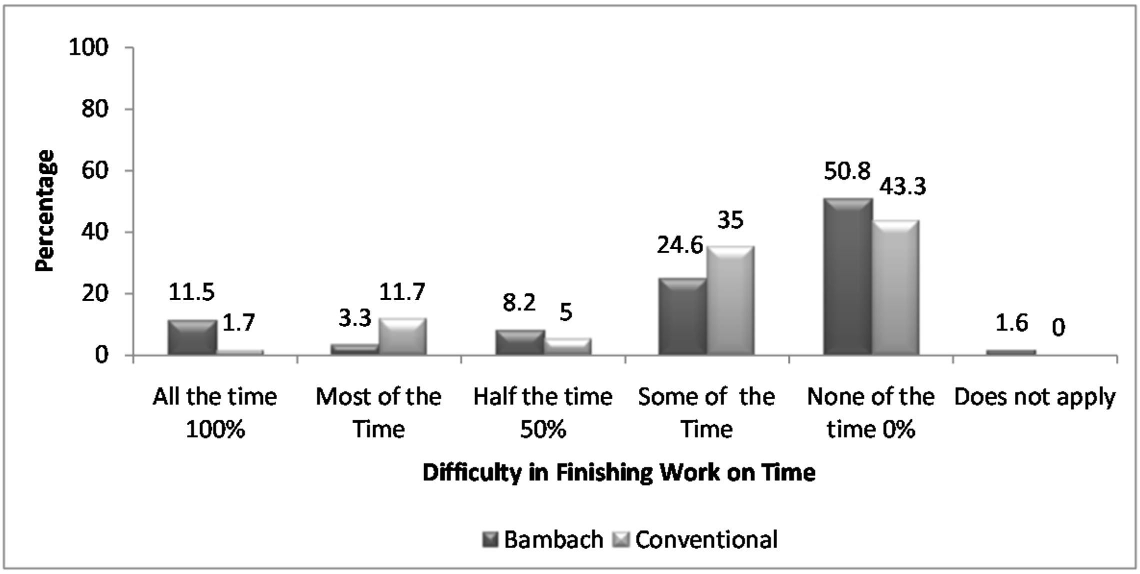


Fig. 2-54. Difficulty in finishing work on time

Difficulty in feeling a sense of accomplishment at work

The results are presented in figure 2-55.

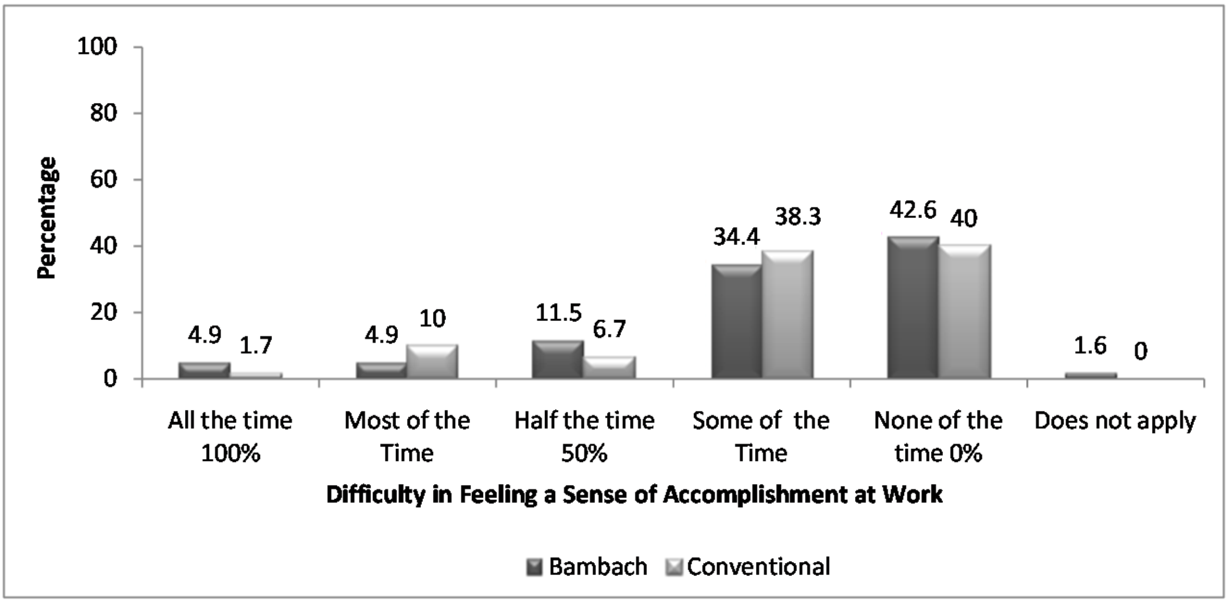


Fig. 2-55. Difficulty in feeling a sense of accomplishment at work

Difficulty in feeling what they are capable of doing

The results are presented in figure 2-56.

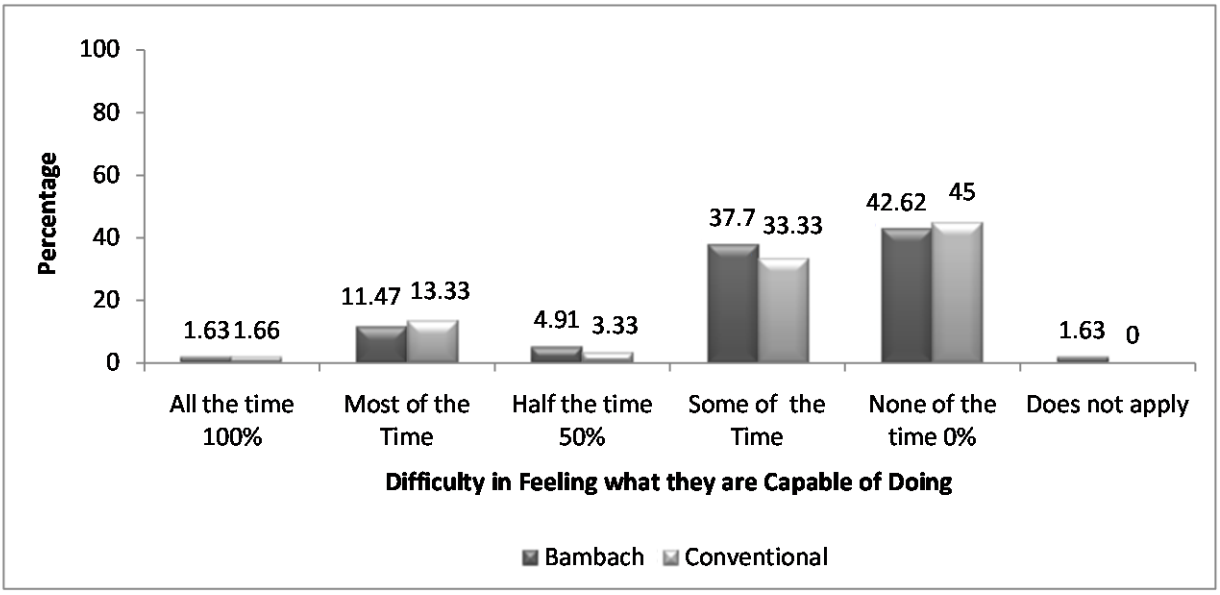


Fig. 2-56. Difficulty in feeling what they are capable of doing

Dentistry requires learning new things

The results are presented in figure 2-57.

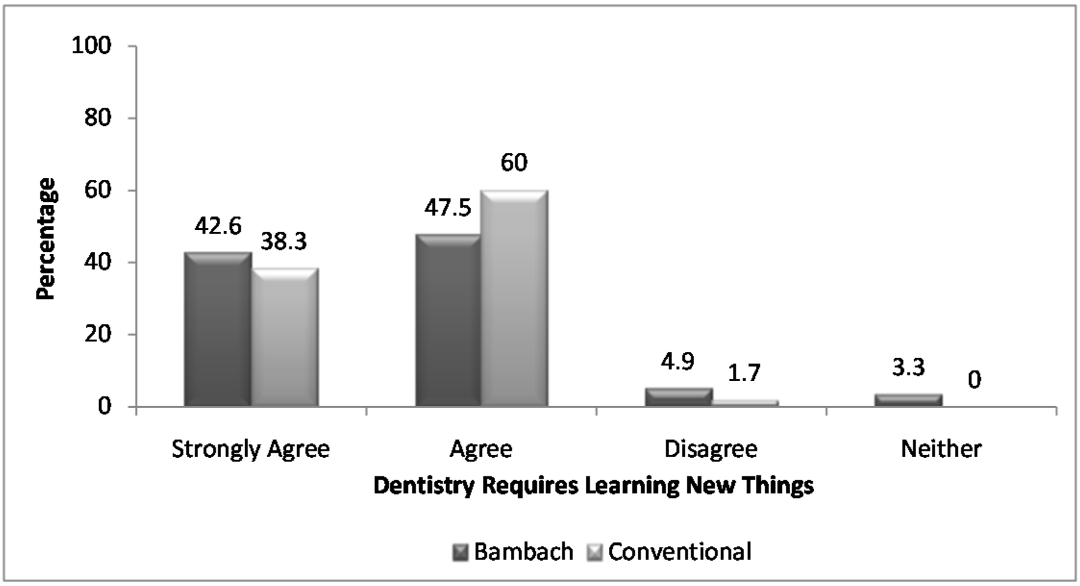


Fig. 2-57. Dentistry requires learning new things

Dentistry involves lot of repetitive work

The results are presented in figure 2-58.

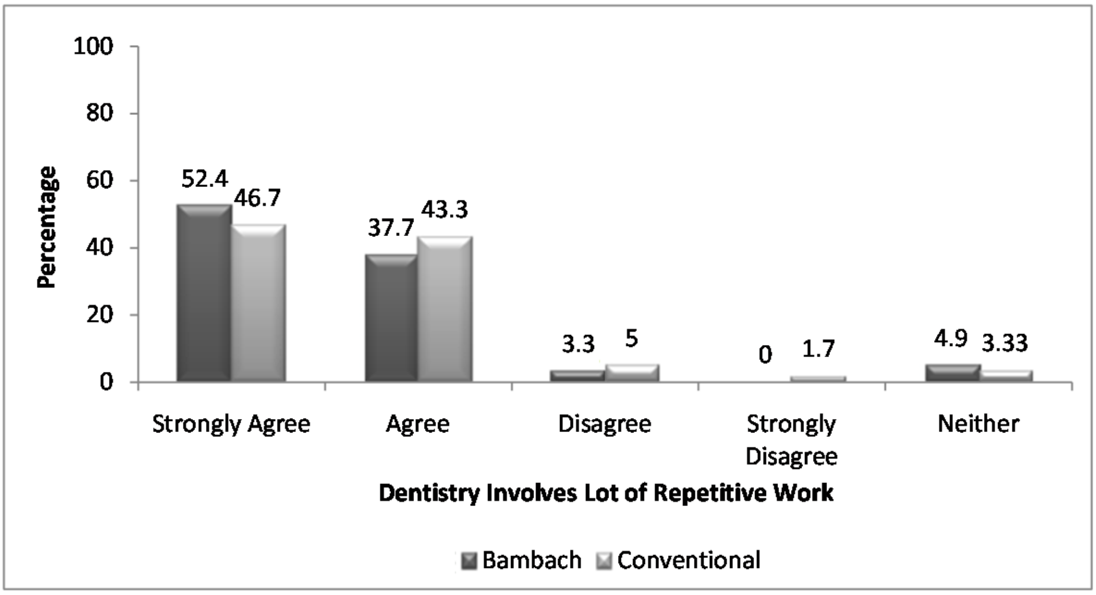


Fig. 2-58. Dentistry involves lot of repetitive work

Dentistry requires dentists to be creative

The results are presented in figure 2-59.

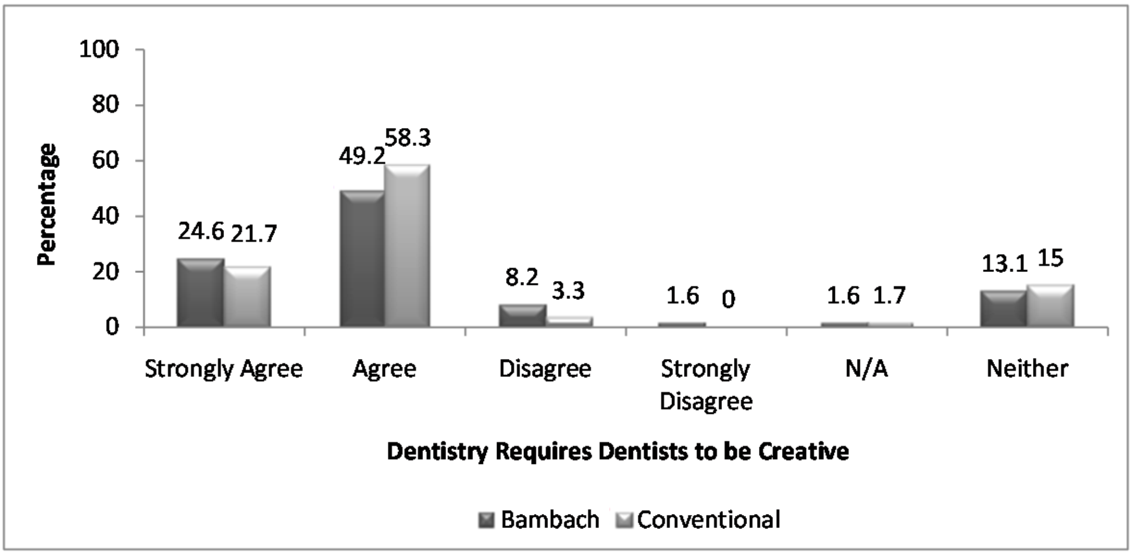


Fig. 2-59. Dentistry requires dentists to be creative

Dentistry allows dentists to make a lot of decisions

The results are presented in figure 2-60.

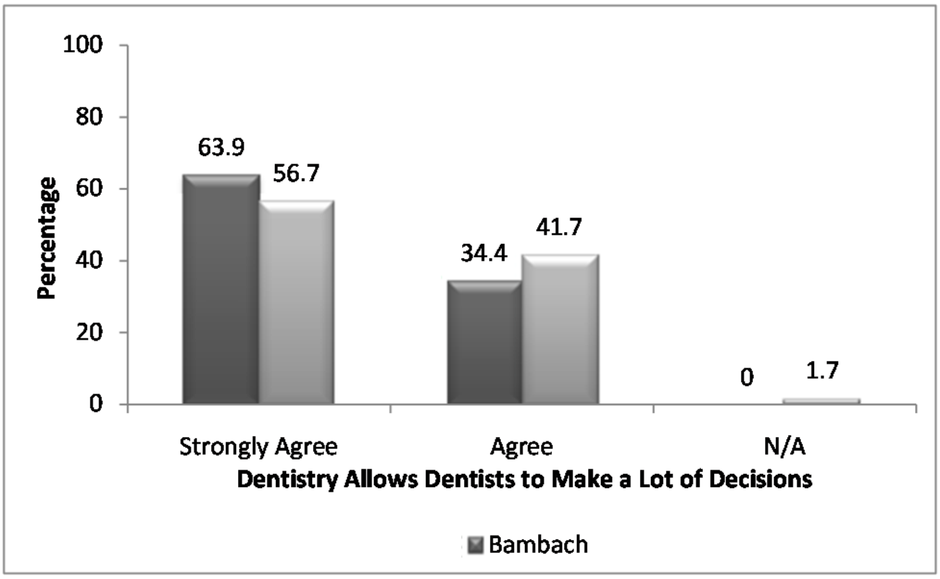


Fig. 2-60. Dentistry allows dentists to make a lot of decisions

Dentistry requires high level of skill

The results are presented in figure 2-61.

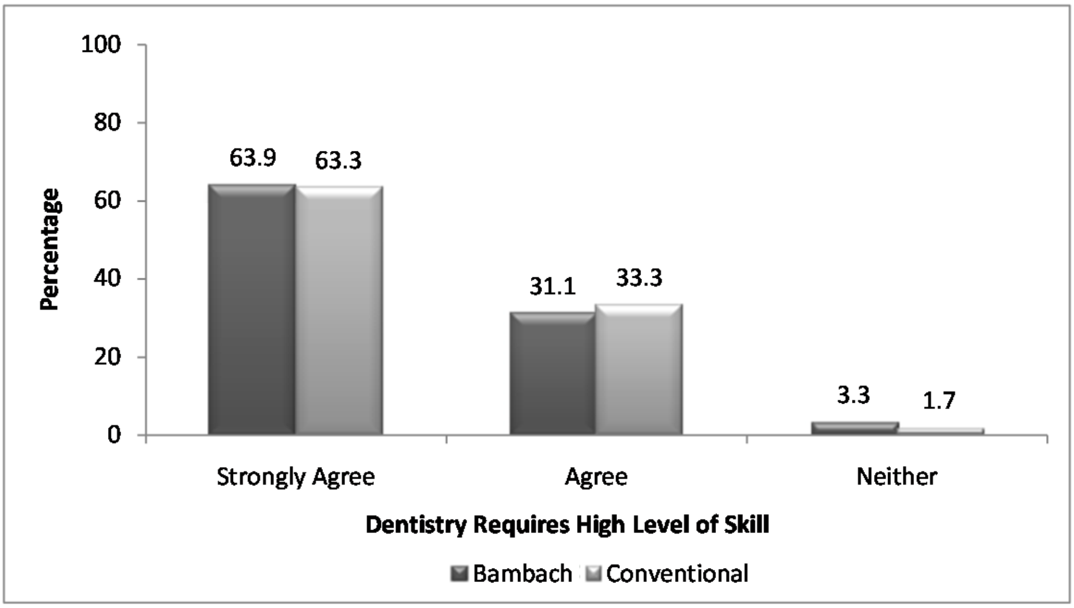


Fig. 2-61. Dentistry requires high level of skill

Dentists have very little freedom to decide about how they work

The results are presented in figure 2-62.

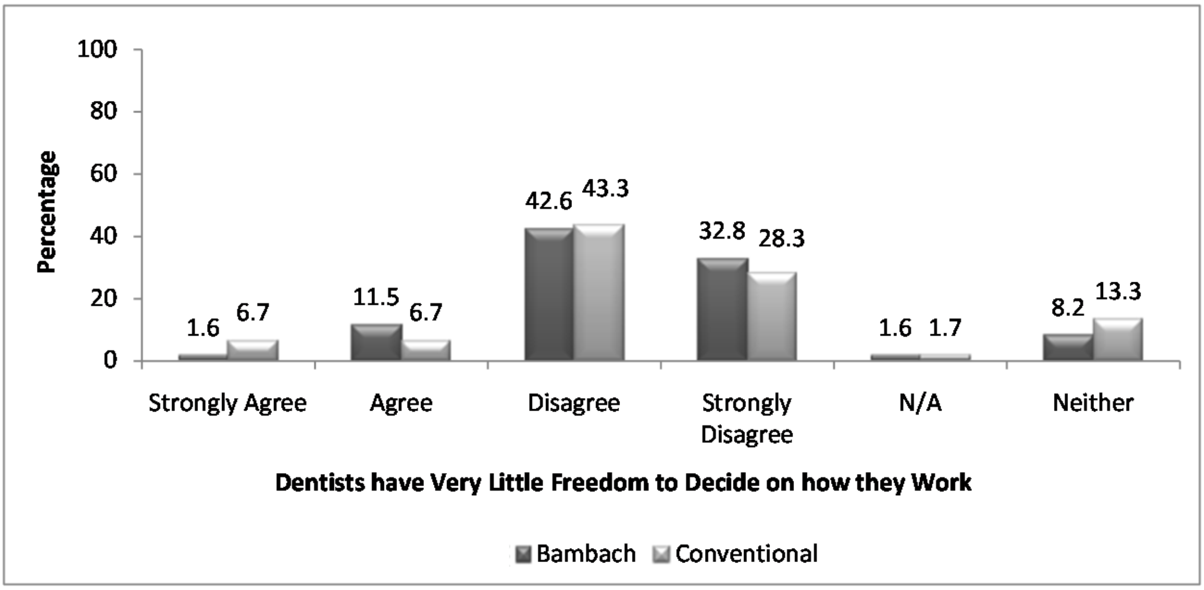


Fig. 2-62. Dentists have very little freedom to decide about how they work

Dentistry has a variety of things

The results are presented in figure 2-63.

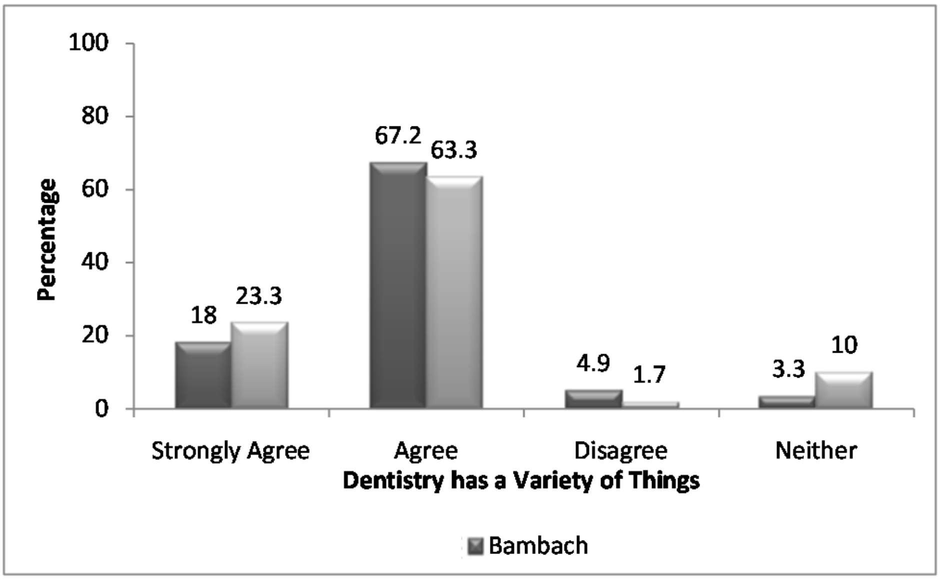


Fig. 2-63. Dentistry has a variety of things

Dentists have lot to say about their job

The results are presented in figure 2-64.

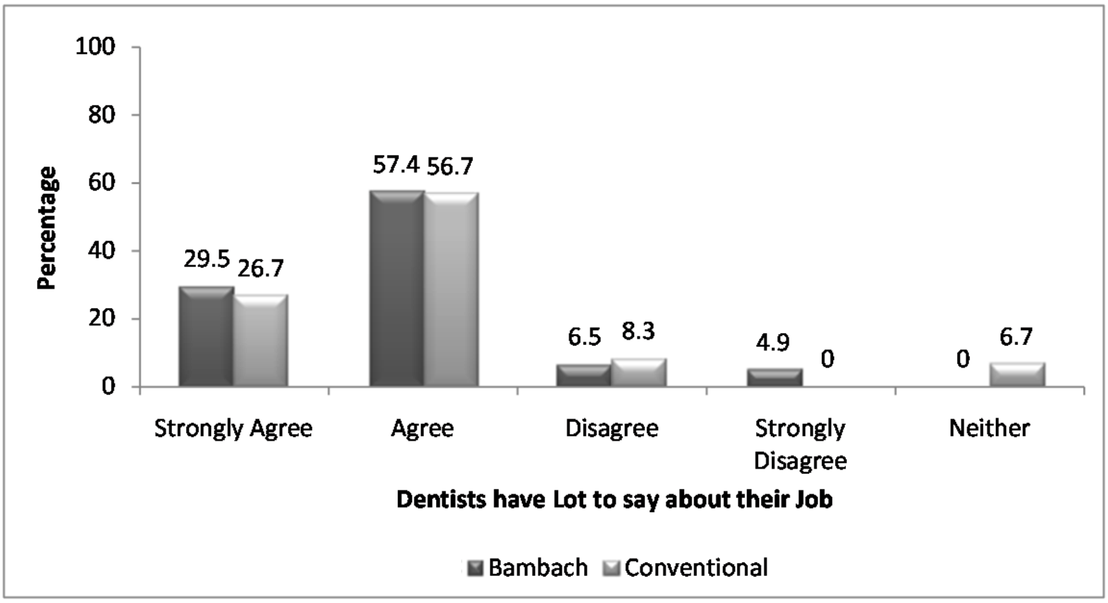


Fig. 2-64. Dentists have lot to say about their job

Dentistry gives an opportunity to develop special abilities

The results are presented in figure 2-65.

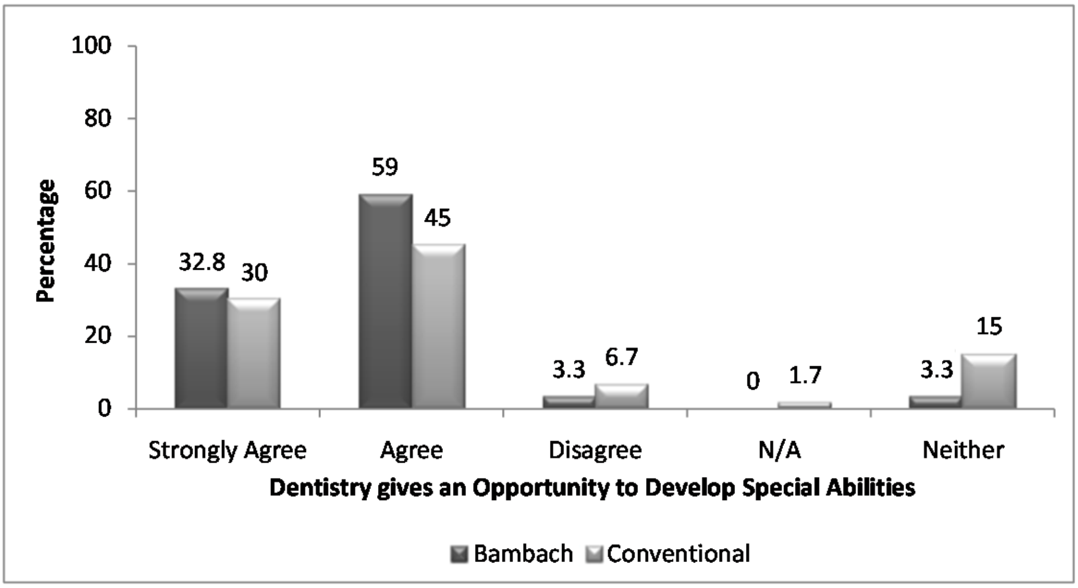


Fig. 2-65. Dentistry gives an opportunity to develop special abilities

Dentistry requires working very fast

The results are presented in figure 2-66.

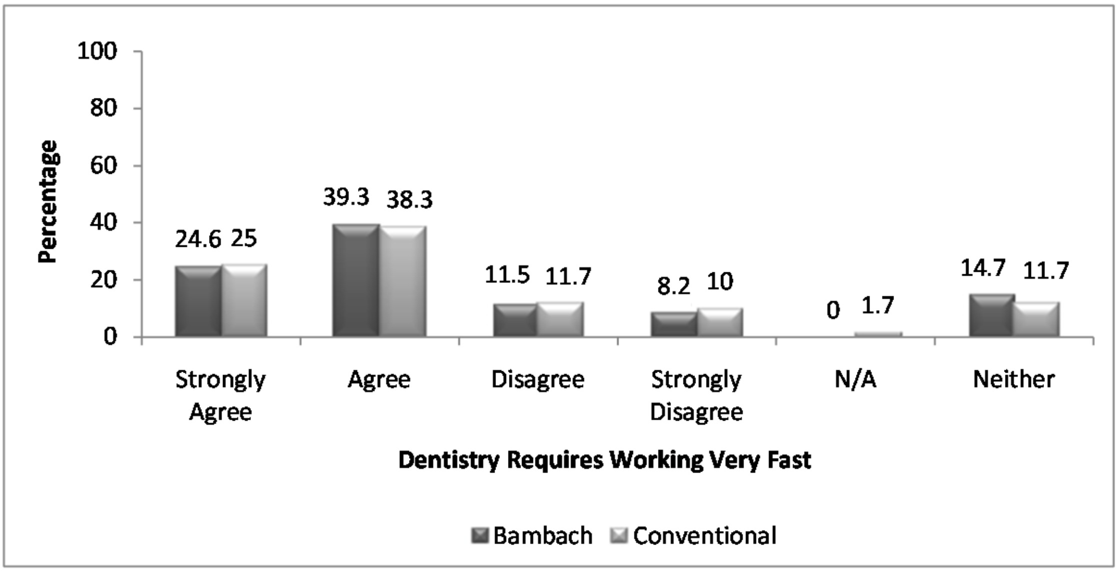


Fig. 2-66. Dentistry requires working very fast

Dentistry requires working very hard

The results are presented in figure 2-67.

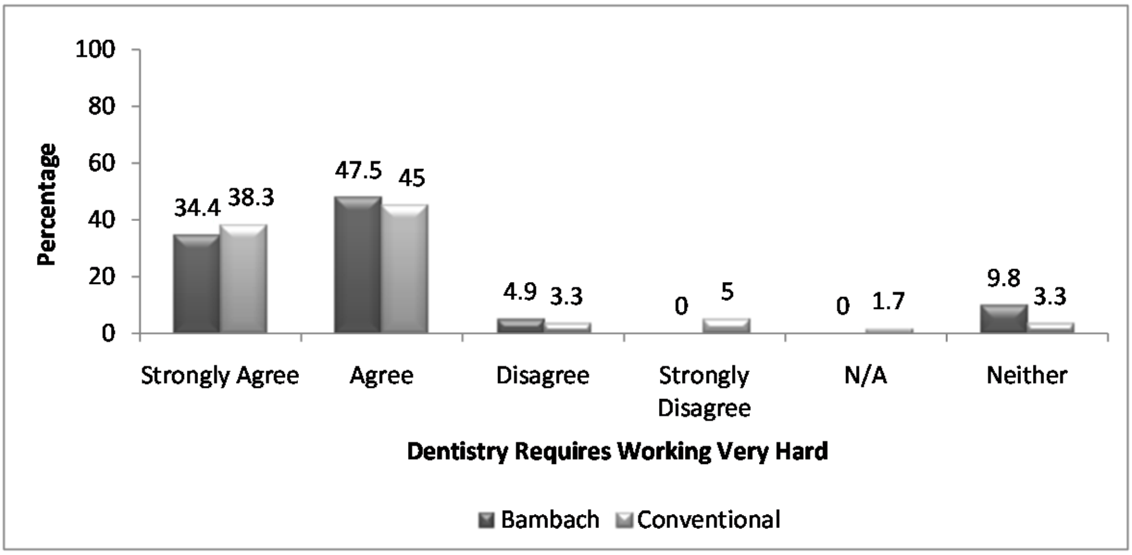


Fig. 2-67. Dentistry requires working very hard

Dentists are not asked to do excessive amount of work

The results are presented in figure 2-68.

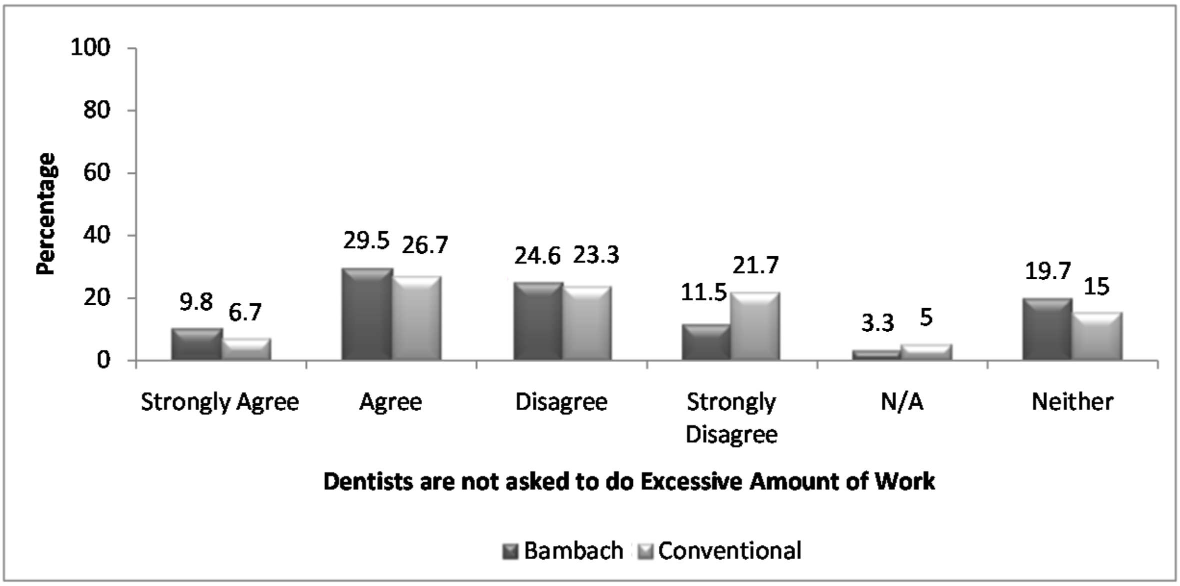


Fig. 2-68. Dentists are asked to excessive amount of work

Dentists have enough time to get their job done

The results are presented in figure 2-69.

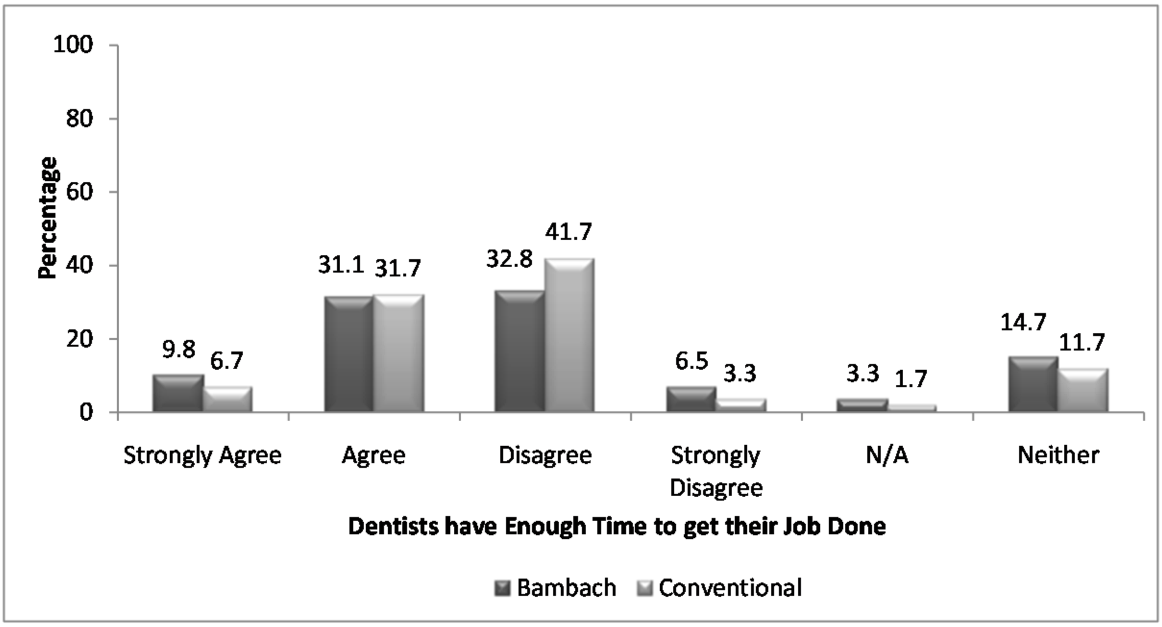


Fig. 2-69. Dentists have enough time to get their job done

Dentists are free from conflicting demands others make

The results are presented in figure 2-70.

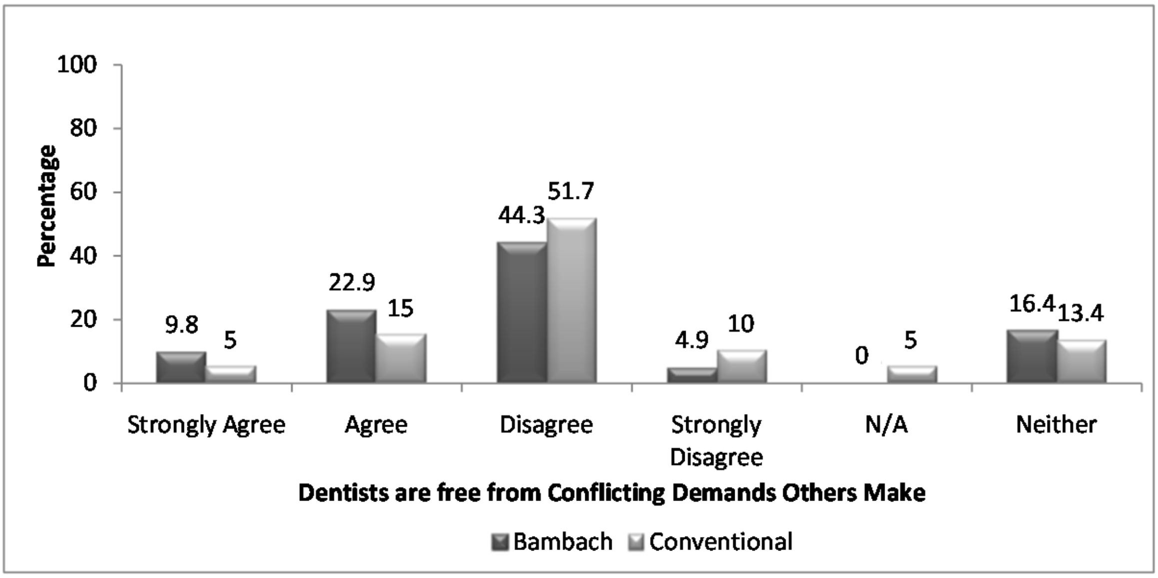


Fig. 2-70. Dentists are free from conflicting demands others make

People dentists work with are helpful in getting the job done

The results are presented in figure 2-71.

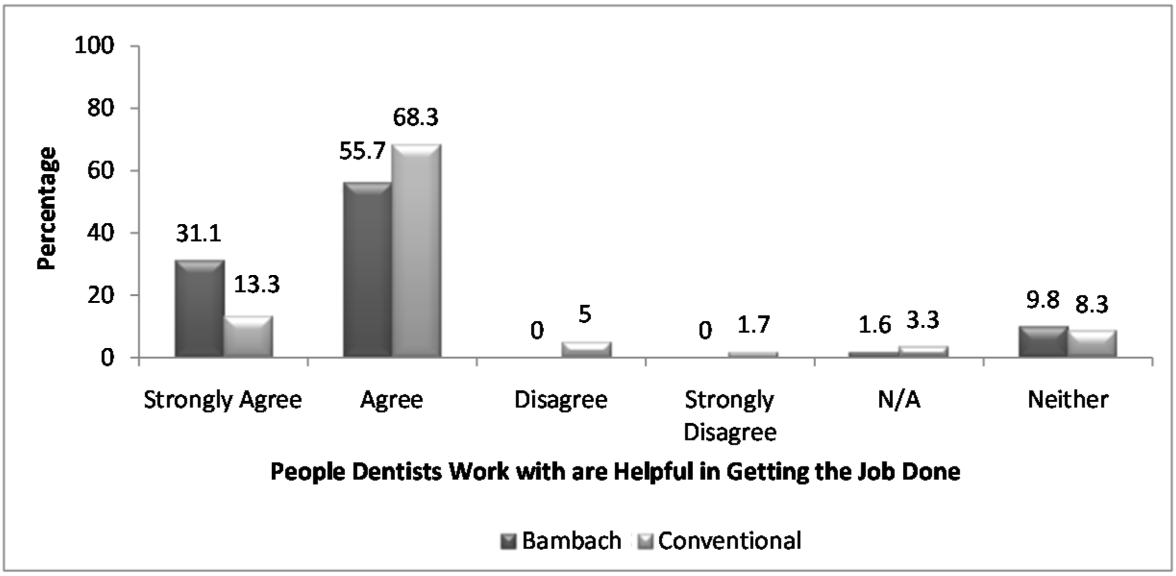


Fig. 2-71. People dentists work with are helpful in getting the job done

The results indicate that 40% to 70% of dentists have no difficulty in performing their dental work, and 15% to 30% of the dentists do have some difficulty in performing their dental work some of the time. Only 5% to 10% of dentists reported difficulty in performing work all the time. However 50% to 60% of dentists reported bodily pain in the questionnaire. This may indicate that many dentists work whilst having bodily pain but may not feel difficulty in performing dental work showing a positive attitude towards work (Thornton et al 2004). Another aspect of this positive attitude is seen among 90% of dentists who agree that dentistry requires learning new things, involves repetitive work, and requires high level of skill and to be creative. However 70% of dentists agree that dental work requires working hard and fast and 50% of dentists disagree that they have enough time to get their job done which may indicate the physical demands placed on dentists (Thornton et al 2004).

2.2.6 Discussion:

The results indicated that the dentists using Bambach seats are younger than the dentists using Conventional seats, which may imply that younger dentists are more aware about the working posture when compared to older dentists. This may be because they have set up their practices and have had a greater choice of dental furniture, whereas the older dentists have kept the first seat that they bought when setting up their surgery.

The results indicated that 77.7% (n=94) of the respondents for the questionnaire were male, and only 22.3% (n=27) were female. In the 94 male respondents the BSD group had 67.2% (n=41) male dentists and the CSD group had 88.3% (n=53) male dentists. In the 27 female respondents BSD group had 16.5%, n=20 female dentists and the CSD group which had 5.8%, n=7 female dentists. This may indicate that generally female dentists have increased interest to improve their occupational health and work habits.

Finsen et al (1998) reported that the dentists on average work around 30 to 40 hours per week, which was confirmed in this study. Approximately half of the dentists (49.2% of BSD and 45% of CSD) had reported that they work around 7-8 hours each workday and 13.1% of BSD and 18.3% of CSD reported working more than 9 hours each workday. 30.6% of the dentists work without taking any rest breaks, which may be a factor in the development of a musculoskeletal pain (Chapter 1, Section 1.1.11), and in due course, into a musculoskeletal disorder. The results indicated that higher number of CSD who does not take regular rest breaks had bodily pain, and significant strength of association was established between dentists reporting bodily pain and taking rest breaks. Around two-thirds of dentists in both the groups reported that they never rest their hands in a typical work day. Investigating the health problems reported by dentists indicated that a quarter of dentists reported musculoskeletal problems and only six to eleven percent of dentists reported medical problems. This suggests that the musculoskeletal disorders are the most common health problem among dentists (29.5%), confirming a view presented by Burke and Freeman (1997).

The use of magnifying loupes may influence the neck pain reported by dentists. The data indicate that 24.6% (n=15) of BSD and 31.1% (n=19) of CSD report neck pain. Only 26.7% (n=4) of BSD and 31.6% (n=6) of CSD using magnifying loupes reported neck pain, indicating that neck posture may affect neck pain as the dentists using magnifying loupes maintain good neck posture, and also the BS assists in facilitating good working posture (Chapter 6, Section 6.7.9). The results indicated that higher number of CSD who disagree that their neck rests comfortably had neck pain, and significant strength of association was established between dentists reporting neck pain and neck comfort.

The results indicate that a larger number of BSD had training on using the correct operating position when compared to CSD. It may be considered that dentists who are more aware of their posture and work habits have purchased the BS. It might be that in setting up the BS the dentists read the instructions about its use whereas the CSD just sat down and started to work, having had a CS during training

Around a third of BSD had indicated that their lumbar spine was not supported while seated on the BS and a third of BSD had indicated that back support is not applicable with BS since backrest is not a standard feature available with the BS. But even without a backrest a third of the dentists agree that their lumbar spine is supported when using BS, since the BS places the lumbar spine in a comfortable position while seated (Pheasant, 1991) (Chapter 3, Section 3.16 and 3.18). Eighty five percent of the BSD agree that the BS provides comfortable bottom support, and 79% agree that the BS allows their arms to rest in a comfortable position while seated, and only 53% of CSD agree that their arms rest comfortable. This may be because these dentists were working in a slumped position when seated on the CS and as a result, may need to strain their arms while working. This has also been indicated as increased EMG activity recorded in the trapezius muscles with the CSD in the EMG study, which is discussed later.

Ninety percent of the BSD agree that their legs and feet were comfortable and 70% agreed that their neck was positioned in a comfortable position while seated on BS, but only 45% of the CSD agree that their neck was in a comfortable position while seated on a CS. Eighty eight percent of the BSD agree that their operator's stool is comfortable and are satisfied in using the BS, while 70% of the CSD agree that their operator's stool is comfortable. This may indicate that the BSD feel more comfortable while working with patients.

Fifty percent of the BSD and 60% of the CSD reported pain during the four weeks prior to answering the questionnaire, of which 67.18% of BSD and 38.32% of CSD had consulted a health professional for their pain. This may indicate that the BSD are more concerned about their pain compared with the CSD, given that the areas of pain reported by both the groups were similar. Exploring the pain affecting dental work indicates that the number of dentists affected by moderate and extreme pain was more with CSD compared with BSD, which is also supported by the results where the CSD reported more intense pain (9 on a 10 point scale) compared with BSD. It could be hypothesized that the BSD have bought their BS because they had pain and this may be a reason why they might be seeing a health professional.

The results indicate interesting patterns with the dentists in respect to pain and hours worked. In the BSD the number of dentists reporting pain reduced as the number of hours they worked increased, whereas the opposite occurs with the CSD in which the number of dentists reporting pain increased as the number of hours they worked increases, which may be considered a typical pattern. This may be because the dentists are comfortable when using the BS as their posture is predominantly maintained by the passive structures of their body. In the BSD the percentage of male dentists reporting pain were less when compared to female dentists; whereas the opposite occurs with the CSD i.e. the percentage of female dentists reporting pain were less when compared to male dentists.

Investigating the psychosocial aspects and characteristics of this questionnaire indicates no significant difference between groups i.e. both the groups of dentists answered the psychosocial questions similarly. But there is a common pattern observed among dentists about considering their attitude towards dental work. Investigating the physical demands of dental work indicates that 30% of dentists find difficulty in working the required number of hours, have difficulty in doing work without extra breaks, and have difficulty working fast enough some of the time. Twenty five percent of dentists have difficulty sticking to a routine or schedule some of the time, and 25% of BSD have difficulty in finishing work on time, whereas 35% of the CSD have difficulty in finishing work on time some of the time. Similarly, 30% of dentists have difficulty in handling their workload some of the time and around 35 to 40% of dentists have difficulty in feeling a sense of accomplishment and feeling what they are capable of doing. However most of the dentists show a positive attitude towards work, with 55% to 60% of dentists reporting that their pain does not affect their work.

Investigating the psychological strain occurring due to dental work indicates that most of the dentists in both groups cope with the stress which occurs due to dental work. Most of the dentists agree or strongly agree that dentistry requires learning new things and to be creative, which requires high level of skill. They also agree or strongly agree that the dental job involves lot of repetitive work, which involves a variety of things (dental procedures) and gives an opportunity to develop special abilities. These show the positive attitude of dentists towards their work.

The dentists also strongly agree that the dental job requires working very hard and fast with 35 to 45% of dentists agreeing that they are asked to do excessive amount of work, and around 40 to 45% of dentists feeling that they don't have enough time to get their job done. These indicate physical demands placed on dentists by dental work. Around 50% to 60% of dentists also disagree or strongly disagree that they are free from conflicting demands others make, which may increase the psychological strain placed on them.

Chapter 3

Assessing Working Postures Using Observational Analysis

3.0 Introduction

It could be considered that the analysis of postures in a workplace requires techniques which are simple and reliable. The recording of posture by observational methods using pen and paper has been carried out from as early as the 17th century, particularly for choreography, such a method being used by Beauchamps-Feuillet in the 17th century (Corlett et al 1979). After this period labanotation (Hutchinson, 1954) and Benesh notation (1956) for ballet dancers were developed to record ballet posture and dance movement. These earlier techniques were not suitable for assessing work postures and hence a numerical observation method to record posture was developed by Priel in 1974. Kember in 1976 was the first to publish the Benesh Movement notation in a study of sitting behaviour. There are a number of techniques to assess risks for work-related musculoskeletal injuries, and these still may include pen and paper-based observational methods. However new technologies have been adapted and developed, including video analysis, and computer analysis using specialised instruments. This chapter describes the various pen and paper observational techniques, their merits and demerits and the method chosen for analysing dentist posture.

3.1 Why Observational Analysis using pen and paper?

Observational analysis using pen and paper are simple, inexpensive and easy to carry out in a workplace without disturbing the person assessed. The advantages of this include

- This method of analysis can be used live or using video recording or by using photographs.

- Static postures can be recorded with precision using this method where the postures are held for longer periods of time
- Simple numerical scoring systems to quantify posture have been used in different methods of observation.
- The method is quick and easy to use

3.1.1 Reliability of observational analysis

Reliability is the degree of stability exhibited when a measurement is repeated under identical conditions (Stedman's Medical Dictionary, 2000)

Yen & Radwin (2000) compared spectral analysis of electrogoniometer data and observational analysis to quantify repetitive motion and ergonomic changes in cyclical industrial work. Six industrial jobs were selected for analysis. Motion of the joints of the upper limbs was analysed using both spectral and observational analysis. Joint angles for the wrist, elbow and shoulder were directly measured using electrogoniometers.

The spectral analysis method involved calculating power spectra for each cycle of sampled electrogoniometer data and averaging all the cycles into a single spectrum (Radwin *et al*. 1994). Visual posture classification involved determining joint angles from a frozen videotape image. Observational analysis was used to measure the frequency of a specific movement, while spectral analysis measured the frequency where spectral peaks occurred. The results showed the correlation between the postural classification and spectral analysis was 0.77 for sustained posture and 0.53 for posture deviation and the correlation increased to 0.81 when large motions were compared (Radwin *et al*. 1994). This high correlation for sustained posture shows that observation analysis may be a reliable technique when large motions are estimated.

The observational analysis may vary between the researchers. Burdorf (1992) stated that observational analysis has problems with reliability because these recording procedures lack precision and are subject to intra and inter-observer variability. Some of the techniques of observation have evaluated the reliability of the procedure and are explained in this chapter. The reliability was better when static jobs are concerned and where the body postures are held for longer periods of time and follows a simple pattern of movement (Li & Buckle, 1998; Yen & Radwin, 2000). To overcome this problem the inter-observer and intra-observer reliability of the chosen technique was tested in this study. The reliability of various observational techniques is explained in section 3.9.

3.1.2 Problems of Observation

The problems associated with observational analysis are discussed below.

Awareness by the worker being observed

This is a major problem when observing any individual in the work environment, this potentially having an influence on the study. The behaviour of the individual in a work environment was studied in a research project (1927 - 1932) of the Hawthorne Plant of the Western Electric Company in Cicero, Illinois. The study showed that the individual's behaviour may be altered because they knew they were being studied. The term 'Hawthorne Effect' was coined in their study; this is explained below:

The Hawthorne Effect – 'an increase in worker productivity produced by the psychological stimulus of being singled out and made to feel important' (http://www.nwlink.com/~donclark/hrd/history/hawthorne.html).

This may also apply for dentists and dental students as they may become aware of being observed and their posture may differ from typical. In the present study, accordingly the following steps were taken to minimise this effect:

- The students were informed about the study through e-mail before the actual study
- The researcher individually described the study to the students and consent was obtained from the interested students beforehand.
- The researcher observed the students at their clinics several times and mingled with the students before starting the study. This was done so that the students could become accustomed to being observed and to reduce the awareness of being observed.

While observing in the actual study the researcher avoided standing prominently in front of the student, which would have given a direct effect of being observed. If the person became aware of being observed the observation was stopped and carried out at a later time.

3.2 Posturegram

Priel (1974) was the first person to report a numerical method for analysis of posture. The method was originally developed to aid equipment design and involved the use of a paper card called Posturegram (Appendix II), which allow postures to be numerically defined and recorded.

According to Posturegram the analyst has to establish

1. The levels at which joints and limbs are located,
2. The base posture of the body within X, Y and Z coordinate planes; and,
3. The direction and amount of movement within these planes.

The numerical definitions include the basic posture of the whole body to indicate inclinations forward, backward, or laterally, as expressed in degrees. The recording chart first establishes the position of the body and represents, in every case, the starting point for the recording of limb position. It is evident that limb movement can take place, within certain limitations, regardless of the posture of the torso. Next, the levels at which joints are located are recorded, and then the angles of the limbs are recorded. The ranges of angles shown in the recording chart are arbitrary and not well established and may be chosen according to specific field of work. The proper identification of study is mandatory and a small sketch may be made in the space provided. A brief verbal explanation of the posture is explained at the bottom of the recording chart. The criterion to establish good posture has not been explained in the study.

3.3 OWAS – Ovako Working Posture Analysis System

The OWAS system was developed by Ovako Oy Steel Co, in Finland, and first described by Karhu et al. (1977). The system was originally developed to evaluate the working postures in the steel industry. The method consists of two parts, the first being an observational technique for evaluating working posture and the second part being a set of criteria for the redesign of working methods and places. The system defines the movements of body segments around the lower back, shoulder and lower extremity (including the hip, knee and ankle) as four types: bending, rotation, elevation and position. To use this system, the analyst makes an instantaneous observation of posture and records a three-digit code, representing the positions of the back (four choices), the arms (three choices), the legs (seven choices) and force (Appendix III). The recording procedure requires only a few seconds, but a possible shortcoming of the system is that the posture categories are too broad to provide accurate posture description (Keyserling, 1986).

OWAS also has action categories to reflect the risk level of the person observed (Karhu et al 1977).

- Class 1 = normal postures which do not need any special attention, except in some special cases
- Class 2 = postures must be considered during the next regular check of working methods
- Class 3 = postures need consideration in near future
- Class 4 = postures need immediate attention

Kivi and Matilla (1991) have examined the use of the OWAS method to analyse work postures in building construction and have developed a portable computer system for the OWAS method. The results have been used as part of the ergonomics training programme of the company and suggestions for work, improving working conditions and practices have been suggested.

Later, Matilla et al (1993) analysed working posture in hammering tasks on building construction sites using the computerised OWAS method. The hammering tasks which included roof boarding, concrete form preparation, clamping support braces, assembling roof frames, roof joisting, shelter form preparation, and fixing fork clamps were observed from 18 construction workers for a two-month period. Of all the observations, poor working postures were observed most frequently in roof joisting (12.4%), followed by concrete form preparation (8.6%), and construction of frames for the roof (7.5%). Overall, out of 593 different postures analyzed, a total of 7.8% of postures adopted by the workers during various hammering tasks were classified into OWAS classes 3 or 4, indicating that these postures should be corrected either soon or immediately.

Using the OWAS, Kant and co-workers (1990) observed working postures of mechanics (n = 84) in 42 garages. During observation, both working postures and work activities were recorded. Five out of 19 observed postures of the subjects were classified as Action Category 2, which suggested they were slightly harmful to the musculoskeletal system and likely to cause discomfort. Of the typical working postures analysed, 31.9% were again classified in Action Category 2, suggesting that during a substantial part of the working day typical working postures occur which are at least slightly harmful to the musculoskeletal system. It has been found that these work postures are observed with mechanics involved in garage work, where the back is bent, arms above shoulder, lower limb in kneeling position and the head bent forward or backward.

Three activities were identified as higher risk and for each of these activities an alternative work method was observed. These were

- Working underneath the car using a vehicle lift
- Working under the bonnet (car on floor)
- Working at the side of the car (car on floor)

Work methods were observed during the following work postures to identify the method that improves posture:

- Maintenance and repair activities underneath the car
- The use of vehicle lift
- Working underneath the car
- Working at the side of the car
- Working under the bonnet and
- Direct access to engines.

The data indicated that the work activities involving the use of a vehicle lift reduced the number of poor working postures, thereby reducing the load on the musculoskeletal system (Kant et al 1990).

Engels et al (1994) analysed working postures of nurses using the OWAS method. Eighteen Dutch nurses in an orthopaedic and urology ward were observed using the

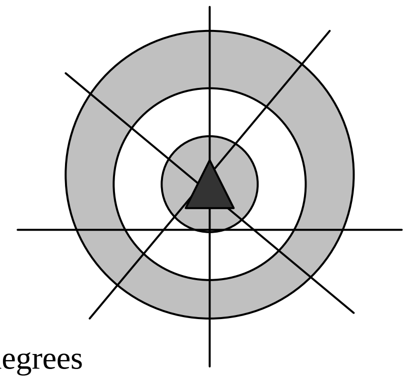
OWAS. During the observation both working postures and activities were recorded and a specially developed computer program was used for data analysis. The software was designed to calculate the working posture load for each activity and the contribution of a specific activity to the total working posture load. The study showed that some activities of the nurses in both wards were performed with poor working postures. The poor postures included postures in which the head is bent forward (orthopaedic and urology ward) and the back is bent forward and twisted (orthopaedic ward). In both wards the administration activities, wound care and patient care were found to have contributed to poor head posture (bent forwards). Poor back posture was observed in the orthopaedic ward in the activities of wound care and patient care. This is likely to be due to the specific nature of tasks undertaken in an orthopaedic ward where the patient is likely to have particular difficulty in bed mobility requiring additional manual handling, due to the specific surgical intervention and requires nursing care different to that required for urology patients who may have undergone abdominal surgery but these will not involve the limbs. Even after the introduction of Manual Handling Operations Regulations (MHOR) in 1992, bad posture was observed in the orthopaedic ward.

In the orthopaedic ward two out of 19 observed postures of parts of the body were classified as Action Category 2. The results suggested that in both wards, working postures that are slightly harmful to the musculoskeletal system occur during a substantial part of the working day. Differences between both wards with respect to working posture load and time expenditure were determined. Activities causing the workload to fall into OWAS higher Action Categories were identified. The data show that poor working postures in the nursing profession not only occur during patient handling activities but also during tasks like 'administration'.

Li and Lee (1999) analysed work postures of construction workers using the OWAS method. They analysed 2,880 working postures for scaffold, form, iron and cement works at two construction sites. They used a computer program, CCOWAS, which was designed for the purpose of this study. They found that more than 30% of the working postures analysed were categorised as Class 1, Class2, Class 3, or Class 4. 43.3% of scaffold workers were identified to be having harmful postures. The most stressful postures identified were sawing, positioning and wire-tying of iron rods for iron workers; brick laying for cement workers; and manual handling of steel frames in confined spaces for scaffold workers.

3.4 Posture Targetting

Posture targeting is a technique to assess postural stress, this having been developed and described by Corlett et al (1979). This is a method of recording the posture for the whole body and considers the limbs, the torso and the head as linked to each other and to the trunk. On a body chart each part of the body is provided with a set of concentric circles or targets (Appendix IV), which are drawn adjacent to the body parts. The body is shown in a standard position. When the body deflects from this standard position it is noted in the targets in the chart, as follows: (Fig. 3-1)



1. 0 – 45 degrees
2. 45 – 90 degrees
3. 90 – 135 degrees
4. 135 – 180 degrees

Fig. 3-1. The Target used for recording body part displacement
(Adapted from Corlett (1979))

Each target has four circles representing a different range of motion in degrees. The circle marked 1 represents 45 degrees from the standard position, circle 2 is 90 degrees and so on and the arrow on the centre indicates the front of the body. The movements are seen in a horizontal plane and are marked according to radial lines. In joints where the degrees of freedom are restricted the lines and segments are deleted from the diagram. The small cross-shown on the target, if referring to the forearm, would indicate that the arm was pointing horizontally at an angle of 45 degrees to the sagittal plane.

In order to know what the person is doing when a posture is adopted, a list of words indicating possible activities is given in the chart to note which activity is being used (Appendix IV). Another method of using the chart is by blocking areas of diagram to cover all the movements for the job assessed (Appendix V). The author stated that this method could be used when the range of motion is less.

Tracy and Corlett (1991) have explained, in their study, about a computer program developed to determine the movements about joints using static tasks using a posture-targetting method. The software differentiates between flexion/extension, rotation and adduction/abduction requirements for various postures. It also evaluates the loads placed on the spine within low-back muscles for purposes of comparison with many manual handling studies.

The posture targeting method was also used in analysing movements in competitive sports. Sen et al (1993) have attempted to develop a simple method for measuring skill in competitive sports, by analysing the movement pattern of five badminton players using string diagram methods. Detailed analysis of the movement paths indicated that the strategy and skill of players could be measured by this method. To identify dynamic postures the OWAS and Posture Targetting technique were modified and tested. Their study concluded that the Posture Targetting technique was helpful in analysing movements and postures during competitive sports.

3.5 Posture Recording: A Model for Sitting Posture

A model for recording sitting posture was proposed by Gil and Tunes (1989). This model was originally developed for seated subjects undergoing classroom activities. The sitting posture is recorded on a card (Appendix VI) which contains space for recording general information and has columns to record four different postural configurations for thigh-trunk, thigh-leg and trunk-arm angles (Figures 3-2, 3-3 and 3-4).

If a segment is supported it is denoted as +, and – if not supported. The bilateral segments are marked on the left and right side of each word in the card. The angular variations between two segments were recorded by ticking the angle which approximately corresponds to the observed variation. Figures 3-2, 3-3 and 3-4 illustrate the angular variation recorded between the segments explained above. The method allows identification of different postures, as well as their relative frequency of occurrence.

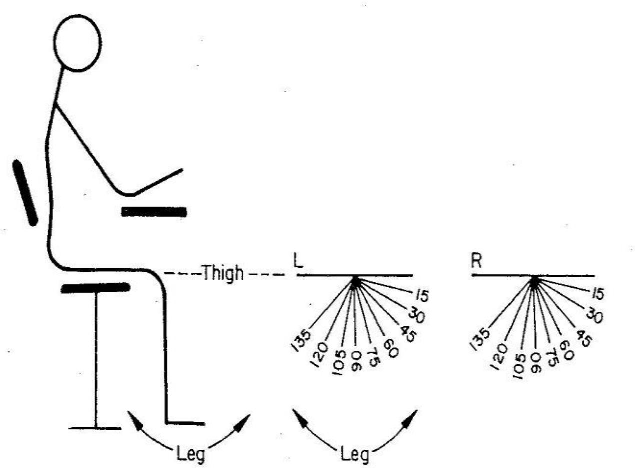


Fig. 3-2. Recording the angles between thigh and left leg, and between thigh and right leg
(Reproduced from Gil and Tunes 1989)

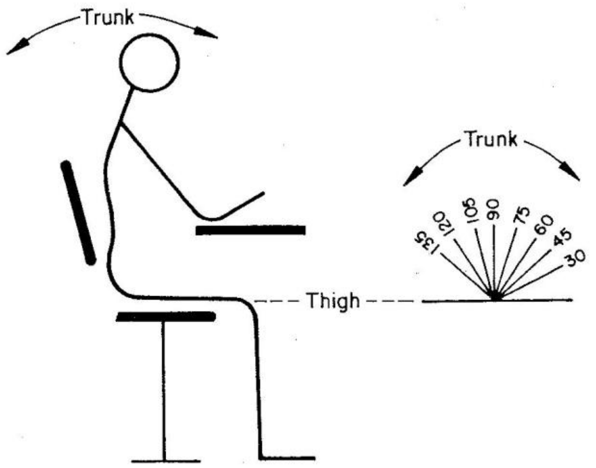


Fig. 3-3. Recording the angles between the thigh and trunk

(Reproduced from Gil and Tunes 1989)

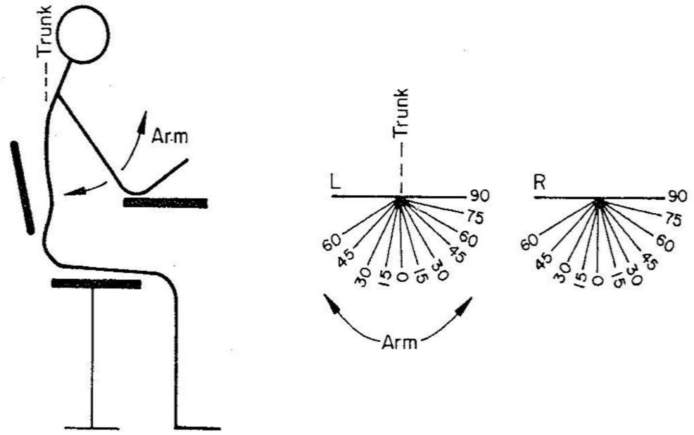


Fig. 3-4. Recording the angles between the trunk and left arm, and trunk and right arm

(Reproduced from Gil and Tunes 1989)

3.6 PLIBEL (Method of identification of musculoskeletal stress factors which may have injurious effects)

This is a method to assess the ergonomic risk factors by using a checklist with relevance to five body regions (Kemmlert and Kilbom, 1987). The checklist has questions regarding awkward work postures, tiresome work movements, poor design of tools in the workplace, environmental and organisational conditions. Interestingly, PLIBEL does not appear to be an acronym and is not explained in the publication.

The workplace assessment using this method starts with a brief interview with the employee. The tasks that are used for most of the working hours and the stressful jobs are selected for assessments. When a hazard is seen the numbered area on the form is ticked or a short note is made. When PLIBEL is used to identify risk factors for a specific body region the questions relevant to the region are answered. The PLIBEL was originally designed to identify musculoskeletal risk factors in industrial workers.

3.6.1 Validity and Applicability

Kemmlert (1995) explained the reliability and validity of the technique. The construct validity, criterion validity, reliability and applicability were explained in the study.

3.6.1.1 Construct Validity: In order to establish construct validity for each item in PLIBEL Kemmlert (1995) made a search of all available scientific literature on occupational risk factors for musculoskeletal disorders and produced as an evidence for items used in his study.

3.6.1.2 Criterion Validity: The German ergonomics job analysis procedure AET (Arbeitswissenschaftliche Erhebungsverfahren zur Tatigkeitsanalyse) (Rohmert and Landau, 1983) was chosen as a reference instrument in field-testing. Two researchers, who had previous experience in using AET and PLIBEL identified 18 matching items in the two methods. The two methods were simultaneously used by both researchers when observing 25 workers (10 postmen, 6 post assistants, 2 cashiers, 1 meat cutter, 1 stone layer, 1 trench digger, 1 warehouse worker, 1 miller and 1 distributor). At 9 of the 25-workplace observations no ergonomic hazards were found by PLIBEL or AET. The matching items in the remaining 16-workplace observations were analysed and 9 of the observation PLIBEL were in agreement with AET. In 6 other observations ergonomic hazards were only registered with PLIBEL. This disagreement in PLIBEL registrations makes it more sensitive than AET in postural analysis. No occurrence was registered for four of the items, and for five items very few registrations were made, with kappa values as 0.00. Fair to moderate agreement between methods was noted for the tasks where repeated lifting of loads, repetition of similar working movements and repetition of similar work movements beyond comfortable reaching distance were observed. The agreement between matching items are moderate between PLIBEL and AET but PLIBEL was more sensitive to ergonomic hazards, which led to poor or slight agreement for some items.

3.6.2 Applicability: The background for using PLIBEL was documented by Kemmlert (1995). The method had been used in several studies by occupational health personnel but details not been published. In some studies a considerable number of workers had been studied and in most cases musculoskeletal injury of one individual employee was assessed. The exact numbers of subjects used in different studies were not specified. The studies were performed in different locations such as the manufacturing and electronics industry, the service industry, home care, catering and refuse collection, post offices, warehouses and harbour terminals, and at carpentry and a bakery in Sweden.

Kemmlert (1995) suggested that items exposed on the PLIBEL were easy to comprehend and would readily be modified as a result of future research and experience. There is no concrete method of using the items in PLIBEL. This method is regarded as a verbal interpretation of ergonomic working conditions and not a quantitative measurement of posture. Kemmlert (1995) also suggested that only continuous use of PLIBEL would increase the understanding of ergonomics hazards at workplaces. Interestingly PLIBEL has only been used by the research team and has not been adopted in any other studies identified in this literature review.

3.7 QEC – Quick Exposure Check (Appendix VIII)

The QEC, a tool to assess work-related musculoskeletal disorders was first described by Li and Buckle in 1998. The tool has been designed to assess the change in exposure to the musculoskeletal risks before and after an ergonomic intervention. Before assessing the posture, a preliminary observation of the job should be made for at least one work cycle. The QEC checklist is shown below and is explained in detail.

3.7.1 Exposure assessment for the back (Back Posture - A1-A3)

The assessment for the back posture was made at the moment when the back is most heavily loaded.

- The back has been regarded as "**Almost neutral**" (Level A1) if the person is seen to work with his/her back flexion/extension, twisting, or side bending less than 20°
- The back has been regarded as "**Moderately flexed or twisted**" (Level A2) if the person is seen to work with his/her back flexion/extension, twisting or side bending more than 20° but less than 60°
- The back has been regarded as "**Excessively flexed or twisted**" (Level A3) if the person is seen to work with his/her back flexion or twisting more than 60° (or close to 90°)

3.7.2 Exposure assessment for the back (Back Movement - B1-B5)

For manual material handling tasks, assess B1-B3, which is the frequency of the movements of the back (Appendix VIII). This refers to how often the person needs to bend, and rotate his/her back when performing the task. Several back movements may happen within one task cycle. For tasks other than manual handling, such as sedentary work or repetitive tasks performed in standing or seated position, B1-B3 is avoided and B4-B5 (static postures) is assessed.

3.7.3 Exposure assessment for the shoulder/arm (Shoulder/arm Posture C1-C3)

(Appendix VIII)

Assessment has been made when the shoulder/arm is most heavily loaded during work, but not necessarily at the same time as the back is assessed.

3.7.4 Exposure assessment for the shoulder/arm (Shoulder/arm movement D1-D3)

The movement of the shoulder/arm is regarded as

- "**Infrequent**" (D1) if there is no regular motion pattern.
- "**Frequent**"(D2) if there is a regular motion pattern with some short pauses.
- "**Very frequent**"(D3) if there is a regular continuous motion pattern during work.

3.7.5 Exposure assessment for the wrist/hand (Wrist/hand posture E1-E2)

This is assessed when the most awkward wrist posture is adopted. The wrist is regarded as "**almost straight**" (Level E1) if its movement is limited within a small angular range (e.g. <15°) of the neutral wrist posture (Fig. 3-5). Otherwise, if an obvious wrist angle can be observed during the performance of the task, the wrist is considered to be "**deviated or bent**" (Level E2) (Fig. 3-6).

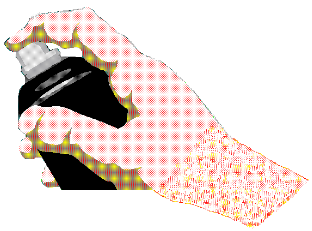


Fig. 3-5. The wrist is almost straight

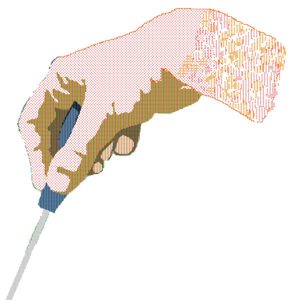


Fig. 3-6. The wrist is deviated or bent

(http://www.geocities.com/qecuk/)

3.7.6 Exposure assessment for the neck

The neck has been considered to be "**excessively bent or twisted**" if it is bent or twisted at an obvious angle (or more than 20°) relative to the torso.

3.7.7 Worker's assessment of the same task (Appendix X)

After the observer makes the assessment, the worker is asked to answer the questions related to the task. The weight handled, time spent, use of force, vibration, stress and visual demand during the task were analysed.

3.7.8 QEC - Calculation of the total exposure scores

The total exposure scores are calculated by combining the assessments from the 'observer' (A-G) and the 'worker' (a-e) by using a table (Appendix XI).

Steele and Stubbs (2002) used the QEC to measure working postures of midwives when assisting women to breast-feed. In their study the QEC was used to gather quantifiable data and following the observational study, midwives were requested to note their perceived musculoskeletal discomfort using self-reporting scores. The results suggest that midwives do experience musculoskeletal discomfort in the back and neck.

Validity: The validity was tested by comparing the practitioners' assessment on simulated tasks with computer-aided 3D motion analysis. Two types of manual handling tasks and two types of repetitive manual assembly tasks were performed. The tasks were randomly performed by one male subject during which tasks were assessed by 18 practitioners divided into five groups. Validity tests were also conducted in field studies by comparing 6 practitioners assessment on 60 tasks. The results indicated that most assessment items were correctly measured at an acceptable level of accuracy (Li and Buckle, 1998).

3.8 RULA – Rapid Upper Limb Assessment

RULA (rapid upper limb assessment) is a survey method originally developed to assess posture in various ergonomics investigations of workplaces where work-related upper limb disorders are reported for example VDU Operators. RULA was developed by McAtamney and Corlett (1993) to provide a method of screening work population for exposure to a likely risk of work-related upper limb disorders and was first described in 1993 in the Journal Applied Ergonomics (McAtamney & Corlett 1993). This is a useful tool, which provides a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function. A coding system is used to generate an action list, which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator (McAtamney & Corlett 1993). The method uses diagrams of body postures and three scoring tables to provide evaluation of exposure to risk factors by providing a risk score. The risk factors investigated in the RULA are based on McPhee (1987) and are described as external load factors, which were originally developed for manual workers. The factors are

- Number of movements
- Static muscle work;
- Force
- Work postures determined by the equipments and furniture
- Time worked without a break.

The RULA was thus developed to assess the first four external load factors mentioned above. According to McAtamney & Corlett (1993) the RULA was developed to provide a method of screening working population for work-related upper limb disorders, and to identify the muscular effort, which is associated with working posture, exerting force and performing static or repetitive work, which may contribute to muscle fatigue. The other aim is to provide a wider ergonomics assessment to fulfil the assessment requirements of the *UK Guidelines on the prevention of work-related upper limb disorders* (McAtamney & Corlett 1993).

3.8.1 Part I: The method for recording working postures with RULA

The body is divided into 2 segments (A and B) and assessed.

1. Upper Arm, Lower Arm & Wrist (Group A) (Appendix XII)
2. Neck, Trunk & Legs (Group B) (Appendix XII)

The range of movement of movement for each body part is divided into sections and recorded appropriately. The minimum score (Score 1) is given to the ranges of movement where the risk factors are minimal and higher numbers (up to 6) are given to ranges of movement with extreme postures.

Upper Limb Posture Score

The scores are individually recorded for the Upper arm, Lower arm and Wrist as shown in Fig.1. Using these scores a separate posture score for upper limb is calculated using Table.1 (Appendix XIII).

Neck Trunk and Leg Score

The scores are individually recorded for the Neck, Trunk and Leg as shown in Fig.2. Using these scores a separate posture score for Neck, Trunk and Legs is calculated using Table.2 (Appendix XIII).

3.8.2 Part II: System for grouping the body part posture scores with RULA

Posture Score: A single score is formed from Group A and B, which will represent the level of postural loading of the musculoskeletal system due to the combined body part postures. The score is ranked from a scale of 1 to 9. A score of 1 is defined as the posture where the least musculoskeletal loading occurred (Appendix XIII).

Muscle Use and Force Scores: A scoring system was developed to include the additional load on the musculoskeletal system caused by excessive static muscle work, repetitive motions and the requirement to exert force or maintain an external load while working. The muscle use scores are estimated for static postures held for longer than 1 minute or repeated more than 4 times per minute. The force load score is given for kilograms of materials handled during the work. Leuder (1996) has modified these score for computer users. The muscle use score is given to continuous use of computer for more than 2hr and the force score is estimated for total hours of use of computer in a day ($\geq$ 4hr and $\leq$ 6 hr = Score 1 and > 6hr / day = Score 2).

3.8.3 Part III: Grand Score and Action List with RULA

The scores from the body segments Group A and B are incorporated into a single grand score whose magnitude provides a guide to the priority for subsequent investigations. Each possible combination of score C and score D was given a rating of l-7 based upon the estimated risk of injury due to musculoskeletal loading. A table to calculate these scores was developed, with higher numbers denoting a larger risk.

The RULA has been used in a variety studies to assess working postures. Choobineh et al (2004) used RULA to evaluate a new workstation design developed in carpet mending. Traditionally, carpet mending is performed in squatting positions, which lead to problems in the knees, back and shoulders. This was found by questioning 72 menders regarding musculoskeletal disorders. The new workstation was designed to work in sitting posture; Choobineh et al (2004) observed eight menders using the new workstation design with RULA and found that the posture improved noticeably.

The RULA has also been used to evaluate professional truck drivers who are considered to have a high incidence of back and neck pain (Massaccessi et al 2003). In a study by Massaccessi et al (2003) 77 drivers of rubbish collection vehicles were analyzed using RULA. These drivers were reported to be driving with neck and trunk both flexed, bent and twisted. The results showed that there was a significant association between trunk and neck scores and reported pain in trunk and neck regions in all subjects. The posture scores were significantly different when the drivers used an adjustable vs. a non-adjustable seat, the posture score being less in adjustable seats, indicating less risk for work related musculoskeletal injury.

Hedge and colleagues (1995) measured the wrist and seated posture using RULA and musculoskeletal discomfort, recorded by self-report questionnaires in 38 office workers while they typed the same text. A pre-test survey was conducted to assess the effects of typing with a conventional keyboard on a desk or on an articulating keyboard tray, and with or without wrist rests. Following this, workers were randomly allocated to either a control group (n = 15), for whom nothing changed, or a test group (n = 23) who used their existing keyboard in a preset tilt down (PT) system. After three weeks of using the PT system a post-test survey was conducted for both groups. Results showed no significant changes in wrist posture, seated posture, or reports of musculoskeletal discomfort for the control group. Significant improvements in wrist posture, seated posture, and upper body musculoskeletal discomfort were found for workers using the PT system. Workers expressed a strong preference for using a keyboard with the PT system.

Herbert et al (1996) evaluated posture in adjustable chairs using RULA in garment workers whose work as spoolers required them to repetitively turn a manual, waist-height crank with their right arm, while simultaneously performing finger movements, with their left hand. The participants were 36 females. At baseline the proportion of pain in the shoulder, elbow and hand on the right side were consistently greater than the left side. Following the introduction of the adjustable chair, there was a significant reduction in the proportion of employees reporting pain in all the regions ($p<0.05$). The RULA, when compared, showed that there was a significant decline ($p<0.05$) in exposure to awkward postures in the left wrist, and small reductions in awkward postures on other sites.

Mohammed et al (1999) investigated postural stress in sedentary workers using RULA. Data entry and VDT terminal tasks and a manual paper handling tasks were assessed to determine postures associated with musculoskeletal disorders. Twelve workers at a data processing centre were videotaped for 30-minute intervals as they performed either a data entry task or document preparation. The videotapes were later analysed using RULA. The results showed the postural analysis for document preparation workers indicated that the postures were not acceptable by RULA and that changes in the job design needed immediate attention.

To analyse the working posture of a dentist the technique should be suitable, quick, easy and reliable. For this reason a review of currently used paper-based observational methods to analyse posture was carried out and the best available method suitable for dentists chosen. The following describes the requirements for assessing dentist's posture, their merits and demerits and the method thereby chosen for assessing dentists working posture.

3.9 Reliability of various Observational Techniques

OWAS: A simple method to evaluate the reliability of OWAS was described by De Bruijn et al in 1998. They used the slides of nurses in different working postures to determine the reliability of observations. Observers looked at each slide for 3 seconds, and a new slide was shown every 30 seconds. The observers then encoded the positions of the back, arms, legs and head of the worker. To evaluate inter-observer reliability, the two observers encoded 45 slides independently. To determine the intra-observer reliability, one observer was asked to score a series of slides twice, 32 of which were identical at both viewings and the interval between the two viewings was 4 weeks. On the second viewing, the slides were shuffled to avoid recall effects. During the period between the first and the second measurement the observer did not have any additional training in the OWAS method. The first measurement was done at the beginning of the study and the second measurement 3.5 months later. Two observers scored a series of slides twice, some of them being identical at both views. A different set of slides was used to evaluate inter-observer and intra-observer reliability. The intra observer reliability could only be scored on the 32 slides used by both testers. The OWAS scores of the corresponding slides were compared and, in almost all comparisons, percentages of agreement over 85% and Kappa's co-efficient over 0.6 were obtained, which was considered as good agreement.

Posture Targetting: The reliability of the procedure was tested in two methods, one using briefly trained observers and other using experienced observers and a motion camera. Ten observers were trained for an hour before they recorded six static postures (3 demonstrated by a living subject and 3 machine operators shown on slides). The observers were given 30 seconds to record each posture on the form. The test was repeated three weeks later, without instruction or practice, and the results were compared to estimate the consistency between the two records. Test-retest correlations of recordings of stationary postures were compared. Ten subjects recorded all ten targets on the form for each of the six postures. The results showed that the correlation coefficients for the targets, when compared, were $r>0.16$ significant at 5% level and $r>0.23$ significant at 1% level, indicating that even after modest training, static postures may be recorded with high consistency even after a three-week interval with no practice.

An experienced observer studied five different industrial tasks, in parallel with a motion camera, and each of the ten body sections given on the recording chart was compared separately. For each task correlations between the observed and a measured value was made. Correlations between recording by the targeting technique and measures from cine film were compared. The results showed that the correlations coefficients were $r>0.17$, significant at 5% level, and $r>0.24$, significant at 1% level indicating high correlations for head and trunk but decreasing levels in other body parts.

Li and Lee (1999) investigated reliability in using the OWAS method with construction workers with two independent observers. The construction workers were videotaped for 1.5 h. The videotapes were played back later in the laboratory with a freeze frame every 30 second so that the working postures for the head, back, arms, legs and weight handled could be coded. The inter-observer reliability reported in the study was 75% to 90% for head/neck postures, 87% to 98% for back postures, 97% to 100% for arm postures, 93% to 98% for leg postures, and 92% to 100% for weight handled respectively. Excluding the analysis of head postures the study indicated high inter-rater reliability in the analysis of other body parts. The study used only two observers and the results may vary if multiple observers are used. This problem was addressed in this study by investigating reliability of using RULA with multiple raters.

PLIBEL: In a study by Kemmlert (1995) 24 people with considerable ergonomics knowledge (17 physiotherapists from occupational health service and 7 researchers with experience in field studies of occupational overuse syndromes) were asked to perform four assessments by PLIBEL. Four jobs with both obvious and minor risks for musculoskeletal injuries were chosen. The jobs were documented by video and were: work at a crosscutting machine in the wood industry; work at a folding machine in a bookbindery; refuse collection on a villa area; and laundry work. At the 4 work situations few ergonomic hazards were identified. For the machine work, one of the 26 possible items were identified by more than 80% of the observers and 8 items were identified as not a risk by 80% of the observers. For 35% of items there was an agreement between observers. The inter observer agreement was stated to be fair to moderate.

QEC Inter-Observer reliability: Eighteen tasks were selected from videos on various ergonomic field studies. Twenty-four practitioners participated in the test and they were divided into five groups and each group assessed the tasks independently. Before watching the videos the observers spent 5-10 minutes going through the 'Guide to the use of the exposure tool' and then the observers made their assessments on each task. The Cohen's kappa and percentage agreement was calculated using the data of 24 observers (Li and Buckle, 1998). There was a fair agreement between 24 practitioners when evaluated by Kappa analysis and more agreement was shown with experienced practitioners but inter-observer agreement on neck posture was not high. With percentage agreement, most assessment items were either close to or above 70%.

Intra-Observer reliability: A test-retest was conducted with 8 observers assessing the same set of 18-recorded tasks twice in 3-week interval (Li and Buckle 1998). The intra-observer reliability for almost all assessment items was at 'moderate agreement' level, and the test-retest agreements were statistically significant.

In general the reliability in using various observational techniques was indicated to be having fair to good agreement. However to overcome some of the problems faced by the observational methods, both Inter-observer and Intra-observer reliability were tested using multiple raters in this study.

3.10 Exposure of dentists to risk factors

Bramson et al (1998) studied the exposures of dentists to risk factors, by recruiting dentists and dental hygienists from four clinics across the United States. Initially the subjects were interviewed and extensively videotaped as they performed various dental procedures. The questions were directed in such a way to determine which of the body regions were experiencing discomforts. The information was then used to identify risk factors using two analysis tools BRIEF (Baseline Risk Identification of Ergonomic Factors) and EASY (Ergonomic Assessment Survey). Two ergonomists concurrently analysed the videotapes of dentists performing dental procedures. Ergonomic risk analyses of nine body areas were performed (left and right hands/wrists, elbows and shoulders and the neck, back and legs) and risk scores were given to each region. The results of the EASY indicated that for tasks, preparing crowns, and restorations, further investigation was needed in the following areas, namely, hands and wrists, shoulders, neck and back. It was also concluded that dentists and hygienists could be at a risk, depending on the procedures they were performing (Bramson et al 1998). The study then analysed the dental hygienists using EMG and goniometry when carrying out probing, scaling, polishing and flossing procedures and indicated significantly low to moderate risk exposures than high-risk exposures.

This study by Bramson et al (1998) provided information on dentist exposure to risk factors and the need for different body regions to be considered during analysis of risk factors, but it failed to produce concrete evidence and results. The numbers of subjects investigated were limited and more dental hygienists were recruited than dentists, thus dentists require further investigation.

3.10.1 Requirements for Analysis of Dentist's Posture

- The technique should analyse the sitting posture which is practised by dentists
- The technique should include detailed analysis of different joints of the body which must include

  Neck, Trunk and Legs

  Shoulder, Elbow and Wrists
- The technique should allow easy analysis of right and left sides simultaneously.
- The technique should be simple but detailed.
- The technique should not be time consuming.
- The technique should give a simple quantitative risk score.
- The technique should be reliable.

3.11 Analysis of Various Techniques of Postural Assessment

The posturegram (Priel, 1974), originally developed for manual and office work, may be useful to analyse certain aspects of dentist's work posture but does not cover all the aspects of posture and joint angles which need to be addressed with dentists. Dentists work mainly in a seated posture and the technique needs to be specific for assessing seated work posture. For example, the technique records the inclination of trunk and side flexion of the trunk and the twist of the whole body in the reference plane. The technique roughly records the levels of all the joints and their angles in a reference plane but it is necessary to record the posture again if analysis of the posture in a different plane is required. This is the main reason that makes the posturegram unsuitable for analysing dentists' posture. Priel (1974) has explained the posturegram in use by a mechanic and an office worker and the posturegram has also been used to analyse standing postures in normal subjects (Angelo & Grieve, 1987).

The OWAS (Karhu et al 1977) system developed for use in steel industries classifies posture broadly. The method was extensively used in building industries, garages and with nurses to some extent. The OWAS can be used with dentists to identify position of back and some aspects of the lower limb, but the upper limb classification is very broad, which is critical in assessing posture of dentists (Appendix III). This system may therefore not be very useful for analyzing working posture of dentists in sitting. Furthermore, the OWAS system identifies various positions of joints in standing posture, which makes it an unsuitable technique for assessing dentists since they work in a seated posture.

The Posture Targetting covers major joints and allows the recording of the joint angles by the observer. The technique is not very accurate and the risk factors associated with the postures observed and the method to evaluate the recorded posture is not explained. This is the main reason which makes the technique unsuitable to assess posture of a dentist.

The posture recording method analyses sitting posture only in one dimension by measuring the angles explained above. The posture of dentists has many components, which should be assessed, for example, the position of the neck, upper arm, lower arm and wrists. The posture assessed by this method is brief and time consuming. The angles recorded using this method are estimated by the observer and may reduce reliability. This method was originally developed for classroom activities and may be suitable for office work but not useful for assessing dentists' work posture. The reliability and validity of this method was not found in the literature.

The QEC roughly records the posture of the back, shoulder/arm, wrist/hand and the neck, which is useful in recording dentist's work posture, but at the same time assessment of the upper arm, lower arm and neck is not clearly defined and assessment of the leg is not covered. The assessment lacks detail and clarity. The other difficulty is that the worker who is observed (Appendix X) needs to complete an assessment form of the task performed. This form was prepared for industrial workers; most of the questions are based on manual work and lack the detail needed for assessing posture of dentists.

Nguyen et al (2004) have used RULA to assess working posture of dentists. Nineteen dentists and dental assistants were observed, interviewed by questionnaire and assessed using RULA. The results showed that the working posture of the dentists was awkward with static and prolonged sitting, raised shoulders, bent and twisted neck, bent trunk and needed immediate attention was indicated. In the questionnaire study 89% of dentists and 80% of dental assistants reported neck problems. More than 50% of the subjects reported pain in both shoulders. Back pain was reported by a third of dentists. The results also indicated that women reported more problems than men.
The following table presents the requirements for analysis of dentist posture and the features available in different techniques for postural analysis

Items Considered		Analysis of Standing and Sitting Postures	Detailed analysis of various joints	Numerical analysis	Simple for analysis	Studies on reliability	Simple Quantitative risk score	Previous use in dentists	Less time consuming
System Of Analysis	**Posturegram**	✓	✓	✓					✓
	OWAS	✓		✓	✓	✓	✓		✓
	Posture Targetting	✓	✓	✓		✓			
	Posture Recording	✓		✓	✓				✓
	PLIBEL	✓				✓			✓
	QEC	✓	✓	✓		✓			
	RULA	✓	✓	✓	✓	✓	✓	✓	✓

Table. 3-1. Techniques of postural analysis and requirements for analysis of dentist's posture

The following describes the development of a modified RULA for dentists, which was specially designed to assess working posture of dentists for a study of working posture of dental students. The RULA was initially developed in 1993 to investigate the exposure of individual workers to risk factors associated with work related upper limb disorders. A part of the development was based on the garment-making industry with VDU operators and operators working in a variety of manufacturing tasks (McAtamney & Corlett, 1993). The risk factors investigated in RULA were based on the factors explained by McPhee (1987) which were originally developed for manual workers but are also relevant to dentist's working posture and the activities that they carry out at chairside. Dentists report a high frequency of musculoskeletal disorders (Burke & Freeman, 1997) which may be due to prolonged work postures and high static muscle load in the neck and shoulder region, which is a risk for the development of musculoskeletal disorders (Finsen et al 1998). Since dentists work in prolonged work postures (Sitting), which resemble some manufacturing tasks, RULA would be a useful tool in assessing working posture of dentists.

3.12 Why choose RULA to assess dentists' posture?

- The method has been previously used to assess dentist's work posture (Nguyen et al 2004).
- Previous studies using RULA assessing sitting posture have been reported, which is the standard working posture of dentists.
- The method has been found to be simple and appropriate for dentists when compared with OWAS (Karhu et al 1977) and Posture Targetting method (Corlett et al 1979).
- The technique has an option to be analysed either live, using photographs or by video recording. Video recording has also been used to test the reliability in analysing posture using Posture Targetting method.
- OWAS (Karhu et al 1977) and QEC (Li and Buckle, 1998) were simple and quick to analyse posture but lack detail. The RULA is not time consuming, like the OWAS and QEC, and also covers all the body segments which should be analysed for dentists
- The tables to calculate risk scores are simple.
- The risk score given for a specific posture using RULA and OWAS (Kant et al 1990) are similar but the range of scores given by RULA is more appropriate for dentists.

3.13 The Development of RULA for dentists

The original RULA was developed to assess one side of the body at a time for the selected work posture. To assess the other side of the body the assessment has to be repeated and the selected work posture to be assessed may have changed. To avoid this difficulty and to save time, the RULA recording chart was modified and designed to record information on both sides of the body at the same time and a separate RULA score (Risk Score) for the right and left side will be ascribed to each posture assessed (Nguyen et al 2004; Chaikumarn, 2005).

In the original RULA the Force/Load Score was given to the physical load held by the individual while assessing the posture i.e. if the load is 2 kg or less and held intermittently no score is awarded, if the intermittent load is 2 to 10 Kg a score of 1 is awarded, and if the load is 2 to 10 kg and is static or repeated a score of 2 is awarded. This score has been modified by Leuder (1996) to suit computer users, i.e. in a work day if the individual works in front of a computer for $\geq$4 to $\leq$6 hours a score of 1 is awarded and if the individual works for more than 6 hours a score of 2 is awarded. This score change may apply, even for dentists, because both are predominantly static work postures. So the force/load score has been modified to dentists similar to that of computer users. If the dentist works for $\geq$4 to $\leq$6 hours he/she gets a score of 1 and if he works more then 6 hours he/she gets a score of 2. The total time observed for a selected posture is noted in minutes, which may range from 5 to 15 minutes. In each joint position, such as the upper arm or lower arm, the time held (seconds to minutes) was noted separately in the recording sheet. This is carried out to determine which joints are more static than others and to relate it with the reported musculoskeletal symptoms.

Nguyen et al (2004) have used RULA to assess working posture of dentists. Nineteen dentists and dental assistants were observed, interviewed by questionnaire and assessed using RULA. The results showed that the working posture of the dentists was awkward, with the dentists in static and prolonged seated postures, raised shoulders, bent and twisted neck, and with bent trunk. The need for immediate attention and ergonomic changes was suggested.

Chaikumarn (2005) used RULA to assess the differences in working posture of dentists when adopting different work concepts i.e. proprioceptive derivation (Pd) and the conventional concept. The Pd concept is a method, which provides dentists with a good posture for optimal control of dental tasks while minimizing musculoskeletal discomfort. The results showed a significant difference in the average RULA score between the two groups of dentists. The results indicated that the dentists using the Pd Concept recorded significantly lower RULA scores (Mean = 3.5) when compared with the dentists using conventional concept (Mean = 5.6) ($p<0.05$). Chaikumarn (2005) has suggested further investigation is needed in order to clearly understand and identify the factors influencing working postures adopted by dentists. Further research should identify the type of dental treatment (Pollack, 1996), tooth and plane, equipment, instruments, patient position, work position, direct / indirect view, work organisation and personal factors (Rundcrantz et al, 1990; Chaikumarn, 2005).

The total time observed for a selected posture is noted in minutes, which may range from 5 to 15 minutes. In each joint position, such as the upper arm or lower arm, the time held (seconds to minutes) was noted separately in the recording sheet. This is carried out to determine which joints are more static than others and to relate it with the reported musculoskeletal symptoms.

In order to explore dentist posture further, the recording of additional information was identified. These are as follows:

- Dental procedure undertaken: To ascertain if there is any difference in posture for different dental procedures (Pollack, 1996).
- Tooth operated: To see the changes in posture in light of the tooth operated on (Rundcrantz et al, 1990; Chaikumarn, 2005)
- Use of mouth mirror (Rundcrantz et al, 1990; Chaikumarn, 2005)
- Use of magnifying loupes (Rundcrantz et al, 1990; Chaikumarn, 2005)
- Dominant hand
- Time observed (Rundcrantz et al, 1990; Chaikumarn, 2005)

3.14 Advantages and Disadvantages of Using Photographs to Assess Posture using RULA method

The use of photographs in assessing working posture may be the most reliable method because the work posture assessed remains unchanged and allows work postures to be easily reassessed (Dunk, Lalonde and Callaghan, 2005; Liu, Zhang, and Chaffin, 1997). In the live postural assessment the posture changes from time to time and reassessing a particular work posture is impossible. However, live postural assessment provides the researcher with a three-dimensional view of the joints assessed. On the other hand the photographs are useful to test the reliability in using RULA as performed in this study. The force load score may also be difficult to calculate when assessing a posture using photographs, since the work hours or the time held with each joint may be unknown to the observer. However, the dental students assessed for reliability in this study worked around 6 hours a day, so each student was awarded a force load score of 1.

3.15 RELIABILITY IN USING RULA

The reliability of the RULA was tested in assessing working posture of dentists. Both Inter-observer and Intra-observer reliability were tested in using photographs for RULA assessment and Inter-observer reliability were tested in performing live RULA assessment.

3.15.1 METHODOLOGY

Research Design

A blinded test design was used to test the inter-rater reliability in assessing the working posture of dental students using RULA. The intra-rater reliability was tested without blinding.

Subjects

The study was introduced to year 3, 4 & 5 dental students who were attending their clinics at the dental hospital. Written consent was obtained from the students willing to participate in the study. Ninety students (30 from each year) were selected at random from the 120 students who agreed to participate in the study. Photographs were taken of the students whilst working in the clinics. Photographs of 20 students were selected at random and assessed using modified RULA to test inter and intra rater reliability. The students were randomly selected using a random number generator.

Procedure:

- Before observing students and taking photographs the details of the study was explained to them verbally. If they were happy to be involved written consent was obtained from each student (Appendix XVI). The patient was also informed about the procedure and verbal consent obtained. The patients wore protective glasses to obscure their faces.
- The following details were recorded:

  Year of the student

  Name of the student

  Procedure undertaken

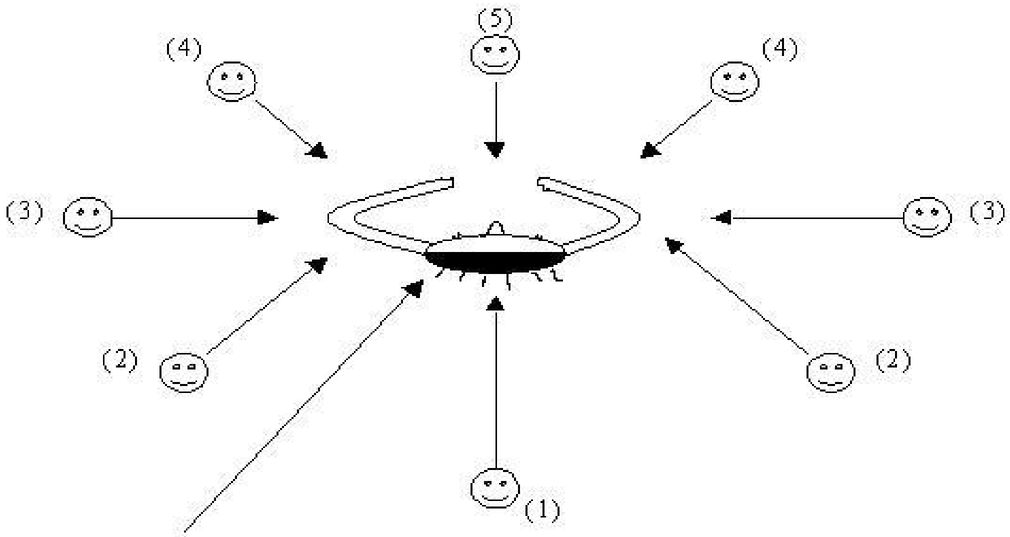
  Tooth operated and

  Number of photographs
- Care was taken that the dentists are not aware of being observed and photographed. This is done by not standing prominently in front of them, since they might react differently if they knew that they are closely watched and this may vary their posture (Hawthorne Effect).
- The photographs were taken ten minutes after the student had started the dental procedure, which was considered sufficient to allow time for the student to become comfortable in their operating position. The photographs were taken in all possible views of the student in order to enable viewing of all joints to be analysed.

- The photographs were taken with a digital camera and the use of flash was avoided as this may make the student aware of being observed and may be a disturbance for both the student and the patient.

The following are the basic angles of photographs that can be taken for analyzing the posture (Fig. 3-7)

Anterior to the dental student



Dental Student **Posterior to the dental student**

These are the possible positions of the researcher for taking photographs.

Fig. 3-7. The angles in which photographs can be taken

Position 1: This enables viewing of the

Neck:	Side-flexion and rotation
Back:	Side-flexion
Legs:	Position of Legs
Upper Arm:	Abduction of shoulder, raising of shoulder

Positions 2 & 3: This enables viewing of the side observed

Neck:	Angle of Flexion
Trunk:	Angle of forward flexion of trunk, slumping of back
Lower arm:	Angle of elbow flexion of the side observed
Wrists:	Angle of wrist flexion/extension and wrist twisting

Positions 4 & 5: This enables viewing of

Lower arm:	Position of both the lower arms
Wrists:	Position of both the wrists

It was difficult to take pictures in positions 4 and 5 because the person was aware of the camera in front of them and due to the arrangement of the clinics. The positions necessary for analysing the dental students' posture are

- Positions 1 and 3 are essential and Position 2 useful.
- Position 4 and 5, if possible, will help provide more complete analyses.

3.15.2 Training on Using Modified RULA: The students and staff (Assessors) selected for the study were individually trained for 20 minutes by the researcher in assessing posture using modified RULA. After training they were asked to analyse a student's posture using photographs and then re-examined by the researcher for accuracy. The researcher clarified problems with the RULA analysis with the subjects if any.

3.15.3 Inter-Observer Reliability (Photographs)

Subjects: Seven physiotherapy Master's students and a lecturer in physiotherapy were selected for the study.

Procedure

- A file containing the information sheet (Appendix XIX) about the study, photographs of 20 dental students randomly arranged and 20 RULA assessment sheets (Appendix XX) were given to each participant.
- Detailed instruction sheets in completing the RULA assessment were provided with the pack.
- The subjects were asked to enter only the joint positions (Individual Scores) in the RULA assessment sheets and instructed not to fill in the final arm and wrist score, neck trunk & leg final score and the grand score.
- The researcher calculated the grand scores.
- The participants were asked to complete their assessment in a week and asked to return the completed assessment forms to the researcher.

Statistical Analysis: Kendall co-efficient of concordance was used to test the inter-rater reliability and was analysed using SPSS 15.0.

Results: The inter-rater reliability between the eight raters showed moderate to high level of agreement ($w = 0.577$, $N = 8$, $n = 15$, $P = 0.000$ for the right grand score; and $w = 0.653$, $N = 8$, $n = 20$, $P = 0.000$) for the left grand score and the ratings were found to be significantly concordant ($p<0.01$ for a one tailed test)

3.15.4 Intra-Observer Reliability (Photographs)

Subject: The researcher.

Procedure

- The same set of photographs were analyzed 5 times by the researcher using Modified RULA
- The photographs were analyzed at a random order at different times of the day.
- The first observation was performed in the morning and the second observation was performed at a different time on the same day. The next two observations were performed after 3 days. The last observation was performed after a week's time.
- Each time the order of photographs were changed to avoid order effect and learning.

Statistical Analysis: Kendall co-efficient of concordance was used to test the intra-rater reliability

Results: The intra-rater reliability within the researcher also showed high level of agreement ($w = 0.893$, $N = 5$, $n = 15$, $P = 0.000$ for the right grand score; and $w = 0.953$, $N = 5$, $n = 20$, $P = 0.000$ for the left grand score) and the ratings were found to be significantly concordant ($p<0.01$ for a one tailed test)

3.15.5 Inter-Observer Reliability (Live Assessment)

Subjects: The researcher and a lecturer in physiotherapy trained in using RULA were selected for the study.

Procedure

- The researcher and the lecturer observed postures of five physiotherapy master's students while they were performing seated research activities.
- Five RULA assessment forms (Appendix XX) were completed simultaneously by the researcher and the lecturer.
- The lecturer was asked to enter only the joint positions (Individual Scores) in the RULA assessment sheets and instructed not to fill in the final arm and wrist score, neck trunk & leg final score and the grand score.
- The researcher calculated the grand scores.

Statistical Analysis: Kendall co-efficient of concordance was used to test the inter-rater reliability.

Results: The inter-rater reliability between the two raters showed high level of agreement ($w = 0.800$, $N = 2$, $n = 5$, $P = 0.171$ for the right grand score; and $w = 0.833$, $N = 2$, $n = 5$, $P = 0.155$) for the left grand score and the ratings were found to be significantly concordant ($p>0.01$ for a one tailed test)

The results indicate high level of intra and inter rater reliability in using RULA both live and in using photographs.

3.16 Assessment of Dental Student Posture in Two Seating Conditions using RULA methodology

The dental students' posture was assessed on two different seats in order to determine if one seat predisposes to a difference in working posture.

3.16.1 METHODOLOGY

Research Design

A between-subject experimental design was selected. The postures in two different seats with different subjects performing the same dental procedure were compared. The working posture adopted by each student was evaluated using RULA (Rapid Upper Limb Assessment) (Appendix XII and XIII). The experimental hypothesis (H_1) is that there is a significant difference between RULA scores between seats. Depending on the results the null hypothesis (Ho), that there is no significant difference between RULA scores between seats, would be accepted or rejected.

Subjects:

The aim and nature of the study was introduced to all the Year 2 dental students at the Dental School who were attending their first classes in the phantom head laboratory. Ninety students were provided with information sheets (Appendix XIV) and consent forms (Appendix XV). The students were asked to return the forms if they were willing to participate in the study. Sixty students were selected at random from the 80 students who returned the forms and agreed to participate in the study. The students were randomly selected using a random number generator (http://www.segobit.com/rng.htm) and allocated to two types of seats (30 students were provided with Bambach seats and 30 students were provided with the

Conventional seats). All students were trained in the use of the seats (*vide infra*). After 10 weeks, photographs were taken of the students whilst working in the phantom head lab. The positions recorded on the photographs were later assessed using RULA.

Training:

The students attended a lecture on the use of seats before commencement of the study. The students were followed up during the first two weeks on their sessions in the phantom head lab and individually trained for 5 to 10 minutes on correct operating posture respective to their seats.

Fig. 3-8. A Dental Student Working seated on a Bambach Saddle Seat

Fig. 3-9. A Dental Student Working seated on a Conventional Seat

Materials:

a. Bambach Seat (Fig. 3-8)

b. Conventional Seat (Fig. 3-9)

c. Phantom Head Apparatus (Fig. 3-8 and 3-9)

d. Digital Camera

Assessment Procedure:

The student's working posture was photographed during their practical sessions in the phantom head lab. The guidelines considered for taking photographs were explained in section 3.14. The photographs were assessed using modified RULA detailed in section 3.12.

The Dental Procedure

The photographs were taken when the students were operating on teeth in the lower jaw of a phantom head whilst preparing the teeth for a restoration. Figures 3-8 and 3-9 show a dental student in two different seats.

Analysis of Photographs:

The photographs of 60 students (30 students using the Bambach Saddle Seat (BSS) and 30 students using the Conventional Seat (CSS)) were analyzed using the modified RULA described in section 3.14.1.3. Each student was given a risk score, which was used for statistical analysis.

Data Analysis

The hypotheses are two tailed. Mann-Whitney Test was used to test the hypothesis that there will be a difference between the RULA scores when compared between Bambach saddle seat and Conventional seat. The level of significance of 0.05 was used for the rejection of the null hypothesis. The Mann-Whitney Test is taken for hypothesis since the RULA scores obtained are Ordinal level data.

3.16.2 RESULTS

The photographs of 60 students were analyzed using RULA. Figures 3-10 and 3-11 show the mean and standard errors for the Right and Left Total Scores comparing the Bambach and Conventional Seat (Appendix XXXVIII – Structure of a box plot). The Mann-Whitney Test results were significant ($Z = -6.015$; $p = 0.000$) for the right total score and ($Z = -6.197$; $p = 0.000$) for left total score. The results confirmed that there was a significant difference in RULA Scores between the seats. Thus the null hypothesis can be rejected and the experimental hypothesis can be accepted. The results also indicated that the CSS recorded significantly higher RULA scores (Mean = 5.06 for the right side; Mean = 5.03 for the left side) when compared with the BSS (Mean = 2.80 for the right side; Mean = 2.66 for the left side) ($p<0.01$), suggesting that there is a lower postural risk when using the Bambach Saddle Seat. The eta^2 (effect-size measure) has been calculated to obtain the effect size, the eta^2 for right total score is 0.43 and eta^2 for left total score is 0.45 which indicates large effect size.

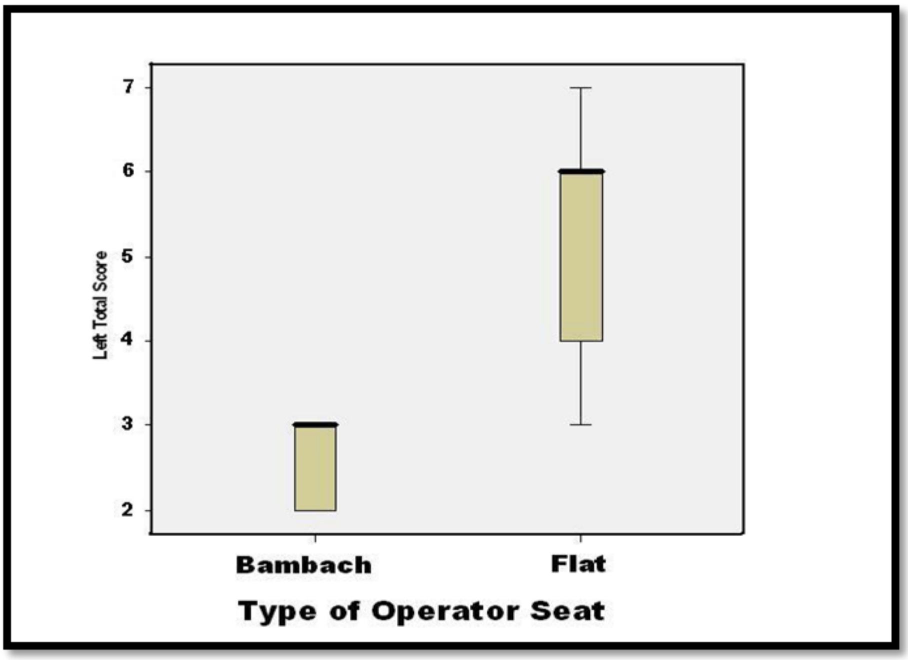


Fig. 3-10. Box plot showing the Left Grand Score (Students)

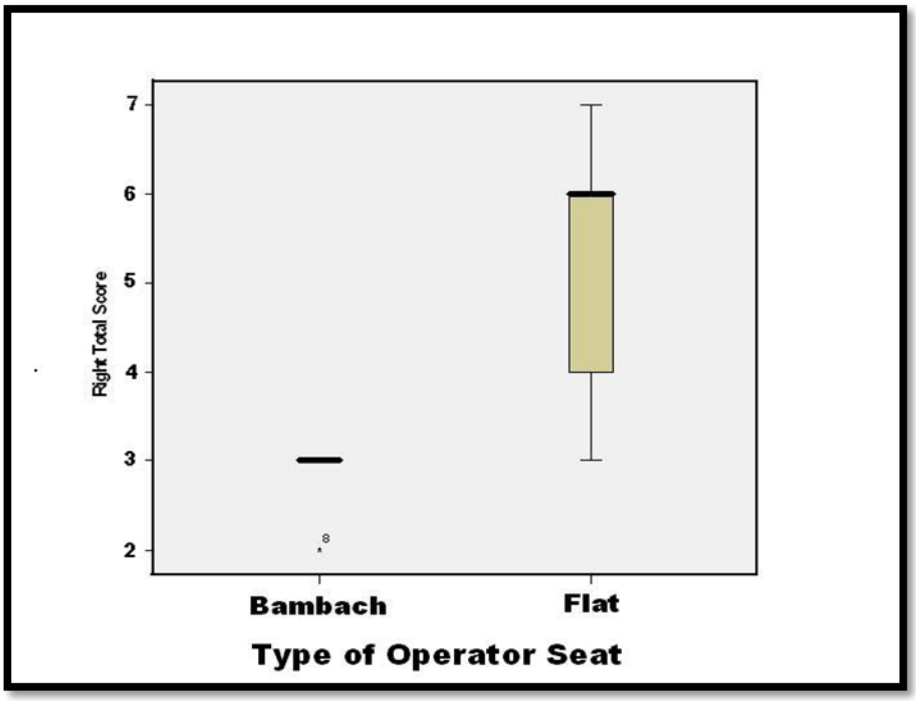


Fig. 3-11. Box plot showing the Right Grand Score (Students)

3.16.3 DISCUSSION

The results indicate that there is a statistically significant difference between the risk scores of the Bambach and Conventional seats. The BSS were able to maintain an acceptable position on the observed joints (Upper Limb, Trunk and Lower Limb), which may be considered to contribute to a healthy working posture. The CSS appeared less able to maintain a healthy posture with the observed joint positions, indicating cause for concern. The results indicate that the standard deviation of the risk scores (Right and Left Grand Scores) for the BSS were negligible when compared with the CSS. However, the left grand score for the BSS had indicated a standard deviation of 0.47 on risk scores. This may be because most of the students operate with the right hand and showed an acceptable risk score on the right side, whereas their left hand was kept at position of reduced risk, close to the body with joints in a safe range, thereby decreasing the final risk score from 3 to 2. There was variation in the position of the left hand, with some students holding the cheek of the phantom head in order to get an improved vision of teeth which were being operated on, while others used a mirror or rested their left hand on their thighs. The CSS recorded higher risk scores with a standard deviation of 1.36 on both the sides observed, indicating poor posture. Even though the position of their left hand was similar to that of the BSS, their slumped posture kept their joints at extreme ranges i.e. their shoulders were kept elevated and abducted with their arm working across the midline of their body, thereby increasing the range of their final risk scores from 3 to 7, indicating extreme concern which requires immediate investigation and changes.

The spine is in its natural curved position ('S' Shape) while standing, which enables the body's line of gravity to pass through the trunk and feet, so requiring minimal muscular activity to maintain the posture and to hold the trunk erect (Corlett and Eklund, 1984). Callaghan & McGill (2001) found that standing produced a uniquely different spine posture compared with sitting, and standing spine postures did not overlap with flexion postures adopted in sitting. Sitting with a 90-degree angle between the trunk and the thighs causes the pelvis to rotate backwards shifting the spine away from the line of gravity (Fig. 3-12). This in turn reduces the lumbar lordosis (Grandjean, 1973), causing the spine to slump and increasing the load placed on the spine (Hedman and Fernie, 1997). Black et al (1996) found that the movement of the lumbar spine influenced the movement of the cervical spine and identified slumped sitting posture (Posterior Pelvic Tilt) as the poor posture for the spine. The CSS may have registered higher risk scores as a result of sitting in posterior pelvic tilt (Kyphosis of the Lumbar Spine). They recorded higher risk scores in the neck (hyper flexion), shoulder (raised and abducted) and trunk (slumped / forward inclined) (Fig. 3-9) since the position of neck, shoulders and trunk are interrelated and an acceptable spinal posture is necessary to maintain good sitting posture (Grandjean, 1973; Hedman and Fernie, 1997). On the other hand, the BSS were able to maintain an acceptable position of the neck, shoulders and trunk, as they were able to maintain anterior pelvic tilted position contributing to the lower risk score (Fig. 3-8). The Bambach Saddle seat is designed to maintain the pelvis in an anterior tilted position in order to achieve a slight lumbar lordosis (Gale et al, 1989) and the angle of hips and knees can be adjusted so that the spinal posture simulates standing, thereby contributing to a healthy spinal posture.

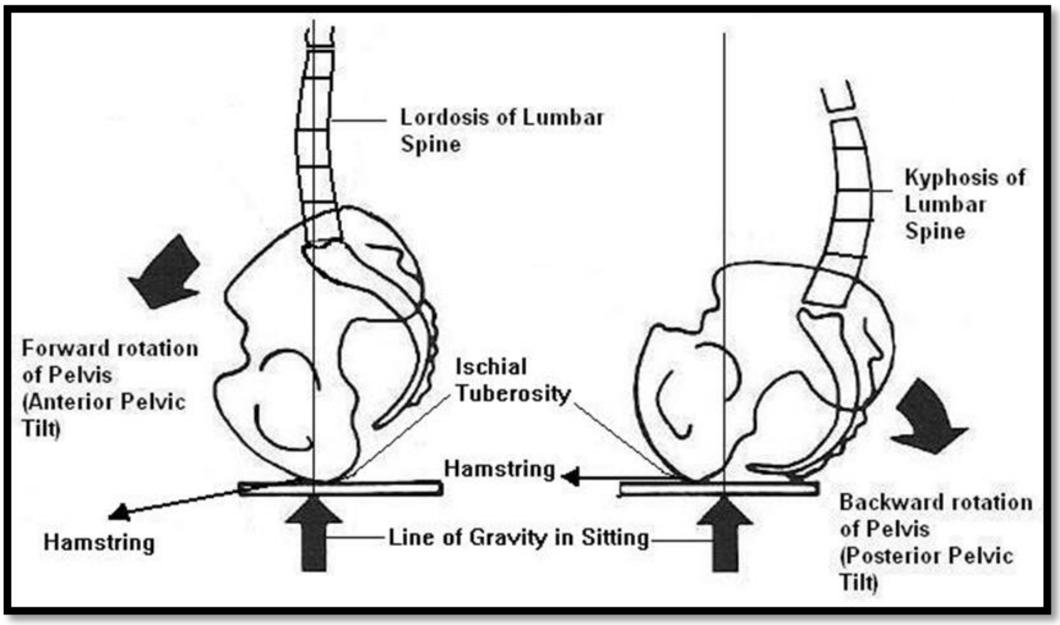


Fig. 3-12. Sitting Posture (Anterior and Posterior Pelvic Tilt)

(Adapted from Zacharkow 1988)

3.16.4 CONCLUSION

The RULA method applied to dental students' work postures allowed a rapid evaluation of their posture during simulated dental treatment. The RULA scores indicated that the BSS are able to maintain an acceptable working posture, whereas for CSS the posture deteriorates over time. This may predispose to the development of a musculoskeletal disorder.

(The assessment of Dental Student Posture in two seating conditions using RULA Methodology has been published in British Dental Journal, see Appendix XXXIX)

3.17 Assessment of Dental Student Posture 'Live' using modified RULA.

The dental students' posture was recorded live in the dental school on Year 3, 4 and 5 students by observing the dental students to determine if there is any difference between years for the recorded grand scores.

3.17.1 METHODOLOGY

Research Design

A between-subject experimental design was selected. The dental students' posture in Year 3, 4 and 5 were compared. The working posture adopted by each student was evaluated using RULA (Appendix XII and XIII). The experimental hypothesis (H_1) is that there is a difference in grand scores between years. Depending on the results the null hypothesis (Ho) that there is no difference in grand scores between years would be accepted or rejected.

Subjects

The aim and nature of the study was introduced to all the Year 3, 4 and 5 dental students at the Dental School who were attending their clinics. e-mail was circulated to all the students of the dental school regarding the study. Two hundred students were provided with consent forms (Appendix XVI). Ninety students (30 from each year) were selected at random using a random number generator (http://www.segobit.com/rng.htm) from the 120 students who agreed to participate in the study.

Procedure

- Before observing students and taking photographs the details of the study were explained to them verbally. If they were happy to be involved written consent was obtained from each student (Appendix XVI). The patient was also informed about the procedure and verbal consent obtained. The patient was wearing protective glasses obscuring the face.

- The details of the procedure undertaken and which teeth they were operating on were noted in a separate sheet as detailed in section 3.14
- Care was taken that the dentists were not aware of being observed. This was done by not standing prominently in front of them, since they might react differently if they knew that they are closely watched and this may vary their posture (Hawthorne Effect).
- The observation was performed ten minutes after the student had started the dental procedure, which was considered sufficient to allow time for the student to become comfortable in their operating position.
- The student's working posture was observed live during their practical sessions in the clinics (Figures 3-13, 3-14 and 3-15). The students were assessed using modified RULA detailed in section 3.12 (Appendix XXI).
- The positions of the joints for each student observed were noted in the RULA assessment form during live assessment. The researcher calculated the grand scores later. Example of the photographs of the Year 3, 4 and 5 dental students were shown in figures 3-13, 3-14 and 3-15.

Data Analysis

The data has been analysed using Wilcoxon Test to explore right and left grand scores of students from each year (Within Subject Factor) and Kruskal-Wallis Test was used to find the difference in grand scores between years 3, 4 and 5 (Between Subject Factor). The level of significance used is 0.016 (0.05/3). SPSS 13.0 was used for statistical analysis.

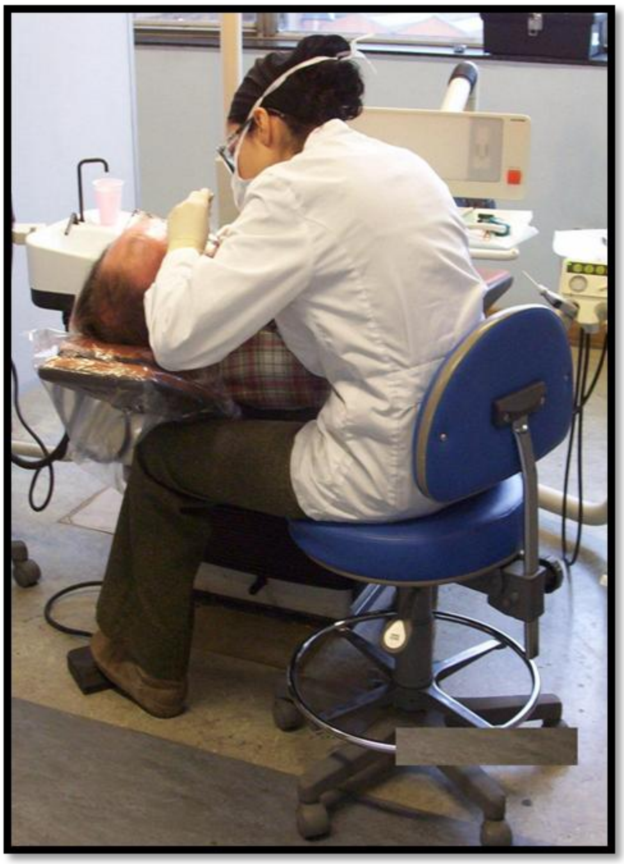


Fig. 3-13. 3rd Year Dental Student Working On Clinics

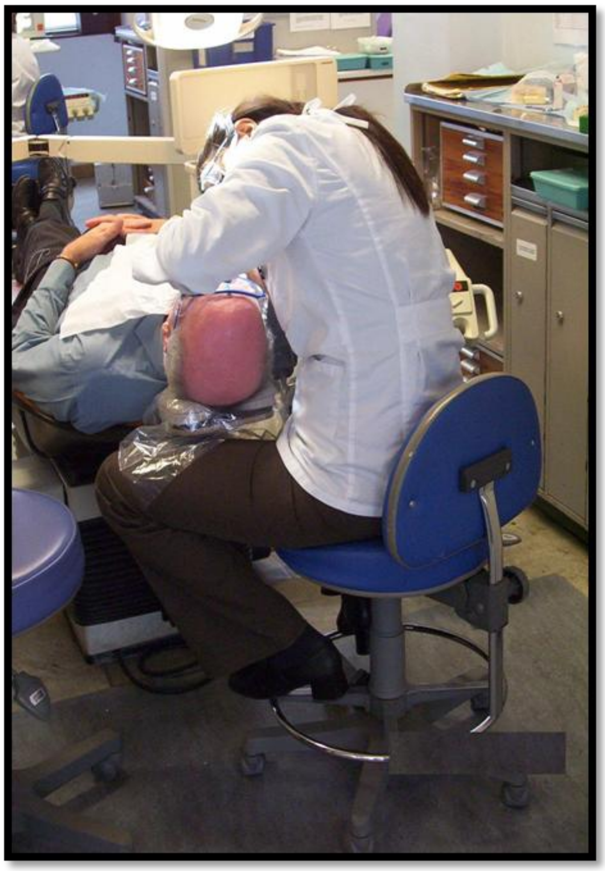


Fig. 3-14. 4th Year Dental Student Working on Clinics

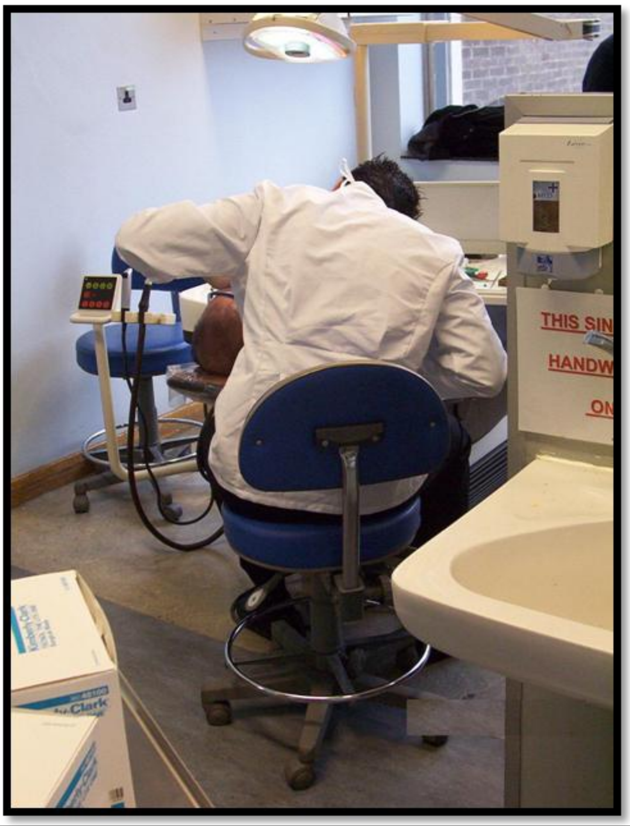


Fig. 3-15. 5th Year Dental Student Working on Clinics

3.17.2 RESULTS

The results indicate that the right and left grand scores are on average around 5 and 6 for all the years, which indicates prompt investigation and changes (McAtamney and Corlett, 1993). The mean and standard deviation for the right and left grand scores are shown in the table below (Table. 3-2). There is a significant difference when compared within years ($p<0.016$) for the Right and Left Grand Scores (Table 3-3). There is no significant difference between years ($p>0.016$) for the Right and Left Grand Scores (Table 3-4) (Since multiple comparisons are made using the same data, a p value of 0.016 i.e. 0.05/3 was taken for analysis).

	Year	Mean	Std. Deviation	N
Right Grand Score	Year 3	4.9667	1.12903	30
	Year 4	5.2000	1.09545	30
	Year 5	5.5667	1.07265	30
	Total	5.2444	1.11488	90
Left Grand Score	Year 3	5.7000	1.26355	30
	Year 4	6.2333	.85836	30
	Year 5	6.3333	.99424	30
	Total	6.0889	1.07729	90

Table. 3-2 Mean of RULA scores in Year 3, 4 and 5 Dental Students

	Left Total Score Year 3 - Right Total Score Year 3	Left Total Score Year 4 - Right Total Score Year 4	Left Total Score Year 5 - Right Total Score Year 5
Z	-3.025(a)	-3.709(a)	-3.442(a)
Asymp. Sig. (2-tailed)	.002	.000	.001

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

Table. 3-3 Results of Wilcoxon Test Comparing Right and Left Total Scores

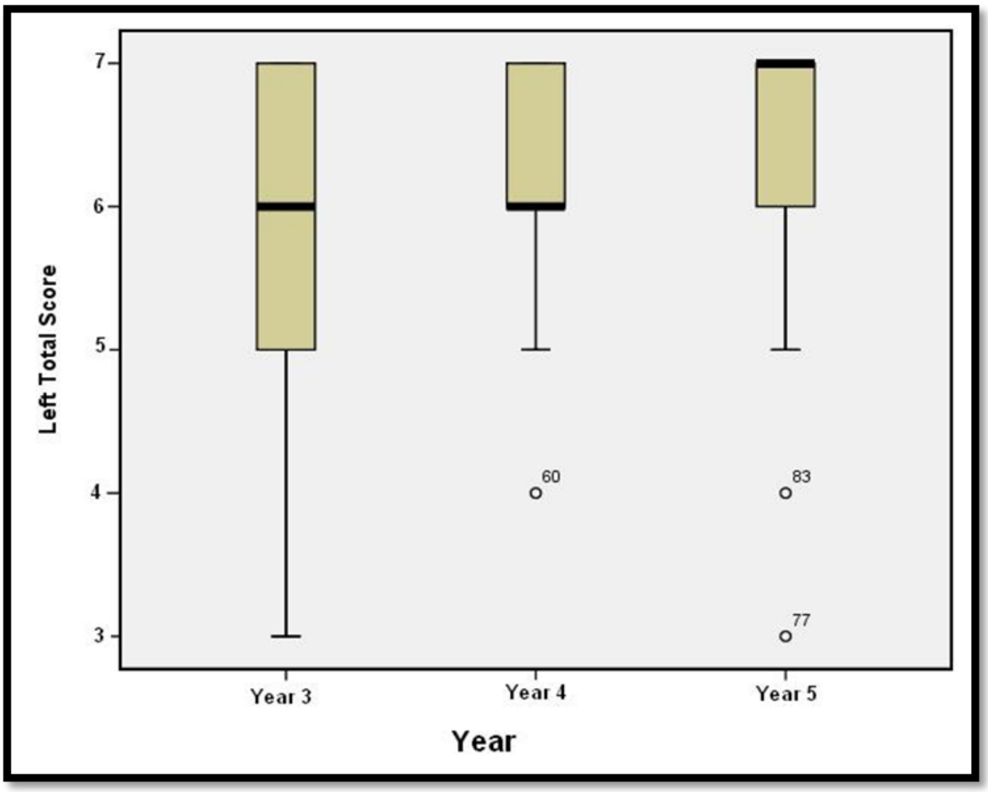


Fig. 3-16. Box plot showing the Left Grand Score of Year 3, 4 and 5

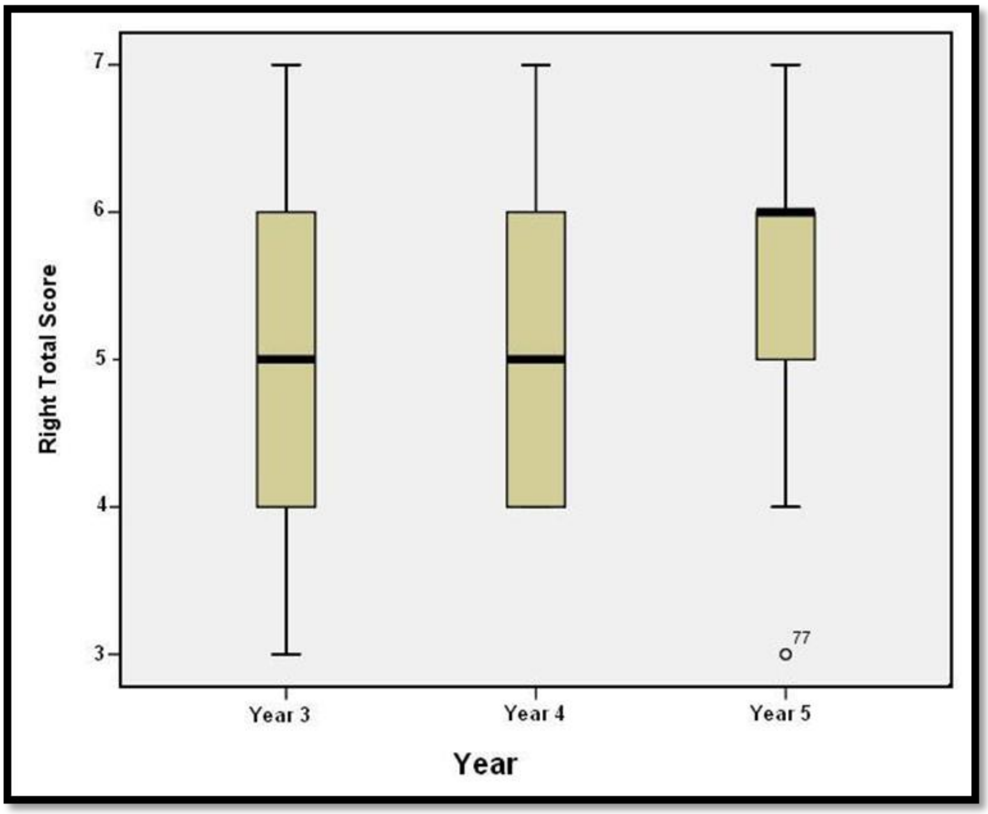


Fig. 3-17. Box plot showing the Right Grand Score of Year 3, 4 and 5

	Right Grand Score	Left Grand Score
Chi-Square	4.676	4.847
df	2	2
Asymp. Sig.	.097	.089

a. Kruskal Wallis Test
b. Grouping Variable: Year

Table. 3-4 Results of Kruskal Test Comparing Year 3, 4 and 5 Right and Left Grand Scores

3.17.3 DISCUSSION

A common pattern was observed when comparing the grand scores of years 3, 4 and 5; the grand scores gradually increase from year 3 to 4 and to 5 (Fig. 3-16 and 3-17) (Appendix XXXVIII). This may indicate that the working posture of students are gradually getting worse i.e. the posture of year 3 students is better when compared to year 5. This phenomenon further supported by the results where the year 3 students recorded lower mean grand scores when compared to year 5 (Table 3-2). This may be because the year 5 students work on more complex dental procedures (e.g. Root Canal Treatment); they also work for longer hours and spend a greater proportion of their time in the clinics when compared to the Year 3 and 4 students. However there is no statistically significant difference between years.

3.18 Assessment of Dentists' Posture in Two Seating Conditions using RULA methodology

Dentists' posture was assessed on two different seats in order to determine if one seat predisposes to a difference in working posture.

3.18.1 METHODOLOGY

Research Design

A between-subject experimental design was selected. The postures in two different seats with different subjects performing a dental procedure were compared. The working posture adopted by dentist was evaluated using RULA (Rapid Upper Limb Assessment) (Appendix XII and XIII). The experimental hypothesis (H_1) is that there is a significant difference between RULA scores between seats. Depending on the results the null hypothesis (Ho) that there is no significant difference between RULA scores between seats would be accepted or rejected.

Subjects:

The subjects were selected from the dentists who agreed to participate in further study in the questionnaire (Refer to Chapter 6, Section 6.7.6). Fifteen dentists using Bambach Saddle Seat (BSD) and 15 dentists using Conventional Seat (CSD) agreed to participate in further study. The aim and nature of the study was introduced to all the dentists individually, following their agreement to participate in further study. Written consent (Appendix XVII and XXIX) was obtained from each dentist. Data was collected from twelve BSD and 10 CSD. Photographs were taken of the dentist whilst working in their dental clinics. The positions recorded on the photographs were later assessed using RULA. The dental procedure / tooth operated by dentists was not standardised since the study was performed with real patients. However the tooth/jaw operated on and the dental procedures used were obtained from the dentists during the study. They were found to be similar between the two groups of dentists, and are reported below:

Jaw/Procedure	BSD	CSD
Upper Jaw	4	4
Lower Jaw	5	4
Scaling & Polishing	3	2
Total Number of Dentists	**12**	**10**

Assessment Procedure:

The dentists' working posture was photographed in their clinics whilst working with the patients. The patients were also informed about the study and written consent (Appendix XVIII) was obtained from the patients since part of their face may be visible in the photographs taken. The guidelines considered for taking photographs were explained in section 3.14. The photographs were assessed using the modified RULA detailed in section 3.12.

Analysis of Photographs:

The photographs were taken when the dentists were operating on their patients in their surgery. Figures 3-18 and 3-19 show dentist working on two different seats. The photographs of 22 dentists (12 BSD and 10 CSD) were analyzed using the modified RULA described in section 3.12. Each dentist was given a risk score, which was used for statistical analysis.

Data Analysis

The hypotheses were two tailed. Mann-Whitney Test was used to test the hypothesis that there will be a difference between the RULA scores when compared between Bambach saddle seat and Conventional seat. The level of significance was taken at 0.05.

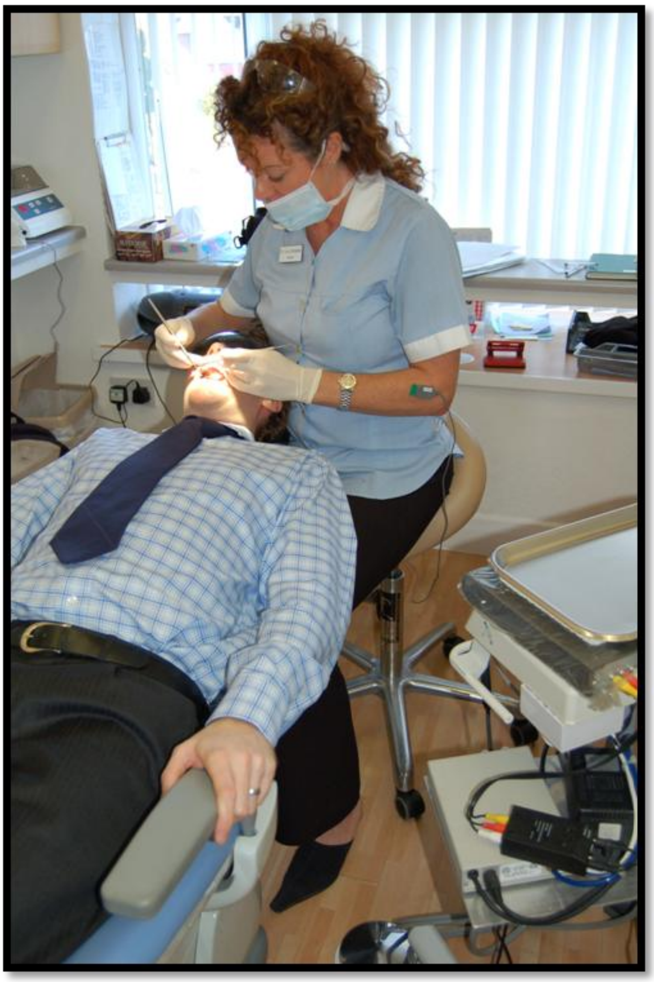


Fig. 3-18. A Dentist Working seated on a Bambach Saddle Seat

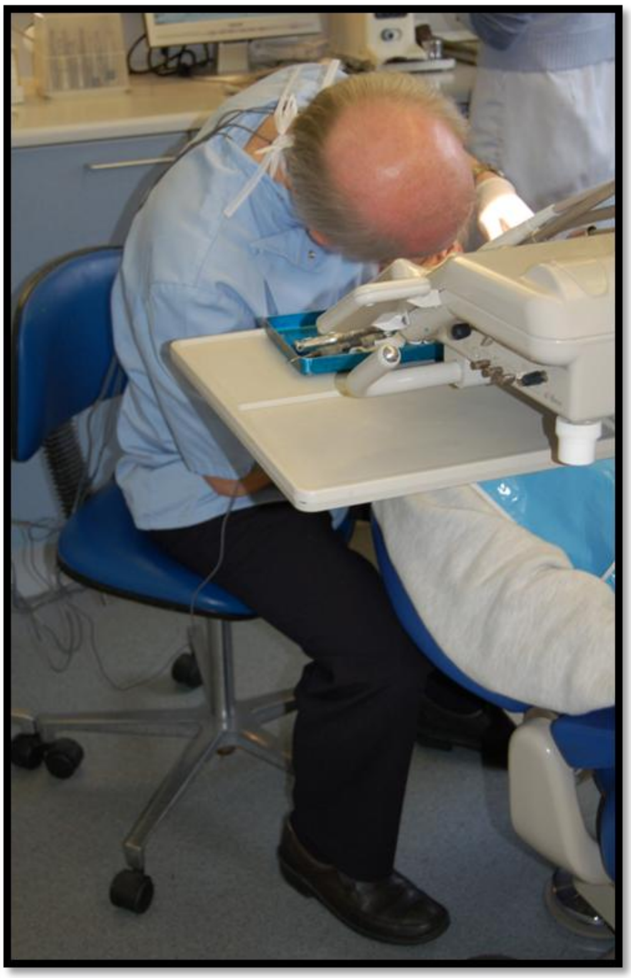


Fig. 3-19. A Dentist Working seated on a Conventional Seat

3.18.2 RESULTS

The photographs of 22 dentists were analyzed using modified RULA. Figures 3-20 and 3-21 show the mean and standard errors for the Right and Left Total Scores comparing the Bambach and Conventional Seat. The Mann-Whitney test results were significant ($Z = -2.791$; $p=0.005$) for right side and ($Z = -2.400$; $p=0.016$) for the left total score. The results confirmed that there was a significant difference in RULA Scores between the seats. Thus the null hypothesis can be rejected and the experimental hypothesis can be accepted. The results also indicate that the dentists using the Conventional Seat recorded significantly higher RULA scores (Mean = 3.40 for the right side; Mean = 3.90 for the left side) when compared with the dentists using Bambach Saddle Seat (Mean = 2.50 for the right side; 2.75 for the left side), suggesting that there is a lower postural risk when using the Bambach Saddle Seat.

3.18.3 DISCUSSION

The results indicate that there is a statistically significant difference between the risk scores of the BSD and CSD. The BSD were able to maintain an acceptable position on the observed joints (Upper Limb, Trunk and Lower Limb), which may be considered to contribute to a healthy working posture. The CSD appeared less able to maintain a healthy posture with the observed joint positions, indicating cause for concern. The results indicate that the standard deviation of the risk scores for the dentists using the Bambach saddle seat (Right Grand Score: SD 0.52; Left Grand Score: SD 0.45) were negligible when compared with the Conventional seat (Right Grand Score: SD 0.96; Left Grand Score: SD 1.66), indicating poor posture. The CSD recorded higher risk scores indicating poor posture. This may be because the CSD worked with slumped posture which kept their joints at extreme ranges i.e. their shoulders were kept elevated and abducted with their arm working across the midline of their body, thereby increasing the range of their final risk scores.

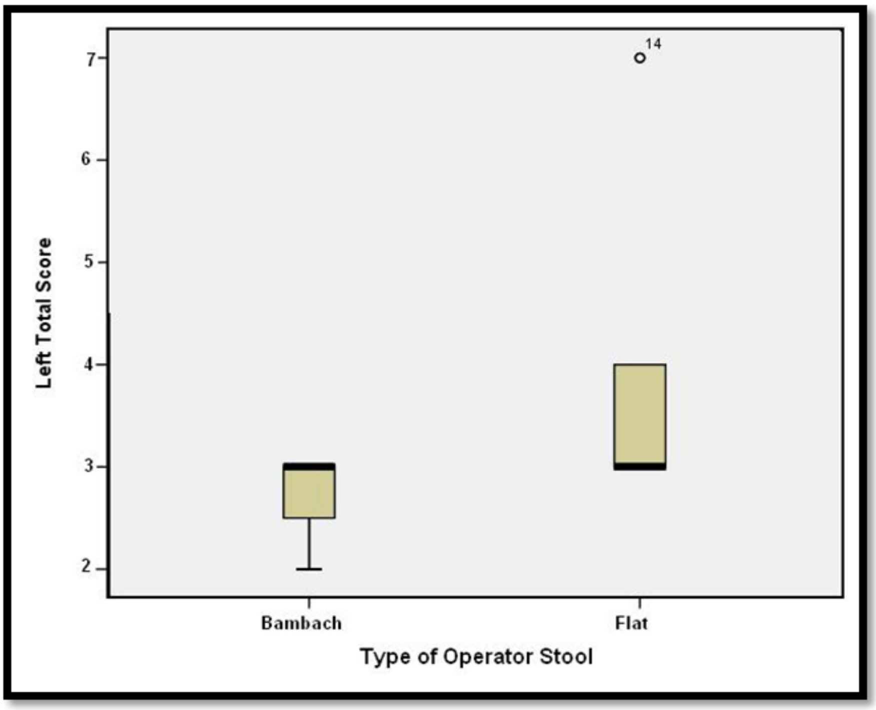


Fig. 3-20. Box plot showing the Left Grand Score (Dentists)

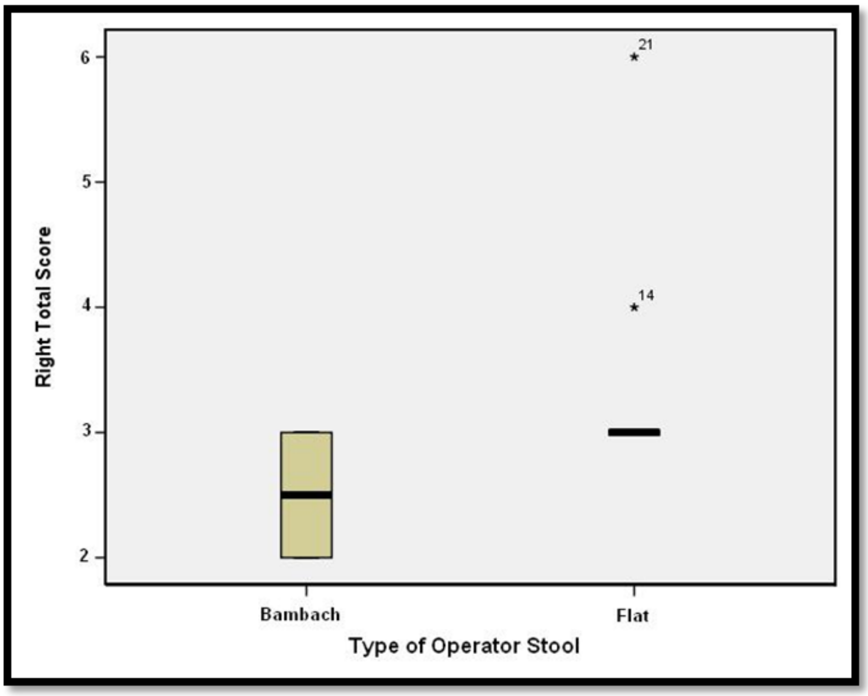


Fig. 3-21. Box plot showing the Right Grand Score (Dentists)

However, the results indicate that the CSD recorded lower average scores when compared with the CSS. Meanwhile, there was no significant difference between the BSS and the BSD. Both Bambach seat groups recorded lower average scores when compared with the Conventional seat groups.

3.18.4 CONCLUSION

The RULA method applied to dentists' work postures allowed a rapid evaluation of their posture during dental treatment. The RULA scores indicated that the BSD are able to maintain an acceptable working posture, whereas CSD the posture deteriorates over time. This may predispose to the development of a musculoskeletal disorder.

3.19 DISCUSSION - Comparing RULA of Students and Dentists:

The results indicate that the CSS recorded higher RULA scores when compared to the CSD; whereas the BSS recorded RULA scores comparable to that of BSD. This may indicate that CSS develop poor postural habits during their undergraduate study at an earlier stage of dental practice (Thornton et.al 2004). Due to musculoskeletal problems the CSD may adapt their posture to a comfortable position, and this may be the reason for the decrease in RULA scores with CSD compared to CSS. The BSS develop healthy postural habits at an earlier stage of dental practice in just 6 months' use of BS. They may be able maintain the good postural habits when they become qualified dentists which is clearly indicated by the lower RULA scores in BSD. The BSD (n=61) were using their seats for an average of 3 years and this may have reduced their musculoskeletal problems; and this may indicate that BSS have less risk of developing musculoskeletal disorders.

The study by Thornton et al (2004), investigating the physical and psychosocial stresses among US dental schools, reported that during the first and second year, the dental students have a course load similar to that of medical students. As the student advances to the clinic level, they must be able to, clinically reason, provide total patient care and perform numerous laboratory procedures i.e., mixing materials, grinding models, carving, and polishing crowns and dentures. In most dental schools the students perform procedures without a dental assistant in their dental clinics.

Wegman (1983) investigated the students working posture and found that the students assumed unnatural body postures, which was clearly identified with the CSS. There was an increase in physical stress among dental students that adversely affected work performance (Wegman, 1983); this is further increased when dental work is performed without an assistant. The effects being cumulative and continuous and increases as the students progress in their course.

Graf et al (1995) have investigated seated activity and postures in five work places including light assembly work, office work, listening/lecture attendance (students), VDU work and cashier work. They found that the assembly workers, VDU workers and cashiers were principally sat in the forward or middle sitting positions similar to dentists, whereas the office workers lean back more often than forwards. The listeners at the lecture were predominantly with their upper torso weight supported either on the table in front of them or the backrest. They also found that the office workers spent 80% of their time in kyphotic positions similar to that of the CSS and CSD, and kypothic positions were rarely observed in the VDU and Assembly groups. The office workers and cashiers changed position frequently, with the listeners moving least.

Two types of chairs were used by the VDU workers, one with seat tilt and one without. The results indicated that all subjects preferred the chairs with synchronized backrests and a seat angle mechanism which is similar to the seat tilt present in BS.

Graf et al (1995) suggest that the task demand has a significant effect on sitting position and posture. General office workers with more varied tasks are able more mobile using multiple sitting positions than those who work in the restricted VDU work and may be at a risk of developing a musculoskeletal disorder, similar to dentists. They suggest use of dynamic, task specific and forward tilting chairs which does not restrict movement and maintain posture, for example a Bambach Saddle Seat.

Chapter 4

Questionnaire Study of UK Dental Schools on Dental Student Posture

4.0 Overview

The first part of the chapter introduces the questionnaire studies on ergonomics in dental education, to include the introduction to the questionnaire, development of the questionnaire, with the final part of the chapter presenting the results.

4.1 Ergonomics in Dental Education

Thornton et al (2004) reported that the dental students train in an environment similar to practicing dentists. The physical and psychological stressors in the dental schools are associated with adverse health outcomes, and the need for ergonomics training in dental schools has been emphasized (Melis et al 2003).

In 2005 the American Dental Association (ADA) conducted an online survey on ergonomics in dental education. A questionnaire was sent to 56 dental schools, 278 dental hygiene, 259 dental assisting and 23 dental laboratory technology education programs in the US. Links to the online survey were sent by e-mail to all 616 individuals with follow-up notices being sent to the schools that had not responded. Data collection was stopped 6 weeks later. The response rate was 60.7% from the dental schools, 65.7% from dental hygiene schools, 61.2% from dental assisting schools, and 52.2% for the dental laboratory technology schools with an overall response rate of 62.7% (n=382).

The overall results of all programs indicated that 93.2% included ergonomic training in their curriculum of which, 0.6% of schools taught ergonomics as a separate course and 98.6% of schools integrated ergonomics into one or more courses. Regarding the importance of ergonomics 58.6% of respondents considered ergonomics as very important, 36.4% considered ergonomics to be somewhat important, 4.0% considered ergonomics to be somewhat unimportant and 1.1% considered ergonomics to be unimportant.

The results of the predoctoral dental programs indicated that 91.2% included ergonomic training in their curriculum of which 3.2% of dental schools taught ergonomics as a separate course and 96.8% of dental schools integrated ergonomics into one or more courses. Regarding the importance of ergonomics 47.1% of respondents considered ergonomics as very important, 44.1% considered ergonomics to be somewhat important, 2.9% considered ergonomics to be somewhat unimportant and 5.9% considered ergonomics to be unimportant.

The results of the dental hygiene programs indicated that 98.2% included ergonomic training in their curriculum of which 98.9% of schools integrated ergonomics into one or more courses and none of the schools taught it as a separate course. Regarding the importance of ergonomics 74.6% of respondents considered ergonomics as very important, 23.7% considered ergonomics to be somewhat important, 1.7% considered ergonomics to be somewhat unimportant and none of the schools considered ergonomics to be unimportant.

The results of the dental assisting programs indicated that 91.0% included ergonomic training in their curriculum of which 0.7% of schools taught ergonomics as a separate course and 98.6% of dental schools integrated ergonomics into one or more courses.

Regarding the importance of ergonomics 46.2% of respondents considered ergonomics as very important, 48.1% considered ergonomics to be somewhat important, 5.1% considered ergonomics to be somewhat unimportant and 0.6% considered ergonomics to be unimportant.

The results of the dental laboratory technology programs indicated that only 50.0% included ergonomic training in their curriculum of which all the dental schools integrated ergonomics into one or more courses, with 16.7% of respondents considering ergonomics as very important, 50.0% considering ergonomics to be somewhat important, 25.0% considering ergonomics to be somewhat unimportant and 8.3% considering ergonomics to be unimportant. The ergonomics training was considered and taught in approximately 93% of all the subject groups but only the predoctoral (3.2%) and dental assisting programs (0.7%) taught ergonomics as a separate course, but large number of dental hygiene programs included ergonomic training compared to the predoctoral programs.

4.2 The Questionnaire Study of Dental Schools

The questionnaire study of dental schools was undertaken with the dental schools across the United Kingdom.

4.2.1 The Questionnaire (Appendix XXII)

The questionnaire was based on the Survey on Ergonomics in Dental Education by the ADA in 2005. The questionnaire included questions on teaching in correct operating posture, work related musculoskeletal disorders, exercises and stretching, use of magnifying loupes, the opinion and future plans about teaching in operating posture.

4.2.2 Pilot Study and Development of the Questionnaire (Appendix XXII)

The questionnaire was sent to 10 lecturers in the University of Birmingham, School of Dentistry and the questionnaire was modified according to their comments. Questions 5, 6, 7, 14, and 17 were newly added to the questionnaire, which was not included in the original questionnaire. Questions 5, 11 and 12 were modified according to the comments.

4.2.3 Methodology of Questionnaire Study of Dentists

Procedure:

A pack containing the questionnaire, covering letter and a reply envelope was sent to the deans of 16 dental schools across the United Kingdom, with a request that it be passed to the person principally involved in the teaching of dental ergonomics.

Response Rate: The initial response rate was 75% (n=12). A follow up letter was sent to the Deans of dental schools who had not responded. After the letter was sent 25% (n=4) responded for the questionnaire, making a final response rate of 100% (n=16). Not all schools answered all the questions so the numbers in the data (n) vary.

4.2.4 Results of the Questionnaire study of Dental Schools:

The results indicate that there are a total of 1251 (Mean 78.18) dental students currently studying their first year in dental schools (n=16) across the U.K. In these 16 dental schools 81.3% (n=13) provide training in the use of correct operating posture (Fig. 4-1)

Stage of Curriculum at which the concept of Operating Posture is introduced:

The results indicate that 56.3% (n=9) of dental schools introduced the concept of operating posture at year 2 term 1, and 25% (n=4) at year 1 term 2. Of these 13 schools, 10 (76.9%) included both patient and dentist positioning in the curriculum while 1 school (7.7%) only taught dentist positioning. Two schools (15.4%) did not respond to this question.

Methods Used to Teach Operating Posture:

Of the 13 schools who teach operating posture, the methods included lectures (n=4), seminars (n=3), practical demonstrations by a dentist (n=13), practical demonstrations by a physiotherapist (n=1), chair-side instruction (n=13) and others (n=3). The results are presented in figure 4-1. The other methods reported in the questionnaire included seat adjustment demonstrations by moving/handling coordinator and video and posture/joint position demonstrations.

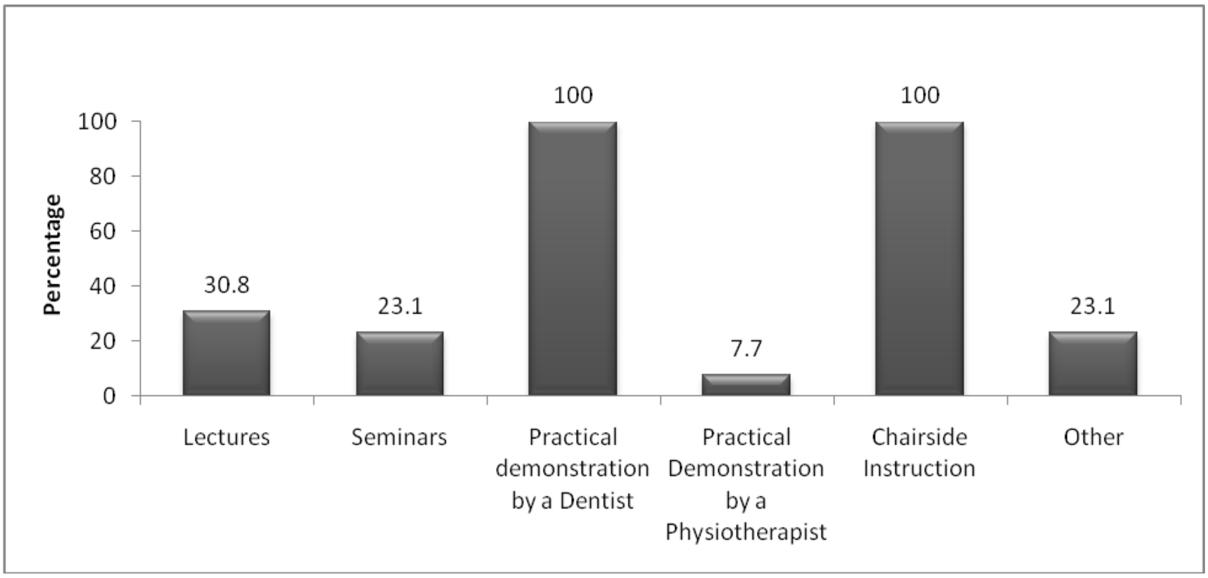


Fig. 4-1. Methods used in teaching Operating Posture

The results indicated that, other than chair-side instruction, the dental schools devote an average of 4.2 hours in the teaching of operating posture across the whole five-year period, and only 10 schools out of 16 devote hours (ranging 30 minutes to 10 hours) to the teaching operating posture. The results indicate that none of the students in the 16 schools had to stop studying dentistry due to musculoskeletal disorders.

Inclusion of Musculoskeletal disorders in the Curriculum:

The results indicate that 62.5% (n=10) of dental schools included teaching on the common types of musculoskeletal disorders in the curriculum, and 68.8% (n=11) of dental schools included contributing features to musculoskeletal disorders in the curriculum, which included work, and non-work related musculoskeletal disorders (Fig. 4-2).

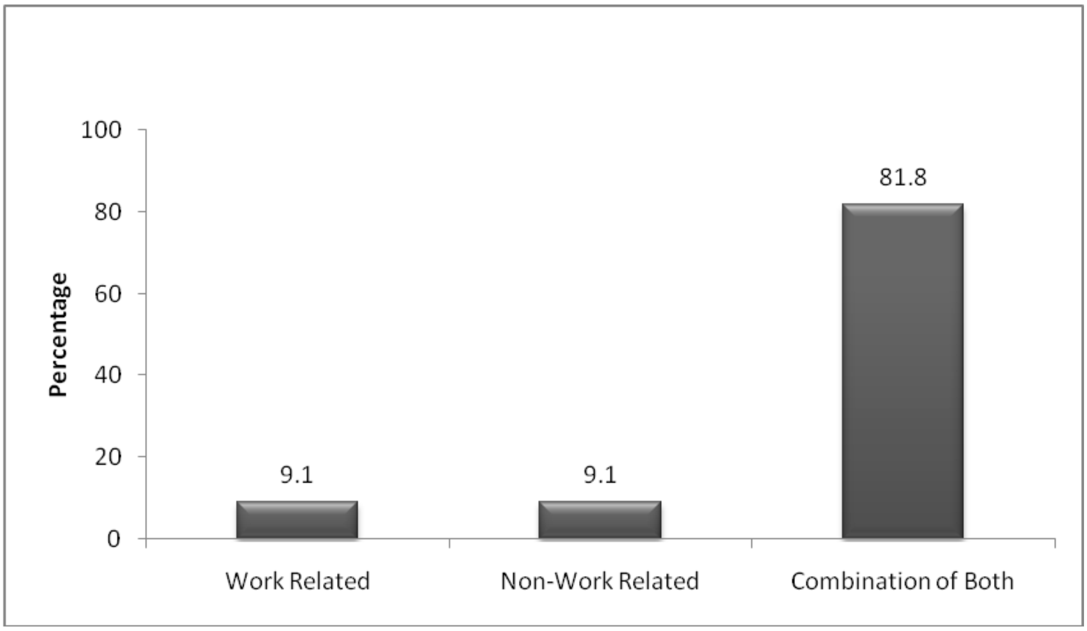


Fig. 4-2. Contributing Factors to Musculoskeletal Disorders included in the Curriculum

4.2.4.4 Stretching and Exercises:

The results indicate that 18.8% (n=3) of dental schools include stretching and exercise education in their curriculum with most of the dental schools 81.3% (n=13) not including any curriculum time to preventative musculoskeletal exercise.

Use of Magnification:

The results indicate that 87.5% (n=14) of dental schools include use of magnification in their curriculum, with types of magnification including loupes and operating microscope (Fig. 4-3).

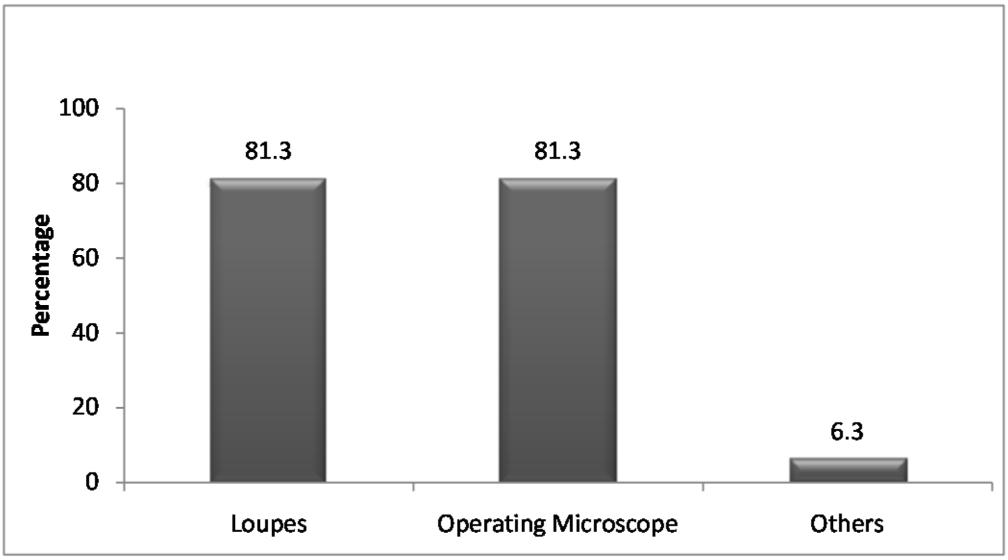


Fig. 4-3. Types of Magnification included in the Curriculum

Four Handed Dentistry:

The results indicate that 81.25% (n=13) of dental schools included four-handed dentistry in their curriculum. Of the 13 dental schools the methods used by the dental schools to teach four-handed dentistry is presented in Figure 4-4. The other methods included use of video and pairing of students in the practical sessions to simulate four-handed dentistry.

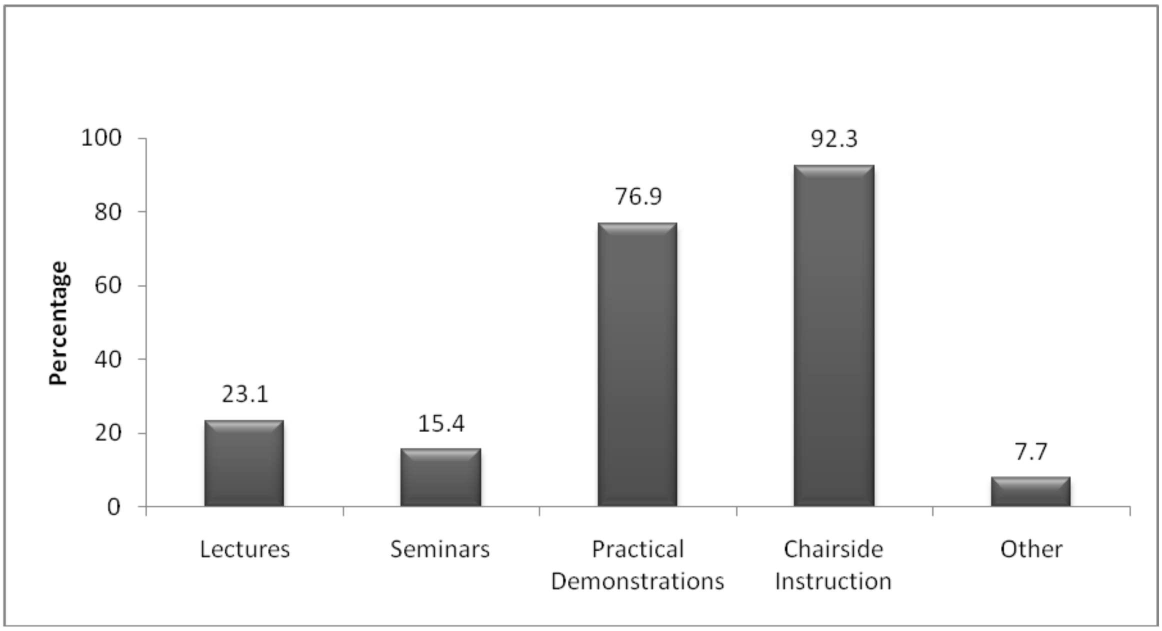


Fig. 4-4. Methods of teaching 4 handed dentistry

Importance of teaching Operating Posture

The results indicate that 75% (n=12) of dental schools identified teaching of operating posture to be very important (Fig 4-5).

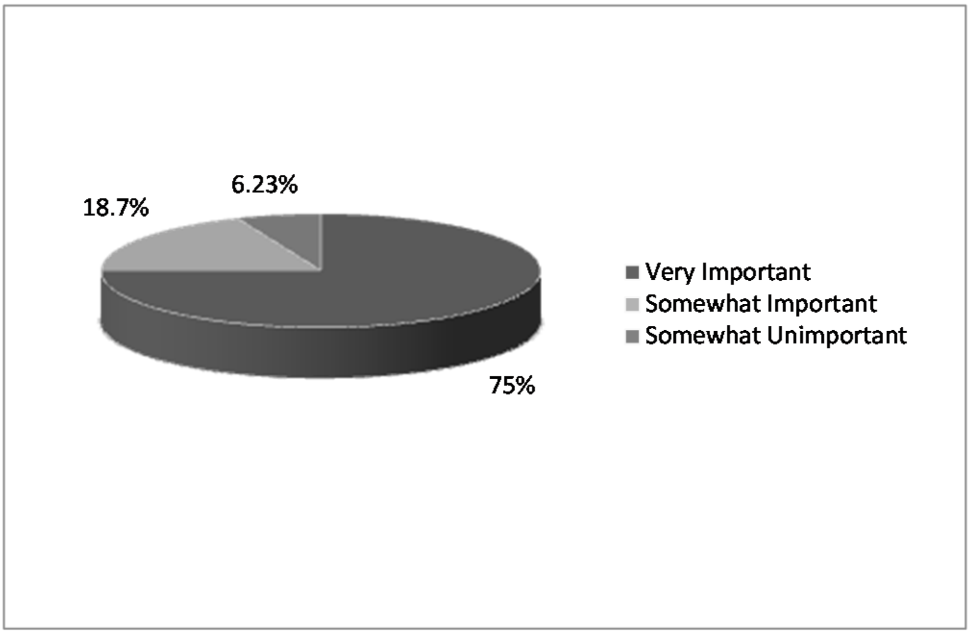


Fig. 4-5. Importance of Teaching Operating Posture

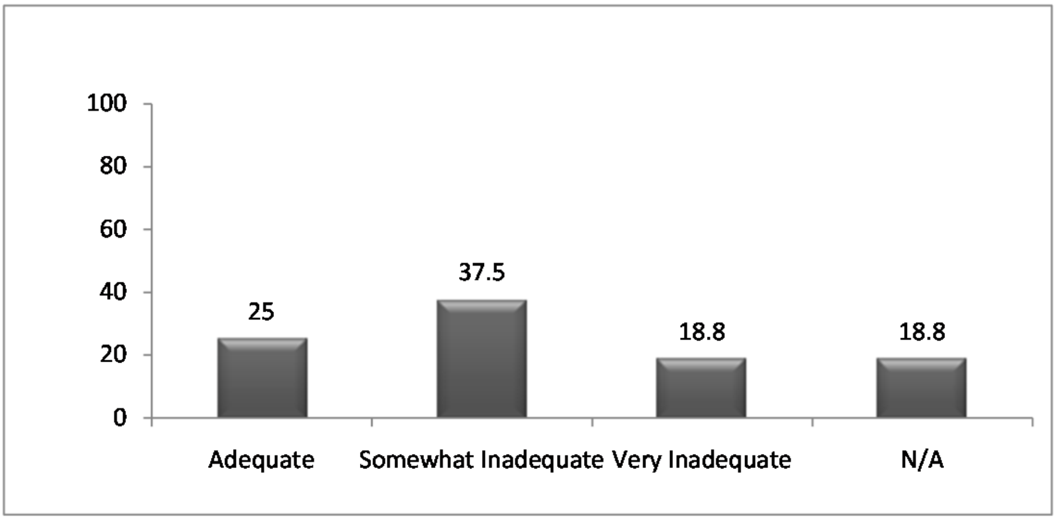


Fig. 4-6. Funding for Teaching Operating Posture

The results indicate that only 2 dental schools including the University of Birmingham had ongoing research on dentists' posture / musculoskeletal problems. The results also indicate that 25% (n=4) of dental schools find the funding to be adequate, 37.5% (n=6) find somewhat inadequate, 18.8% (n=3) find very inadequate (Fig. 4-6).

Future Plans Regarding Length of Time Allocated in Teaching Operating Posture: The results indicate that 31.3% (n=5) of dental schools had plans to increase the time allocated to teach operating posture

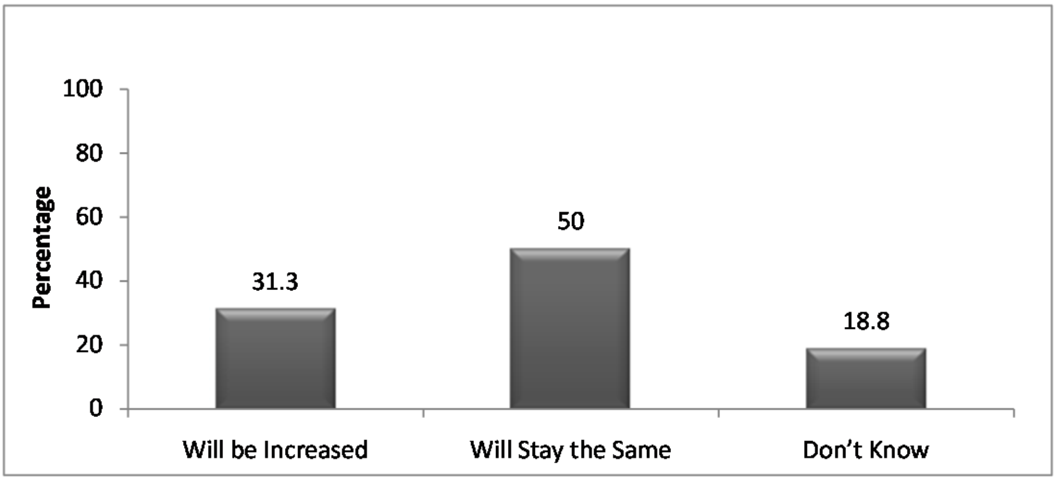


Fig. 4-7. Future Plans in Teaching Operating Posture

4.2.5 Discussion:

The results indicate that most of the dental schools across the U.K incorporate teaching of operating posture during undergraduate training at some time of the course, and three schools have indicated that they reinforce the use of correct operating posture throughout the 5-year period of undergraduate study. These results were similar to the study conducted by the ADA. On the contrary to these results the questionnaire study of dentists (BSD and CSD) indicate that only 24.8% (n=30) of dentists had undergraduate training on operating posture, and 21.5% (n=26) of dentists had postgraduate training and 10.7% (n=13) of dentists had both undergraduate and postgraduate training on using correct operating posture. This may be because the concept of correct operating posture has been introduced recently in undergraduate curriculum; the results also indicate that only four schools have mentioned the years they have been responsible for teaching operating posture, which on average is only 4.3 years or it could be that the ergonomic training/awareness was included within another subject area and hence the students did not see it as an entity, or that if they were reminded of their posture during clinics they did not associate this as ‘training’.

The results indicate that most of the schools use practical demonstration by a dentist as a method used to teach operating posture with only one school using a therapist to teach correct operating posture. A dedicated person such as a physiotherapist has not been considered by the dental schools may be because of lack of funding or lack of interest among dental schools. One school has planned to appoint a nurse coordinator in order to increase the awareness of posture among dental students; this may not be a solution because specialised knowledge on posture is necessary to train the students on correct operating posture. The methods used in ergonomics training in the schools across the US dental schools were not included in the survey by the ADA.

The results indicate that only 18.8% of dental schools have included stretching and exercises in their curriculum, but 81.3% have incorporated 4-handed dentistry and 68.8% incorporated contributing factors to musculoskeletal disorders in their curriculum. This indicates that schools are increasingly aware of posture and the related problems and consider it important but only three schools had incorporated preventing /

managing these disorders through stretching and exercises in their curriculum. The results of the survey by ADA indicate that 45.2% of the dental schools included stretching and exercises in the curriculum which was more than double comparing the results of this study, and all the dental schools in the USA had included four-handed dentistry in their curriculum. This may be because the schools in the US are increasingly aware of the benefits of stretching, exercises and four-handed dentistry.

The results indicate that the common types of musculoskeletal disorders included in the curriculum were similar to the study by ADA, but the inclusion of work related contributing factors in the curriculum were greater in the US dental schools compared to the dental schools in the U.K. The main reason for these results may be because the schools in the US are increasingly aware of the benefits of ergonomics in dentistry.

4.2.6 Views of Schools on Operating Posture

- The training the students receive on operating posture is minimal
- Good posture is encouraged, but emphasis is placed on achieving competence in operating procedures for the benefit of the patient and this may inevitably lead to bad postural habits.
- The problem exists with all the teaching and not just the teaching of posture and the students learn from what they have been taught.
- Postural training is considered very important but there is a difficulty in providing enough hours of close support dentistry practical experience (Four Handed / Team Based Dentistry)

4.2.7 Current Methods used in teaching Operating Posture by dental schools

- Reinforcement of posture at the chairside by the clinical staff
- Posture and joint position are taught at the phantom head lab.
- Clinical tutors and a therapist lead a 20 minute instruction session at the start of Junior Restorative Course (JRC) and continue training at the start of the clinical training
- Seat adjustment demonstration by Moving/Handling Coordinator.
- Use of video to show correct operating posture.

4.2.8 Future Plans of Schools on Operating Posture

- Plans to start a formal/dedicated lecture on operating posture in future
- Plans to introduce a programme based on team dentistry
- Appointment of a Nurse Co-ordinator to the Clinical Simulation unit
- Plans to introduce Alexander Technique session in the curriculum or the students will be encouraged to take outside courses on Alexander technique
- Plans to introduce a formal course on four handed dentistry
- Plans to introduce postural training as part of a pre-clinical cons programme

Considering the views, suggestions and future plans indicated by the dental schools indicate that most of the schools are interested to provide training on correct operating posture but a formal course or dedicated lectures/practical demonstrations needs to be introduced in all the schools in order to attempt solving the problems related to musculoskeletal disorders associated with dentistry.

Chapter 5

Daily Symptom Survey

5.0 Introduction

The aim of this study is to determine if there is a difference in musculoskeletal symptoms over the working week with dental students and dentists using two seats.

5.1 Symptom Survey

Amick et al (2003) used the daily symptom survey to examine the effect of an ergonomics intervention in office workers. The workers were assigned to three groups. Group1 received a highly adjustable chair with office ergonomics training, Group 2 received only training and Group 3 was a control group receiving the training at the end of the study. In the study data was collected two months and one month before the intervention and 2, 6 and 12 months post intervention. During these periods a short daily symptom survey was completed at the beginning, middle and the end of the workday over five consecutive work days to record bodily pain. The results indicated that the workers who used a highly adjustable chair and office ergonomics training had reduced symptoms during the workday.

Rising et al (2005) investigated bodily pain among dental student population in University of California, San Francisco School of Dentistry using a questionnaire. A total of 271 dental students participated in the study, with 85% response rate. The average age of the students was 26.3 years. A four-page self-reporting questionnaire was given to students at mid-year. Body pain was investigated in 18 body regions based on a body pain diagram (Fig. 5-1). For analysis the 18 body regions were condensed to five regions: neck/shoulder, mid-back, lower back, left arm/hand, right arm/hand.

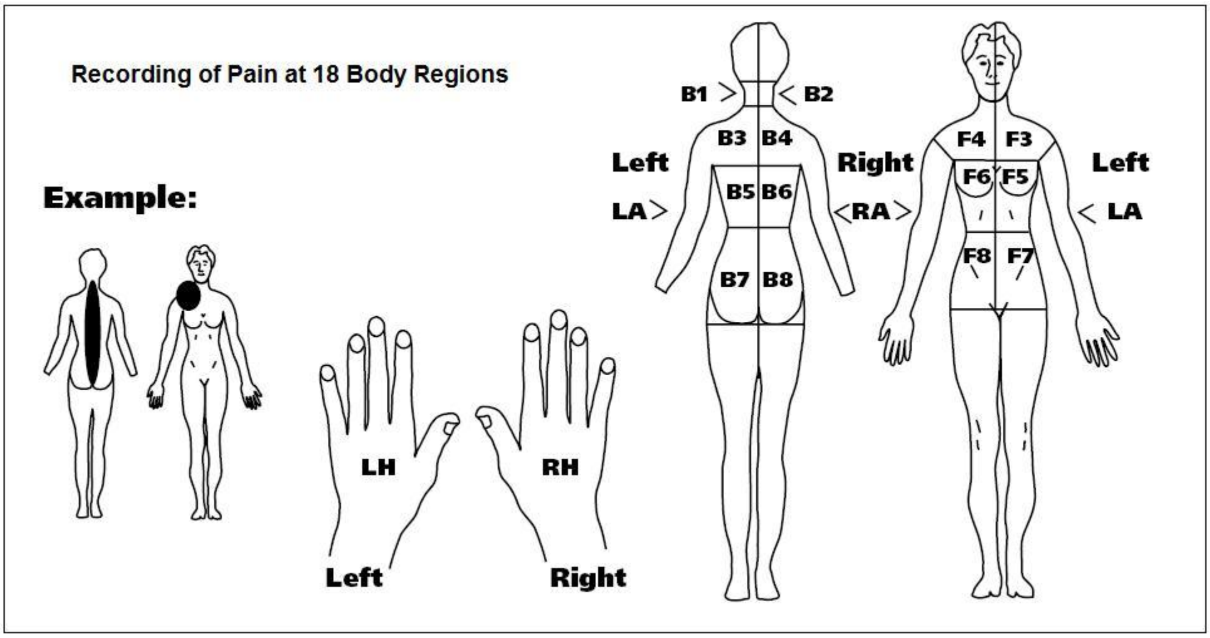


Fig. 5-1. Body Pain Chart (Rising et al. 2005)

A visual analog scale (VAS – 0 to 10) was used to record the level of pain. For the most symptomatic body region the duration of the pain was measured using a five-point scale (1 = less than one hour a day, 2 = 1 to 3 hours a day, 3 = 4 to 8 hours a day, 4 = 9 to 16 hours a day, 5 = 17 to 24 hours a day). The results of the study indicated high percentage of students (46% to 71 %) reported some type of body pain. They also found that the number of students reporting pain increased with number of years in dental school. Women reported having worst pain in the neck/shoulder region and men having worst pain in the lower back region. The frequency and duration of worst pain were found to be higher in the third year compared to first year. Pain intensity was found to be higher in women when compared to men, the pain intensity ranging from 3 to 5. The study reported the occurrence of chronic musculoskeletal pain at an early stage in dental careers, with 70% of dental students reporting pain by third year in dental school.

Melis et al (2003) investigated the upper body musculoskeletal symptoms in dental students from Sardinia. One hundred and fourteen dental students from the University of Cagliari were surveyed by questionnaire (Fig 5-2) and their responses were compared with 114 matched psychology students from the same university. The results indicated that increased numbers of dental students reported lower back pain when compared to psychology students and there was no difference for the pain reported in other areas. The need for ergonomics education among dental students was emphasized.

Student survey of musculoskeletal pain

Age: ______ **Gender: M** ☐ **F** ☐

Do you suffer, or have you recently suffered, from one of the following symptoms?
Put an X in the corresponding box.

		No	Mild	Moderate	Severe
Headache	Left	☐	☐	☐	☐
	Right	☐	☐	☐	☐
Arm pain/tingling/numbness	Left	☐	☐	☐	☐
	Right	☐	☐	☐	☐
Neck pain/stiffness	Left	☐	☐	☐	☐
	Right	☐	☐	☐	☐
Upper back pain/stiffness	Left	☐	☐	☐	☐
	Right	☐	☐	☐	☐
Lower back pain/stiffness	Left	☐	☐	☐	☐
	Right	☐	☐	☐	☐

Be sure you have completed every row. If you do not have the symptom described, put an X in the box corresponding with "No."
Thank you for your time!

Fig. 5-2. Student Survey Questionnaire (Melis et al. 2003)

5.2 Why use the Daily Symptom Survey

- The Daily Symptom Survey gives an idea of the musculoskeletal symptom growth over a workday by indicating the level of pain at beginning, middle and end of the workday.
- The results of survey may indicate the difference between musculoskeletal symptoms of the participants using a Bambach seat (BS) and conventional seat (CS).
- Previous use by Amick et al (2003) has found the survey useful in examining the effect of an ergonomic intervention.

5.3 Daily Symptom Survey of Dental Students

5.3.1 Methodology:

Subjects

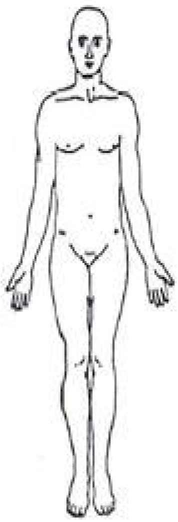
A total of 30 Year 2 dental students from the University of Birmingham - School of Dentistry took part in the study. Fifteen students were using BS (BSS) and 15 students were using CS (CSS). The seats were allocated to the students at the beginning of the term (25th April 2005) and the Daily Symptom Survey was conducted at the end of term (week beginning 11th July 2005).

The Daily Symptom Survey Chart

The Daily Symptom Survey chart was adapted for dentists and dental students from Amick et al (2003) with permission (Appendix XXIII). The chart starts with questions regarding the time of the day, the activity they have undertaken. Nine body regions were identified in the chart and for each body region a scale of 1 to 10 was ascribed

(Fig. 5-3), to identify the amount of pain at a specified time. Either side of the nine body regions there is a body chart to spot the region of pain by a cross. At the bottom of the chart there is a space to fill the cause of the pain if known.

Anterior



Part of the body	Discomfort or Pain level										
	None					Moderate				Severe	
Neck	0	1	2	3	4	5	6	7	8	9	10
Shoulders	0	1	2	3	4	5	6	7	8	9	10
Upper back	0	1	2	3	4	5	6	7	8	9	10
Elbow	0	1	2	3	4	5	6	7	8	9	10
Lower back	0	1	2	3	4	5	6	7	8	9	10
Lower arm/wrist/ Hand	0	1	2	3	4	5	6	7	8	9	10
Buttocks/thighs	0	1	2	3	4	5	6	7	8	9	10
Knees	0	1	2	3	4	5	6	7	8	9	10
Lower legs/ankles/ feet	0	1	2	3	4	5	6	7	8	9	10

Posterior

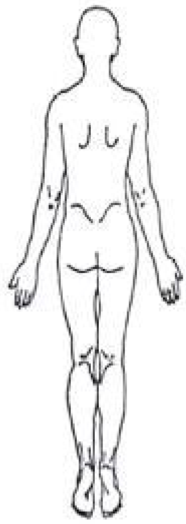


Fig. 5-3. Daily Symptom Survey (Body Pain Chart) (Based on Amick et al. 2003)

Procedure

- Fifteen daily symptom charts were given to 30 students (Appendix XXIII).
- A detailed instruction sheet (Appendix XXIV) about the procedure were also given to each student.
- For each day the students were instructed to complete three symptom charts, one form at the beginning of the day, one in the afternoon (middle of the day) and one in the evening (end of the day) over a working week from Monday to Friday.
- The chart contains the date and time (Morning / Afternoon / Evening)

- The students were asked to circle one of the activity (Beginning of the day / Following a Lecture Session / Following a Practical Session)
- They were also asked to circle the type of seat used if it was a practical session (Conventional/Saddle)
- The discomfort or pain level (scale of 0 to 10 - VAS) for nine regions of the body has to be indicated next (0 being no pain, 1 being minimal pain and 10 being intense pain) (Rising et al 2005).
- The nine body regions included the Neck; Shoulders; Upper Back; Elbow; Lower Back; Lower Arm/Wrist/Hand; Buttocks/Thighs; Knees; and Lower Legs/Ankles/Feet
- A question regarding the cause of pain (if known) was included at the end of the chart.

5.3.2 Results

The number of students who returned the completed survey was

- Bambach Seat Students (BSS): 14
- Conventional Seat Students (CSS): 13

All students using the BS reported pain sometime during the week. Twelve out of 13 students using CS reported pain sometime during the week.

Beginning of the Day

Number of students reporting pain (Fig. 5-4)

BSS: 35.7% (n=5) reported pain at the beginning of the day sometime during the week due to dentistry, and 21.4% (n=3) reported pain for other reasons including bike riding, playing tennis, "slept funny the previous day" and use of high heels.

CSS: 53.8% (n=7) reported pain at the beginning of the day sometime during the week due to dentistry, and 23.1 (n=3) reported pain for other reasons including painting shelves, carrying boxes, playing football, rowing in gym and playing tennis the previous day.

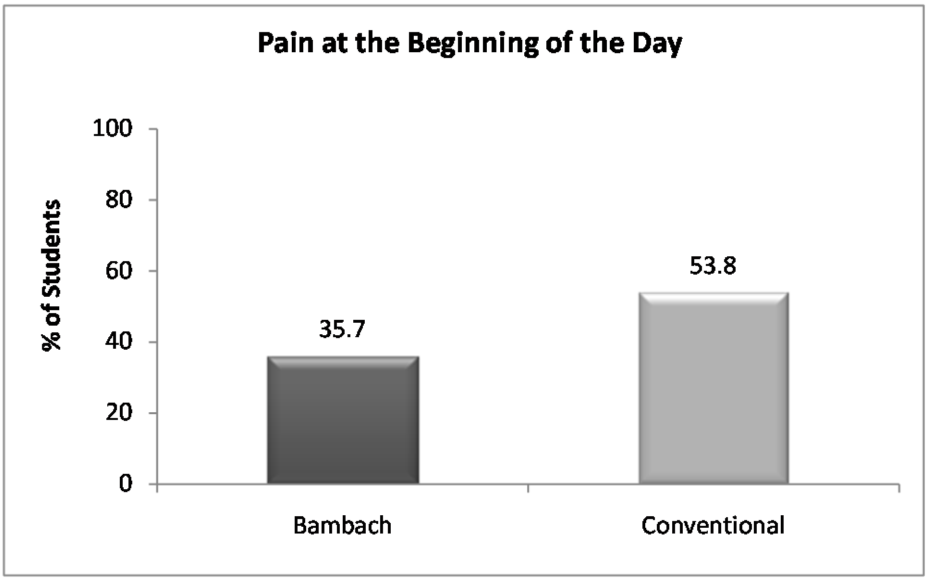


Fig. 5-4. Students reporting pain at the beginning of the day due to dental work

Level of pain

The results which are presented in table 5-1 indicate that the level of pain reported by students ranged from 1 to 5. The results indicate that the level of pain reported by BSS was less when compared to the CSS.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Lower back, upper back, neck, wrist and hand.	50%	1	Neck, shoulders, lower back and knees.	23.1%
2	Lower back, upper back, neck, buttocks, thighs, knees, ankles and feet.	21.4%	2	Neck, shoulders, upper back, elbow, lower back, wrist, hand, buttocks, thighs, knees, ankles and feet.	38.5%
3	Upper back, buttocks, thighs, knees, ankles and feet.	21.4%	3	Lower back.	7.7%
4	Lower back.	14.2%	4	Upper back and lower back.	15.4%
5	Upper back.	7.1%	5	Neck, shoulders and lower back.	15.4%

Table. 5-1. Level of pain at the beginning of the day (Students)

Level of Pain: 1 - Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-5 indicate that the pain was reported in all the regions except elbows, wrists and hands. Lower back region is the most frequent area of pain reported by the students at the beginning of the day.

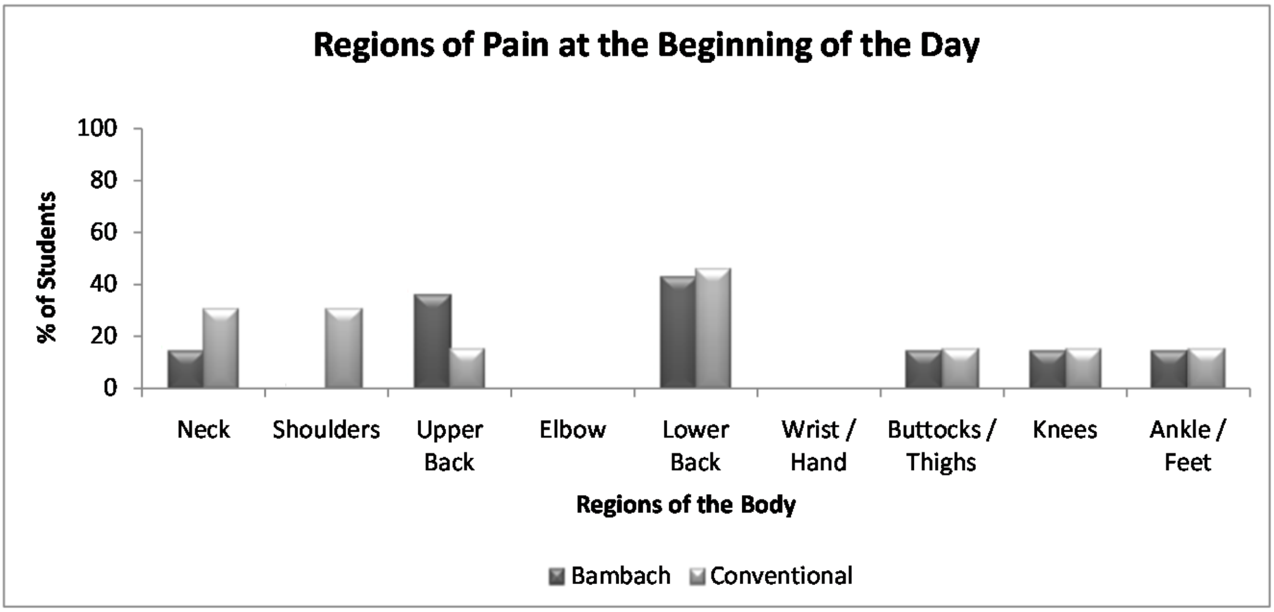


Fig. 5-5. Regions of pain at the beginning of the day (Students)

Middle of the Day

Number of students reporting pain (Fig. 5-6)

BSS: 50 % (n=7) reported pain in at middle of the day sometime during the week due to dentistry, and 42.8 % (n=6) reported pain for other reasons including using high heels, bike riding, driving for long hours, and interestingly, four of the students specified use of conventional seat at home as a reason for pain.

CSS: 76.9 % (n=10) reported pain in at middle of the day sometime during the week due to dentistry, and 15.38 % (n=2) reported pain for other reasons including playing tennis and sitting in the car for long hours.

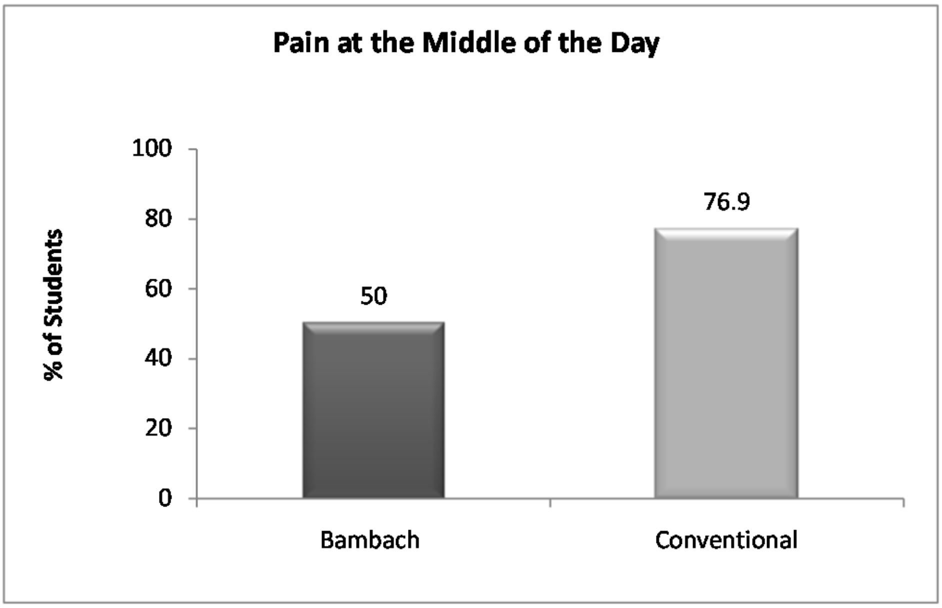


Fig. 5-6. Students reporting pain at the middle of the day due to dental work

Level of pain

The results presented in table 5-2 indicate that the level of pain reported by students ranged from one to six. The results indicate that the level of pain reported by BSS were less when compared to the CSS. The CSS reported level of pain up to six, whereas the BSS only reported level of pain up to five.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Lower back, upper back, neck, shoulders, buttocks and thighs.	35.8%	1	Neck, shoulders, upper back and lower back.	61.5%
2	Lower back, neck, upper back, buttocks, thighs, ankles and feet.	85.7%	2	Neck, shoulders, upper back, elbow, lower back, wrist, hand, buttocks, thighs, knees, ankles and feet.	53.8%
3	Wrist, hand, buttocks and thighs.	21.4%	3	Neck, shoulders, upper back, elbow, lower back,, wrist, hand, buttocks, thighs, knees, ankles and feet.	38.5%
4	Lower back, wrist and hand.	14.3%	4	Shoulders, upper back, lower back, wrist, hand and knees.	23.1%
5	Lower back and upper back	14.3%	5	Lower back and neck.	23.1%
6	Nil	Nil	6	Neck.	7.7%

Table. 5-2. Level of pain at the middle of the day (Students)

Level of Pain: 1 – Minimal Pain; 10 – Intense Pain

Regions of pain

The results are presented in figure 5-7 indicate that the pain was reported in all the regions investigated. Neck is the most frequent area of pain reported by the students followed by lower back at the middle of the day.

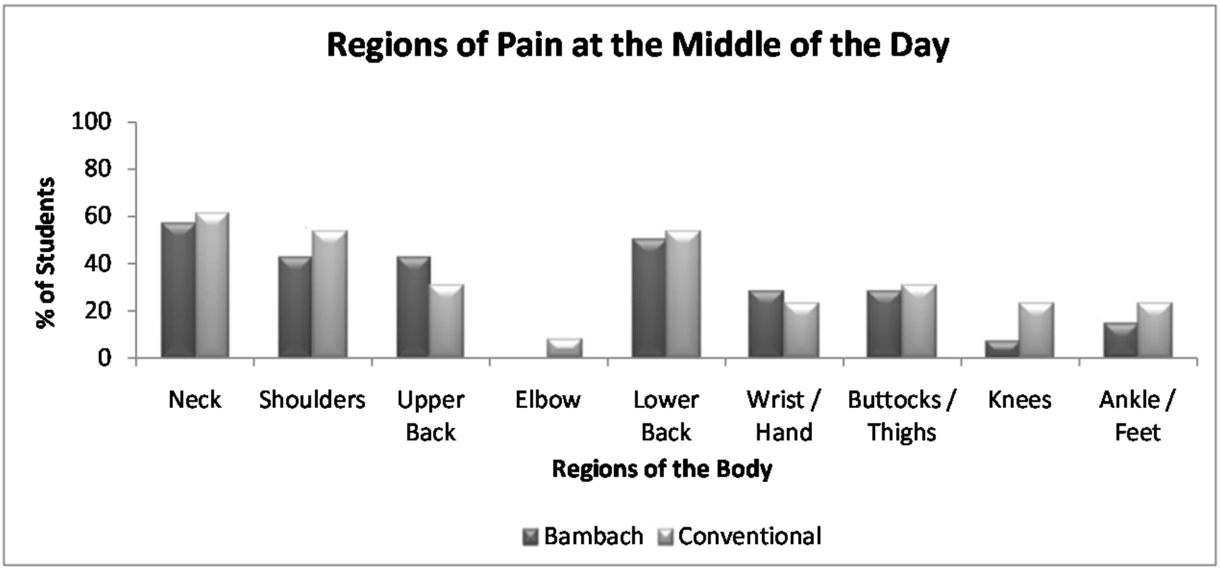


Fig. 5-7. Regions of pain at the middle of the day (Students)

End of the Day

Number of students reporting pain (Fig. 5-8)

BSS: 28.6 % (n=4) reported pain at the end of the day sometime during the week due to dentistry, and 50 % (n=7) reported pain for other reasons including walking for long hours, using a conventional seat, working at a computer for long hours, driving, swimming and attending a lecture session.

CSS: 46.2 % (n=6) reported pain at the end of the day sometime during the week due to dentistry, and 23.1 % (n=3) reported pain for other reasons including walking for long hours, sitting in a car and playing tennis.

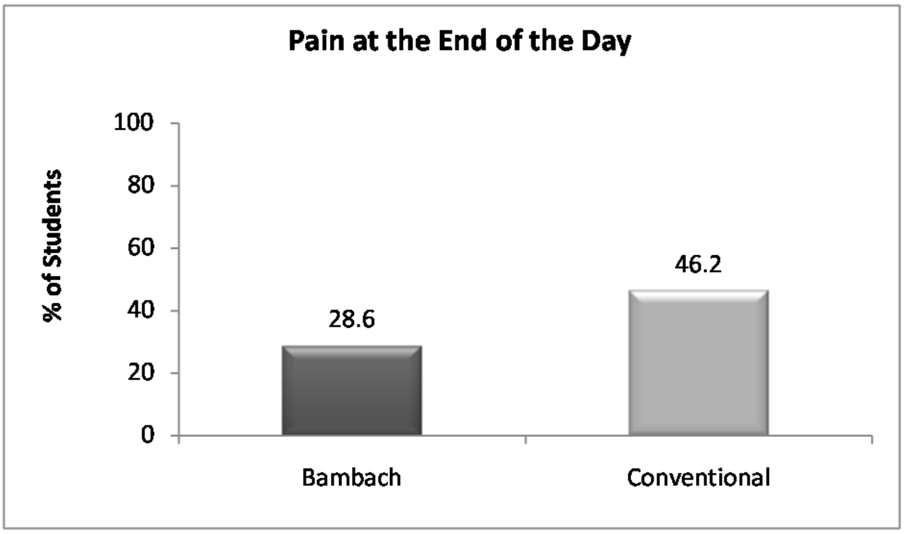


Fig. 5-8. Students reporting pain at the end of the day due to dental work

Level of pain

The results presented in table 5-3 indicate that the level of pain reported by students ranged from one to six. The results indicate that the level of pain reported by BSS were less when compared to the CSS. The CSS reported pain level up to nine, whereas the BSS only reported pain level up to five, indicating that for the CSS the level of pain increases as the day progresses.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Shoulders, neck, upper back, lower back,, wrist, hand, ankles and feet.	42.9%	1	Lower back, shoulders, knees, neck, wrist, hand and upper back.	46.2%
2	Neck, upper back and lower back.	42.9%	2	Neck, shoulders, upper back, elbow, lower back, wrist, hand, buttocks, thighs, knees, ankles and feet.	69.2%
3	Neck, lower back and upper back.	21.4%	3	Neck, lower back and shoulders.	38.5%
4	Neck, shoulders, lower back and upper back.	28.6%	4	Neck.	7.7%
5	Upper back.	7.1%	5	Lower back and neck.	7.7%
7	Nil	Nil	7	Lower back and neck.	7.7%
9	Nil	Nil	9	Lower legs ankles and feet.	7.7%

Table. 5-3. Level of pain at the end of the day (Students)

Level of Pain: 1 - Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-9 indicate that pain was reported in all the regions investigated. Again, neck and lower back was the most common area of pain reported by CSS, whereas the BSS reported upper back.

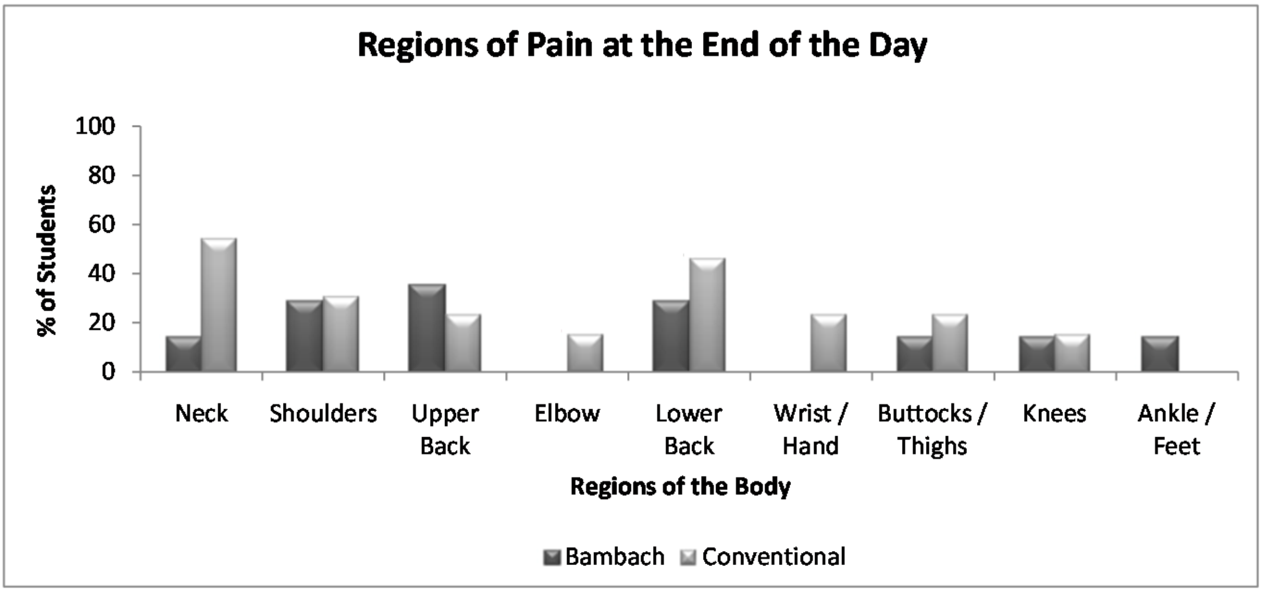


Fig. 5-9. Regions of pain at the middle of the day (Students)

After a Lecture Session

Both groups of students used conventional seats in the lecture theatre.

Number of students reporting pain (Fig. 5-10)

BSS: 57.1 % (n=8) reported pain after a lecture session.

CSS: 46.2 % (n=6) reported pain after a lecture session.

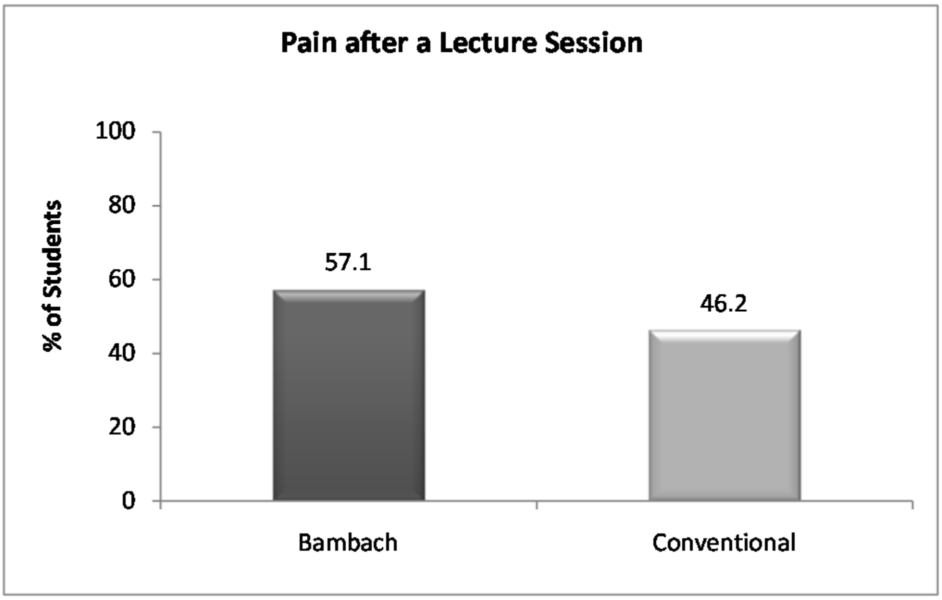


Fig. 5-10. Students reporting pain after a lecture session

Level of pain

The results presented in table 5-4 indicate that the level of pain reported by students ranged from one to seven. The BSS reported level of pain up to seven, whereas the CSS only reported level of pain up to 3, indicating that the BSS may not feel comfortable seated in a lecture theatre.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Lower back, upper back and neck.	28.6%	1	Shoulders and lower back.	7.7%
2	Lower back, shoulders and upper back.	14.3%	2	Lower back, upper back, shoulders.	30.8%
3	Lower back, shoulders and upper back.	14.3%	3	Knees, ankles and feet.	7.7%
4	Buttocks, thighs, ankles and feet.	7.1%	4	Nil	Nil
7	Lower back and upper back.	7.1%	7	Nil	Nil

Table. 5-4. Level of pain after a lecture session (Students)

Level of Pain: 1 – Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-11 indicate that pain was reported in all the regions investigated except the elbows, wrists and hands, the lower back being the most frequent area of pain to be reported.

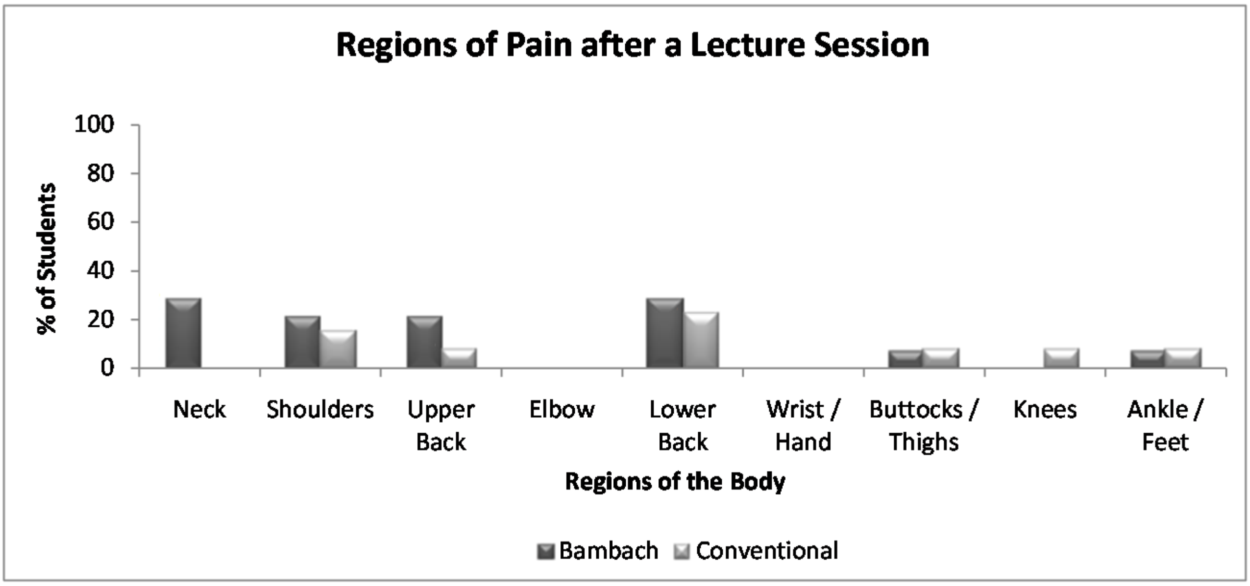


Fig. 5-11. Regions of pain after a lecture session (Students)

After a Practical Session

Number of students reporting pain (Fig. 5-12)

BSS: 50 % (n=7) reported pain after a practical session.

CSS: 61.5 % (n=8) reported pain after a practical session.

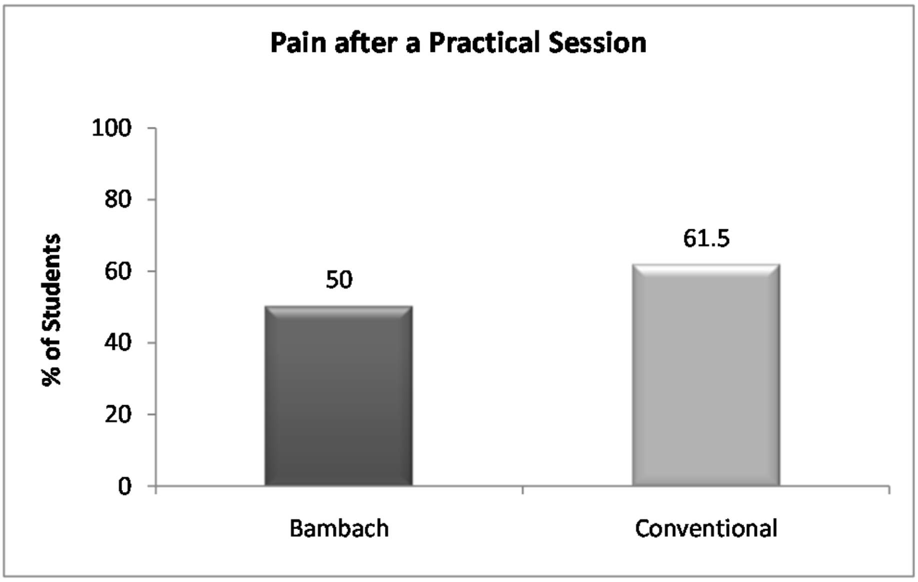


Fig. 5-12. Students reporting pain after a practical session

Level of pain

The results presented in table 5-5 indicate that the level of pain reported by students ranged from one to six. The level of pain reported by BSS was less when compared to the CSS. The CSS reported level of pain up to six, whereas the BSS only reported level of pain up to 4, indicating that the CSS report more pain after a practical session.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Neck, shoulders, wrist, hand, buttocks and thighs.	21.4%	1	Ankles, feet and knees.	7.7%
2	Neck, Shoulders, upper back, lower back, wrist, hand, knees, ankle and feet.	42.9%	2	Neck, shoulders, upper back, lower back, buttocks and thighs.	53.8%
3	Upper back and shoulders.	7.1%	3	Neck, shoulders, upper back and lower back.	23.1%
4	Lower back and shoulders.	7.1%	4	Lower back, wrist, hand, elbow, knees, ankle and feet.	15.4%
5	Nil	Nil	5	Lower back, upper back and shoulders.	15.4%
6	Nil	Nil	6	Lower back and upper back.	7.7%

Table. 5-5. Level of pain after a practical session (Students)

Level of Pain: 1 – Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-13 indicate that the pain was reported in all the regions investigated, with the neck being the most frequent area of reported pain followed by shoulder, upper and lower back after a practical session.

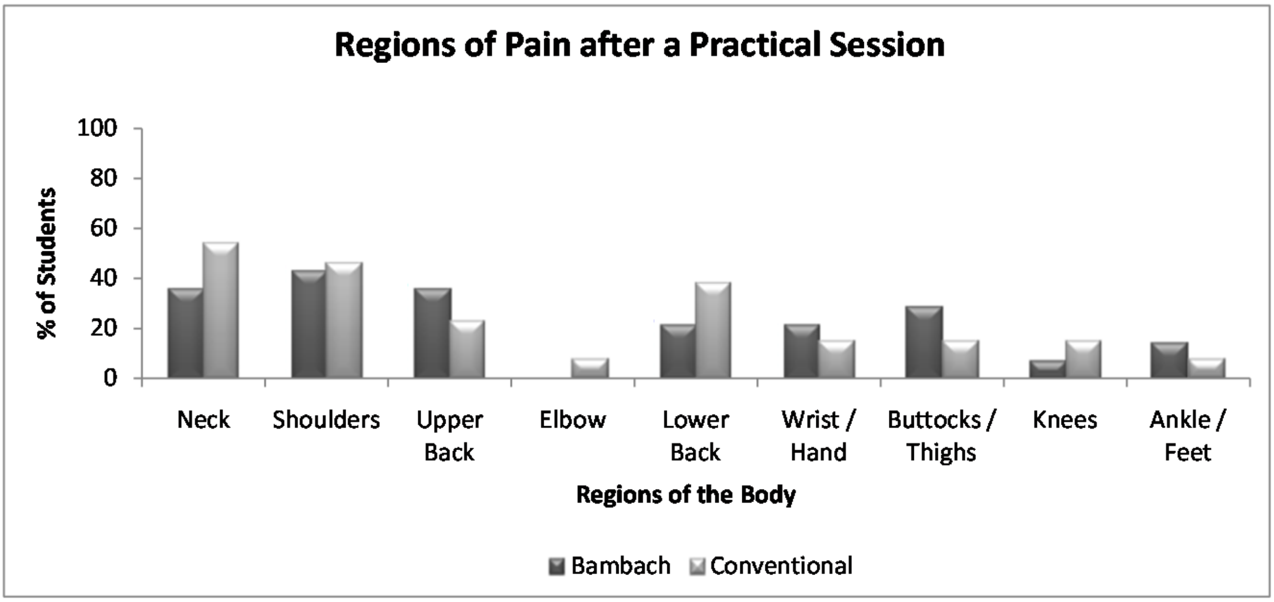


Fig. 5-13. Regions of pain after a lecture session (Students)

5.3.3 Analysis of the pain reported by dental students

There is a common pattern observed with the number of students reporting pain during a typical workday over a work week. The number of students reporting pain increased in the middle of the day in both BSS and CSS (Fig 5-14). This may indicate that some of the students who had no pain at the beginning of the day develop pain at the middle of the day, and this may strongly indicate the stress associated with dental work. However only fewer BSS reported pain when compared to CSS at each time of the day recorded.

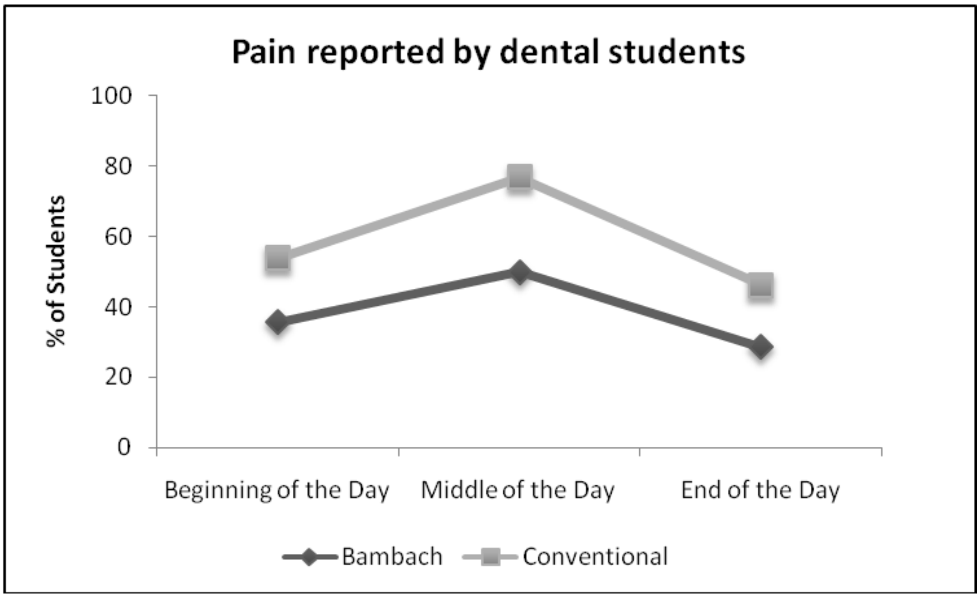


Fig. 5-14. Pattern of pain reported by dental students

The variation in the average level of pain during a typical workday indicates that for both groups of students the level of pain reported increased at the middle of the day and slightly decreased at the end of the day (Fig. 5-15). However the level of pain recorded at the middle of the day and the end of the day were less with BSS compared with CSS.

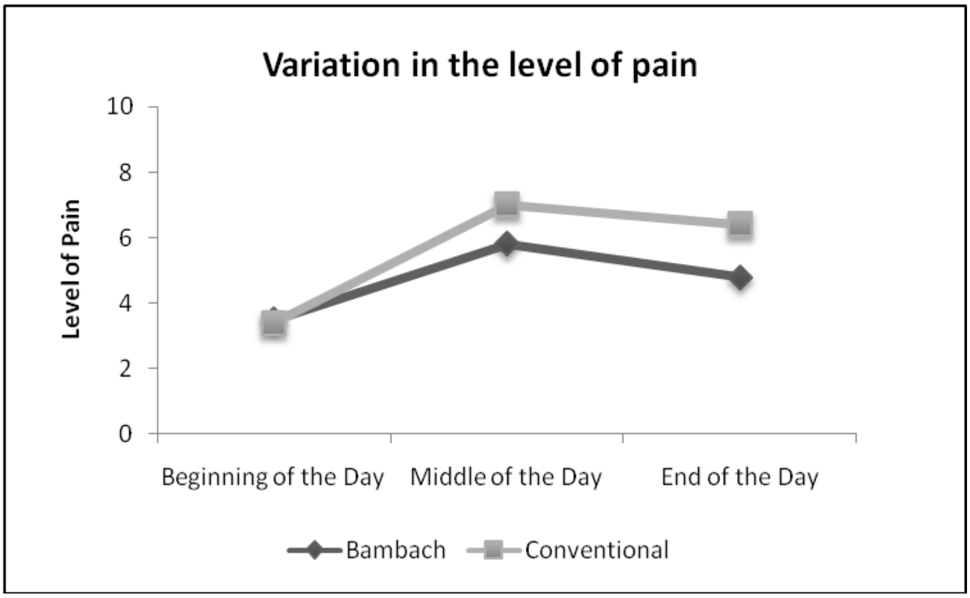


Fig. 5-15. Variation in the level of pain reported by dental students

The relationship between dental students reporting pain and the level of pain reported are presented in figure 5-14 and 5-15. A common pattern is observed with dental students where the number of students reporting bodily pain increases in the middle of the day along with an increase in level of pain reported at the middle of the day. Statistical association was measured using Pearson Chi-Square where the results indicate no significant association between the dental students reporting bodily pain and the level of pain reported, $\chi^2 = 0.279$; df = 2; p = 0.870. The strength of association was measured using Phi Coefficient (Φ = 0.095; p = 0.870), and Cramér's V (Cramér's V = 0.095; p = 0.870) indicating no significant strength of association between reporting bodily pain and the level of pain reported.

There is a common pattern observed with dental students reporting pain in the neck, shoulders, upper back and lower back, with higher number of students reporting pain in the middle of the day (Fig 5-16 and 5-17). However less variation was observed in CSS, with greater number of CSS reporting pain (Fig 5-17). The number of CSS reporting pain was higher in all the regions when compared to BSS, except upper back. However analysing the level of pain reported indicated that BSS reported lower intensity of pain compared to CSS.

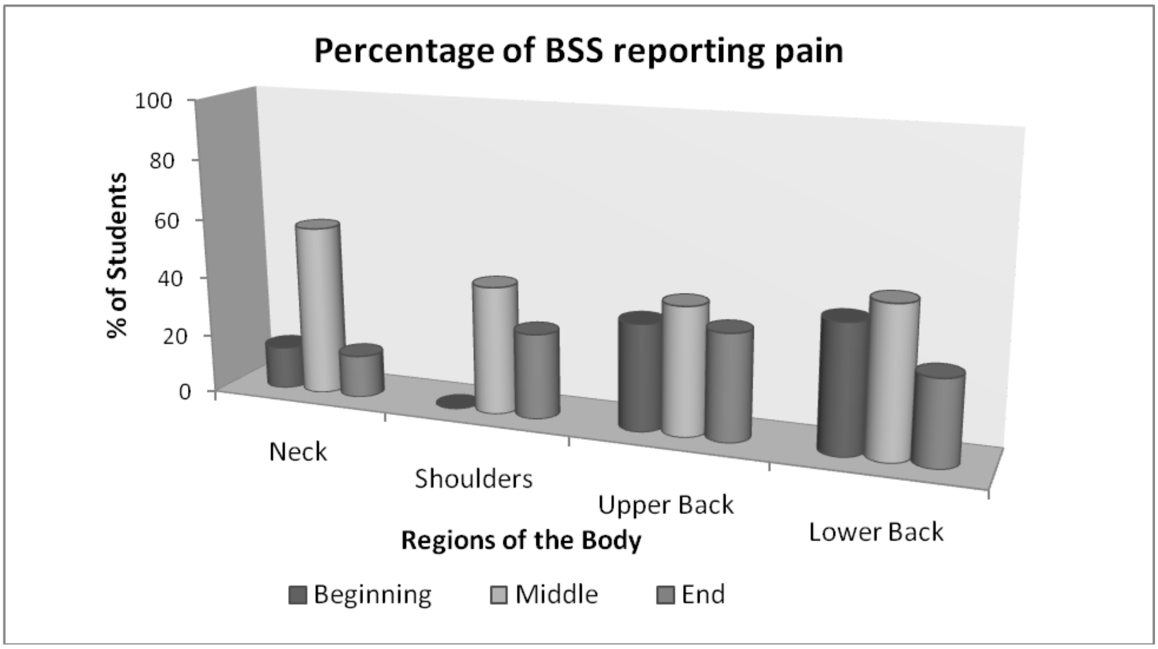


Fig. 5-16. Variation in the number of BSS reporting pain in various regions of the body

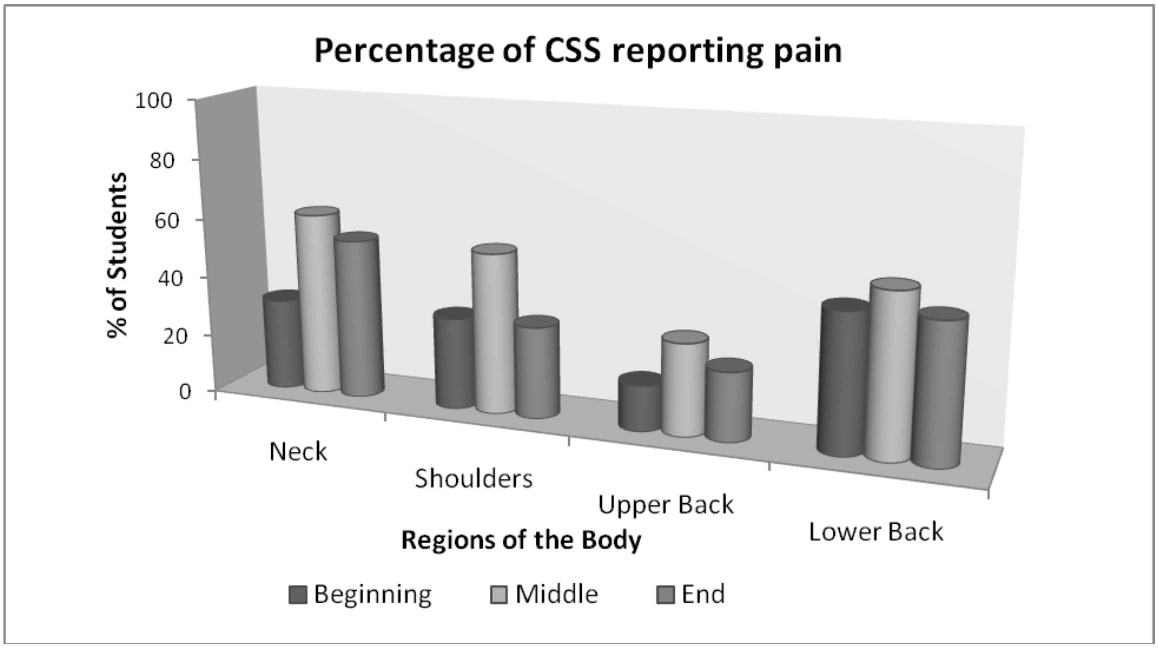


Fig. 5-17. Variation in the number of CSS reporting pain in various regions of the body

5.3.4 Discussion

The results indicated that the BSS recorded lower levels of pain and discomfort on the workdays over a week compared with the CSS. The students were using the seats for eleven weeks before the daily symptom survey was conducted. It is interesting to note that after eleven weeks of using the seats, even at the beginning of the day the number of BSS reporting pain was less when compared to CSS but the level of pain reported was similar, with low back pain reported to be most frequent region of pain (Rising et al 2005).

At the middle of the day the number of BSS reporting pain was less when compared to CSS (Fig 5-16, Fig 5-17); the neck was reported to be the most frequent region of pain in the middle of the day (Rising et al 2005). Also at the end of the day the number of BSS reporting pain were less when compared to CSS with the BSS reporting less pain (Fig 5-16, Fig 5-17); the neck and low back was reported to be the most frequent region of pain at the end of the day.

It is interesting to note that the number of BSS reporting pain was more after a lecture session; the BSS also reported increased intensity of pain at this time. The lecture sessions were conducted in a lecture theatre with conventional seating and the BSS may have been become used to sitting with correct posture in Bambach seats and sitting in a conventional lecture theatre seat may have increased their pain as they may have adopted a slumped position (Chapter 1, Section 1.1.11). The low back is reported to be the most frequent region of pain after a lecture session (Rising et al 2005).

After a practical session the BSS reported less pain, with fewer BSS reporting pain. The neck and the shoulders were reported to be the most frequent region of pain after a lecture session followed by pain in the low back. It is interesting to note that the low back pain was reported less in BSS.

The results indicated that the CSS reported pain in all the 9 body regions used in the symptom chart, whereas the BSS report no pain in the elbows. They also report pain in the shoulders, wrist and hand only in the middle of the day, whereas the CSS report pain throughout the workday. Low back pain is the most frequently reported in both the groups of students but the number of BSS reporting low back pain decreased at the end of workday.

5.4 Daily Symptom Survey of Practising Dentists

5.4.1 Methodology:

Subjects

The symptom survey was conducted with dentists who had agreed to participate in further study on the questionnaire. A total of 30 practising dentists took part in the study. Only ten dentists completed the symptom survey and returned it, a response rate of 33.3%.

Procedure

- Fifteen daily symptom charts were given to 30 dentists (Appendix XXV).
- Detailed instruction sheet (Appendix XXVI) about the procedure were also given to each dentist.
- For each day the dentists were instructed to complete three symptom charts.
- The dentists were instructed to fill in one form at the Morning (Beginning of the day), one in the afternoon (Middle of the day) and one in the evening (End of the day) over a working week from Monday to Friday.
- The chart contains date and time (Morning / Afternoon / Evening)
- The dentists were asked to circle one of the activities (Beginning of the day / Middle of the Day / End of the Day), along with the discomfort or pain level (scale of 1 to 10) for nine regions of the body.
- The nine body regions include the Neck; Shoulders; Upper Back; Elbow; Lower Back; Lower Arm/Wrist/Hand; Buttocks/Thighs; Knees; and Lower Legs/Ankles/Feet.
- A question regarding the cause of their pain if known was also included.

5.4.2 Results

The number of dentists who returned the completed survey was

- Bambach Seat Dentists (BSD): 4
- Conventional Seat Dentists (CSD): 6

All the dentists who responded to the Daily Symptom Survey reported pain sometime during the week.

Beginning of the Day

Number of dentists reporting pain

BSD: 75 % (n=3) reported pain at the beginning of the day sometime during the week.

CSD: 100% (n=6) reported pain at the beginning of the day sometime during the week.

Level of pain

The results presented in table 5-6 indicate that the level of pain reported by dentists ranged from one to eight. The results indicate that the level of pain reported by BSD were less when compared to the CSD. The CSD reported level of pain up to eight; whereas the BSD only reported level of pain up to seven. The results also indicate that more number of CSD reported pain at the beginning of the day.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Neck, shoulders, upper back, elbow, lower back, wrist, hand, buttocks, thighs and knees.	75%	1	Neck, shoulders, lower back, upper back, wrist, hand, buttocks and thighs.	100%
2	Nil	Nil	2	Neck, shoulders, upper back, lower back, wrist hands, knees, buttocks and thighs.	83.3%
3	Nil	Nil	3	Neck, shoulders and lower back.	50%
4	Nil	Nil	4	Lower back.	16.7%
5	Nil	Nil	5	Shoulders and elbow.	33.3%
6	Nil	Nil	6	Elbow.	16.7%
7	Lower back.	25%	7	Nil	Nil
8	Nil		8	Elbow.	33.3%

Table. 5-6. Level of pain at the beginning of the day (Dentists)

Level of Pain: 1 - Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-18 indicate that the pain was reported in all the regions investigated. Lower back is the most common area of pain reported followed by upper back and neck at the beginning of the day.

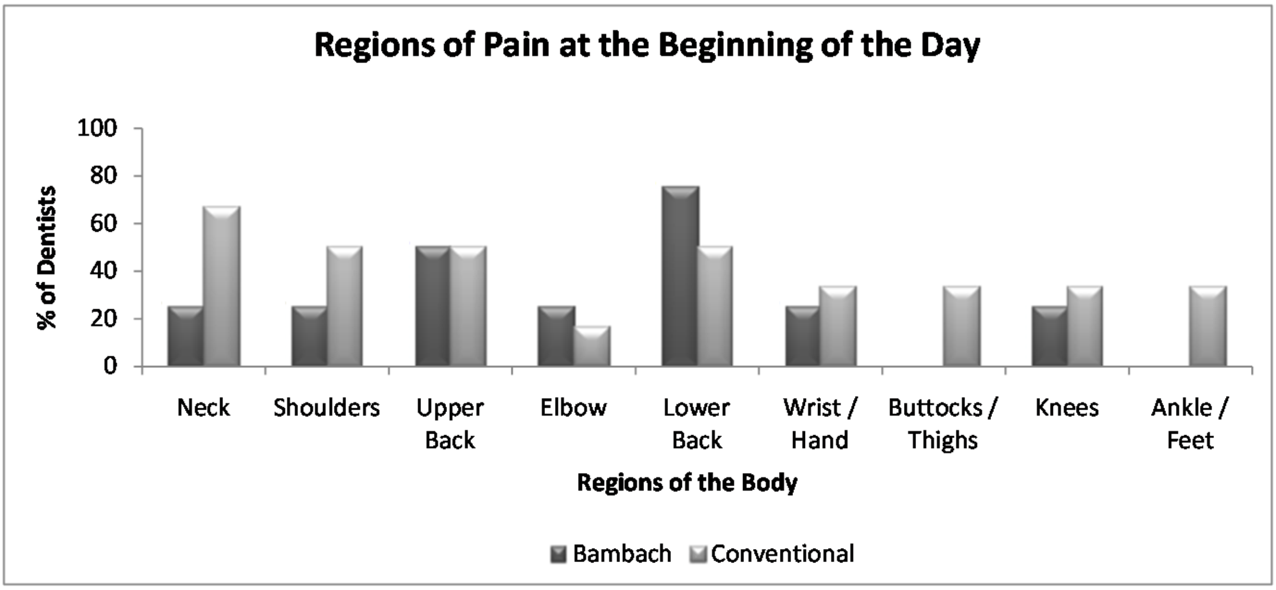


Fig. 5-18. Regions of pain at the beginning of the day (Dentists)

Middle of the Day

Number of dentists reporting pain

BSD: 75% (n=3) reported pain in at middle of the day sometime during the week.

CSD: 100% (n=6) reported pain in at middle of the day sometime during the week.

Level of pain

The results presented in table 5-7 indicate that the level of pain reported by dentists ranged from one to nine. The results indicate that the level of pain reported by BSD were less when compared to the CSD. The CSD reported level of pain up to nine; whereas the BSD only reported level of pain up to seven. The results also indicate that more number of CSD report pain at the middle of the day.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Lower back, upper back, shoulders, ankles and feet.	50%	1	Neck, shoulders, upper back, wrist, hand, lower back, buttocks and thighs.	83.35
2	Lower back, upper back, wrist, hand, buttocks and thighs.	50%	2	Neck, shoulders, upper back, lower back, wrist, hand, buttocks, thighs and knees.	66.7%
3	Upper back.	25%	3	Neck, shoulders and lower back.	66.7%
4	Upper back.	25%	4	Neck.	16.7%
5	Nil	Nil	5	Elbow, lower back and shoulders.	33.3%
6	Nil	Nil	6	Elbow.	16.7%
7	Lower back.	25%	7	Nil	
8	Nil	Nil	8	Lower back.	16.7%
9	Nil	Nil	9	Lower back.	16.7%

Table. 5-7. Level of pain at the middle of the day (Dentists)

Level of Pain: 1 - Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-19 indicate that the pain was reported in all the regions except ankles and feet. Lower back is the most common area of pain reported followed by upper back and shoulders at the middle of the day.

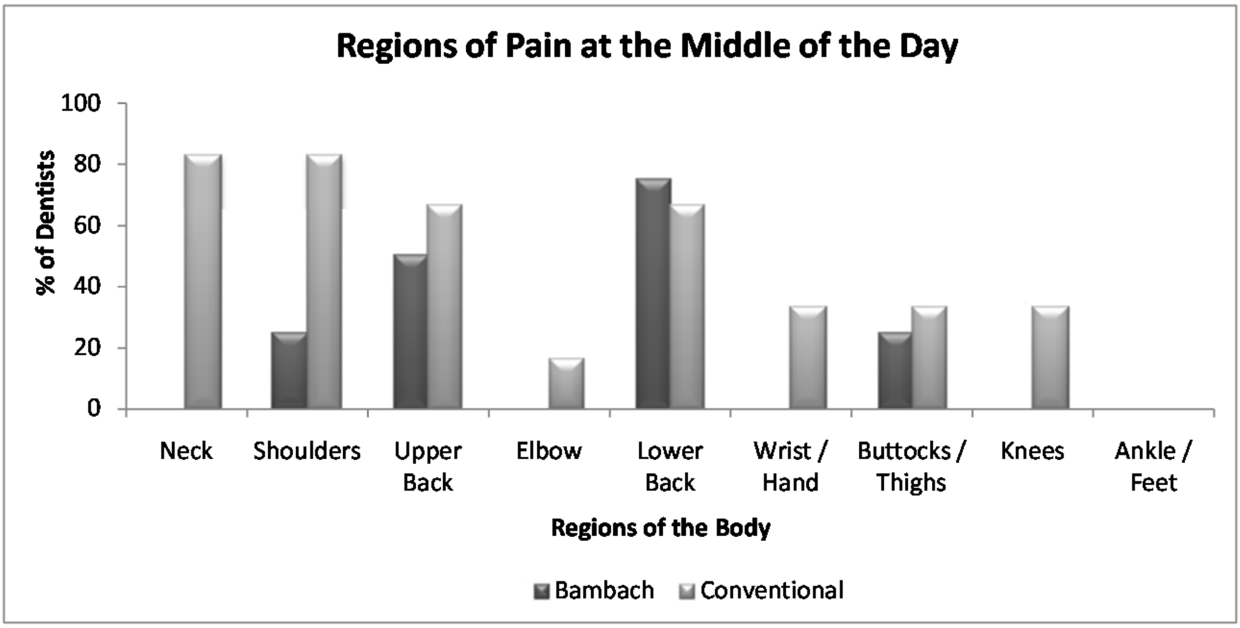


Fig. 5-19. Regions of pain at the middle of the day (Dentists)

End of the Day

Number of Dentists reporting pain

All the Dentists reported pain at the end of the day sometime during the week.

Level of pain

The results presented in table 5-8 indicate that the level of pain reported by dentists ranged from one to nine. The results indicate that the level of pain reported by BSD were less when compared to the CSD. The CSD reported level of pain up to eight; whereas the BSD only reported level of pain up to seven. The results also indicate that more of CSD reported pain at the end of the day.

Level of Pain	Regions of Pain Bambach	Percentage Bambach	Level of Pain	Regions of Pain Conventional	Percentage Conventional
1	Upper back, shoulders, lower back.	50%	1	Neck, shoulders, upper back, lower back, wrist, hand, buttocks and thighs.	66.7%
2	Lower back, upper back, buttocks and thighs.	25%	2	Neck, shoulders, upper back, lower back, wrist and hands.	83.3%
3	Nil	Nil	3	Neck, shoulders, upper back, lower back, buttocks and thighs.	33.3%
4	Upper back.	25%	4	Neck, shoulders, upper back and lower back.	33.3%
5	Nil	Nil	5	Lower back.	33.3%
6	Nil	Nil	6	Lower back and elbow.	16.7%
7	Lower back.	25%	7		
8	Nil	Nil	8	Lower back and elbow.	16.7%

Table. 5-8. Level of pain at the end of the day (Dentists)

Level of Pain: 1 - Minimal Pain; 10 – Intense Pain

Regions of pain

The results presented in figure 5-20 indicate that the pain was reported in all the regions except ankles and feet. Lower back is the most common area of pain reported followed by upper back and shoulders at the end of the day, similar to that reported at the middle of the day.

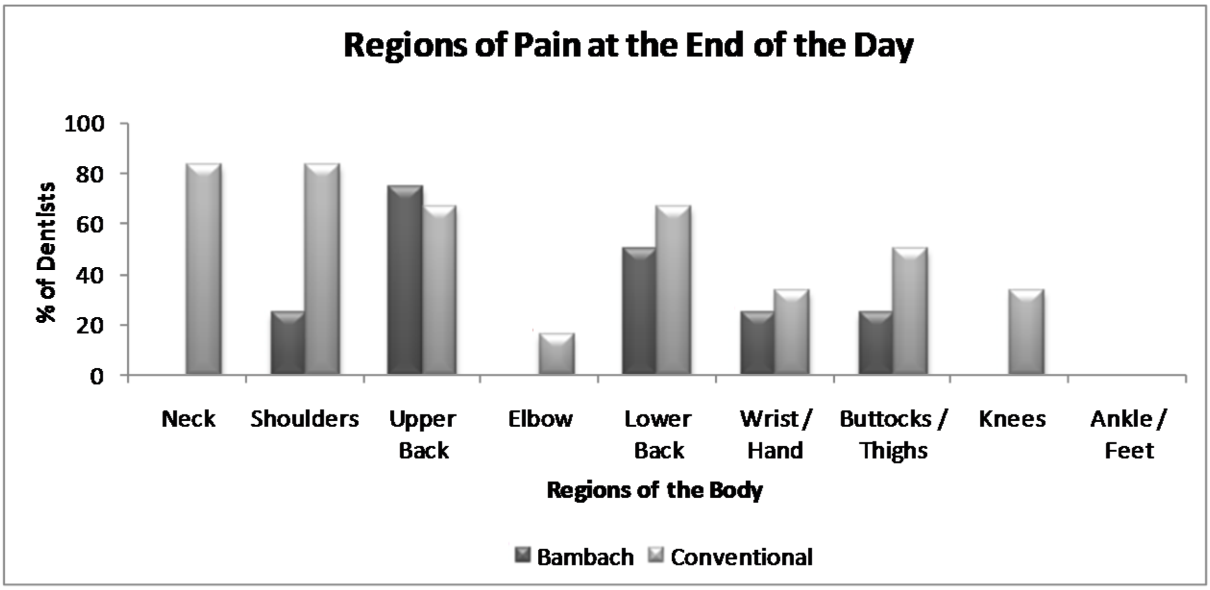


Fig. 5-20. Regions of pain at the middle of the day (Dentists)

Due to lower response rate from dentists (n=10) detailed analysis of the dentists reporting pain was not performed.

5.4.3 Discussion:

Only 10 dentists responded for the daily symptom survey and the results may be different with a large sample size. This was the main limitation of the DSS of dentists; the dentists may have considered the DSS as additional work. The results indicate that the BSD recorded decreased level of pain and discomfort on the workdays over a working week compared with the CSD. The dentists had been using the BS for approximately 3 years ranging from 6 months to 8 years before the daily symptom survey was conducted; the dentists were using the CS for an average of 6.6 years ranging from 3 months to 25 years. The number of BSD reporting pain at the beginning and middle of the day were less when compared with CSD; but all the dentists were reporting pain at the end of the day. The response rate was very low and may not be a true representation of the groups. The level of pain reported by BSD ranged between 1 and 7, but the pain reported by conventional seat dentists ranged from 1 and 9 with increased level of pain reported at the middle of the day.

The results indicate that the CSD report pain in all the 9 body regions used in the symptom chart, whereas the BSD report no pain in lower leg, ankles, and feet. They also report pain in the neck, elbows and knees only in the beginning of the day, whereas the CSD report pain throughout the workday. Low back pain is the most frequently reported in both the groups of dentists but the number of BSD reporting low back pain decreased at the end of workday, whereas the number of CSD reporting pain increased at the end of the workday (Marshall et al 1997; Newell and Kumar, 2004).

The results of the DSS of the students were not greatly comparable to that of dentists with respect to the regions of pain and level of pain. However low back pain is the most commonly reported area of pain in both dentists and dental students. The levels of pain reported by BSD were comparable to that of BSS, whereas the levels of pain reported by CSD were higher compared to CSS. However the results may vary with a larger sample size of dentists.

The results of the daily symptom survey suggest that regular use of the Bambach seat may reduce the development of a musculoskeletal disorder in dental students and dentists by decreasing the pain and by encouraging good posture (Thornton et al 2004; Smith et al 2002). However a larger sample size of dentists needs to be investigated for more convincing results.

Chapter 6

Introduction to Electromyography

EMG Studies on Ergonomics and Dentistry

The EMG Study

6.0 Overview

The first part of this chapter defines electromyography (EMG), the anatomy and physiology of muscle fibres, neurophysiology of EMG, and electrical activity of muscles. The second part of the chapter details the EMG study of dentists and dental students.

6.1 Definitions of Electromyography (EMG)

Electromyography is the measure of change in membrane voltage over time as the electrical impulses travel down the length of the muscle fibre. EMG provides an extracellular view of the changes in membrane potentials associated with propagation of action potentials (AP) along the muscle fibres (Kamen, 2005).

"It is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fibre membranes."

(Basmajian & DeLuca, 1985)

6.2 The Motor Unit

The smallest functional unit for the neural control of the muscular contraction process is called a motor unit (Fig. 6-1). It is defined as:

“The cell body and dendrites of a motor neuron, the multiple branches of its axon, and the muscle fibres that innervates it” (Enoka, 1994 p.151)

The term ‘unit’ outlines the behaviour, i.e. all muscle fibres of a given motor unit act as one within the innervation process.

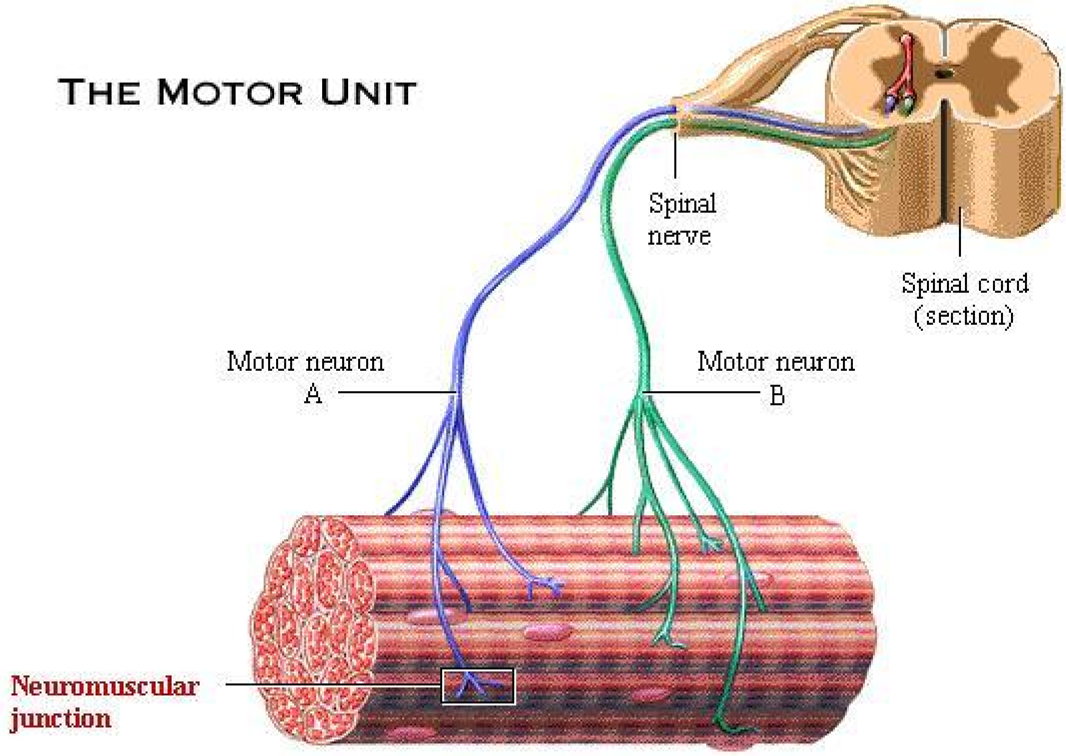


Fig. 6-1. Motor Unit (Adapted and Modified from Basmajian and Deluca, 1985; Cummings and Hoehn, 2005)

In order to produce a muscular contraction the muscle fibres should receive an afferent input from a motoneuron. This is schematically shown in figure 6-2.

Activation of Motoneuron from the Central Nervous System

↓

Propogation of Electrical Impulses to Motoneuron

↓

Propogation of Electrical Impulses from Motoneuron to each Motor Endplate

↓

Contraction of Muscle Fibre

Fig. 6-2. Muscle Contraction

6.3 Anatomy and Physiology of Skeletal Muscle Fibres

Skeletal muscle tissue is striated, with fibres containing alternating light and dark bands (striations) that are perpendicular to the long axes of the fibres (Williams, 2004). Skeletal muscle tissue is voluntary in nature. There are different types of skeletal muscle fibres, which contract with different velocities, depending on their ability to split Adenosine Triphosphate (ATP). Faster contracting fibres have greater ability to split ATP. In addition, skeletal muscle fibres vary with respect to the metabolic processes they use to generate ATP. They also differ in terms of the onset of fatigue. On the basis of various structural and functional characteristics, skeletal muscle fibres are classified into three types (Type I, Type II A, and Type II B). The types of muscle fibres are explained in detail in Chapter 1 (Section 1.1.10) (Williams, 2004; Guyton and Hall, 2005)

6.3.1 Types of Skeletal Muscle fibre and conduction velocity

The conduction velocity depends both on histochemical and architectural features of the muscle fibre. The amplitude of muscle fibre AP tends to be larger in fast twitch fibres (Type II B). Moreover, the shapes of the APs of fast-twitch and slow-twitch fibres (Type I) differ, causing the fast-twitch fibre AP to occur more quickly than the corresponding slow-twitch AP. Larger diameter fibres produce larger APs than do smaller fibres (Andreassen and Arendt-Nielsen, 1987), partly because of greater Na^+ inside muscle fibre. Atrophied fibres have distinctly slower conduction velocities (Buchthal and Rosenfalck, 1958). Increases in length of the muscle fibre also tend to reduce the conduction velocity. This may result from architectural changes that occur in the fibre (Dumitru and King, 1999)

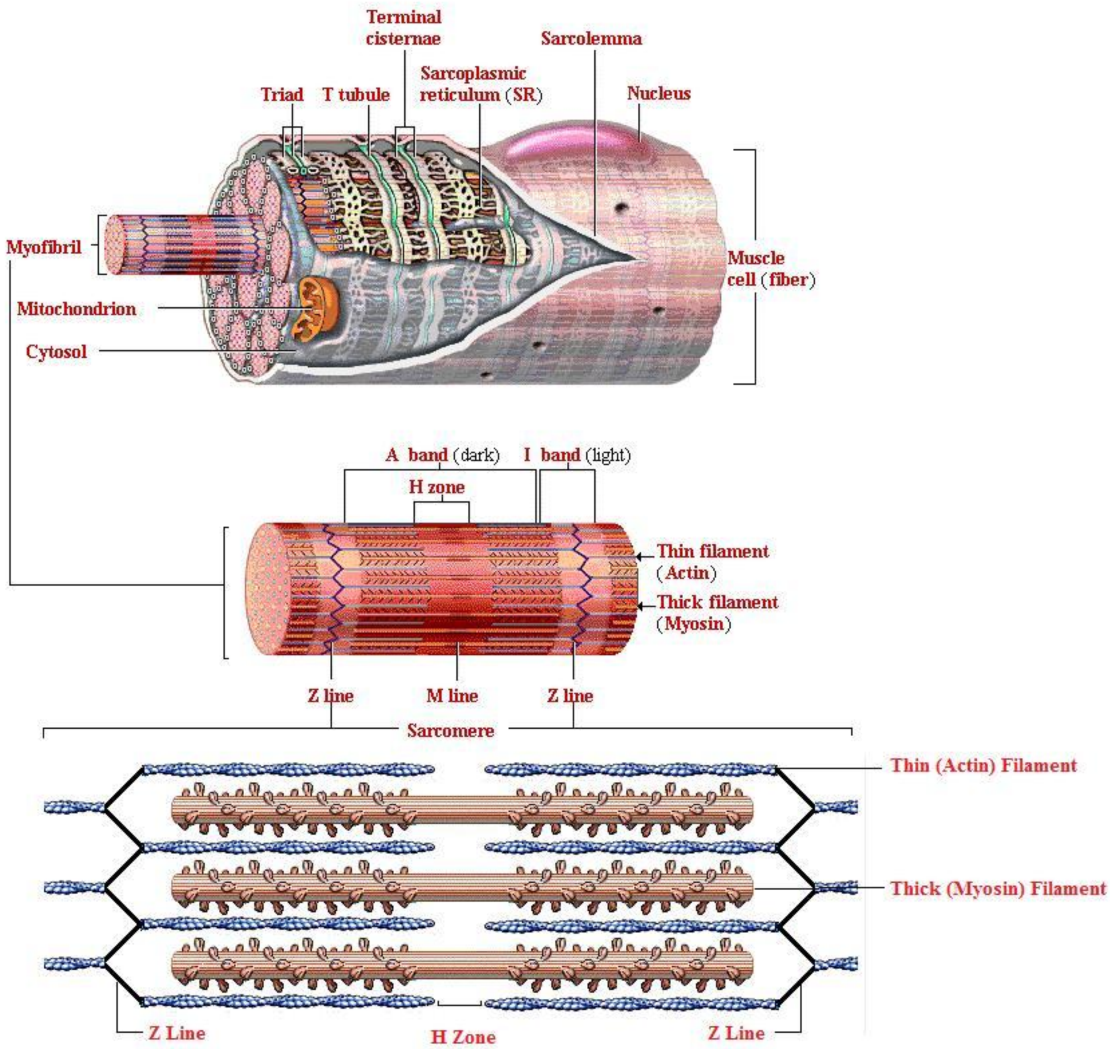


Fig. 6-3. Structure of a Skeletal Muscle Fibre

(Adapted and modified from Marieb, 2001; Cummings and Hoehn, 2005)

6.3.2 Resting Membrane Potential (RMP)

The inside of a muscle fibre normally has an electrical potential of about –70 millivolts (mV). This voltage gradient is due to the presence of sodium (Na^+), Potassium (K^+), and Chloride (Cl^-) ions across the sarcolemma in different concentrations (Fig. 6-4). The RMP is about 9 to 15 mV more positive in slow twitch fibres; because of the greater Na^+ permeability and higher intracellular Na^+ activity than those of fast twitch fibres (Hammelsbeck and Rathmayer, 1989).

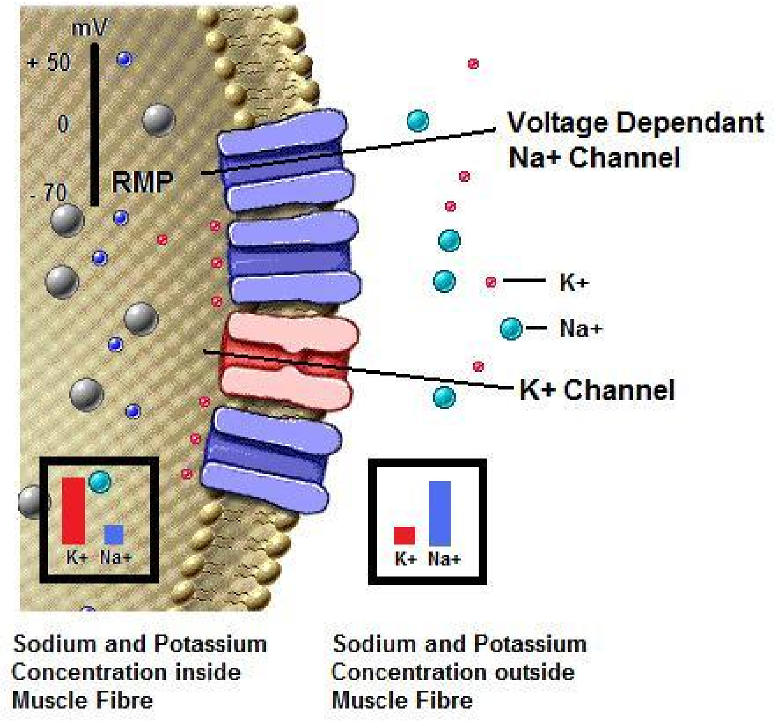


Fig. 6-4. Resting Membrane Potential in a Skeletal Muscle Fibre
(Adapted and modified from Marieb, 2001; Cummings and Hoehn, 2005)

6.3.3 Action Potentials (AP)

The action potential is a neural impulse for activating every segment of the muscle fibre in order that each sarcomere (the segment of a myofibril between two adjacent Z lines, representing the functional unit of striated muscle) (Fig. 6-3) contributes to the generation of muscle force (Kamen, 2004). The process of generation of action potential is schematically shown in figure 6-5.

The AP generated in one small segment should spread to adjoining segments in order activate the muscle fibre completely. In a passive process the AP propagates along each adjacent section of the muscle fibre in both directions from the neuromuscular junction so that the entire muscle is activated (Fig.6-4). As the AP spreads the membrane potential of each muscle fibre changes from negative to positive and then positive as each adjacent muscle fibre area is activated. The deeper portion of the muscle fibre is activated by the transverse tubule system (Kamen, 2004).

Change in the muscle fibre membrane permeability to Na^+ **(Resting Potential)**

↓

Influx of Na^+ ions across the membrane **(Depolarisation)**

(Movement of Na^+ ions from greater concentration to lesser concentration)

↓

Sufficient Na^+ ions enter the cell to reverse the polarity of the membrane potential and the muscle fibre becomes positive (30 mV) with respect to surrounding extracellular medium

↓

The permeability of the membrane to K^+ changes

↓

K^+ exits the cell

↓

Efflux of K^+ repolarises the cell and restores the resting membrane potential **(Repolarisation)**

↓

Generation of Action Potential

Fig. 6-5. Generation of Action Potential

The EMG signal is based upon APs at the muscle fibre membrane resulting from depolarization and repolarization processes as described schematically in figure 6-5. The extent of this depolarization zone is described as approximately 1-3 mm² (Winter

1990). After initial excitation this zone travels along the muscle fibre at a velocity of 2-6m/s and passes the electrode side.

6.3.4 Neurophysiology of Neural Transmission

The motor system is one of the important systems of the Central Nervous System. It activates muscles for movement as explained above. The nervous system also controls the secretion of hormones from glands, regulates the rate and depth of breathing, and is involved in modulating and regulating numerous other physiological processes. To perform these functions, the nervous system depends on neurons. The neurons are designed for the rapid transmission of information from one cell to another by conducting electrical impulses and secreting chemical neurotransmitters. The electrical impulses propagate along the length of nerve fibre processes to their terminals, where they initiate a series of events that cause the release of chemical neurotransmitters. These specialized junctions are termed a synapse.

The release of neurotransmitters occurs at these synaptic terminals where there is contact between two nerve cells. The released neurotransmitters bind with their receptors on the postsynaptic cell membrane. The activation of these receptors either excites or inhibits the postsynaptic neuron. By the propagation of action potentials, the release of neurotransmitters, and the activation of receptors in the post synaptic cell the nerve cells communicate and transmit information to each other and to other non-neuronal tissues. Finally, when the impulse reaches the muscle there is contraction of the skeletal muscle (Kamen, 2004).

6.3.5 Conduction Velocity of Muscle Fibres

Conduction velocity is important in determining the characteristics of the EMG i.e. APs moving at a slower rate contribute low-frequency components in surface EMG, and fatigue of muscles may change the rate of AP and may alter the surface EMG. The generation of AP is an ionic process and the velocity at which the AP is conducted depends on the rate of exchange of ions. The other factors are the passive membrane permeability characteristics and the active metabolic mechanism for pumping Na^+ back out of fibre (Kamen, 2004).

6.3.6 Motor Unit Action Potential (MUAP)

Each motoneuron may innervate several hundred muscle fibres, although this may vary between different muscles from as low as ten to as many as several thousand. This is termed as the innervation ratio, which is the number of muscle fibres per motoneuron. The individual unit of motor action is the motor unit (Refer to Section 6.2), that being one motoneuron and all of the muscle fibres innervated by the motoneuron (Kamen, 2004). The MUAP represents the summated electrical activity of all the muscle fibres, which are activated within the single motor unit. The amplitude of the MUAP is determined by the innervation ratio, number of muscle fibre and the size of the muscle fibre. In this respect, motor units with larger or more numbers of muscle fibres have a larger MUAP.

6.3.7 Motor Unit Recruitment and Firing

In a muscle, the muscular force is initiated by activating a number of motor units, which is termed as recruitment. To produce a muscle contraction, smaller motor units are recruited first. This is followed by the activation of larger motor units as the demand for force increases. The recruitment and firing of muscle fibres is controlled by the nervous system, where the frequency of motor units activated depends on the need. This is termed as discharge or firing rate. The recruitment and firing rate are important factors in influencing the magnitude and density of the observed signal in the EMG (Kamen, 2004; Konrad, 2005).

6.4 The EMG Signal

In a flicker of muscle contraction, a single motor unit may be activated, which is recorded at the surface as the MUAP, followed by electrical silence until the next firing. When the demand for force increases, other motor units may be recruited and firing rate increases. At any point of time, the EMG signal is the composite electrical sum of all the active motor units. A large peak in the EMG signal may be indicated as a result of activation of two or more motor units separated by short interval. The phenomenon is observed when performing isometric resistance[1] to a muscle group when measuring the Maximum Voluntary Contraction (Kamen, 2004; Konrad, 2005).

The EMG signal has both positive and negative components. When a signal crosses the baseline, a positive phase of one MUAP is likely balanced by the negative phase of other MUAPs. The amplitude of the EMG signal may vary with the task and the group of muscle observed. Usually the amplitude of the EMG increases as the intensity of muscle contraction increases. The relationship between the EMG amplitude and force is non-linear (Konrad, 2005). This phenomenon is clearly expressed, as the co-contraction activity from the antagonists may require

[1] Isometric Resistance: The manual or mechanical resistance against a muscle without producing any movement of the associated joints.

compensatory activity from the agonist muscle group, which may be measured for EMG activity. Thus increases in EMG activity cannot be assumed as increase in force. This phenomenon is important when force component is considered in a study.

6.4.1 Factors influencing the EMG Signal (Konrad, 2005)

- **Characteristics of the Tissue:** The human body is a good conductor of electricity, however electrical conductivity varies with the type of tissue and its thickness, the physiological changes and temperature of the body. These conditions may vary from subject to subject (and even within subject) and prevent a direct quantitative comparison of the EMG amplitude parameters calculated on the unprocessed EMG signal.
- **Physiological cross talk:** This may be caused by electrical activity of neighbouring muscles and may produce a significant amount of EMG that is detected by the local electrode site. Typically this "cross talk" does not exceed 10%-15% of the overall signal contents or is not available at all. ECG spikes may interfere with the EMG recording, especially when performed on the upper trunk / shoulder muscles.
- **Changes in the geometry between muscle belly and electrode site:** Any change of distance between signal origin and detection site will alter the EMG reading. It is an inherent problem of all dynamic movement studies and can also be caused by external pressure. Using electrode interfaces between the skin and the electrode surface decreases the chance for altering the geometry.
- **External noise:** Special care must be taken in very noisy electrical environments. The most demanding is the direct interference of power hum,

typically produced by incorrect grounding of other external devices. The EMG apparatus used in this study was a portable model which is battery operated. This decreases electrical interference.

- **Electrode and amplifiers:** The selection/quality of electrodes and internal amplifier noise may add signal contents to the EMG baseline. Internal amplifier noise should not exceed 5 Vrms (ISEK Standards).

Most of these factors can be minimized or controlled by accurate preparation and checking the given room/laboratory conditions.

6.5 Maximum Voluntary Contraction (MVC) and Evaluation of Problems in standardisation of assessing MVC

MVC is the maximum amount a muscle can contract against manual / mechanical resistance and this can be recorded using EMG. The MVC is used as an indicator of the maximum effort a muscle can obtain, and it varies for every individual as the strength and endurance of each individual differs. The MVC is considered as a standard procedure to calculate the effort of a muscle for a particular activity (Konrad, 2005)

6.6 Various Studies in Ergonomics and Dentistry using Surface Electromyography

Hardage et al (1983) studied the working posture of dentists using surface EMG. The study was conducted to evaluate two accepted criteria in 1983 for correct work posture relating to dentists. The objectives of the investigation were to measure myoelectric activity of the upper and lower back at different sitting heights, and to study the influence of lumbar back support on this myoelectric activity. Three levels of stool height were evaluated with and without lumbar support. Twenty male dental students and faculty members were selected for the study.

Surface EMG electrodes were placed 3 cm lateral to the third lumbar (lower back) and the fifth thoracic (upper back) vertebrae. The active electrodes were placed 3 cm apart and parallel to the spinal column. Muscle activity from the two sites was amplified. EMG activity of the upper and lower back was integrated and recorded at 4-second intervals. A narrow band filter was used to minimise EMG artefact. A time constant of 0.1 second was used. Each participant spent approx 1 minute in each condition and the entire test period was 30 minutes.

The subjects sat with both feet flat on the floor and the legs perpendicular to the floor. The stool height was adjusted so that the thigh to leg angle (knee angle) was 105 degrees, 90 degrees or 75 degrees on different trials. A class I amalgam preparation was done on the lower left first molar on a phantom head with its head one inch below the upper end of the patient's chair. The mouth was placed at a level two inches above the operator's elbow. The operator was positioned in the 11 o' clock position. Muscle activity of both the upper and lower back was less when the back was supported. This occurred at each stool height. The results show that there was no consistent effect of stool height on back muscle activity. In each test condition, activity of the upper back (T5 level) was higher than that of the lower back (L3 level). This may be because only lumbar support was used in the study. For the group data there was no significant difference in EMG for three stool heights and between the two treatments. The results indicated that the main factor that influenced back muscle activity was the back support. They suggested that the dental operator should sit low with lumbar support always in contact with the lower back. This however may weaken the spinal extensors and may therefore lead to back pain.

Christensen (1986) studied the muscle activity and fatigue in the shoulder muscles of assembly-plant employees. They evaluated shoulder muscle activity to determine whether muscle fatigue occur during a workday with monotonous work processes at an assembly plant. The study by Hardage et al (1983) had considered the amount of muscle activity for analysis, but fatigue and muscle activity during actual work conditions were not evaluated. This is considered to be an important factor and was evaluated in this study. Twenty-five subjects employed in a modern assembly plant were examined, namely, eight young women (19-32 yrs) employed 3 months to 11 years, eight middle aged women (34-58 yrs) employed 4.5 – 18.2 yrs, and nine men aged (20 – 40 yrs) employed 0.5 – 15.3 yrs.

The women's job was to assemble printed circuits of different kinds, and assembling between 40 - 120 units on one print. Their preferred hand did the assembling and the other hand handled 75-100 units from small boxes under the table top in a 5 min period. The women had a tendency to work with elevated shoulders. The men soldered the circuit boards together and were either working sitting or standing with their elbows at 90 degrees flexion.

The subjects' heart rate was recorded. All subjects answered a standardised questionnaire about pain and discomfort in the shoulder region. EMG was recorded using bipolar electrodes. Muscles recorded were trapezius (descending part), deltoid (anterior part), and the infraspinatus with inter electrode distance of 3 cm. All signals were transmitted telemetrically through the transmitter carried in a belt around the waist of the subject. The muscle force MVC was measured using a strain-gauge dynamometer with the subject in sitting position.

- Deltoid Muscle: A strap was fixed around the upper arm and the subject performed maximal shoulder anterior flexion.
- Infraspinatus Muscle: The strap was fixed around the forearm just proximal to wrist with elbow in 90 degree flexion, an outward rotation of the shoulder were performed
- Trapezius Muscle: The strap was fixed around the shoulder at the acromion and a maximal bilateral shoulder lift was performed.

The EMG electrodes were mounted at the start of the day and the MVC was performed. The relationship between the EMG amplitude and force (calibration curves) was recorded by visual feedback during a contraction of gradually increasing force in the linear fashion from 0 to 100 % for 10 seconds. For each muscle three EMG force curves were recorded. Thereafter a contraction of 20 % of the MVC was sustained for 2 minutes and recorded for each of the three muscles. EMG was then recorded during work situations continuously for 10 minutes at the start of the workday and for seven ten-minute periods throughout the day (before and after each break). At the end of the day, a two minute 20% of the MVC was repeated to see any sign of muscular fatigue at the end of the day. The RMS (Root Mean Square) of the three calibration curves was analysed for the first 7 seconds (0-70 % MVC) as a means of avoiding muscle fatigue at higher effort. The values of each amplitude and force relation were fitted to a linear function and to a power function. There was no difference between the correlation coefficients from these two methods. The calibration curve with the highest correlation coefficient was used in the analysis of APDF (Amplitude Distribution Probability Function). The APDF, evaluated in the manner described by Jonsson (1976), is a technique to estimate muscle activity during work activities. The mean power frequency (MPF) of the power spectrum was calculated, with the Fast Fourier Transformation, from the EMG during the sustained contraction at 20% MVC.

The subjects were also given a standardised questionnaire about pain. Forty eight percent of the subjects reported that they had experienced pain or discomfort in the neck and shoulder region. Sixteen percent had trouble only in the neck area and 8 % had trouble only in the shoulder area. The women had an increased rate of perceived exertion during the day. There was no difference in the APDF between the three groups. The subjects who had any pain or discomfort showed a high static level in the deltoid muscle. There was no difference in the static level of 3 muscles between those subjects with pain for the last few days and those without pain or trouble. The decrease in MPF was the same for 3 muscles. The decrease per unit time was same in the morning and afternoon recordings. The initial value of trapezius was higher in the morning and than in the afternoon. The initial value of infraspinatus was lower in the morning than afternoon. The questionnaire showed high incidence of shoulder and neck problems in assembly plant employees. The EMG showing correspondingly high activity during work corresponds to the high incidence of pain reported among employees. The subjects experienced fatigue in the shoulder muscles at the end of the day; however the EMG did not reveal any muscle fatigue in either amplitude or frequency. This may be because the subjective experience of fatigue may occur due to general tiredness and this may not be revealed during EMG analysis.

Schuldt, Ekholm, and co-workers (1987) studied the effects of arm support or suspension on neck and shoulder muscle activity during sedentary work. Ten skilled workers from an electronics plant participated in the study. In a laboratory they performed a simulated work cycle in different postures with and without ergonomic aids. EMG was recorded by using surface electrodes attached to the skin in the direction of muscle fibres. The level of muscle activity was recorded as full-wave rectified low-pass filtered and time-averaged EMG, using a time constant of 0.1 s. To make comparisons possible between activities in different muscles a normalisation was performed. A reference level was recorded for all subjects obtained by performing a series of maximum voluntary isometric test contractions against resistance and with the trunk stabilised in a sitting position. The level of activity recorded in each work posture during the actual work cycle was then divided by this level. The values thus obtained were presented as a percentage of the time averaged myoelectrical potential (TAMP%) during the maximal isometric test contraction.

The maximum voluntary isometric test contractions were performed (Schuldt et al 1987). The method (or) type of resistance used in the study is not identified. The test contractions were

- Attempted elevation of arm and shoulder with resistance at distal forearm
- Same with resistance proximal to elbow
- Attempted abduction of arm at 45 degrees in plane of scapula, with resistance to proximal elbow
- Vertical elevation of shoulder against resistance
- Attempted scapula movement in medial cranial direction against resistance with cervical spine stabilised
- Flexion of cervical spine with resistance against forehead
- Extension of cervical spine with resistance at occiput
- Neck extension with resistance at upper cervical spine and chest stabilised

The muscles investigated and the locations of electrodes are as follows.

- Upper Trapezius covering Erector Spinae: Over the upper part of the descending portion of the trapezius muscles covering the cervical erector spinae with one electrode at the level of Vertebrae C2 (C3) and the other 0.03m caudally.
- Upper Trapezius: at the anterolateral margin of the descending portion of the trapezius muscle at the midpoint between muscular origin and insertion.
- Middle Trapezius covering Supraspinatus: At the lateral part of the shoulder, where the transverse (middle) portion of the trapezius covers the supraspinatus

- Erector Spinae Thoracalis covering the Rhomboids: Over the triangular aponeurosis of trapezius located at level of C7-T1, with the underlying rhomboids covering the thoracic erector spinae: One electrode at the level of C7-T1 vertebrae and the other about 0.03 m caudally.
- Levator Scapulae: Over the upper part of the muscle with both electrodes between the posterior margin of the sternocleidomastoid and the anterior margin of the trapezius muscle
- Sternocleidomastoid: At the midpoint of the muscle

Ergonomic Aids Used in the study: The elbow supported by a horizontal slightly padded plate to allow small horizontal plane movements. The arm supported by a sling around elbow region and cord connected to arm balancer adjusted to give constant elevating force.

The work postures investigated in the study were:

- Flexed cervico-thoracic-lumbar spine (Slumped sitting) and attachment frame (A frame in which the activity is performed) horizontal
- Whole spine vertical and straight and attached frame angled 35 degrees
- Thoraco-lumbar spine inclined slightly backward, cervical spine vertical and straight with frame angled 75 degrees

The task initially consisted of keeping a soldering pen aimed precisely at a central dot on a card in the attachment frame, followed by a slow clockwise movement aiming the pen successfully at nine positions from top left of the card.

In whole spine flexed sitting posture the elbow support gave a highly significant reduction of muscle activity in the descending part of the trapezius muscle and horizontal part of the trapezius muscle. No differences were found in cervical erector spinae, levator scapulae or the sternocleidomastoid muscle with elbow support. In whole spine vertical and straight, elbow support gave significantly reduced levels of activity in upper trapezius, erector spinae and rhomboids. No differences were found in cervical erector spinae, levator scapulae or the sternocleidomastoid muscle with elbow support. In the thoraco-lumbar spine inclined posture low levels of muscle activity were recorded even without elbow support, and elbow support did not contribute any further reduction in activity.

The results showed that a reduction in the level of activity in the neck and shoulder muscles could be obtained with either aid. This is a preventive measure for reducing neck and shoulder muscles work in sitting assembly work. Schuldt et al (1987) suggest use of these ergonomic aids as primary prevention and there is a likelihood of developments in design in future. Currently some of the dental seats have a dynamic arm/elbow support to help support the arm during dental activities. The effects and feasibility of these ergonomic aids on dentists are yet to be studied.

Milerad and colleagues (1991) studied dental working using surface EMG. The aim of the study was to describe and quantify shoulder, neck and arm muscular load in dentistry, using EMG, and to compare the muscle strain between different dental practice activities and to identify the most demanding work task in dentistry. Twelve dentists (2 M and 10 F) participated in the study. Dentists were asked about length of employment, working hours, about neck, shoulder and arm symptoms. General anthropometric parameters were also recorded. Nine out of eleven dentists complained of symptoms in the neck, shoulder or arm and all were right handed. The muscles investigated were right and left – trapezius (upper fibres) –shoulder girdle elevator (the descending part of the muscle was selected since it was reported to be the common site of neck pain among dentists), infraspinatus (shoulder stabiliser), extensor carpi radialis (wrist stabiliser) muscle (Refer to Section 6.7.2).

The Dentists worked in the seated posture. Before the procedure the MVC was obtained. The test contractions were:

- Attempted arm abduction with the arm vertical in the plane of scapula (trapezius muscle)
- Attempted external arm rotation with the arm vertical and the elbow at right angle (infraspinatus muscle)
- Attempted dorsal flexion of the wrist (extensor carpi radialis muscle)

They also performed a sub-maximal contraction holding a 2 kg weight in either hand. Then they carried out dental treatment on one or two patients. Treatment time varied from 10 minutes to 1hour 30 minutes. The longer treatments included several waiting periods. The EMG was registered during rest, maximal and sub maximal test contractions and then continuously during dental treatment. The dentists' work was documented with video recordings for later work task analysis. The main work tasks were treatment in the upper and lower jaw. Other work tasks were drilling, tooth cleaning, amalgam filling, root filling, and tooth extraction.

Surface electrodes were used. The electrodes were placed parallel to the muscle fibres above the muscle belly on the following muscles

- Upper Trapezius: at the antero-lateral border, at about a third of the distance between occiput and acromion
- Infraspinatus: over the centre of the muscle belly
- Extensor Carpi Radialis: at proximal part of the muscle over the centre of muscle belly

The results showed the following:

- Maximal and sub maximal reference volume contraction showed large variation between subjects. The highest value was recorded for the trapezius muscles.
- EMG recording: Mean treatment time was 18.5 minutes (SD 7.9 minutes). The trapezius muscles had highest muscle activity; the right extensor carpi radialis muscle had a higher mean amplitude value than left and both infraspinatus. On other muscles there was no difference between right and left. There was no statistically significant difference in myoelectric activity between preparation in the upper and lower jaw.

Milerad et al (1991) concluded by saying that dental work generates a relatively high mean load in the trapezius and extensor carpi radialis muscles in the dominant hand. The static load in this region may be the cause of their findings.

Finsen et al (1998) studied dental work using surface EMG. Eight female dentists were selected for the study. The three common tasks (Dental Examination, Tooth Cleaning and Filling Therapy) registered in the questionnaire study were selected and video recording was done. The EMG was recorded using bipolar electrodes. The muscles measured were

- Splenius muscle (level of C2 – C3): represents extensor muscles of the neck
- Descending part of the trapezius muscle (Lateral Portion)

An inter electrode distance of 2 cm was used and ground electrode was placed on the upper thoracic vertebrae. Maximal Voluntary Contraction (MVC) was performed as below:

- Splenius muscles: Neck extension in sitting
- Trapezius Muscles: Shoulder Elevation in standing using straps fixed on floor

The resistance was given for 3 seconds and 3 contractions were performed. The highest value of three contractions was taken for analysis. In five working operations (Dental Examination, Scaling, Polishing, Drilling and Filling) EMG and Video were recorded. The EMG was analysed for the first 60% of the operating time (approx 4 minutes) 259 seconds with SD of 20 Seconds. The probability level of 10% (p=0.1; the static activity level), 50% (p=0.5; the median activity level) and 90% (p=0.9; the maximum activity level) were used for each curve to represent the activity pattern. They indicated that EMG of the trapezius was more than that of splenius and analysis of the EMG data did not show any significant difference between the five work operations.

McLean (2005) studied the effect of postural correction on muscle activation in the cervicobrachial region. Normalized surface EMG data were recorded from the levator scapulae, upper trapezius, supraspinatus, posterior deltoid, masseter, rhomboid major, cervical erector spinae, and sternocleidomastoid muscles of the dominant side of each of eighteen healthy subjects. The subjects performed five repetitions of each of four seated typing postures (habitual, corrected, head-forward and slouched) and four standing postures (habitual, corrected, and head-forward and slouched). The results indicated that in sitting, postural correction decreased the level of muscle activation required in all muscles studied during seated computer work; however this finding was not statistically significant. Corrected posture in sitting did, however, produce a statistically significant reduction in muscle activity compared to forward head posture. Corrected posture in standing required more muscle activity than habitual or forward head posture in the majority of cervicobrachial and jaw muscles. The results suggested that a graduated approach to postural correction exercises might be required in order to train the muscles to appropriately withstand the requirements of the task, which is also an important factor with dentists.

The above studies investigating work postures using EMG have investigated the spinal extensors (lumbar paravertebrals), deltoid, infraspinatus, trapezius, levator scapulae, sternocleidomastoid, splenius and extensor carpi radialis muscles during dental and assembly work. The important muscles investigated were the splenius (neck extensor), upper trapezius (shoulder elevator), spinal extensors (multifidus lumborum and longissimus thoracis) and extensor carpi radialis longus (wrist extensors). These muscles were chosen for this study since this will provide an indication of the muscle activity in the regions of the body commonly affected by a musculoskeletal disorder reported by dentists (e.g. lower back, neck and shoulder). The studies also have used a time period varying from 1 minute to 10 minutes to investigate the activity of various muscles. Ten minutes of investigating time is used in this study, which is considered to provide sufficient time to ascertain the variation of muscle activity against time.

6.7 The EMG Study

The EMG study was based on the studies on general and dental ergonomics detailed in Section 6.6. The EMG study was performed on dentists and dental students.

6.7.1 The Task

Dental Students: There were no studies on dental students looking at dental tasks using surface electromyography. The EMG study was carried out on second year dental students who were working on the phantom heads. In order to make the task simple for the students and to standardise the task, they were given a task of drilling a tooth in the lower jaw. The task of drilling is simple, and it also incorporates both force and skill (precision) components.

Dentists: The procedures for the present study with dentists will not be specified since the study was performed in the dental surgery and with patients. The tooth/jaw operated on and the dental procedures used were obtained from the dentists during the study. They were found to be similar between the two groups of dentists, and are reported below:

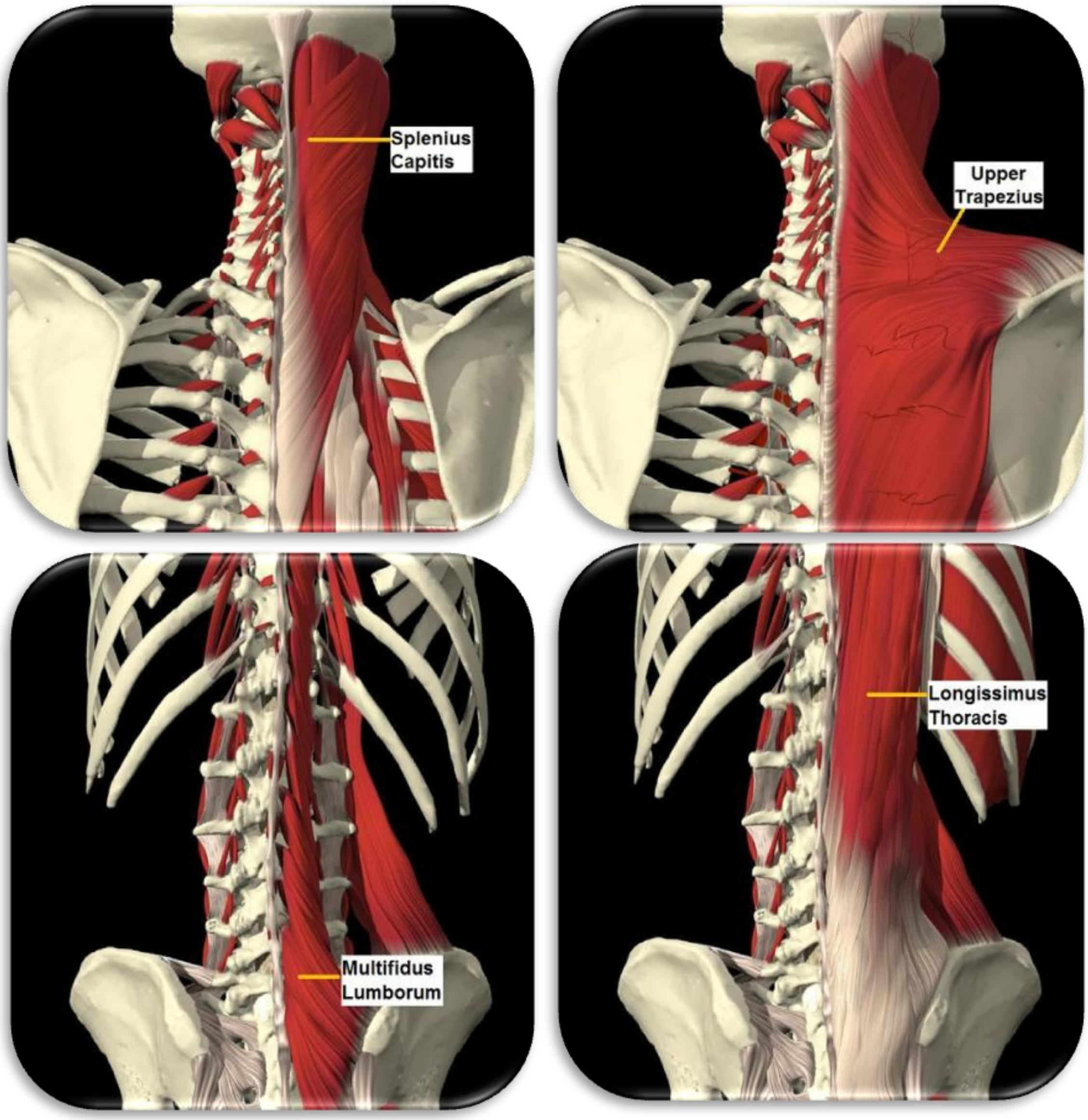
Jaw/Procedure	BSD	CSD
Upper Jaw	4	4
Lower Jaw	5	4
Scaling & Polishing	3	2
Total Number of Dentists	**12**	**10**

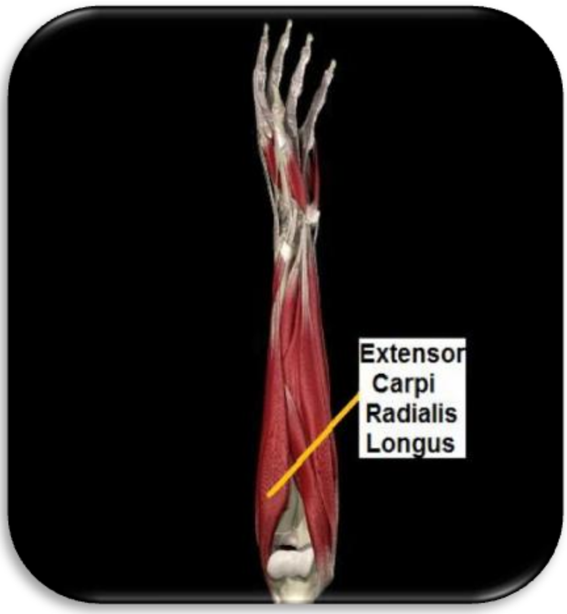
6.7.2 Muscles Chosen for the Study

The muscles for the study were chosen based on various studies on general and dental ergonomics (Table 6-1; Figure 6-6).

Muscles		Based on Study by	Type of Work
Splenius Capitis (Neck Extensors)		Finsen et al (1996)	Dental surgery with patients
Upper Trapezius Muscles (Shoulder Elevators)		Schuldt et al (1987)	Sedentary Work (Electronics Plant)
		Milerad et al (1991)	Dental surgery with patients
		Finsen et al (1998)	Dental surgery with patients
		Christensen (1986)	Assembly plant employees
Lumbar Paravertebral Muscles (Spinal Extensors)	Longissimus Thoracis (L1 Level)	Hardage et al (1983)	Amalgam preparation on phantom head
	Multifidus Lumborum (L5 Level)	Kramer et al (2005)	Electromyography in low back pain
		Stokes et al (2003)	Surface EMG electrode study
Extensor Carpi Radialis Longus (Wrist Extensors)		Milerad et al (1991)	Dental surgery with patients

Table. 6-1. Muscles chosen for the study





1. **Splenius Capitis**
2. **Upper Trapezius**
3. **Multifidus Lumborum**
4. **Longissimus Thoracis**
5. **Extensor Carpi Radialis Longus**

Fig. 6-6. The location of muscles chosen for the study
(Adapted and Modified from Primal Pictures © 2001)

6.7.3 Recommendations for Placement of Electrodes from Various Authors:

The electrodes (Fig. 162) were placed perpendicular to the muscle fibres and on the muscle bulk rather than the motor point (Table 6-2)

Muscle		**Author**	**Recommended Placement of Electrodes**
Upper Trapezius Muscles (Shoulder Elevators)		Jensen et al 1996	3cm lateral to the midpoint between the C7 and the acromion
Extensor Carpi Radialis Longus (Wrist Extensors)		Milerad et al 1991	Extensor Carpi Radialis Longus (Muscle Bulk)
Lumbar Paravertebral Muscles (Spinal Extensors)	General	Hardage et al 1983	3 cm lateral to L3 and 20 mm inter electrode distance
	Longissimus Thoracis (Thoracic)	Elfving et al 2002; SENIAM 2005	L1 Level 2-finger width lateral to midline
	Multifidus Lumborum (Lumbar)	Kramer et al 2005; Stokes et al 2003	1cm lateral to L5 (Kavcic et al 2004; Elfving et al 2002), 2cm paramedian to L4, L5
		SENIAM 2005	2-3 cm lateral to midline at L5 level
Splenius Capitis (Neck Extensors)		Finsen et al 1998; Finsen, 1999	C2 - C3 Level: Interelectrode distance will be 2 cm
		Sommerich et al 2000; Takebe et al 1974	3 cm below mastoid process and 3 cm lateral from midline

Table. 6-2. Recommendations for Placement of Electrodes

6.7.4 Methodology of the EMG study (Dental Students):

The EMG study on the dental students was undertaken at the phantom head laboratory located in the School of Dentistry - University of Birmingham (Fig. 6-9).

Subjects

The study was introduced to all the Year 2 dental students at the Dental School who were attending their first classes in the phantom head laboratory. They were given information sheets (Appendix XIII) and consent forms (Appendix XIV) and asked to return the forms if they were willing to participate in the study.

Year 2005

A total of 60 out of 81 students returned the forms and agreed to participate in the study. From the 60 students, 54 students were randomly selected for the study using a random number generator (http://www.segobit.com/rng.htm) and allocated the two types of operating stools (Twenty Seven students were provided with BS (Fig. 6-7) and 27 students were provided with the CS (Fig. 6-8). The seats were allocated to the students at the beginning of the Year 2 summer term when their clinical practice started (25th April 2005). The seats were used for the clinical skills sessions in the phantom head lab at the school of dentistry.

For the EMG study a total of 30 Year 2 dental students were selected using a random number generator (http://www.segobit.com/rng.htm), with 15 students using BS and 15 students using CS (20 Female and 10 Male Students). All the selected students were given an appointment for the EMG study. Two sets of data collection were performed. The first set in 2005 (after 3 months) was conducted with 21 students at the end of term after 10 weeks clinical skills teaching – 3 days per week (From 11th July 2005 till 22nd July 2005) and the second set in 2005 (after 6 months) with 16 students at the end of term after 24 weeks clinical skills teaching – 3 days per week (From 22nd Nov 2005 till 6th Dec 2005). In the second set of data collection five students were new and 14 students repeated the procedure. Baseline measurements were not taken in 2005.

The EMG study was planned to be conducted with 30 students, but there was a low response rate for the study in 2005. This is because five students dropped out of the study, two students have failed their exams, one student discontinuing the degree course and two students had back or neck pain and did not want to participate in the study. Due to the low response rate from the Year 2 students in 2005 the EMG study was repeated with the Year 2 students in 2006. The study was similarly introduced to the Year 2 students in 2006. Again, they were given information sheets and consent forms and asked to return the forms if they were willing to participate in the study.

Year 2006

A total of 50 out of 77 students returned the forms and agreed to participate in the study. From the 50 students, 40 students were randomly selected for the study using a random number generator (http://www.segobit.com/rng.htm) and allocated the seats (20 students were provided with Bambach seats (Fig. 6-7) and 20 students were provided with the conventional seats (Fig. 6-8)). The seats were allocated to the students at the beginning of the Year 2 summer term when their clinical practice teaching started (24th April 2006).

For the EMG study a total of 32 Year 2 dental students were selected using a random number generator (http://www.segobit.com/rng.htm), sixteen students were using BS and 16 students using CS (17 Male and 15 Female Students). The selected students were given an appointment for the EMG study. Three sets of data collection were performed in 2006, including baseline measurements. The first set (baseline 0 months) was conducted with 25 students at the beginning of the term (10th May 2006 till 25th May 2006) and the second set (after 3 months) was conducted with 16 students at the end of term, after 10 weeks of clinical skills teaching – 3 days per week (From 13th July 2006 till 21st July 2006) and the third set (After 6 Months) with 17 students at the end of term after 24 weeks of clinical skills teaching – 3 days per week (From 22nd Nov 2006 till 14th Dec 2006). In the second set of data collection one student was new and 15 students repeated the procedure. In the third set of data collection all the students repeated the procedure. Similar to the year 2005, some students dropped out of the study because of reasons similar to the year 2005 (n=7).

Apparatus:

a. Bambach Seat (Fig. 6-7)

b. Conventional Seat (Fig. 6-8)

c. Phantom Head Apparatus (Fig. 6-9)

d. EMG Apparatus (Fig 6-10)

e. Electrodes: Bipolar Electrodes (Fig. 6-11), interfaces (Fig. 6-12) and reference electrode (Fig. 6-13)

f. Protective Goggles, Facemask and Gloves

g. Lower Jaw to attach in the phantom head

h. Bur for drilling

Fig. 6-7. Bambach Saddle Seat
(Reproduced with permission from Bambach)

Fig. 6-8. Conventional Seat

Fig. 6-9. Phantom Head Lab (School of Dentistry – University Of Birmingham)

Fig. 6-10. Delsys - MyoMonitor II Portable EMG System (www.delsys.com)

Fig. 6-11. Delsys Bipolar Electrode

Fig. 6-12. Delsys Bipolar Electrode with Interface

Fig. 6-13. Dermatrode Reference Electrode

Procedure:

Before the study the students were given an information sheet (Appendix XXVII) detailing the procedure to be undertaken and a consent form (Appendix XXVIII) for them to complete and sign if they agreed to participate in the study. The students were instructed to bring protective goggles, facemask, gloves, lower jaw and a bur for drilling a tooth. The procedure and the placement of electrodes were also verbally explained to the participant.

Skin Preparation for placement of EMG electrodes:

The skin was cleaned using an alcohol rub and the alcohol was allowed to vaporise so that the skin was dry before the electrodes were placed (SENIAM, 2005).

Placement of Electrodes:

The electrodes were then cleaned using alcohol rub and allowed to dry. The interfaces were then attached to the electrodes. The bony landmarks were palpated and the electrodes placed on the following locations:

- **Splenius Muscles:** Level - C2 - C3 (Finsen et al 1998; Finsen 1999), 3 cm below mastoid process and 3 cm lateral from midline (Sommerich et al 2000; Takebe et al 1974) (Fig. 6-13)
- **Trapezius Muscle (Upper Fibres):** 3 cm lateral to the midpoint between the C7 and the acromion (Jensen et al 1996) (Fig. 6-14)

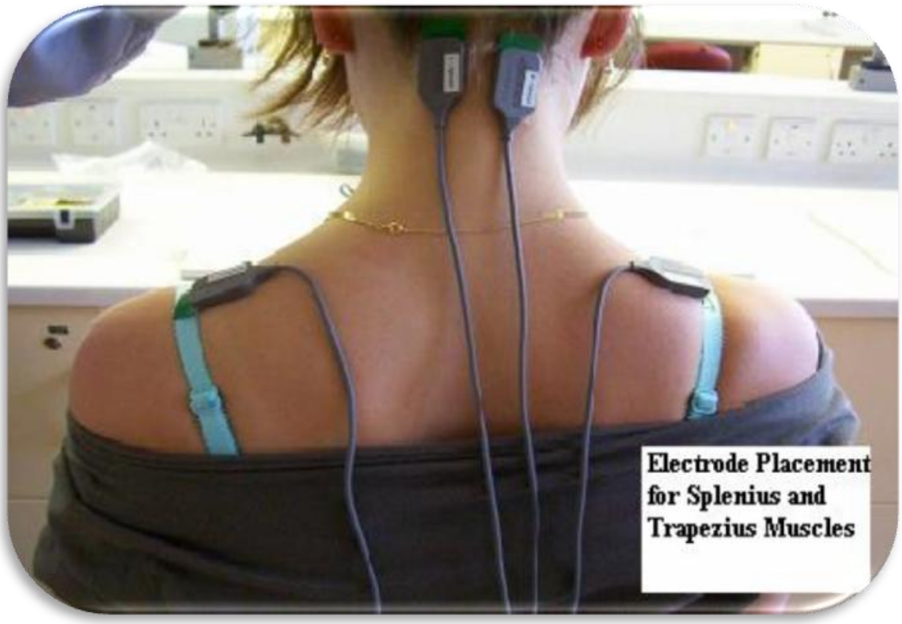


Fig. 6-14. Location of Electrodes for Splenius and Trapezius Muscles

- **Wrist Extensors:** Extensor Carpi Radialis Longus (Muscle Bulk) (Milerad et al 1991) (Fig. 6-15)

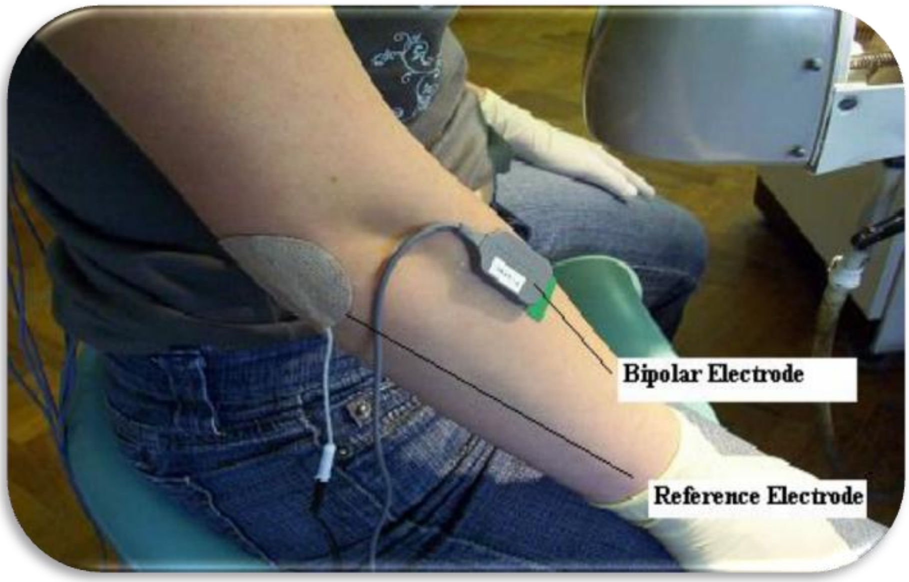


Fig. 6-15. Location of Electrodes for Extensor Carpi Radialis Longus (right side) and the reference electrodes

- **Lumbar Paravertebral Muscles** (Fig. 6-16)

  Longissimus Thoracis: L1 Level 2-finger width lateral to midline (Elfving et al 2002; SENIAM, 2005)

  Multifidus Lumborum: L5 Level 2 cm lateral to midline (Kramer et al 2005; Stokes et al 2003; SENIAM, 2005)

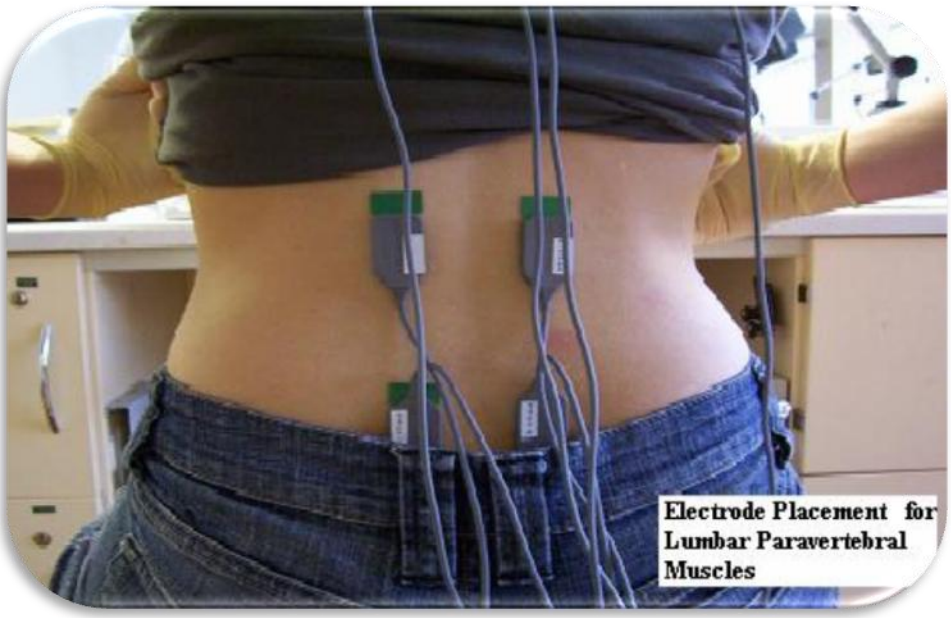


Fig. 6-16. Location of Electrodes for Lumbar paravertebral muscles

Setting up the EMG Apparatus

The EMG apparatus was switched on and set up ready for data collection.

Maximum Voluntary Contraction (MVC):

Isometric manual resistance is applied to all the muscles observed and EMG was measured during the process. The subjects were trained before the measurements for MVC is undertaken. Three measures of isometric resistance, each for three seconds, were applied for each muscle with a two second rest period. For each trial the researcher counted to three and then instructed the participant to relax. The procedure was repeated for a total of three trials. The trial that recorded maximum EMG was taken for analysis. The procedure was explained and demonstrated to the participant before the trial. The isometric resistance was applied to the muscles as follows:

- Splenius Muscles (Neck Extensors): The participant was seated in a chair and instructed to sit and look straight. The researcher stood at the side of the participant, one hand supports the participant's shoulders and the other hand kept above the external occipital protuberance. The participant was instructed to push the researcher's hand behind the head and to contract the neck muscles, thus isometric resistance was applied.
- Upper Trapezius Muscles (Shoulder Elevators): The participant was seated in a chair and instructed to sit straight (Christensen, 1986). The researcher knelt behind the participant and hooked his/her hands around the shoulders. The participant was instructed to raise the shoulders and isometric resistance was applied (Christensen, 1986).

- Lumbar Paravertebral Muscles (Back Extensors): The participant was instructed to kneel down on a mat facing a wall, then was instructed to be straight, with the front of his/her body in contact with the wall, and their arms hanging at the sides. The researcher stood behind the participant, held the back of the participant's shoulders standing behind and instructed the participant to push the researcher's hand behind contracting their back muscles pushing their hips/abdomen which is in contact with the wall and thus isometric resistance was applied.
- Extensor Carpi Radialis Muscles (Wrist Extensors): The participant was seated in a chair in front of a table. The participant was instructed to keep the forearm pronated (palm facing the table) on the table with straight elbow and then instructed to make a fist with their hand. The researcher stood at side of the participant and held the participant's fist at the level of the knuckles. The participant was then instructed to extend the wrist and isometric resistance was applied.

After the recording of MVC the participant was instructed to sit on their respective seats and the EMG apparatus was set for recording the muscular activity of the task.

Setting the Phantom Head Apparatus:

The participant was instructed to adjust the height of their seat, and then to adjust the level of phantom head so the base of the phantom head lies at their elbow level. Then they were instructed to don their gloves, protective goggles and facemask and to fix the lower jaw on the phantom head. They were then instructed to set up the high-speed drills and to check that they were working.

The use of percentage Maximum Voluntary Contraction (MVC) for analysis.

The EMG data should be normalized before it is used for analysis. Normalization allows the results to be compared across subjects, thus compensating for differences in strength, muscle tone, body fat, and muscle geometry. A method commonly used for normalizing EMG data for comparison is to measure the MVC of the muscle being studied. Each subject's MVC is then considered as a reference point of 100% and the muscle work (relative effort) during the task performed can be calculated to obtain a percentage MVC (Ankrum, 2000; De Luca, 1997; Lawrence and De Luca, 1983).

If a study reports the results in microvolts without normalizing the data, comparison between subjects is impossible due to individual differences. This may also lead to misinterpretation of results as either unacceptably high or low. This is the reason for not considering the measurement of resting EMG for analysis.

Dental work is considered to be predominantly sedentary (static task) involving static muscle work, and using percentage MVC is considered a reliable method in studying static muscle work (Netto and Burnett, 2006; Dankaerts et al 2003). The MVC is also considered as a standard procedure to calculate the effort of a muscle for a particular activity (Konrad, 2005). MVC was previously used in the analysis of muscle load in dentistry (Dong et al 2005, 2006; Milerad et al, 1991; Finsen et al 1998) and other professions such as sonographers (Bravo et al 2005), and assembly plant employees (Christensen, 1986) where work related musculoskeletal disorders are commonly reported.

Recording of the EMG: (Fig 6-17)

When the participant was ready the EMG apparatus was switched on and the participant was instructed to start the dental procedure (Crown Preparation (or) Preparation for Restoration) on a tooth on lower jaw and to continue for ten minutes.

Photos:

During the procedure photos were taken at various angles, which were explained in Chapter 2 (Section 2.14.1). After the ten-minute period, the EMG apparatus was switched off and the participant was instructed to stop the procedure. The electrodes were removed from the participant by the researcher.

Fig. 6-17. The Phantom Head Lab (The picture shows a participant drilling a tooth on the lower jaw; The EMG apparatus and electrodes are also seen).

6.7.5 Results - Students:

The data were analysed with SPSS 13.0 for windows. A Between Groups One Way ANOVA was performed to find the difference between the muscle activities and P value < 0.05 was used to indicate level of significance. The Baseline (0 Months) EMG was measured only in 2006 participants, but the 3 months and 6 months EMG were measured both in the year 2005 and 2006 participants. The results from the year 2005 and 2006 for the EMG study were found to be similar, so were combined for statistical analysis.

The results were divided into Baseline (0 Months), 3 Months, and 6 months and individually presented. For each set of data the results were presented in the following order

- Minute 1 Average (Average of the first minute EMG)
- Minute 5 Average (Average of the fifth minute EMG)
- Minute 10 Average (Average of the Tenth minute EMG)
- 10 Minute Average (Average of the full 10 minutes EMG)
- Fatigue Analysis comparing Minute 1, 5 and 10 (Chair*Time Interaction)

	Bambach Seat Students	**Conventional Seat Students**	**Total**
Baseline (0 Months) 2006	**14**	**11**	**25**
3 Months (2005 + 2006)	**12 + 9 = 21**	**9 + 7 = 16**	**37**
6 Months (2005 + 2006)	**9 + 10 = 19**	**7 + 7 = 14**	**33**

Table 6-3. Total number of students who participated in the study

Baseline: Results of Minute 1 Average MVC (Baseline Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.025).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (P = 0.000)

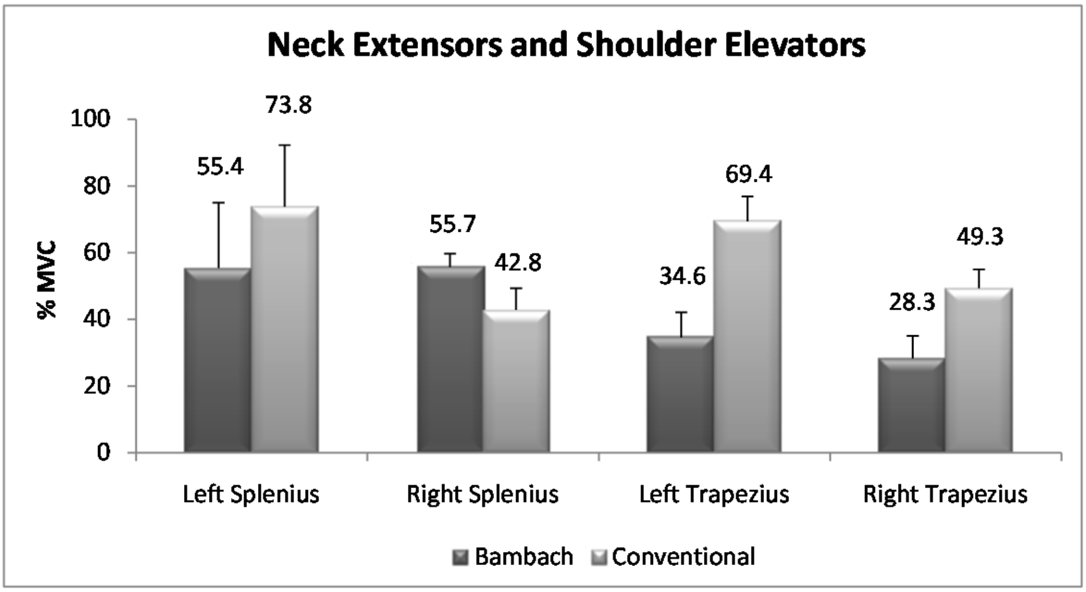


Fig. 6-18. Minute 1 Average of Splenius and Trapezius Muscles (Baseline Students)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (P=0.000).

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Left Splenius	Bambach	14	55.38	19.66	5.25	44.03	66.73	23.01	84.83
	Conventional	11	73.81	18.43	5.55	61.42	86.19	37.68	87.82
Right Splenius	Bambach	14	55.66	3.99	1.06	53.35	57.97	49.56	62.30
	Conventional	11	42.79	6.55	1.97	38.39	47.20	30.67	55.57
Left Trapezius	Bambach	14	34.62	7.56	2.02	30.26	38.99	22.24	49.11
	Conventional	11	69.37	7.47	2.25	64.35	74.39	57.09	78.70
Right Trapezius	Bambach	14	28.29	6.80	1.81	24.36	32.22	20.09	46.08
	Conventional	11	49.34	5.68	1.71	45.51	53.16	41.40	59.43

Table. 6-4. Descriptive Statistics (Baseline Students; Minute 1 Average)

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.000).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (P = 0.228)

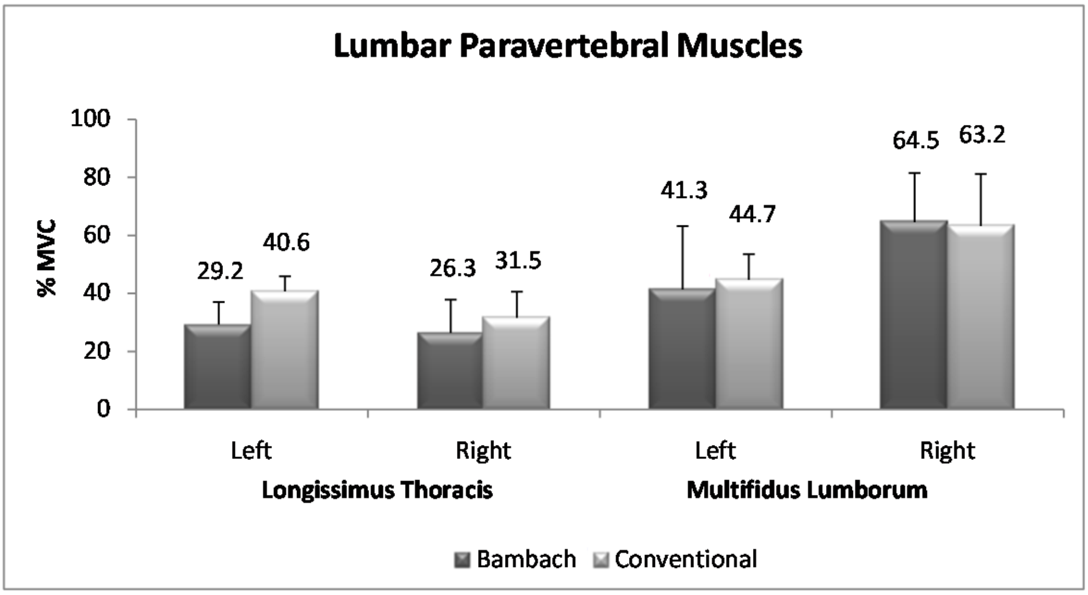


Fig. 6-19. Minute 1 Average of Lumbar Paravertebral Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	14	29.15	7.82	2.09	24.64	33.67	13.59	38.83
	Conventional	11	40.64	5.22	1.57	37.13	44.14	29.80	45.42
Right Longissimus Thoracis	Bambach	14	26.28	11.49	3.07	19.64	32.91	7.31	56.65
	Conventional	11	31.52	9.05	2.72	25.44	37.60	21.43	51.27
Left Multifidus Lumborum	Bambach	14	41.31	21.85	5.84	28.69	53.93	11.17	78.40
	Conventional	11	44.68	8.83	37.33	-1.23	165.14	34.07	44.58
Right Multifidus Lumborum	Bambach	14	64.53	16.93	4.52	54.75	74.31	38.29	81.93
	Conventional	11	63.22	17.94	5.40	51.16	75.27	29.78	88.59

Table. 6-5. Descriptive Statistics (Baseline Students; Minute 1 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.238).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (P = 0.853).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (P = 0.000).

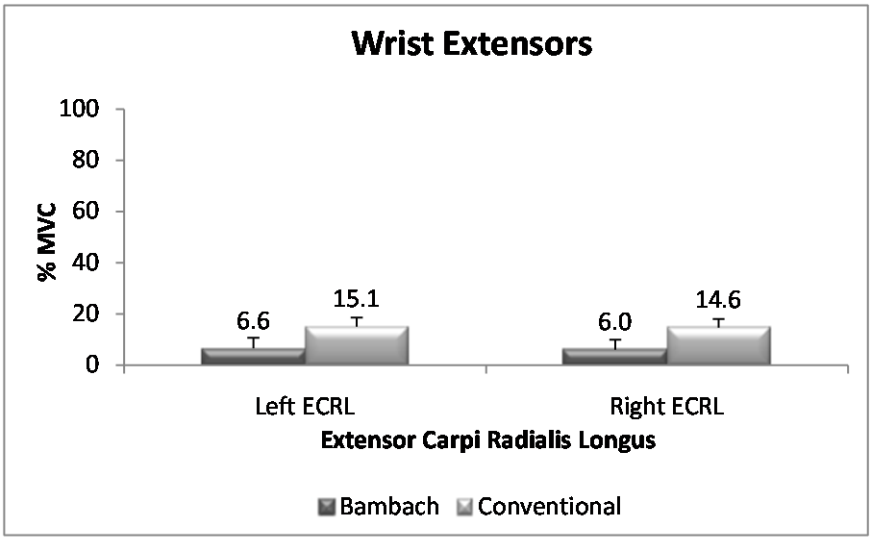


Fig. 6-20. Minute 1 Average of Wrist Extensor Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	14	6.61	4.08	1.09	4.25	8.97	2.05	14.83
	Conventional	11	15.05	3.56	1.07	12.66	17.45	10.44	22.96
Right ECRL	Bambach	14	6.02	3.92	1.04	3.76	8.29	1.90	16.34
	Conventional	11	14.62	3.43	1.03	12.31	16.92	9.69	21.90

Table. 6-6. Descriptive Statistics (Baseline Students; Minute 1 Average)

Results of Minute 5 Average MVC (Baseline Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.015).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (P = 0.000).

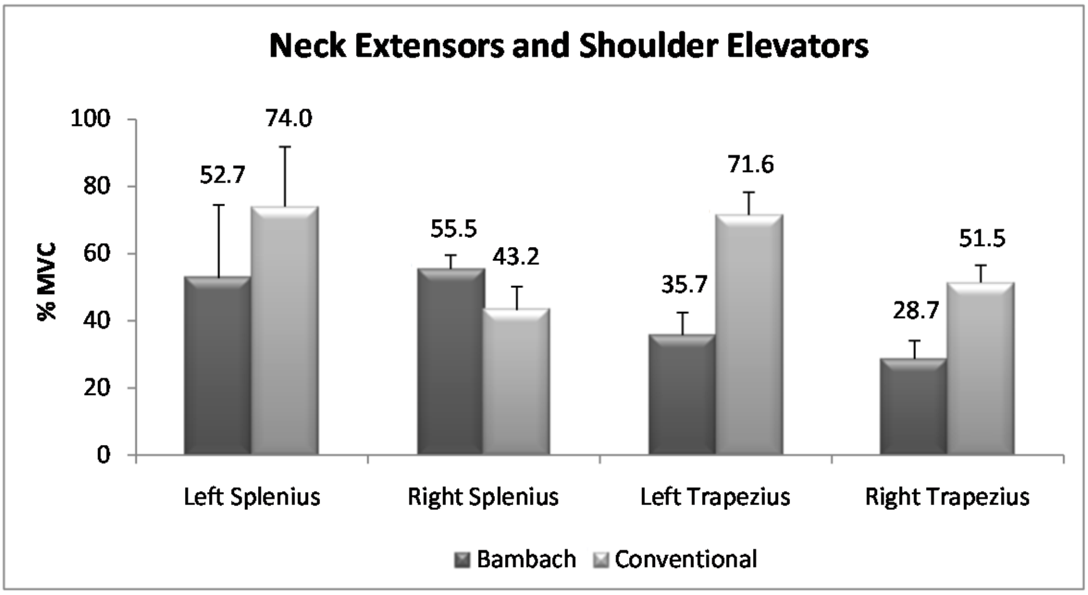


Fig. 6-21. Minute 5 Average of Splenius and Trapezius Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left Splenius	Bambach	14	52.69	21.79	5.82	40.11	65.28	14.73	82.83
	Conventional	11	74.04	17.81	5.37	62.07	86.01	38.41	85.99
Right Splenius	Bambach	14	55.50	4.05	1.08	53.15	57.84	48.29	63.30
	Conventional	11	43.20	7.06	2.13	38.45	47.94	32.68	58.20
Left Trapezius	Bambach	14	35.70	6.79	1.81	31.78	39.62	24.80	47.12
	Conventional	11	71.55	6.76	2.03	67.00	76.09	59.23	81.12
Right Trapezius	Bambach	14	28.73	5.35	1.43	25.64	31.83	21.49	40.34
	Conventional	11	51.46	5.17	1.55	47.98	54.93	42.92	59.71

Table. 6-7. Descriptive Statistics (Baseline Students; Minute 5 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results a indicated significant difference between the two seats for the left longissimus thoracis muscles (P = 0.000).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (P = 0.283).

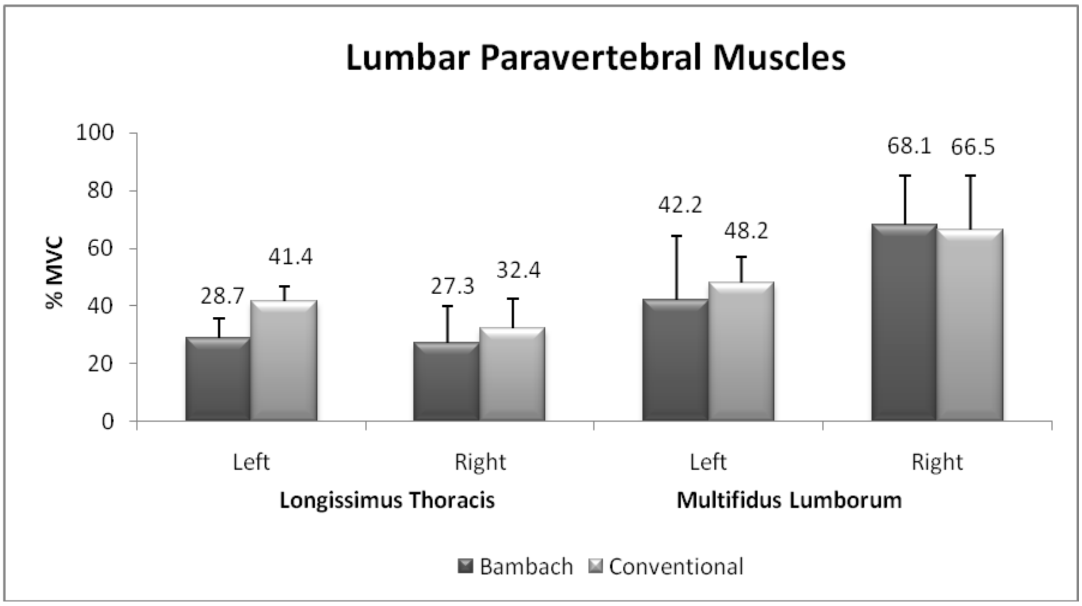


Fig. 6-22. Minute 5 Average of Lumbar Paravertebral Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left Longissimus Thoracis	Bambach	14	28.68	7.08	1.89	24.58	32.77	14.17	37.08
	Conventional	11	41.40	5.38	1.62	37.77	45.02	31.0	46.18
Right Longissimus Thoracis	Bambach	14	27.34	12.52	3.34	20.11	34.58	5.41	61.19
	Conventional	11	32.42	9.87	2.97	25.79	39.05	22.67	55.15
Left Multifidus Lumborum	Bambach	14	42.23	22.07	5.89	29.49	54.98	11.98	78.18
	Conventional	11	48.20	8.68	2.61	42.37	54.04	36.78	61.49
Right Multifidus Lumborum	Bambach	14	68.07	16.97	4.53	58.26	77.87	41.16	84.40
	Conventional	11	66.50	18.67	5.63	53.95	79.05	31.81	95.00

Table. 6-8. Descriptive Statistics (Baseline Students; Minute 5 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.407).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (P = 0.829).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.000).

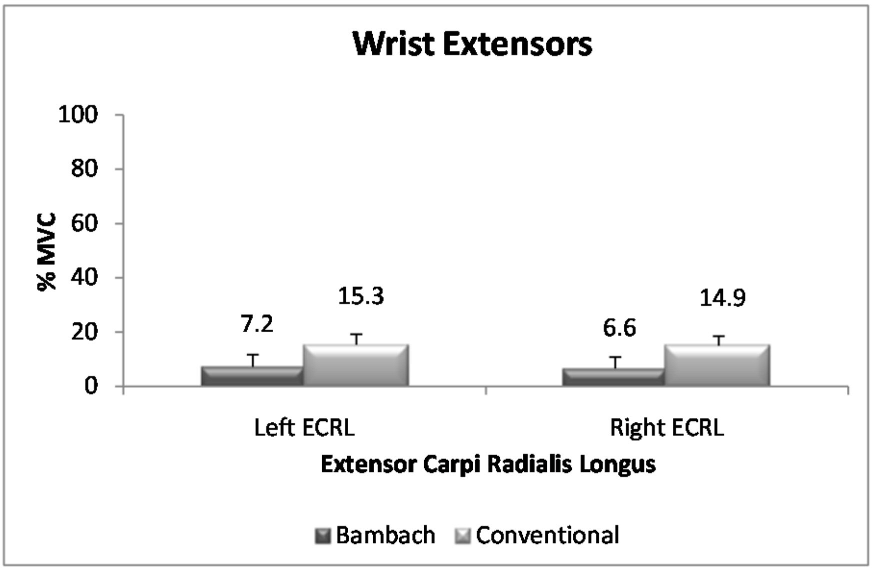


Fig. 6-23. Minute 5 Average of Wrist Extensor Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	14	7.21	4.42	1.183	4.65	9.77	2.21	15.94
	Conventional	11	15.31	3.89	1.17	12.69	17.93	10.95	24.67
Right ECRL	Bambach	14	6.55	4.25	1.13	4.09	9.00	2.08	17.82
	Conventional	11	14.89	3.62	1.09	12.46	17.32	10.38	23.49

Table. 6-9. Descriptive Statistics (Baseline Students; Minute 5 Average)

Results of Minute 10 Average MVC (Baseline Students):

Splenius Muscles:

Left: The results indicated a near significant difference between the two seats for the left splenius muscles (P = 0.056).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (P = 0.000).

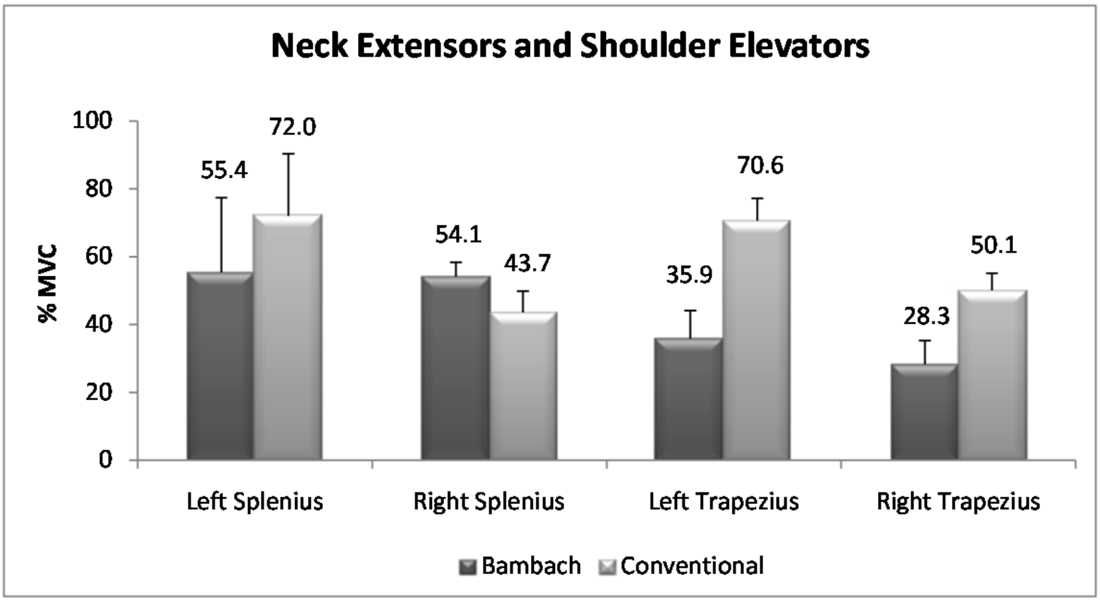


Fig. 6-24. Minute 10 Average of Splenius and Trapezius Muscles (Baseline Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Left Splenius	Bambach	14	55.37	22.05	5.89	42.64	68.11	13.79	87.54
	Conventional	11	72.04	18.39	5.54	59.69	84.40	37.81	89.25
Right Splenius	Bambach	14	54.14	4.26	1.14	51.68	56.60	47.68	63.30
	Conventional	11	43.65	6.29	1.89	39.42	47.88	32.44	53.87
Left Trapezius	Bambach	14	35.87	8.34	2.22	31.05	40.68	23.92	55.09
	Conventional	11	70.63	6.61	1.99	66.18	75.07	58.40	78.64
Right Trapezius	Bambach	14	28.29	7.05	1.88	24.21	32.36	20.35	46.94
	Conventional	11	50.13	5.00	1.50	46.76	53.49	42.21	58.85

Table. 6-10. Descriptive Statistics (Baseline Students; Minute 10 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated significant difference between the two seats for the right trapezius muscles (P = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.000).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.232).

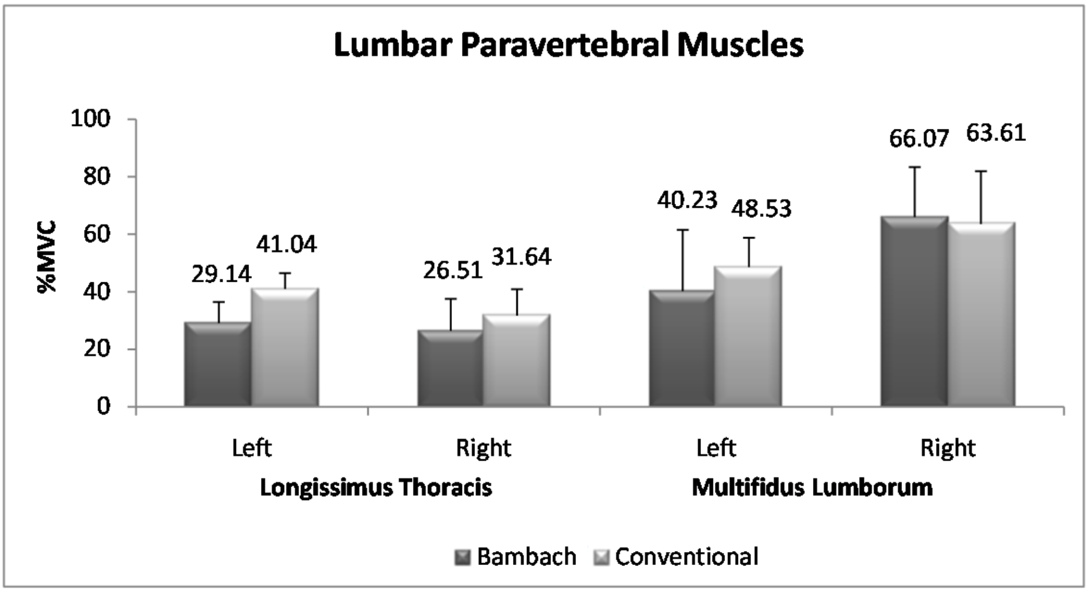


Fig. 6-25. Minute 10 Average of Lumbar Paravertebral Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left Longissimus Thoracis	Bambach	14	29.14	7.30	1.95	24.92	33.36	13.18	39.86
	Conventional	11	41.04	5.46	1.64	37.36	44.71	31.23	46.69
Right Longissimus Thoracis	Bambach	14	26.51	11.09	2.96	20.11	32.92	11.66	57.69
	Conventional	11	31.64	9.30	2.80	25.38	37.89	21.76	52.30
Left Multifidus Lumborum	Bambach	14	40.23	21.30	5.69	27.92	52.53	11.29	73.66
	Conventional	11	48.53	10.30	3.10	41.61	55.46	34.33	63.44
Right Multifidus Lumborum	Bambach	14	66.07	17.27	4.61	56.09	76.04	38.77	85.78
	Conventional	11	63.61	18.27	5.50	51.33	75.88	29.88	92.37

Table. 6-11. Descriptive Statistics (Baseline Students; Minute 10 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles ($p = 0.248$).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles ($p = 0.734$).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (p = 0.000).

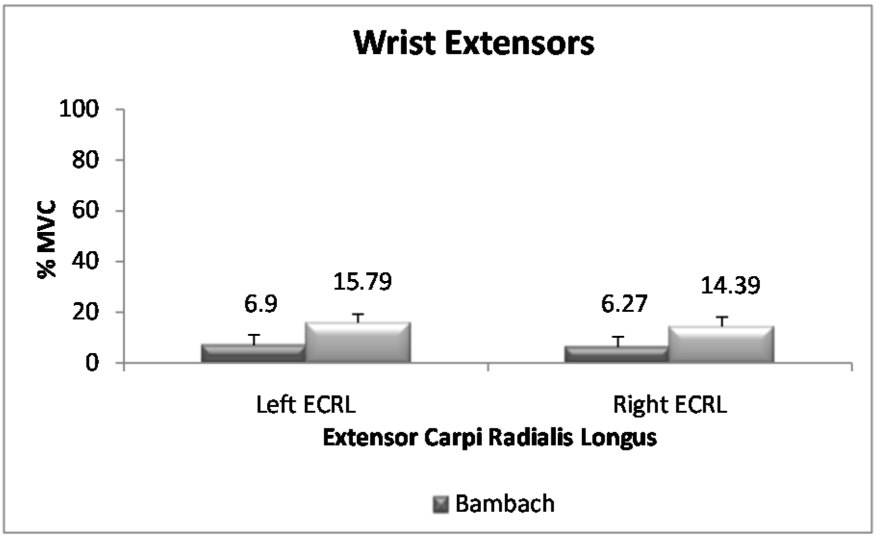


Fig. 6-26. Minute 10 Average of Wrist Extensor Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	14	6.90	4.20	1.12	4.47	9.33	2.08	15.06
	Conventional	11	15.79	3.47	1.04	13.46	18.12	11.02	23.29
Right ECRL	Bambach	14	6.27	4.07	1.08	3.92	8.62	1.96	16.75
	Conventional	11	14.39	3.71	1.12	11.89	16.89	10.02	22.17

Table. 6-12. Descriptive Statistics (Baseline Students; Minute 10 Average)

Results of 10-Minutes Average MVC (Baseline Students):

Splenius Muscles:

Left: The results indicated no significant difference between the two seats for the left splenius muscles (p = 0.109).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

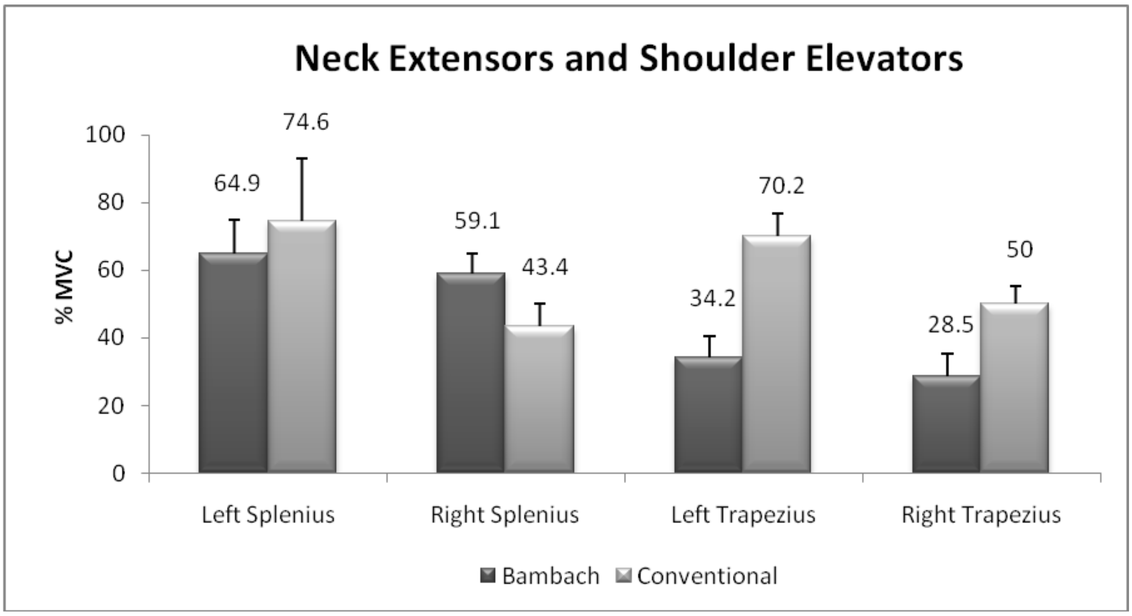


Fig. 6-27. Ten-Minutes Average of Splenius and Trapezius Muscles (Baseline Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Left Splenius	Bambach	14	64.87	10.14	2.71	59.02	70.73	45.36	88.93
	Conventional	11	74.56	18.56	5.59	62.09	87.03	38.24	89.87
Right Splenius	Bambach	14	59.08	5.79	1.54	55.74	62.43	50.89	69.08
	Conventional	11	43.40	6.64	2.00	38.93	47.86	31.78	55.44
Left Trapezius	Bambach	14	34.17	6.33	1.69	30.51	37.83	23.52	45.21
	Conventional	11	70.22	6.62	1.99	65.76	74.67	58.42	78.66
Right Trapezius	Bambach	14	28.53	6.98	1.86	24.50	32.57	20.43	47.38
	Conventional	11	49.99	5.17	1.56	46.52	53.47	42.27	59.25

Table. 6-13. Descriptive Statistics (Baseline Students; 10 Minutes Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.004).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.102).

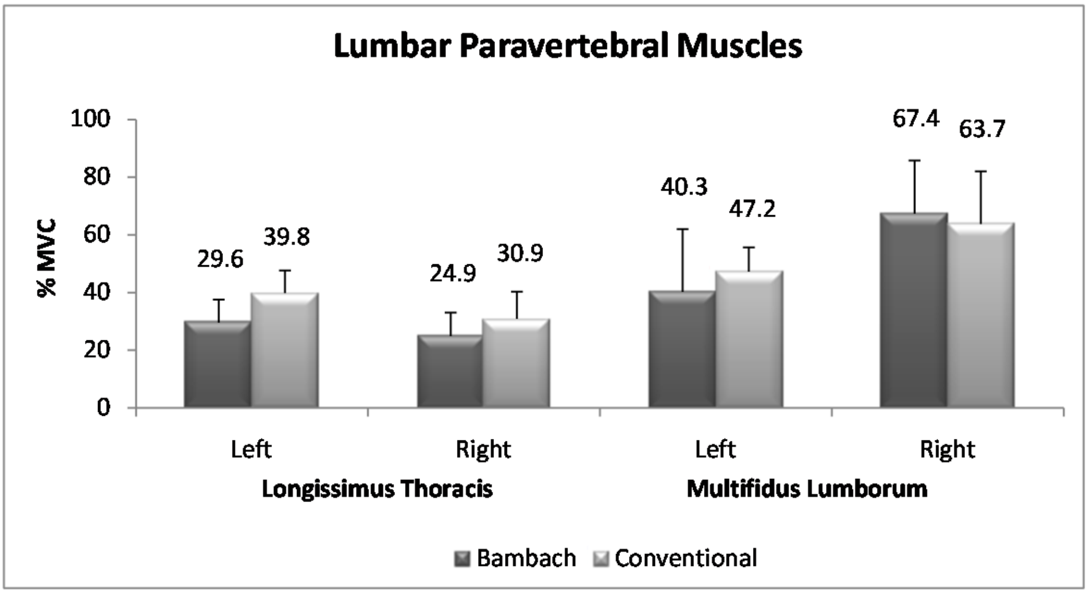


Fig. 6-28. Ten-Minutes Average of Lumbar Paravertebral Muscles (Baseline Students).

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	14	29.60	7.97	2.13	24.99	34.21	13.48	39.96
	Conventional	11	39.78	7.87	2.37	34.49	45.07	20.59	45.93
Right Longissimus Thoracis	Bambach	14	24.92	8.07	2.159	20.26	29.59	13.43	50.00
	Conventional	11	30.90	9.49	2.86	24.53	37.28	21.00	53.00
Left Multifidus Lumborum	Bambach	14	40.30	21.72	5.80	27.75	52.84	11.43	75.01
	Conventional	11	47.24	8.44	2.54	41.57	52.91	34.89	58.63
Right Multifidus Lumborum	Bambach	14	67.41	18.42	4.92	56.77	78.05	39.08	91.43
	Conventional	11	63.76	18.31	5.52	51.45	76.06	30.23	91.38

Table. 6-14. Descriptive Statistics (Baseline Students; 10 Minutes Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left longissimus thoracis muscles (P = 0.328).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.626).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (p = 0.000).

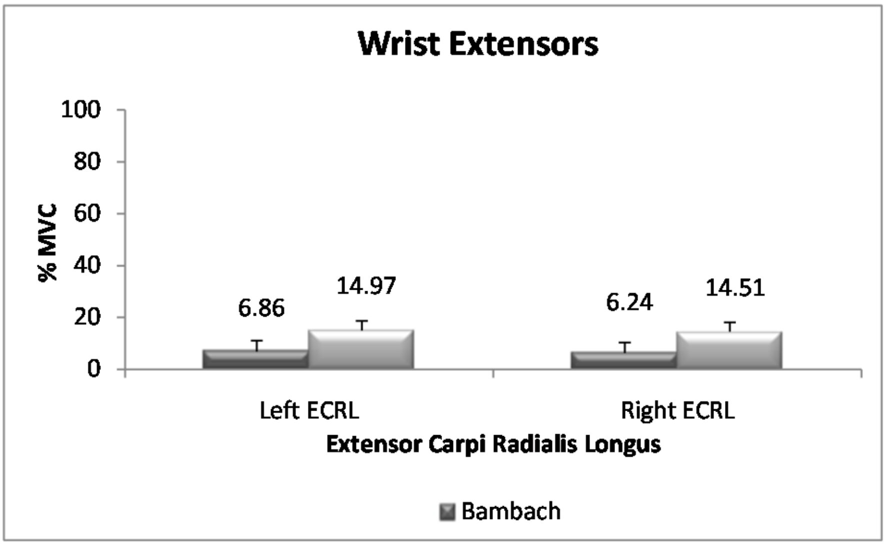


Fig. 6-29. Ten-Minutes Average of Wrist Extensor Muscles (Baseline Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	14	6.86	4.20	1.12	4.43	9.29	2.10	15.16
	Conventional	11	14.97	3.73	1.127	12.45	17.48	10.14	23.46
Right ECRL	Bambach	14	6.24	4.05	1.08	3.90	8.58	1.97	16.88
	Conventional	11	14.51	3.51	1.05	12.15	16.87	10.01	22.32

Table. 6-15. Descriptive Statistics (Baseline Students; 10 Minute Average)

Summary of the Baseline EMG Results of Students

The results for the baseline EMG varied between different muscles when the two groups were compared. Comparing the neck extensors and shoulder elevators the BSS recorded significantly less muscle activity when compared with CSS except with the right splenius muscle where the conventional seat recorded significantly less muscle activity. Comparing the lumbar paravertebral muscles, there was no significant difference in muscle activity between seats except with the left longissimus thoracis muscle where the BSS recorded significantly less muscle activity. Comparing the wrist extensors the BSS recorded significantly less muscle activity when compared with the CSS.

Fatigue Analysis of Students EMG at Minute 1, 5 and 10 (Baseline)

A common pattern was observed with the students comparing minute 1, 5 and 10 of their Baseline EMG activity. The %MVC of minute 1 and 10 are comparable to the 10-minute average in most of the students, but the %MVC of minute 5 is a little increased on average in most of the students. The increase in the EMG activity from minute 1 to 5 indicates a small increase in recruitment and synchronisation of motor unit activity indicative of fatigue (Cram and Vinitzky; 1995). Further, the observed drop in the EMG activity between minute 5 and 10 occurs as fatigue sets in, where the muscles are no longer capable of meeting the metabolic requirements needed to sustain a contraction. The initial increase in muscular support is followed by a reduction of %MVC (The Failure Point) along with a reduction of EMG activity of muscles.

Left Splenius Muscle: The EMG activity remained the same from minute 1 to 5 and decreased in minute 10 in CSS, but the EMG activity reduced at minute 5 and increased at minute 10 for the BSS indicating less fatigue when using Bambach seat (Fig. 6-30).

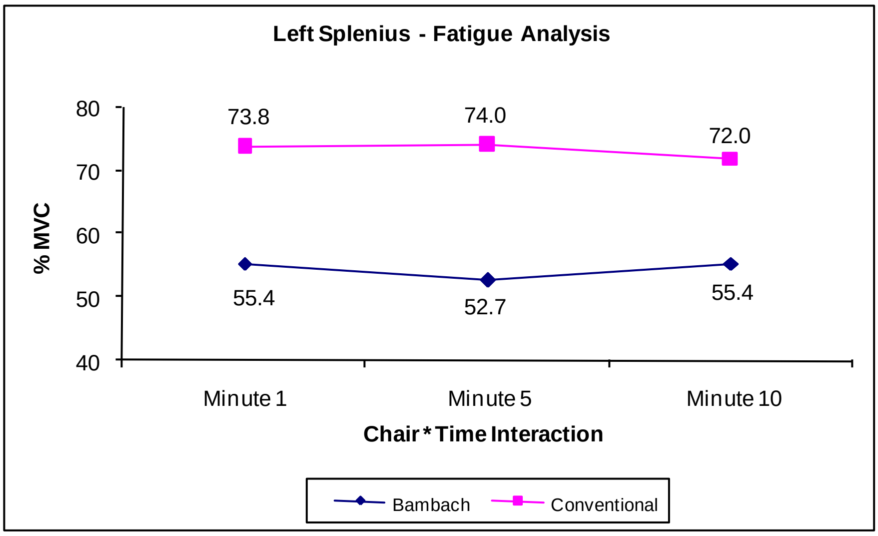


Fig. 6-30. Left Splenius Muscle (Fatigue Analysis of Students Baseline EMG)

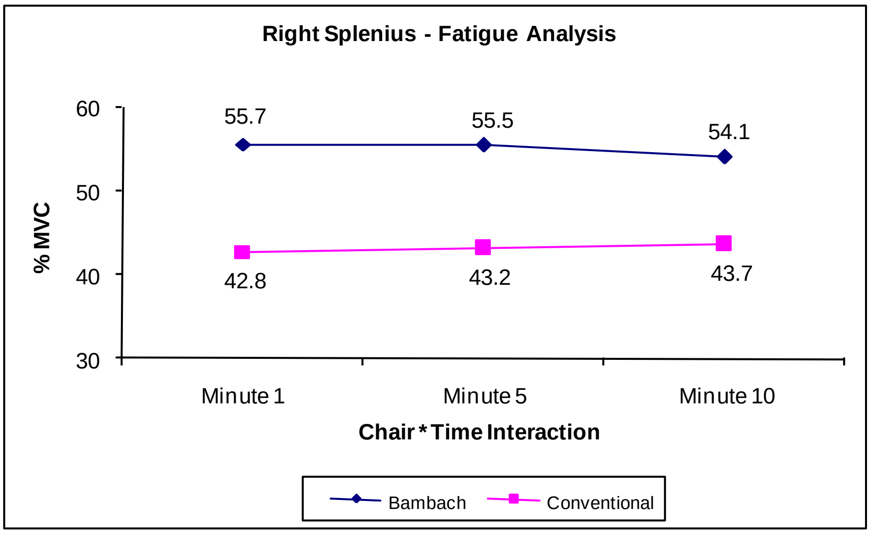


Fig. 6-31. Right Splenius Muscle (Fatigue Analysis of Students Baseline EMG)

Right Splenius Muscle: The EMG activity remained the same from minute 1 to 5 for both the groups of dentists, but at minute 10 the EMG activity slightly decreased for BSS and slightly increased for CSS (Fig. 6-31).

Left Trapezius Muscle: The EMG activity slightly increased from minute 1 to 5 and decreased at minute 10 in CSS (Fig. 6-32).

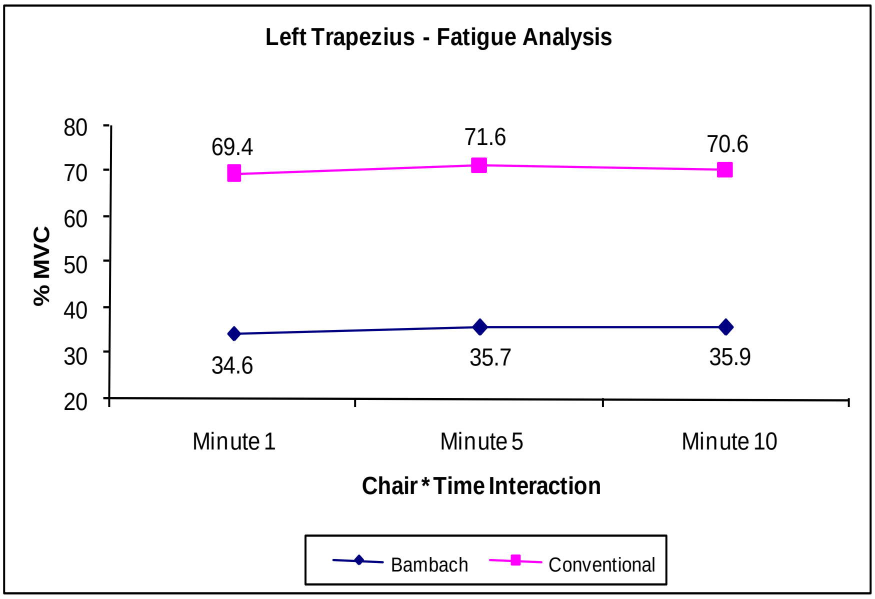


Fig. 6-32. Left Trapezius Muscle (Fatigue Analysis of Students Baseline EMG)

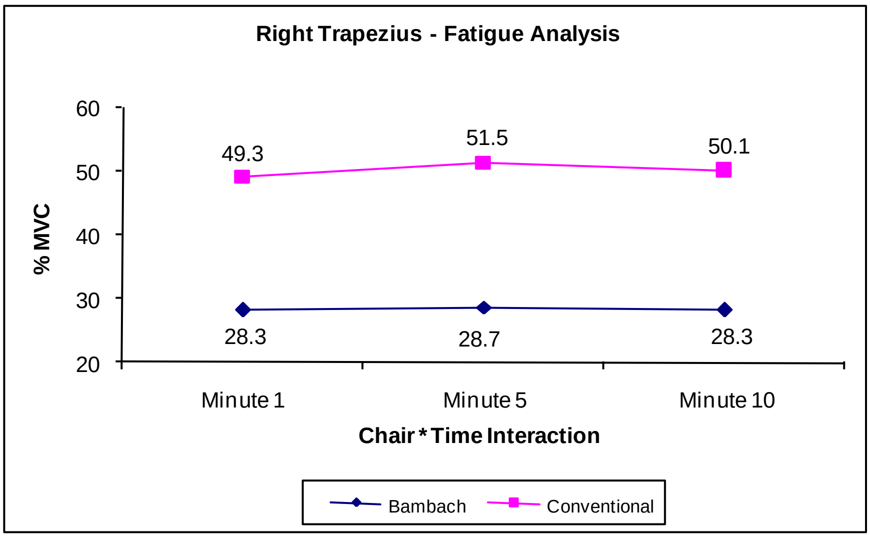


Fig. 6-33. Right Trapezius Muscle (Fatigue Analysis of Students Baseline EMG)

Right Trapezius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-33).

Left Longissimus Thoracis Muscle: The EMG activity gradually decreased from minute 1 to 5 and slightly increased at minute 10 with Bambach students, whereas the EMG activity slightly increased from minute 1 to 5 and remained the same at minute 10 with the CSS (Fig. 6-34).

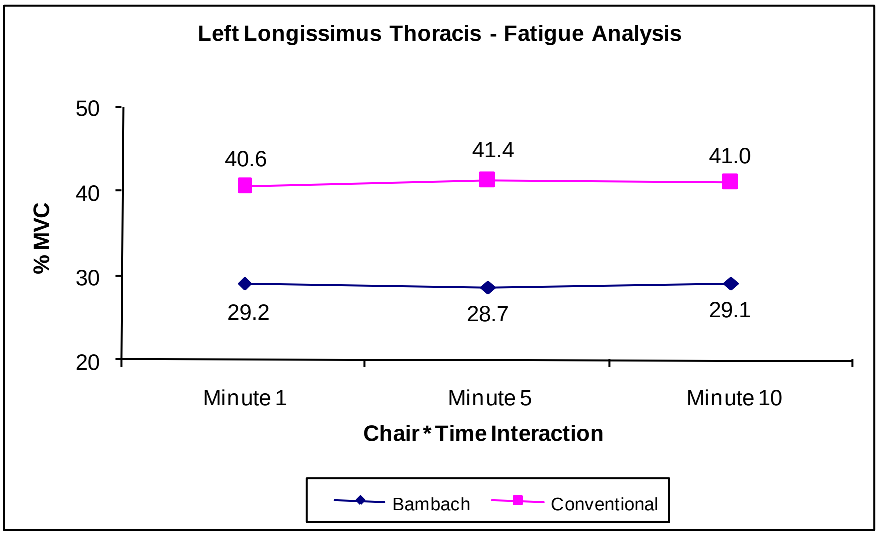


Fig. 6-34. Left Longissimus Thoracis (Fatigue Analysis of Students Baseline EMG)

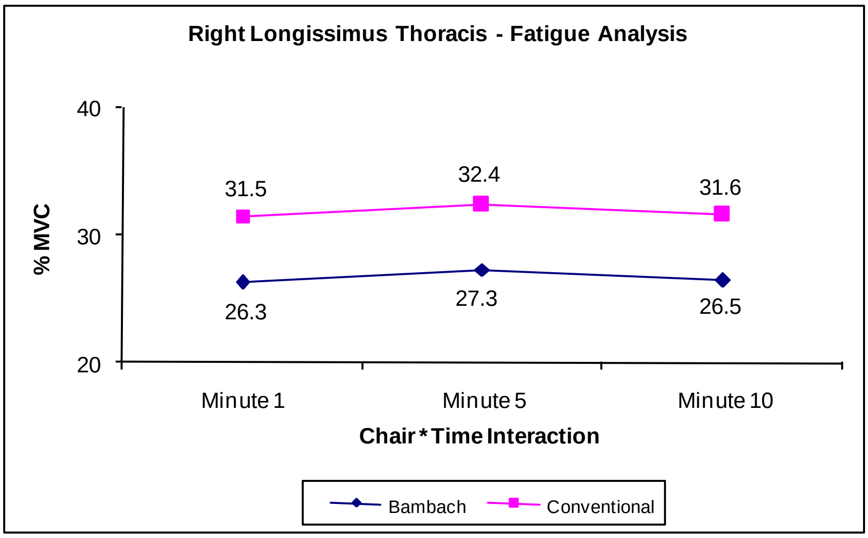


Fig. 6-35. Right Longissimus Thoracis (Fatigue Analysis of Students Baseline EMG)

Right Longissimus Thoracis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-35).

Left Multifidus Lumborum Muscle: The EMG activity of BSS slightly increased from minute 1 to 5 and slightly decreased at minute 10, whereas the EMG activity of CSS significantly decreased at minute 5 and significantly increased at minute 10, indicative of fatigue in CSS (Fig. 6-36).

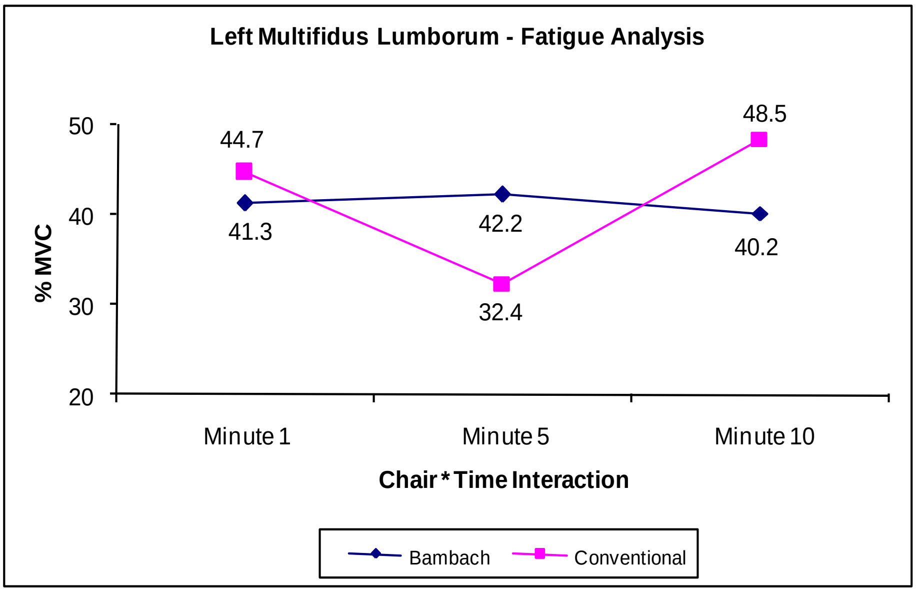


Fig. 6-36. Left Multifidus Lumborum (Fatigue Analysis of Students Baseline EMG)

Right Multifidus Lumborum Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-37).

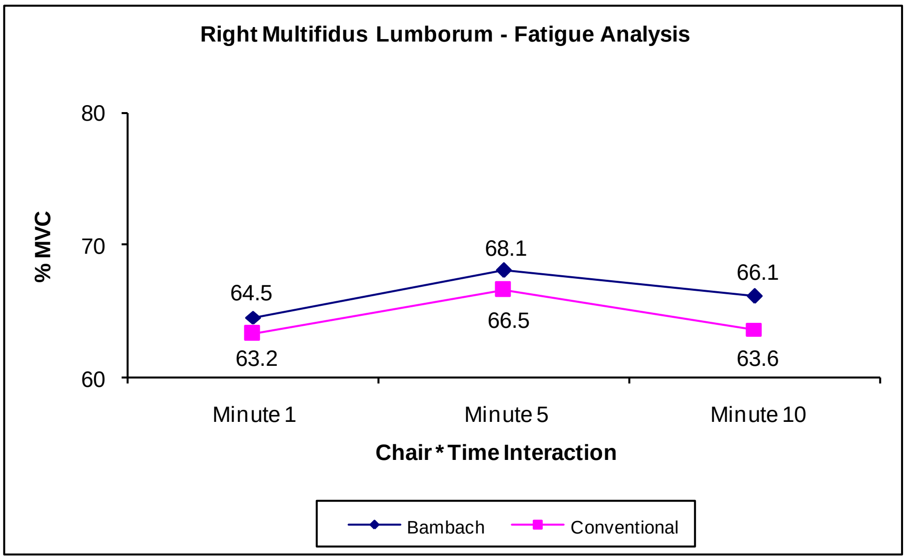


Fig. 6-37. Right Multifidus Lumborum (Fatigue Analysis of Students Baseline EMG)

Left Extensor Carpi Radialis Muscle: The EMG activity slightly increased from minute 1 to 5 and remained the same at minute 10 in students using both the seats (Fig. 6-38).

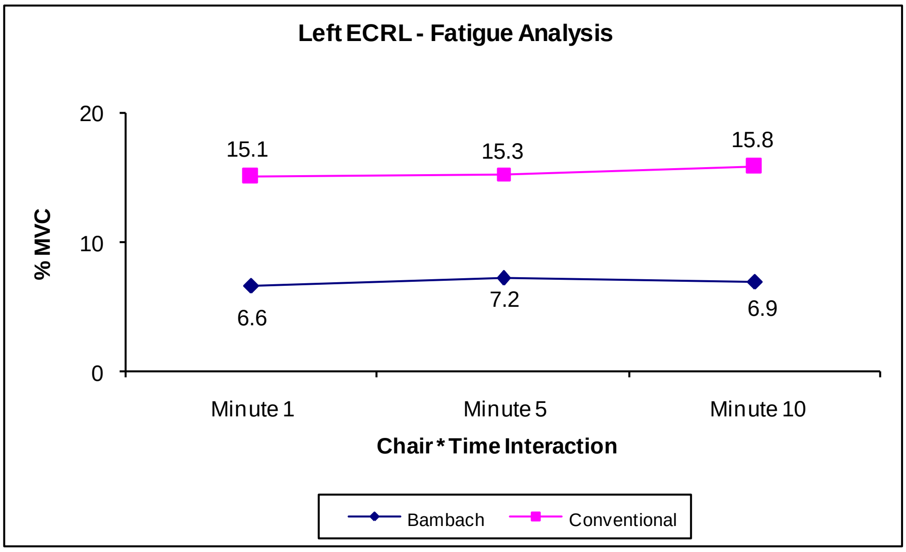


Fig. 6-38. Left ECRL (Fatigue Analysis of Students Baseline EMG)

Right Extensor Carpi Radialis Muscle: The EMG activity increased from minute 1 to 5 and remained the same at minute 10 in students using both the seats (Fig. 6-39).

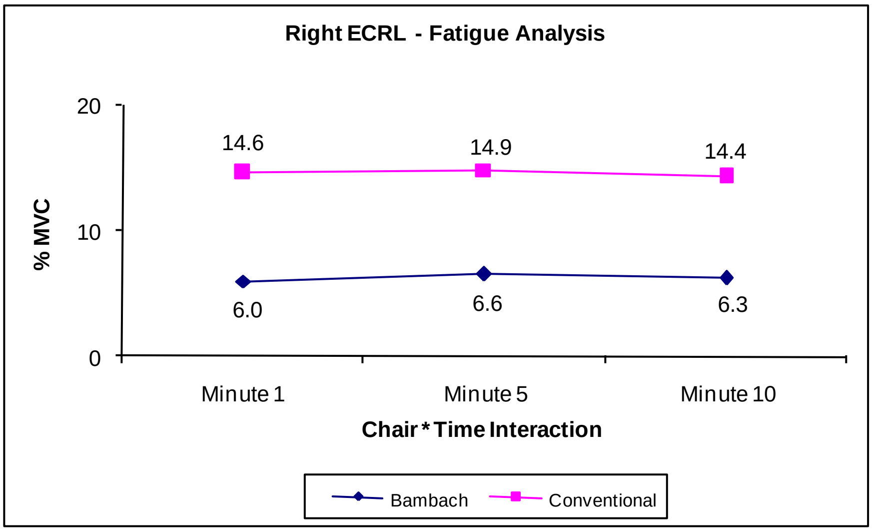


Fig. 6-39. Right ECRL (Fatigue Analysis of Students Baseline EMG)

Generally, the pattern of fatigue is similar in students using both the seats but there is a significant difference observed between the seats except for EMG activity in back muscles. Overall, the students using BS recorded lower muscle activity, which is more important than the fatigue component during activity, which is negligible with BSS.

After 3 Months: Results of Minute 1 Average MVC (3 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.004).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

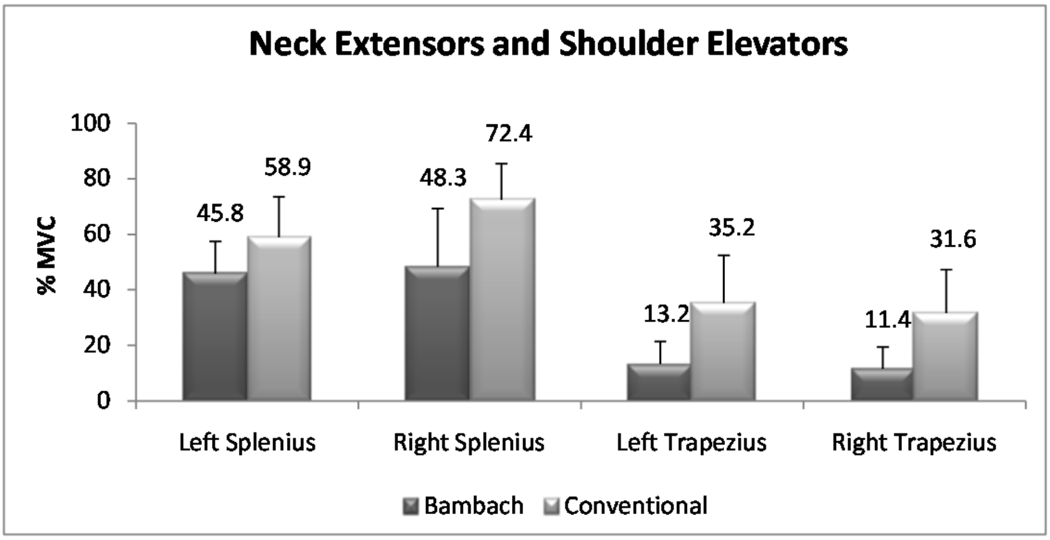


Fig. 6-40. Minute 1 Average of Splenius and Trapezius Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	21	45.80	11.55	2.52	40.55	51.06	23.65	71.18
	Conventional	16	58.92	14.57	3.64	51.16	66.69	33.12	79.00
Right Splenius	Bambach	21	48.34	20.86	4.55	38.84	57.84	7.36	78.15
	Conventional	16	72.37	13.05	3.26	65.42	79.33	51.94	87.80
Left Trapezius	Bambach	21	13.21	8.20	1.79	9.48	16.95	1.31	36.30
	Conventional	16	35.21	17.26	4.31	26.01	44.41	12.57	78.86
Right Trapezius	Bambach	21	11.44	7.96	1.73	7.81	15.06	1.96	35.27
	Conventional	16	31.64	15.57	3.89	23.34	39.93	14.37	79.36

Table. 6-16. Descriptive Statistics (3 Months Students; Minute 1 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated no significant difference between the two seats for the left longissimus thoracis muscles (P = 0.937).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.402).

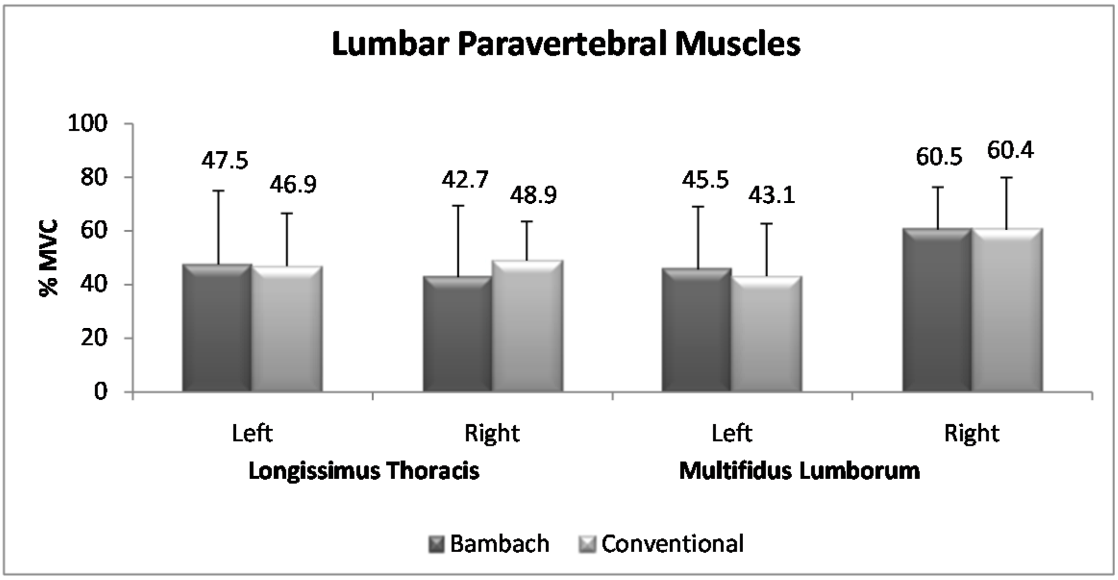


Fig. 6-41. Minute 1 Average of Lumbar Paravertebral Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	21	47.51	27.41	5.98	35.03	59.99	14.38	94.09
	Conventional	16	46.86	19.65	4.91	36.39	57.33	20.24	79.61
Right Longissimus Thoracis	Bambach	21	42.67	26.67	5.82	30.53	54.81	13.81	90.27
	Conventional	16	48.95	14.61	3.65	41.16	56.74	32.34	76.49
Left Multifidus Lumborum	Bambach	20	45.55	23.50	5.25	34.55	56.55	19.08	83.68
	Conventional	16	43.09	19.66	4.91	32.61	53.57	24.84	81.95
Right Multifidus Lumborum	Bambach	21	60.49	15.82	3.45	53.29	67.69	18.51	86.57
	Conventional	16	60.36	19.48	4.87	49.98	70.75	28.73	87.55

Table. 6-17. Descriptive Statistics (3 Months Students; Minute 1 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.739).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (p = 0.982).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.023).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.170).

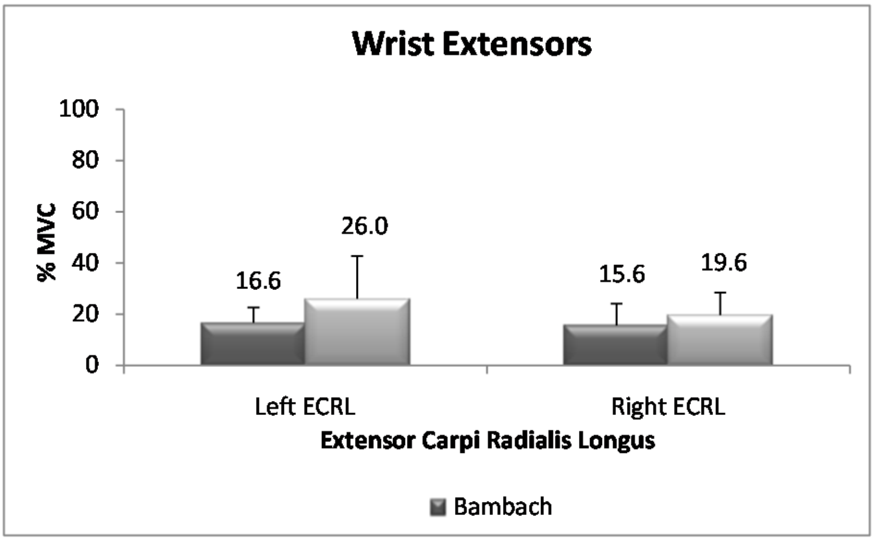


Fig. 6-42. Minute 1 Average of Wrist Extensor Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	21	16.64	6.04	1.31	13.89	19.39	7.97	27.61
	Conventional	16	25.98	16.73	4.18	17.06	34.90	8.16	66.11
Right ECRL	Bambach	21	15.57	8.50	1.85	11.69	19.44	5.41	30.46
	Conventional	16	19.61	8.89	2.22	14.87	24.35	5.42	41.03

Table. 6-18. Descriptive Statistics (3 Months Students; Minute 1 Average)

Results of Minute 5 Average MVC (3 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.009).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

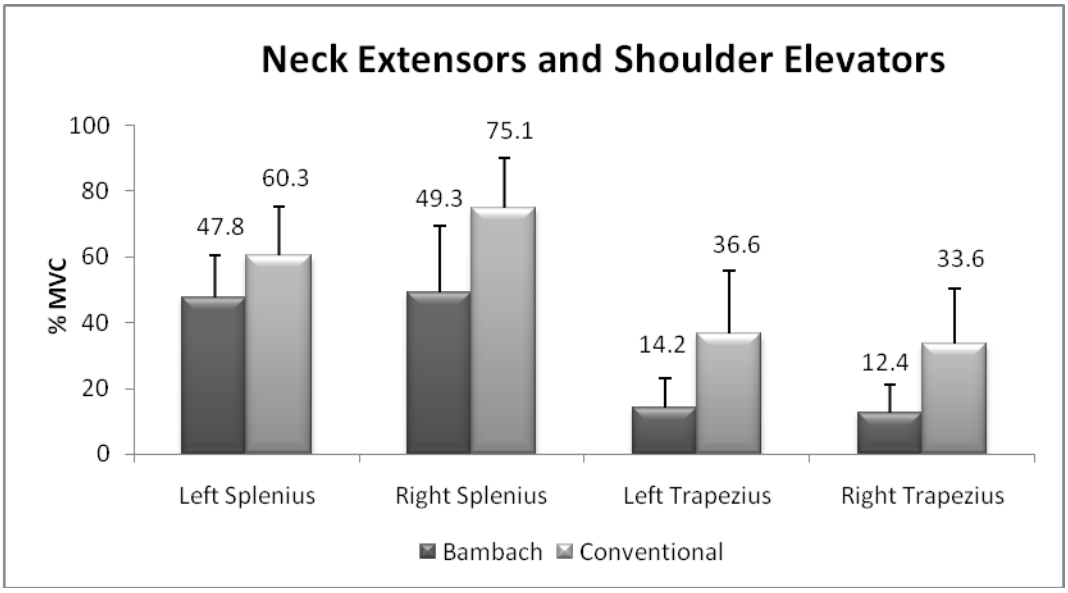


Fig. 6-43. Minute 5 Average of Splenius and Trapezius Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left Splenius	Bambach	21	47.77	12.71	2.77	41.98	53.56	25.40	76.27
	Conventional	16	60.28	14.90	3.72	52.34	68.23	34.63	84.11
Right Splenius	Bambach	21	49.25	20.26	4.42	40.02	58.47	7.89	76.74
	Conventional	16	75.10	15.08	3.77	67.06	83.14	52.49	93.53
Left Trapezius	Bambach	21	14.15	8.69	1.89	10.19	18.10	3.23	41.33
	Conventional	16	36.57	19.09	4.77	26.40	46.75	13.42	89.19
Right Trapezius	Bambach	21	12.36	8.81	1.92	8.34	16.37	1.84	38.94
	Conventional	16	33.61	16.76	4.19	24.68	42.55	15.57	85.19

Table. 6-19. Descriptive Statistics (3 Months Students; Minute 5 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated no significant difference between the two seats for the left longissimus thoracis muscles (P = 0.707).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.426).

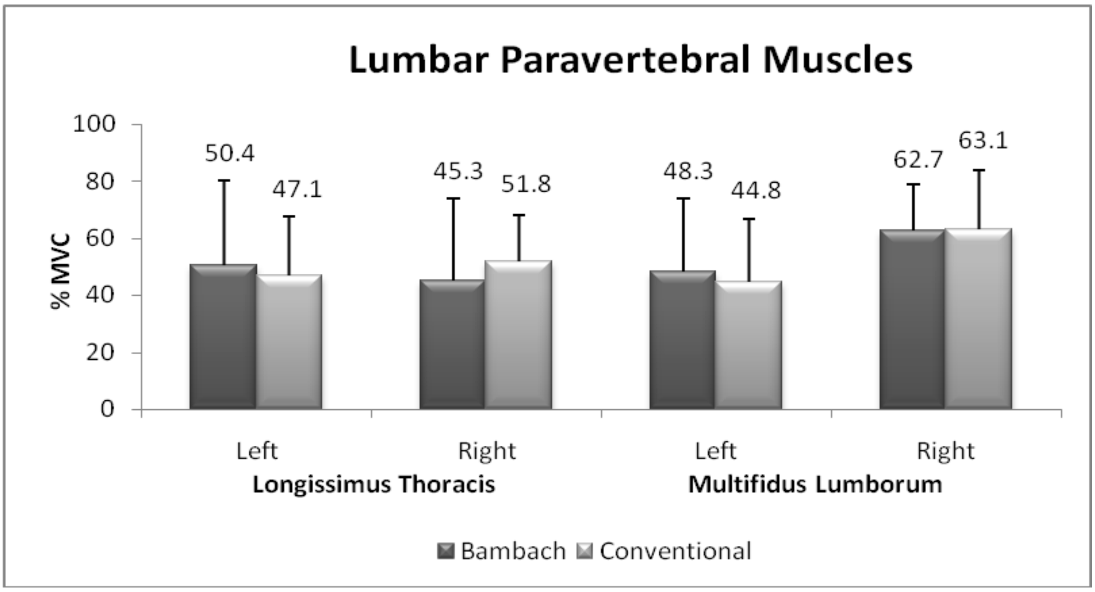


Fig. 6-44. Minute 5 Average of Lumbar Paravertebral Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	21	50.40	29.73	6.48	36.86	63.94	14.34	100.88
	Conventional	16	47.12	20.44	5.11	36.22	58.01	22.34	85.31
Right Longissimus Thoracis	Bambach	21	45.31	28.58	6.23	32.30	58.32	14.70	97.21
	Conventional	16	51.75	16.25	4.06	43.09	60.41	33.38	82.21
Left Multifidus Lumborum	Bambach	20	48.34	25.43	5.68	36.43	60.24	18.92	90.07
	Conventional	16	44.81	21.84	5.46	33.16	56.45	21.09	88.18
Right Multifidus Lumborum	Bambach	20	62.68	15.98	3.57	55.19	70.16	20.51	87.57
	Conventional	16	63.10	20.61	5.15	52.12	74.08	29.73	88.55

Table. 6-20. Descriptive Statistics (3 Months; Minute 5 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.663).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (p = 0.945).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.028).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.228).

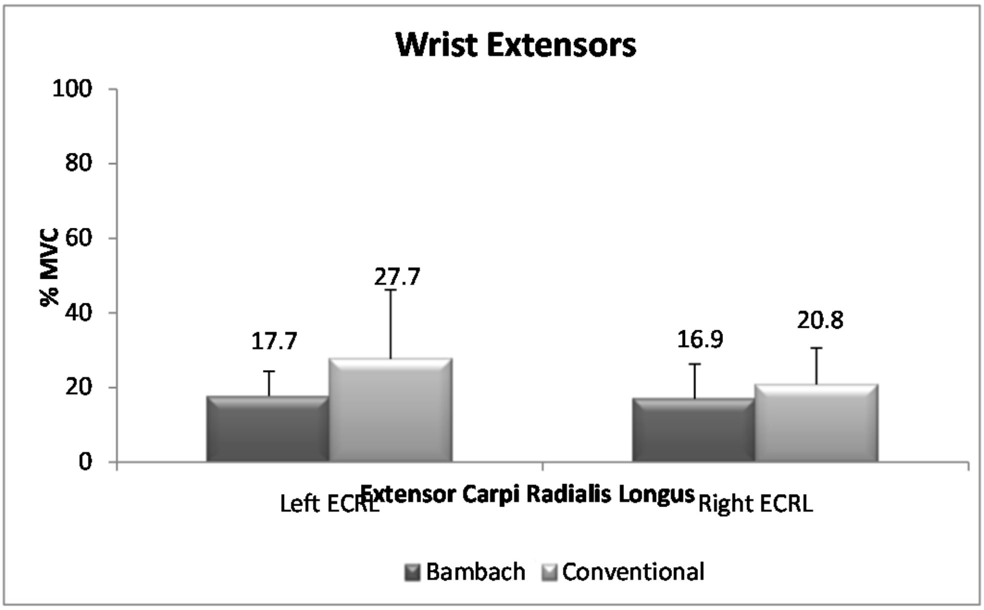


Fig. 6-45. Minute 5 Average of Wrist Extensor Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	21	17.71	6.60	1.44	14.70	20.71	8.55	29.66
	Conventional	16	27.70	18.53	4.63	17.83	37.58	7.75	71.04
Right ECRL	Bambach	21	16.94	9.40	2.05	12.66	21.22	5.82	33.49
	Conventional	16	20.83	9.80	2.45	15.61	26.06	5.83	44.13

Table. 6-21. Descriptive Statistics (3 Months Students; Minute 5 Average)

Results of Minute 10 Average MVC (3 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.010).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.001).

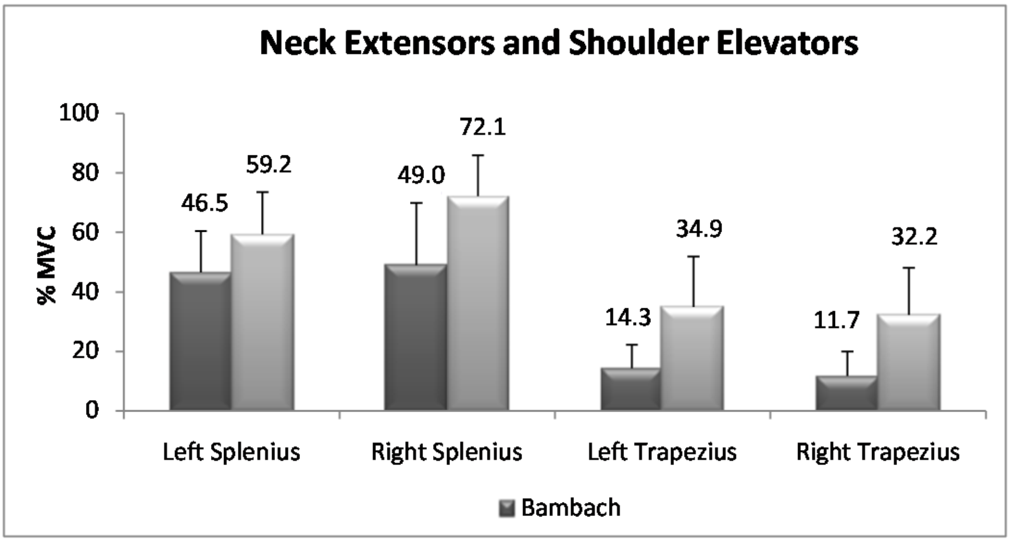


Fig. 6-46. Minute 10 Average of Splenius and Trapezius Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	21	46.49	13.96	3.04	40.13	52.85	13.43	79.13
	Conventional	16	59.23	14.26	3.56	51.63	66.83	33.35	80.29
Right Splenius	Bambach	21	48.95	20.94	4.57	39.42	58.49	7.46	79.33
	Conventional	16	72.10	13.75	3.43	64.77	79.43	51.35	89.06
Left Trapezius	Bambach	21	14.27	7.97	1.73	10.64	17.90	3.52	39.38
	Conventional	16	34.92	16.87	4.21	25.92	43.91	12.47	78.08
Right Trapezius	Bambach	21	11.68	8.22	1.79	7.93	15.42	1.49	35.51
	Conventional	16	32.23	15.90	3.97	23.75	40.71	14.67	81.10

Table. 6-22. Descriptive Statistics (3 Months Students; Minute 10 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated no significant difference between the two seats for the left longissimus thoracis muscles (P = 0.988).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.485).

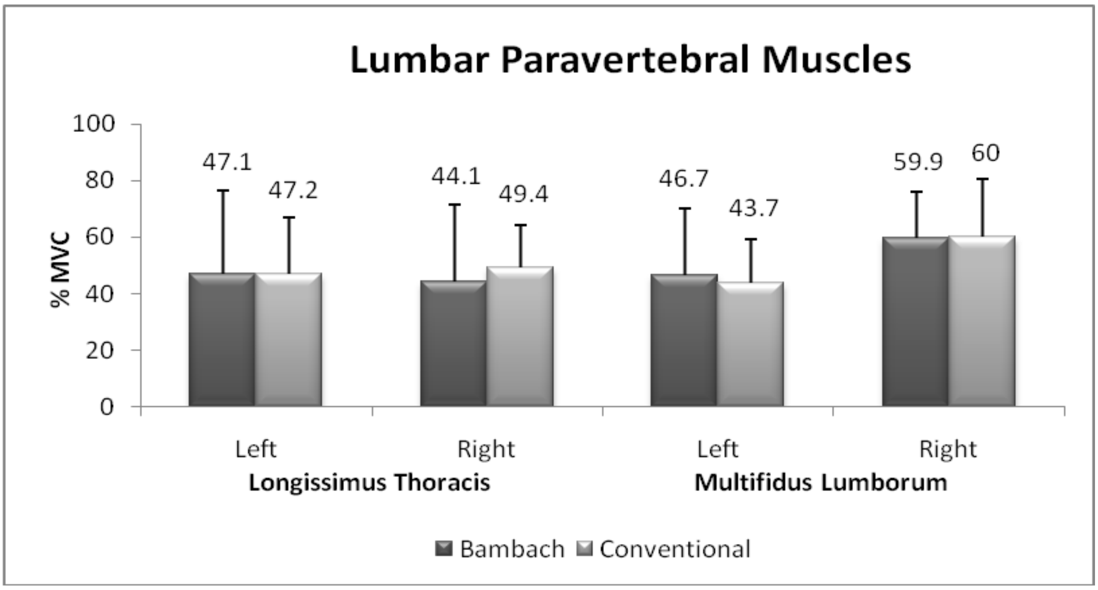


Fig. 6-47. Minute 10 Average of Lumbar Paravertebral Muscles (3 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Longissimus Thoracis	Bambach	21	47.07	29.45	6.42	33.66	60.47	12.70	95.08
	Conventional	16	47.19	19.80	4.95	36.64	57.75	20.65	80.57
Right Longissimus Thoracis	Bambach	21	44.08	27.34	5.96	31.63	56.53	13.33	91.75
	Conventional	16	49.44	15.04	3.76	41.42	57.46	31.10	77.96
Left Multifidus Lumborum	Bambach	20	46.73	23.52	5.25	35.74	57.74	19.29	85.10
	Conventional	16	43.72	15.60	48.90	14.37	194.08	20.52	81.74
Right Multifidus Lumborum	Bambach	20	59.85	16.23	3.63	52.25	67.45	17.51	83.57
	Conventional	16	59.97	20.45	5.11	49.08	70.84	26.73	85.55

Table. 6-23. Descriptive Statistics (3 Months Students; Minute 10 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.334).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (p = 0.983).

6.7.5.9.5 Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.020).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.171).

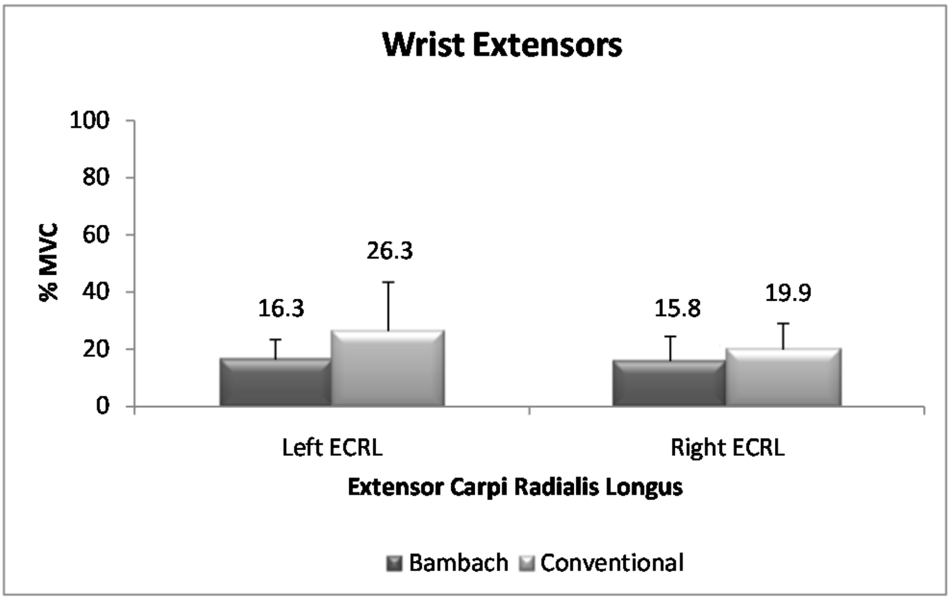


Fig. 6-48. Minute 10 Average of Wrist Extensor Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	21	16.31	7.00	1.52	13.12	19.50	.73	28.04
	Conventional	16	26.33	17.09	4.27	17.23	35.44	8.27	67.12
Right ECRL	Bambach	21	15.80	8.68	1.89	11.85	19.75	5.48	31.04
	Conventional	16	19.91	9.08	2.27	15.07	24.75	5.47	41.69

Table. 6-24. Descriptive Statistics (3 Months Students; Minute 10 Average)

Results of 10-Minutes Average MVC (3 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.005).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.001).

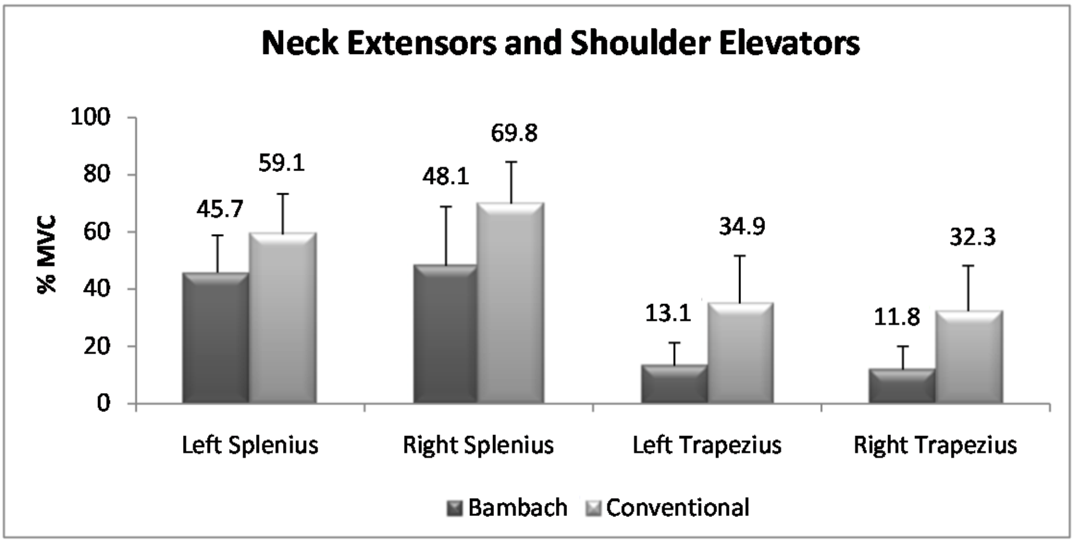


Fig. 6-49. Ten-Minutes Average of Splenius and Trapezius Muscles (3 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Splenius	Bambach	21	45.72	13.13	2.86	39.74	51.70	21.81	79.57
	Conventional	16	59.10	14.21	3.55	51.52	66.68	33.52	80.57
Right Splenius	Bambach	21	48.11	20.66	4.50	38.70	57.51	7.51	82.43
	Conventional	16	69.78	14.65	3.66	61.97	77.59	48.80	89.47
Left Trapezius	Bambach	21	13.13	8.13	1.77	9.43	16.83	3.07	38.80
	Conventional	16	34.94	16.69	4.17	26.04	43.84	12.71	78.64
Right Trapezius	Bambach	21	11.79	8.24	1.79	8.03	15.54	1.70	36.13
	Conventional	16	32.28	15.88	3.97	23.82	40.75	14.78	81.15

Table. 6-25. Descriptive Statistics (3 Months Students; 10 Minutes Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated no significant difference between the two seats for the left longissimus thoracis muscles (P = 0.821).

Right: The results indicated no significant difference between the two seats for the right longissimus thoracis muscles (p = 0.458).

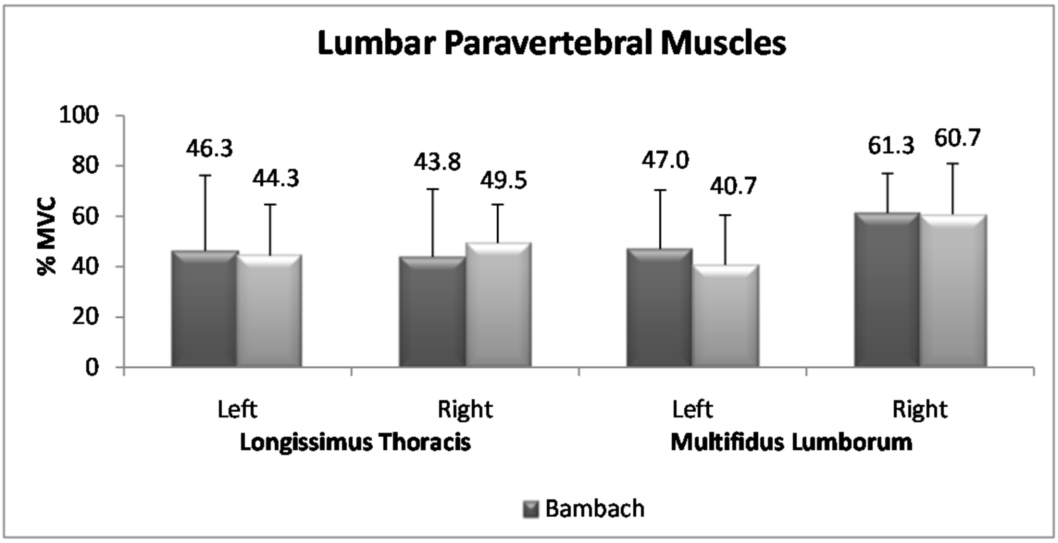


Fig. 6-50. Ten-Minutes Average of Lumbar Paravertebral Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	21	46.30	29.97	6.54	32.66	59.95	1.06	95.90
	Conventional	16	44.32	20.33	5.08	33.48	55.16	18.54	81.15
Right Longissimus Thoracis	Bambach	21	43.82	26.88	5.86	31.58	56.06	20.00	92.24
	Conventional	16	49.46	15.26	3.81	41.32	57.59	31.22	78.21
Left Multifidus Lumborum	Bambach	21	47.01	23.38	5.10	36.37	57.66	19.11	85.57
	Conventional	16	40.69	19.76	4.94	30.15	51.22	23.40	83.83
Right Multifidus Lumborum	Bambach	21	61.30	15.73	3.43	54.14	68.47	19.51	85.57
	Conventional	16	60.71	20.15	5.03	49.97	71.45	27.73	86.55

Table. 6-26. Descriptive Statistics (3 Months Students; 10 Minutes Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated no significant difference between the two seats for the left multifidus lumborum muscles (P = 0.390).

Right: The results indicated no significant difference between the two seats for the right multifidus lumborum muscles (p = 0.920).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.026).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.237).

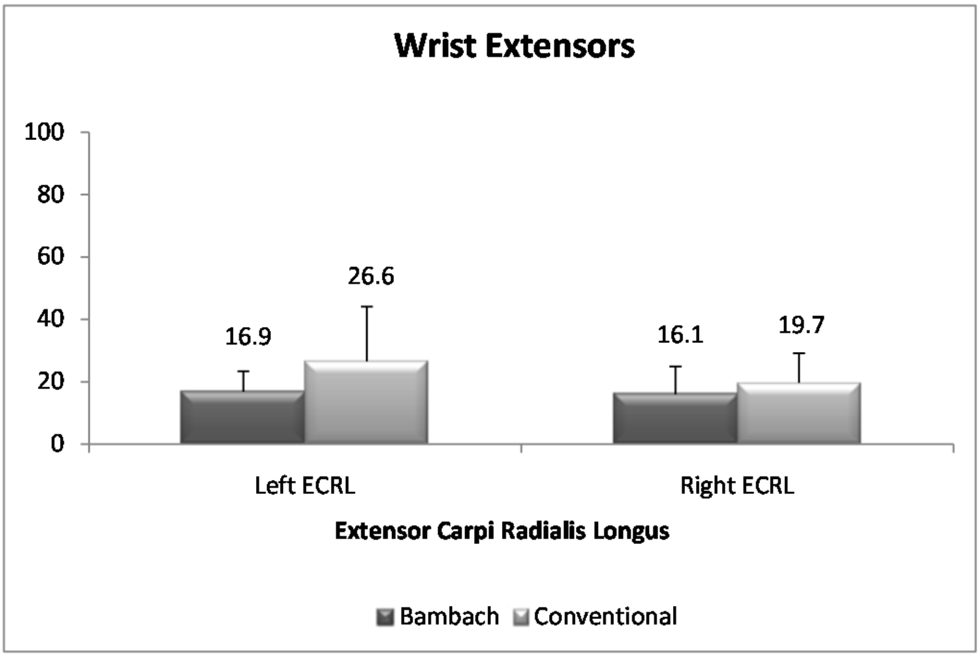


Fig. 6-51. Ten-Minutes Average of Wrist Extensor Muscles (3 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	21	16.87	6.53	1.42	13.90	19.85	8.03	28.55
	Conventional	16	26.55	17.60	4.40	17.17	35.93	8.35	67.54
Right ECRL	Bambach	21	16.05	8.87	1.93	12.01	20.09	5.52	31.33
	Conventional	16	19.69	9.41	2.35	14.68	24.71	5.52	41.94

Table. 6-27. Descriptive Statistics (3 Months Students; 10 Minutes Average)

Summary of the 3 Months EMG Results of Students

The results for the 3 Months EMG were different when compared with the Baseline. Comparing the neck extensors and shoulder elevators, the BSS recorded significantly less muscle activity when compared with CSS. The BSS 3 month muscle activity was significantly less when compared to the Baseline. Comparing the lumbar paravertebral muscles there was no significant difference in muscle activity between seats. Comparing the wrist extensors, the BSS recorded significantly less muscle activity on the left ECRL when compared with the CSS and there was no significant difference between seats for the right ECRL muscle activity.

Fatigue Analysis of Students EMG at Minute 1, 5 and 10 (3 Months)

A common pattern was observed with the students comparing minute 1, 5 and 10 of their 3 months EMG activity. The %MVC of minute 1 and 10 are comparable to the 10-minute average in most of the students, but the %MVC of minute 5 is a little increased on average in most of the students. A similar pattern was also observed with students at Baseline EMG and Dentists.

Left Splenius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-52).

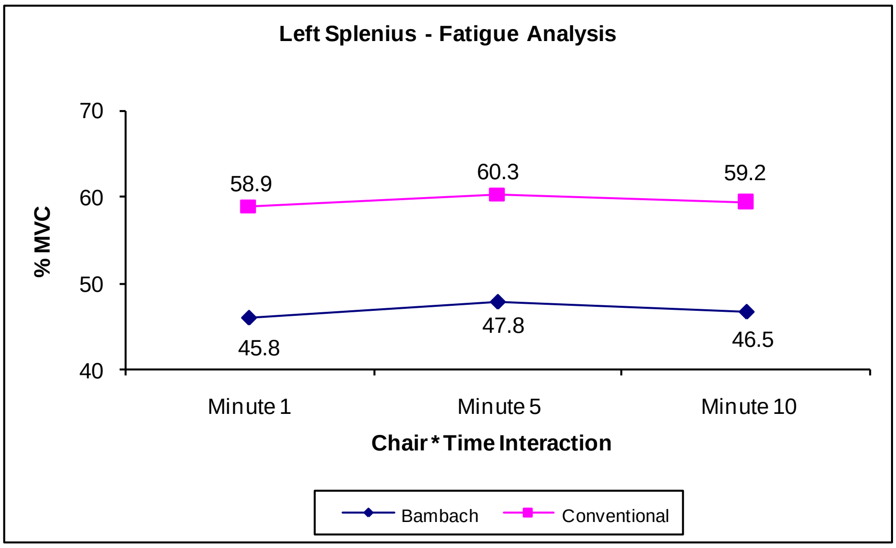


Fig. 6-52. Left Splenius Muscle (Fatigue Analysis of Students 3 Months EMG)

Right Splenius Muscle: The EMG activity gradually increased from minute 1 to 5 with both the groups of students, whereas at minute 10 the EMG activity decreased with the CSS but remained the same with BSS (Fig 6-53).

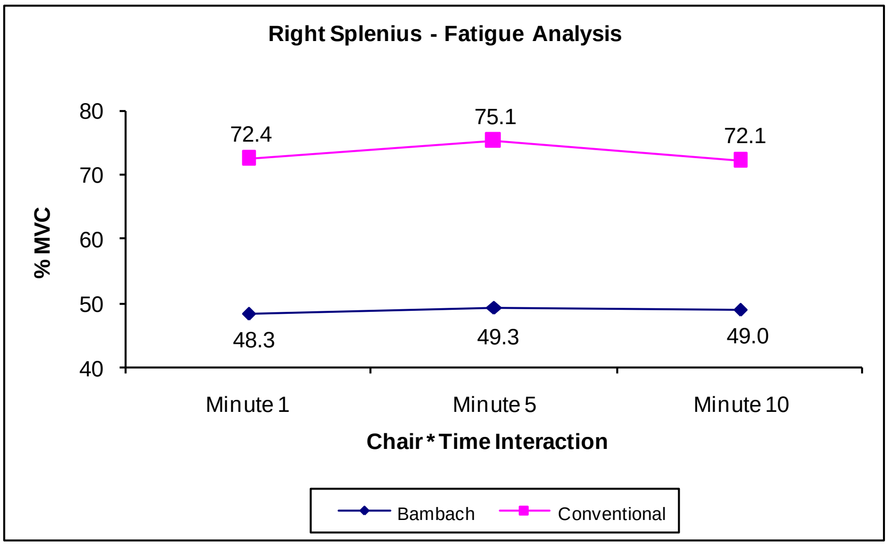


Fig. 6-53. Right Splenius Muscle (Fatigue Analysis of Students 3 Months EMG)

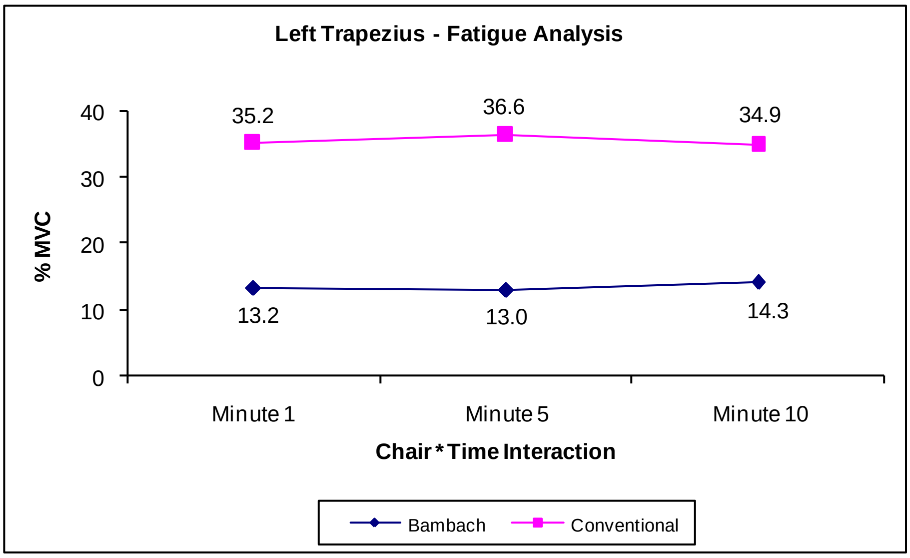


Fig. 6-54. Left Trapezius Muscle (Fatigue Analysis of Students 3 Months EMG)

Left Trapezius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased at minute 10 with CSS, whereas the EMG activity slightly decreased from minute 1 to 5 and slightly increased at minute 10 with BSS (Fig. 6-54).

6.7.5.12.4 Right Trapezius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-55).

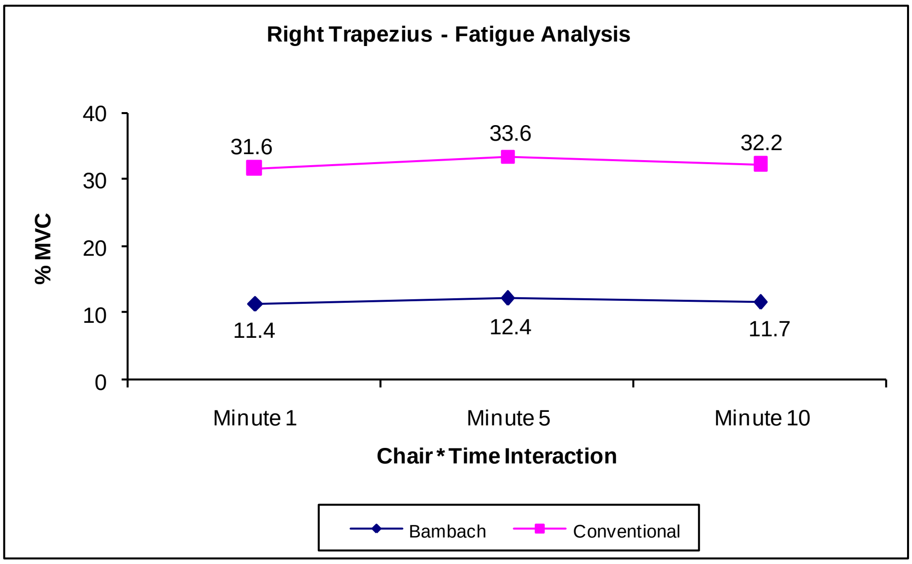


Fig. 6-55. Right Trapezius Muscle (Fatigue Analysis of Students 3 Months EMG)

Left Longissimus Thoracis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 with BSS, whereas the EMG activity remained the same across the minutes 1, 5 and 10 with CSS (Fig. 6-56).

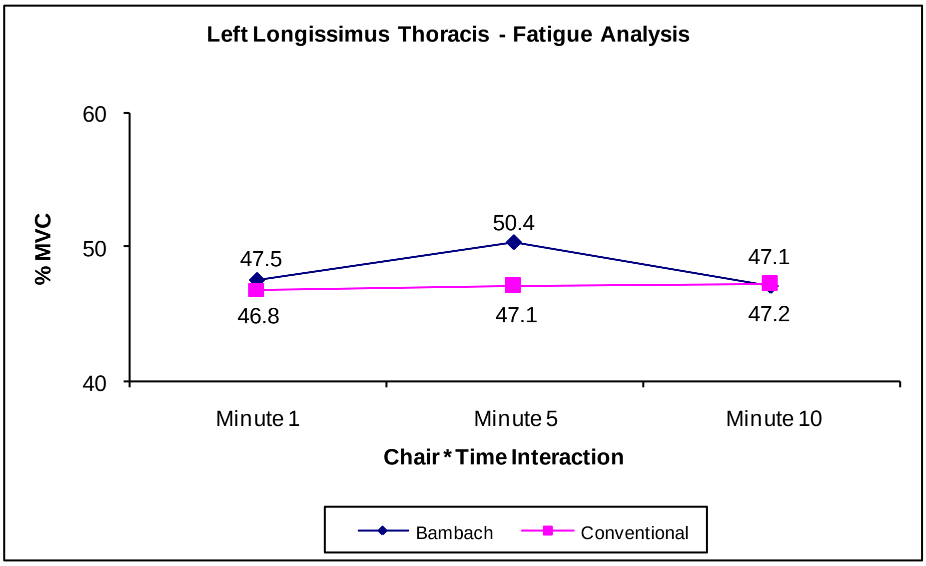


Fig. 6-56. Left Longissimus Thoracis (Fatigue Analysis of Students 3 Months EMG)

Right Longissimus Thoracis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-57).

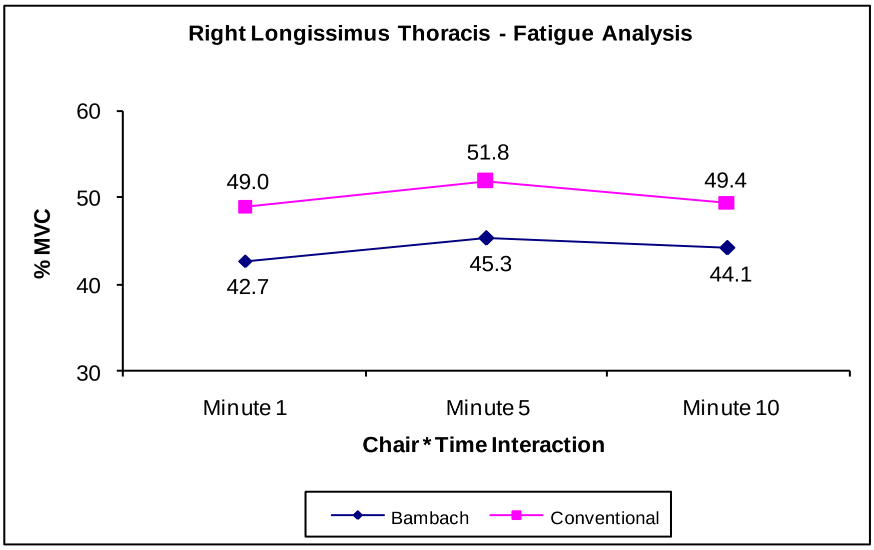


Fig. 6-57. Right Longissimus Thoracis (Fatigue Analysis of Students 3 Months EMG)

Left Multifidus Lumborum Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-58).

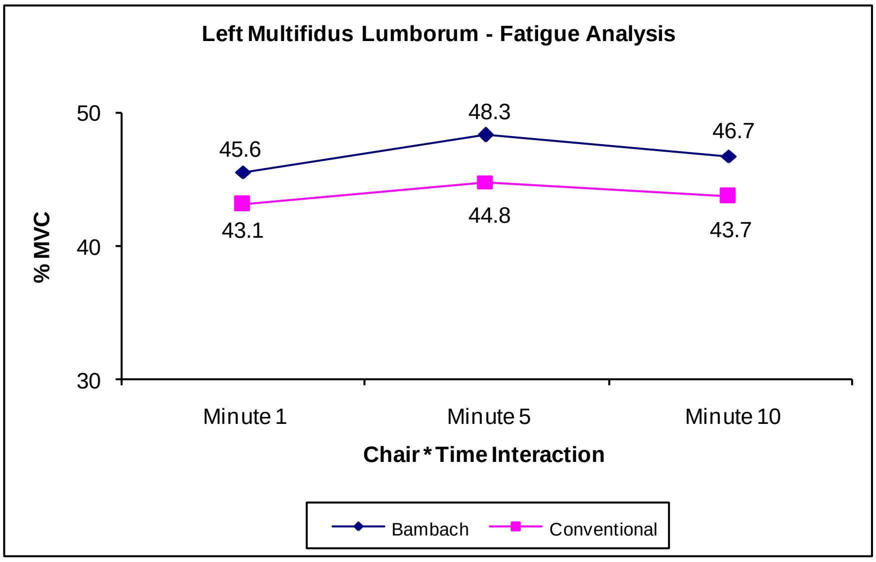


Fig. 6-58. Left Multifidus Lumborum (Fatigue Analysis of Students 3 Months EMG)

Right Multifidus Lumborum Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased at minute 10 with CSS, whereas the EMG activity gradually decreased across minutes 1, 5 and 10 with the BSS indicative of less / no fatigue in using Bambach seat (Fig. 6-59).

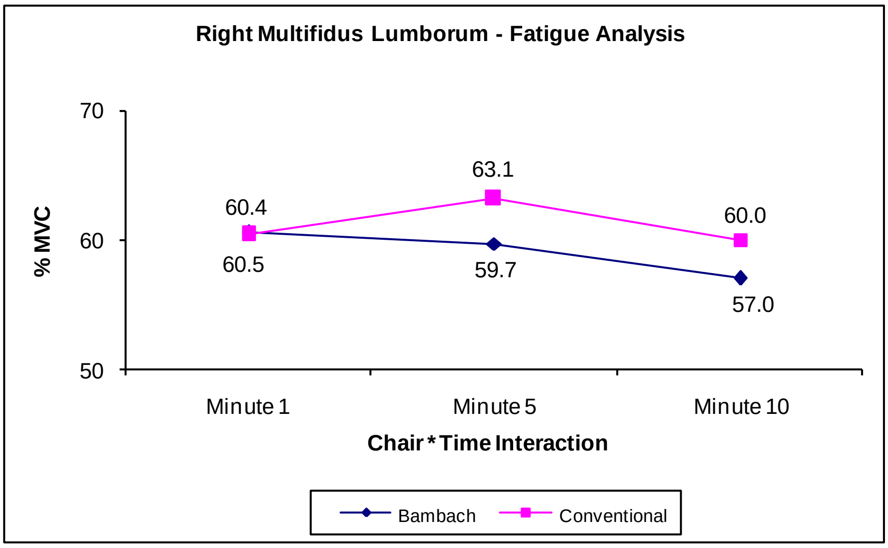


Fig. 6-59. Right Multifidus Lumborum (Fatigue Analysis of Students 3 Months EMG)

Left Extensor Carpi Radialis Muscle: The EMG activity slightly increased from minute 1 to 5 and 10 in students using both the seats (Fig. 6-60).

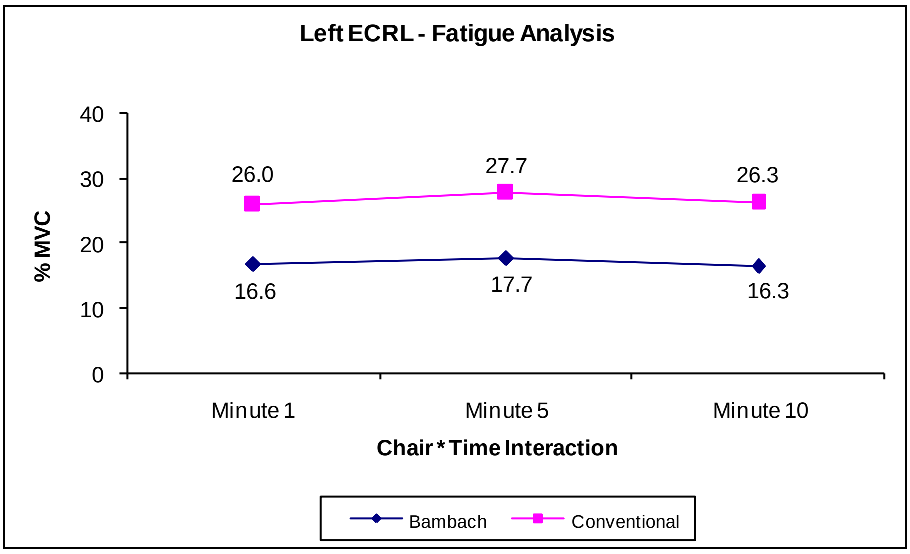


Fig. 6-60. Left ECRL (Fatigue Analysis of Students 3 Months EMG)

Right Extensor Carpi Radialis Muscle: The EMG activity slightly increased from minute 1 to 5 and remained the same at minute 10 in students using both the seats (Fig. 6-61).

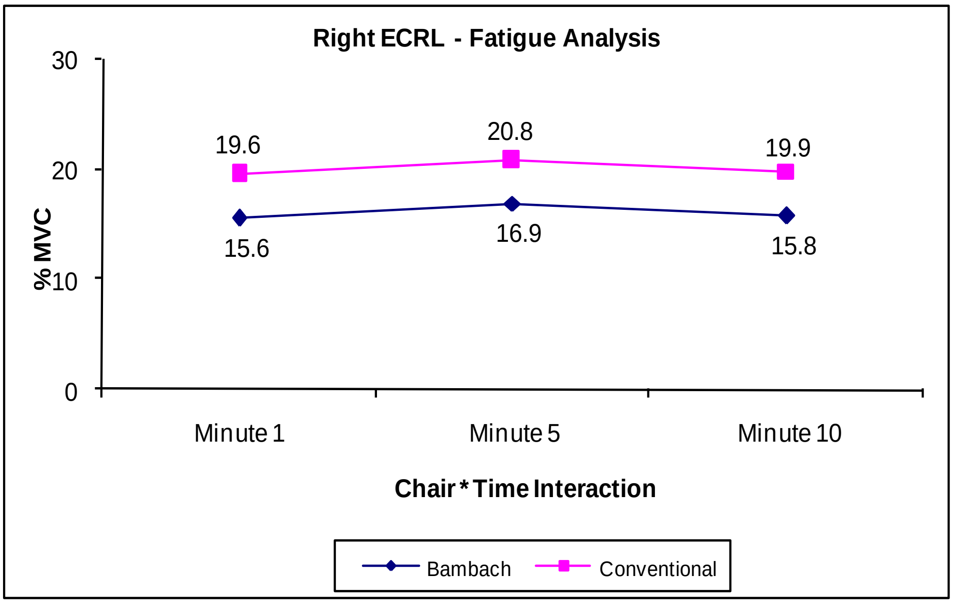


Fig. 6-61. Right ECRL (Fatigue Analysis of Students 3 Months EMG)

Generally, the pattern of fatigue was similar in students using both the seats, but there was less fatigue with back muscles was observed with BSS. There was a significant difference in the EMG activity between the seats with most of the muscles, except for back muscles in which a similar pattern was observed with the Baseline EMG. Overall, the students using BSS recorded lower muscle activity, which is more important than the fatigue component during the activity, which is negligible in BSD.

After 6 Months: Results of Minute 1 Average MVC (6 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

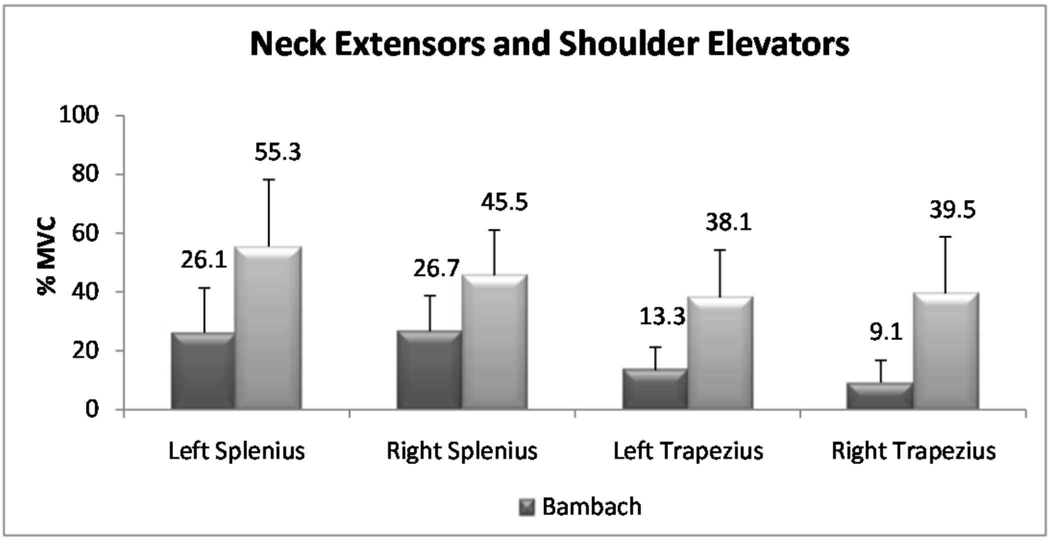


Fig. 6-62. Minute 1 Average of Splenius and Trapezius Muscles (6 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Splenius	Bambach	19	26.06	15.25	3.50	18.70	33.41	5.22	51.51
	Conventional	14	55.33	22.84	6.10	42.14	68.52	22.82	90.06
Right Splenius	Bambach	19	26.66	12.01	2.75	20.87	32.45	6.53	48.39
	Conventional	14	45.53	15.48	4.13	36.58	54.47	17.69	73.03
Left Trapezius	Bambach	19	13.27	7.89	1.81	9.46	17.07	4.1	30.4
	Conventional	14	38.06	16.18	4.32	28.71	47.40	18.0	72.3
Right Trapezius	Bambach	19	9.07	7.59	1.74	5.41	12.73	3.21	30.31
	Conventional	14	39.45	19.32	5.16	28.30	50.61	18.82	75.10

Table. 6-28. Descriptive Statistics (6 Months Students; Minute 1 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.001).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

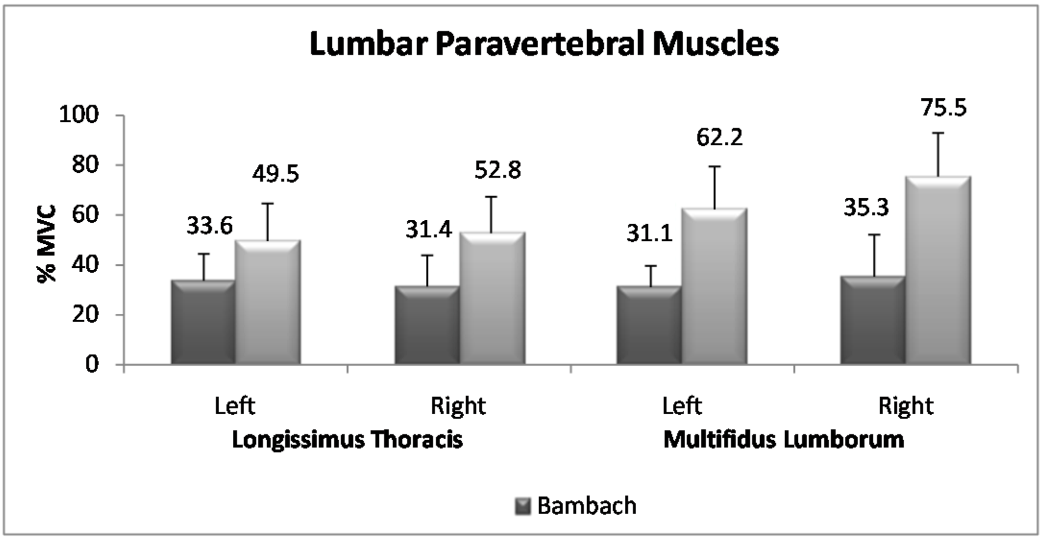


Fig. 6-63. Minute 1 Average of Lumbar Paravertebral Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	19	33.62	10.74	2.46	28.44	38.80	13.21	54.67
	Conventional	14	49.54	15.15	4.05	40.79	58.29	24.71	76.11
Right Longissimus Thoracis	Bambach	19	31.36	12.53	2.87	25.32	37.40	14.84	51.66
	Conventional	14	52.77	14.55	3.88	44.36	61.17	30.02	77.51
Left Multifidus Lumborum	Bambach	19	31.07	8.67	1.98	26.89	35.25	16.20	47.38
	Conventional	14	62.23	17.27	4.61	52.26	72.20	35.44	85.84
Right Multifidus Lumborum	Bambach	19	35.28	16.88	3.87	27.14	43.42	15.95	91.38
	Conventional	14	75.45	17.51	4.68	65.34	85.56	47.18	95.25

Table. 6-29. Descriptive Statistics (6 Months Students; Minute 1 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.013).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (p = 0.004).

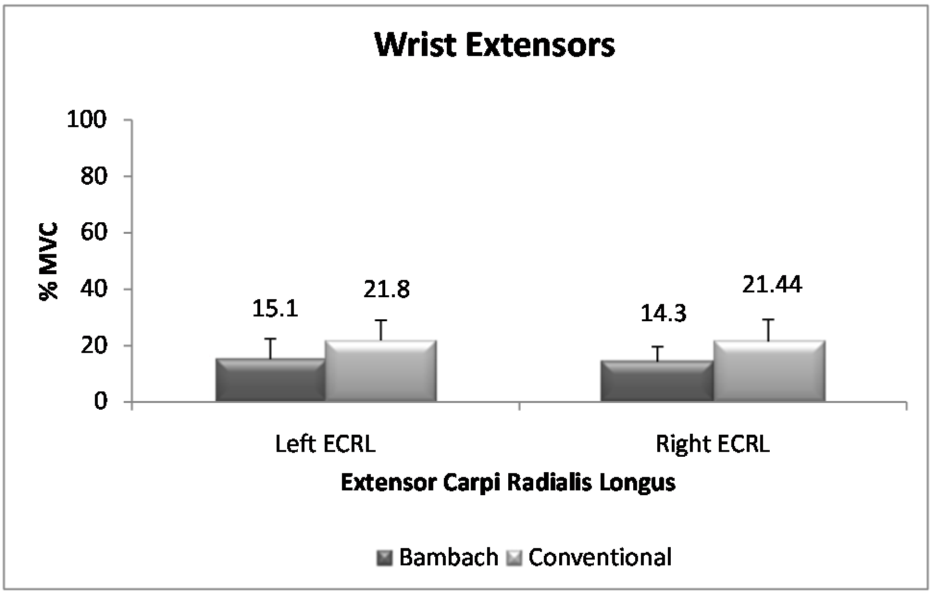


Fig. 6-64. Minute 1 Average of Wrist Extensor Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	19	15.14	7.25	1.66	11.65	18.64	4.64	33.07
	Conventional	14	21.83	7.12	1.90	17.71	25.95	9.35	33.02
Right ECRL	Bambach	19	14.30	5.26	1.20	11.76	16.84	5.95	23.71
	Conventional	14	21.43	7.85	2.09	16.90	25.96	10.02	33.38

Table. 6-30. Descriptive Statistics (6 Months Students; Minute 1 Average)

Results of Minute 5 Average MVC (6 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

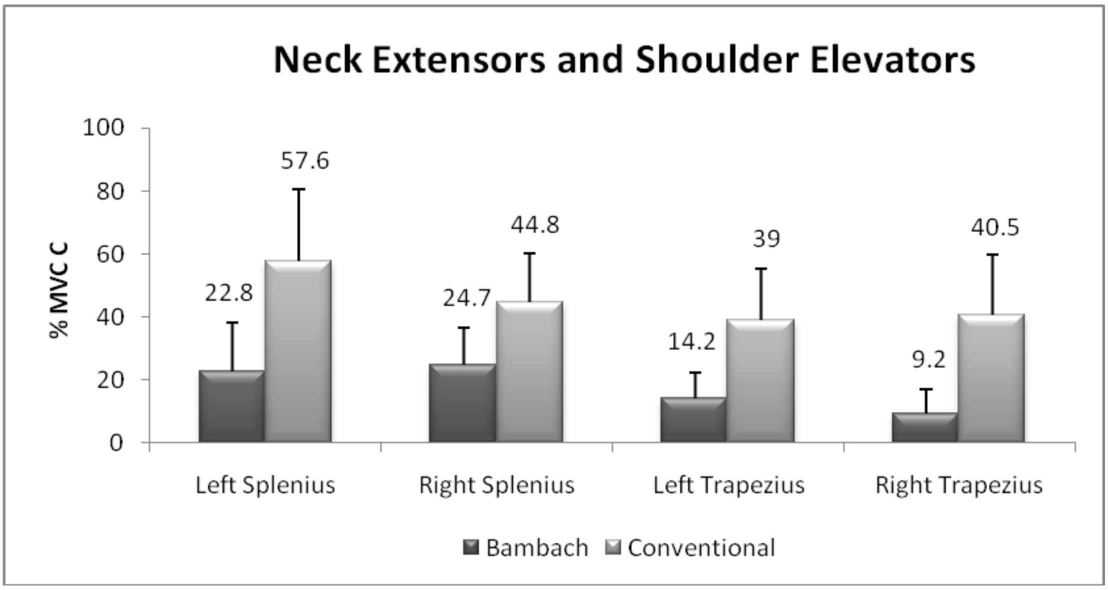


Fig. 6-65. Minute 5 Average of Splenius and Trapezius Muscles (6 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Splenius	Bambach	19	22.83	12.08	2.77	17.01	28.65	5.60	40.27
	Conventional	14	57.61	24.84	6.63	43.27	71.96	24.51	97.49
Right Splenius	Bambach	19	24.74	10.53	2.41	19.66	29.81	6.98	44.76
	Conventional	14	44.82	16.27	4.35	35.42	54.21	19.58	78.57
Left Trapezius	Bambach	19	14.17	7.51	1.72	10.55	17.80	4.66	32.84
	Conventional	14	38.95	20.04	5.35	27.38	50.52	19.77	80.28
Right Trapezius	Bambach	19	9.21	5.98	1.37	6.32	12.09	3.41	22.42
	Conventional	14	40.48	21.58	5.76	28.02	52.94	17.12	80.29

Table 6-31. Descriptive Statistics (6 Months Students; Minute 5 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

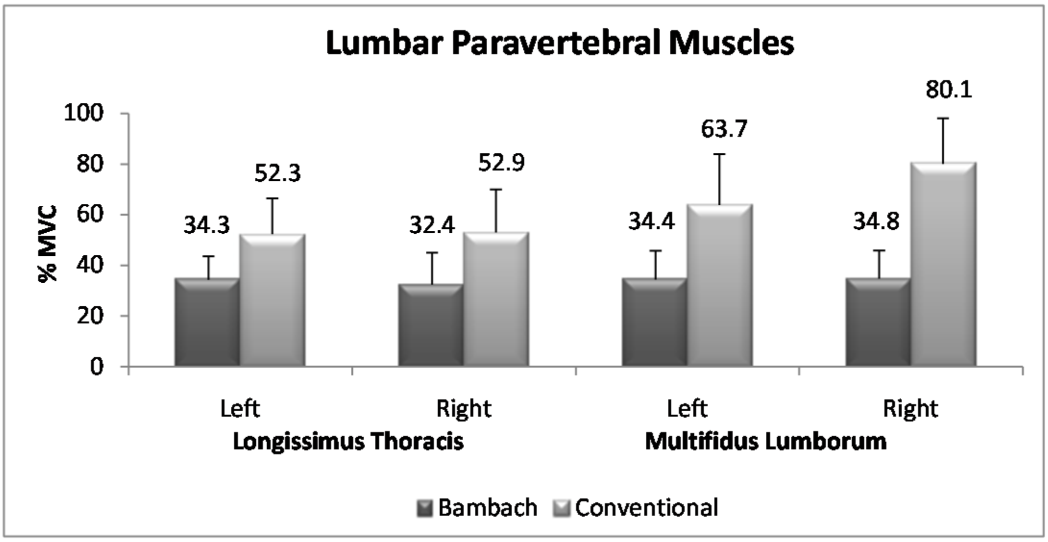


Fig. 6-66. Minute 5 Average of Lumbar Paravertebral Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	19	34.33	9.29	2.13	29.85	38.80	17.49	55.54
	Conventional	14	52.33	14.04	3.75	44.23	60.44	26.95	81.61
Right Longissimus Thoracis	Bambach	19	32.35	12.71	2.91	26.22	38.48	15.81	52.78
	Conventional	14	52.92	17.06	4.55	43.07	62.77	32.19	83.23
Left Multifidus Lumborum	Bambach	19	34.38	11.40	2.61	28.89	39.88	14.19	53.04
	Conventional	14	63.74	20.16	5.38	52.10	75.38	36.74	87.15
Right Multifidus Lumborum	Bambach	19	34.78	11.08	2.54	29.44	40.12	16.38	55.04
	Conventional	14	80.09	18.01	4.81	69.69	90.49	50.66	98.95

Table. 6-32. Descriptive Statistics (6 Months Students; Minute 5 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.001).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (p = 0.000).

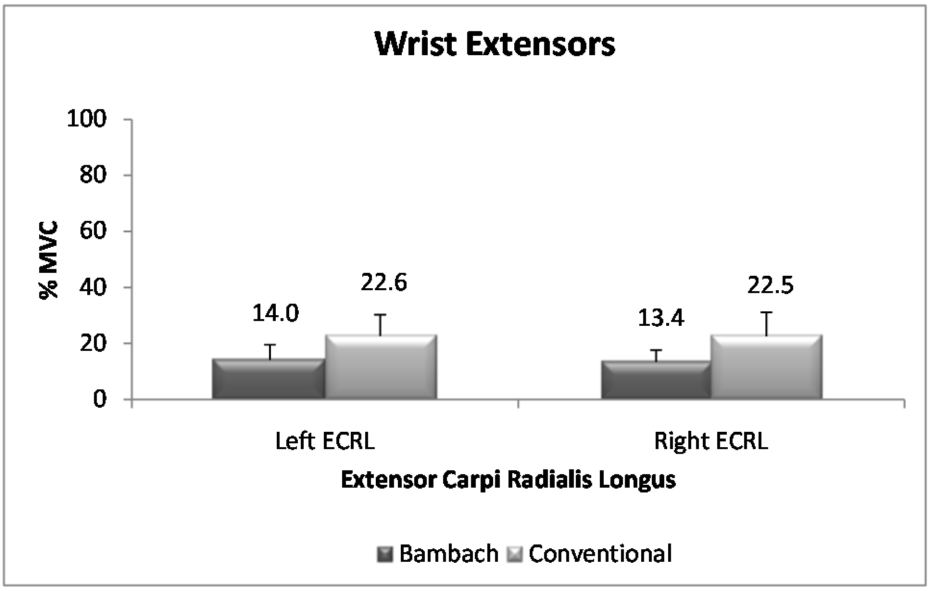


Fig. 6-67. Minute 5 Average of Wrist Extensor Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	19	14.04	5.46	1.25	11.41	16.68	4.72	24.37
	Conventional	14	22.58	7.67	2.05	18.15	27.01	9.99	39.47
Right ECRL	Bambach	19	13.35	4.27	.98	11.29	15.41	6.37	24.93
	Conventional	14	22.53	8.50	2.27	17.62	27.44	10.70	35.92

Table. 6-33. Descriptive Statistics (6 Months Students; Minute 5 Average)

Results of Minute 10 Average MVC (6 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

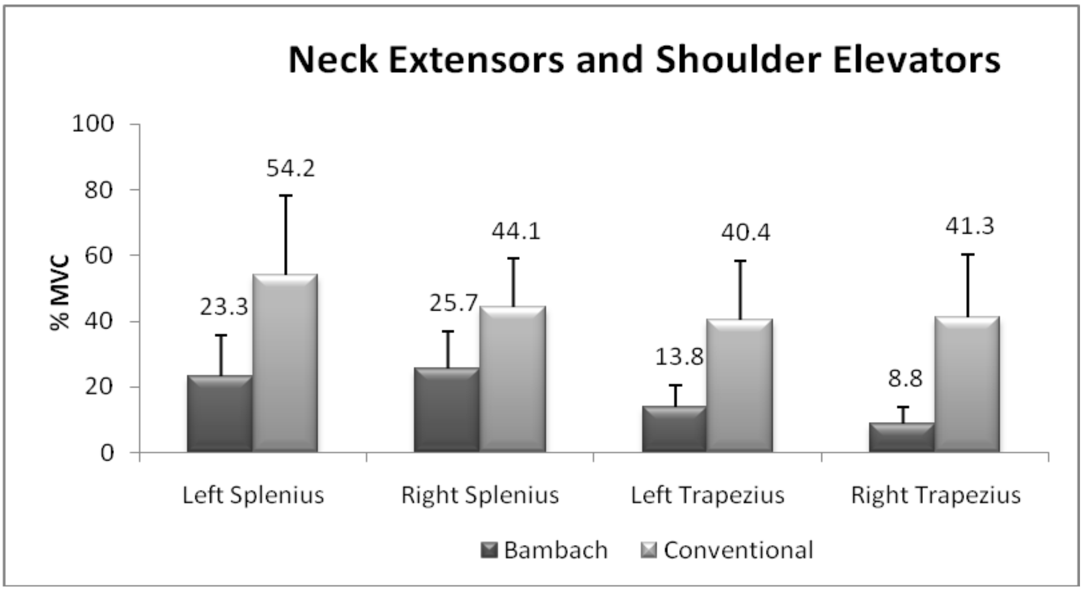


Fig. 6-68. Minute 10 Average of Splenius and Trapezius Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	19	23.25	12.41	2.84	17.26	29.23	5.27	40.25
	Conventional	14	54.19	24.11	6.44	40.27	68.12	23.16	92.46
Right Splenius	Bambach	19	25.72	11.01	2.52	20.41	31.04	6.63	41.12
	Conventional	14	44.14	14.97	4.00	35.49	52.79	19.27	74.23
Left Trapezius	Bambach	19	13.84	6.57	1.50	10.67	17.01	4.76	30.09
	Conventional	14	40.41	17.84	4.77	30.11	50.72	19.91	77.55
Right Trapezius	Bambach	19	8.84	5.08	1.16	6.38	11.29	4.07	20.96
	Conventional	14	41.28	19.06	5.09	30.27	52.29	19.30	77.27

Table. 6-34. Descriptive Statistics (6 Months Students; Minute 10 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.001).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

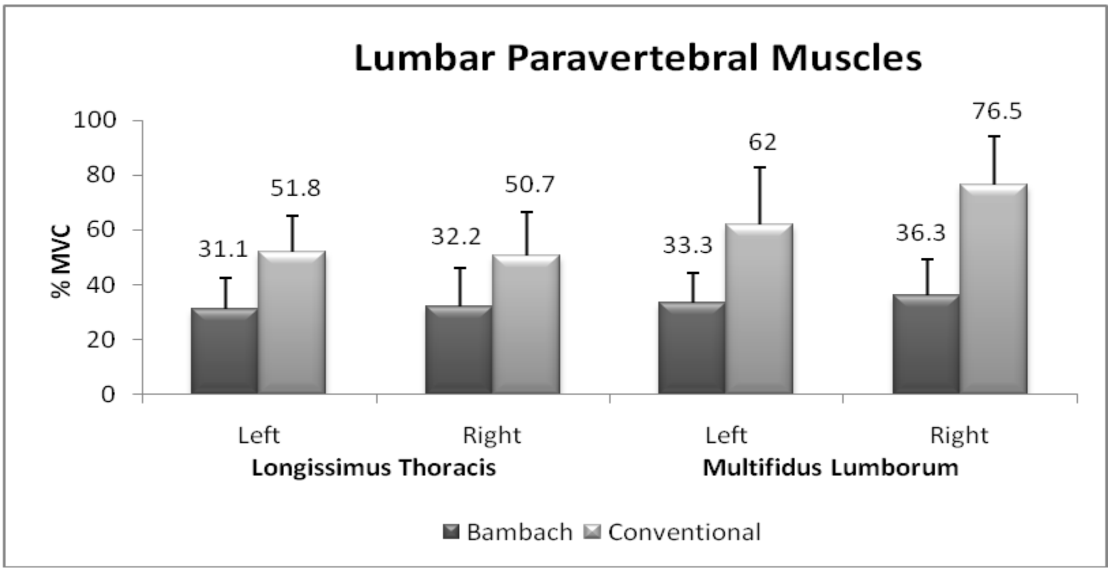


Fig. 6-69. Minute 10 Average of Lumbar Paravertebral Muscles (6 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Longissimus Thoracis	Bambach	19	31.06	11.29	2.59	25.62	36.51	8.30	49.83
	Conventional	14	51.80	13.55	3.62	43.97	59.62	24.39	76.90
Right Longissimus Thoracis	Bambach	19	32.23	14.08	3.23	25.44	39.02	14.85	52.52
	Conventional	14	50.70	15.79	4.22	41.58	59.82	30.16	78.66
Left Multifidus Lumborum	Bambach	19	33.28	10.74	2.46	28.10	38.46	19.47	53.54
	Conventional	14	62.04	21.00	5.61	49.91	74.17	33.33	89.10
Right Multifidus Lumborum	Bambach	19	36.28	13.14	3.01	29.95	42.62	16.00	54.87
	Conventional	14	76.46	17.75	4.74	66.21	86.72	47.81	96.96

Table. 6-35. Descriptive Statistics (6 Months Students; Minute 10 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated a significant difference between the two seats for the left ECRL muscles (P = 0.002).

Right: The results indicated a significant difference between the two seats for the right ECRL muscles (p = 0.004).

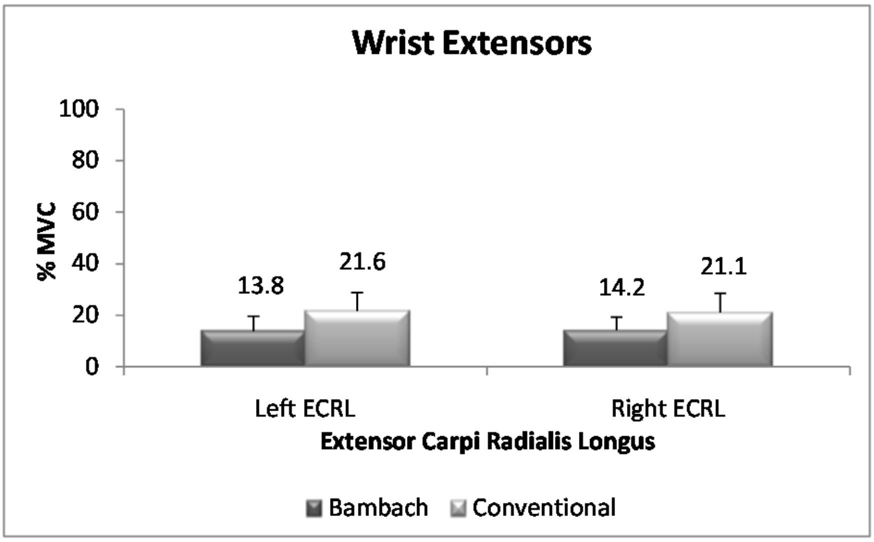


Fig. 6-70. Minute 10 Average of Wrist Extensor Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	19	13.83	5.81	1.33	11.02	16.63	4.55	23.21
	Conventional	14	21.60	7.16	1.91	17.47	25.74	9.49	33.53
Right ECRL	Bambach	19	14.22	5.00	1.14	11.80	16.63	5.99	23.48
	Conventional	14	21.09	7.53	2.01	16.74	25.44	10.14	33.92

Table. 6-36. Descriptive Statistics (6 Months Students; Minute 10 Average)

Results of 10-Minutes Average MVC (6 Months Students):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.001).

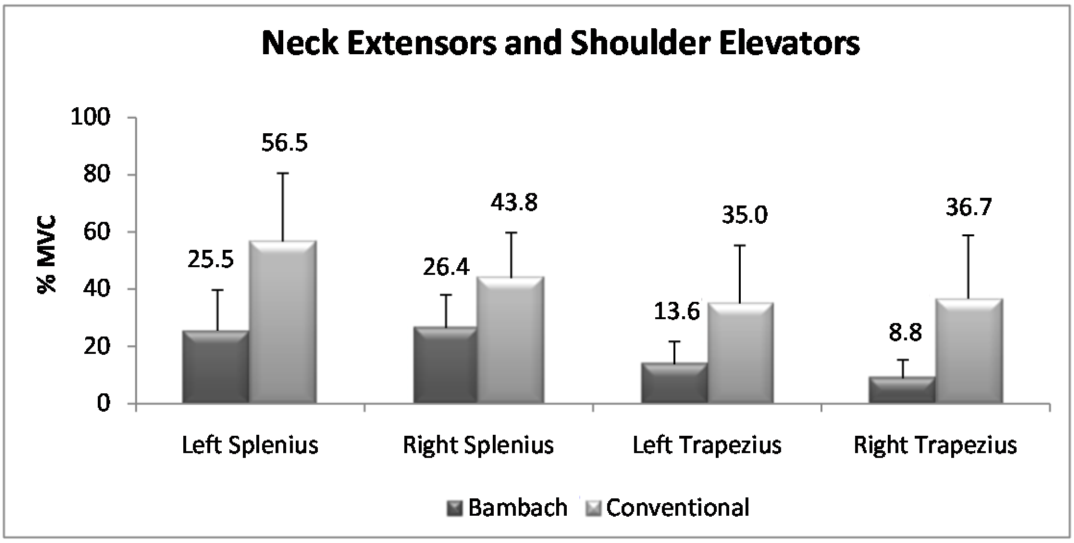


Fig. 6-71. Ten-Minutes Average of Splenius and Trapezius Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	19	25.49	14.23	3.26	18.63	32.35	5.31	43.42
	Conventional	14	56.54	23.94	6.39	42.71	70.36	23.31	92.55
Right Splenius	Bambach	19	26.35	11.66	2.67	20.72	31.97	6.68	50.15
	Conventional	14	43.80	15.97	4.26	34.57	53.02	19.05	74.66
Left Trapezius	Bambach	19	13.64	8.00	1.83	9.78	17.50	4.20	31.46
	Conventional	14	34.95	20.28	5.42	23.24	46.66	15.94	76.39
Right Trapezius	Bambach	19	8.80	6.47	1.48	5.68	11.92	3.27	23.45
	Conventional	14	36.65	22.18	5.92	23.84	49.46	16.72	76.83

Table. 6-37. Descriptive Statistics (6 Months Students; 10 Minutes Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (P = 0.007).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

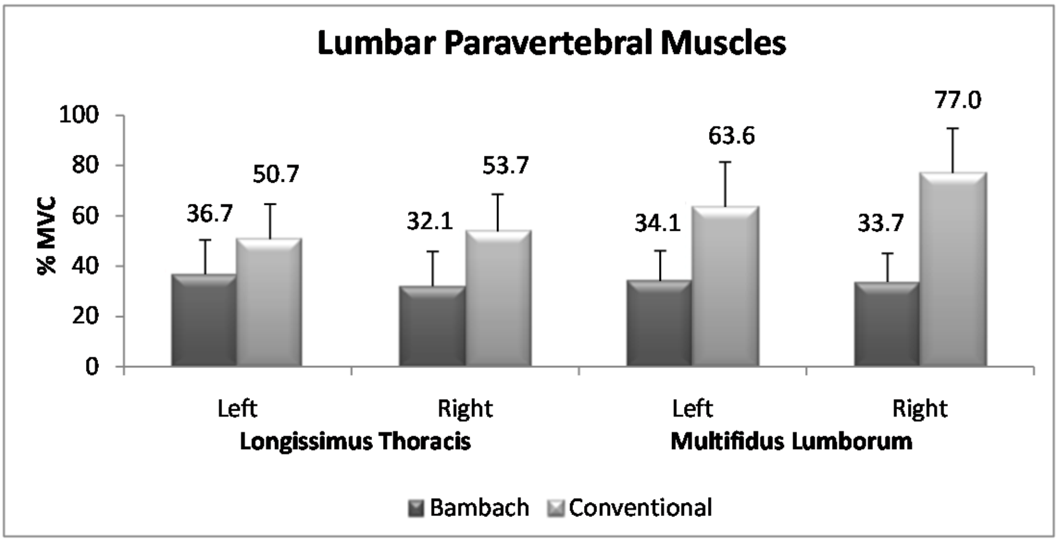


Fig. 6-72. Ten-Minutes Average of Lumbar Paravertebral Muscles (6 Months Students)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	19	36.71	13.71	3.14	30.10	43.32	16.71	61.92
	Conventional	14	50.69	14.00	3.74	42.60	58.77	23.65	77.47
Right Longissimus Thoracis	Bambach	19	32.05	13.77	3.16	25.41	38.69	15.07	53.10
	Conventional	14	53.69	14.94	3.99	45.07	62.32	29.67	79.13
Left Multifidus Lumborum	Bambach	19	34.07	12.05	2.76	28.26	39.88	13.21	55.08
	Conventional	14	63.56	17.89	4.78	53.23	73.90	41.43	84.63
Right Multifidus Lumborum	Bambach	19	33.69	11.46	2.63	28.16	39.21	16.06	52.39
	Conventional	14	76.97	17.85	4.77	66.66	87.28	48.05	97.45

Table. 6-38. Descriptive Statistics (6 Months Students; 10 Minutes Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (P = 0.000).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (P = 0.097).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.063).

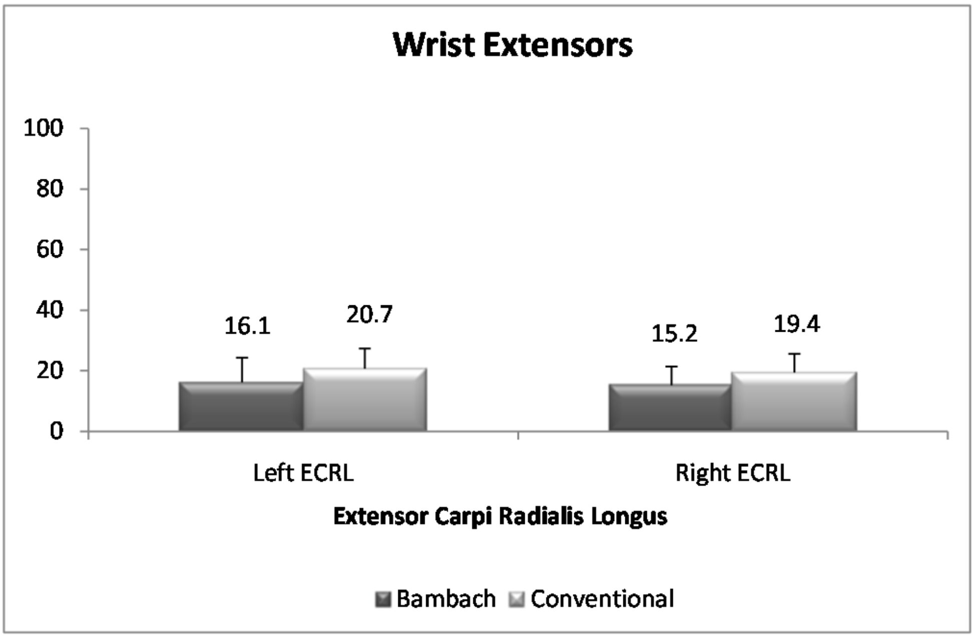


Fig. 6-73. Ten-Minutes Average of Wrist Extensor Muscles (6 Months Students)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left ECRL	Bambach	19	16.10	8.27	1.89	12.12	20.09	4.61	33.29
	Conventional	14	20.71	6.64	1.77	16.87	24.54	9.54	33.75
Right ECRL	Bambach	19	15.22	6.17	1.41	12.24	18.19	6.06	26.41
	Conventional	14	19.43	6.23	1.66	15.83	23.03	10.21	32.91

Table. 6-39. Descriptive Statistics (6 Months Students; 10 Minutes Average)

Summary of the 6 Months EMG Results of Students

The results for the 6 Months EMG were different when compared with the Baseline and 3 months' EMG. Comparing the neck extensors and shoulder elevators, the BSS recorded significantly less muscle activity when compared with CSS. The BSS 6 months' muscle activity was significantly less when compared to the baseline and 3 months but the CSS 6 months' muscle activity was significantly increased when compared with Baseline and 3 Months. Comparing lumbar paravertebral muscles, the Bambach seat students recorded significantly less muscle activity when compared with Conventional seat students. The results were significantly different when compared with Baseline and 3 Months EMG where there was no significant difference in EMG activity found between seats. Comparing the wrist extensors there was no significant difference between seats, this being different when baseline and 3 months EMG for this muscle were compared.

Fatigue Analysis of Students EMG at Minute 1, 5 and 10 (6 Months)

A common pattern was observed with the students comparing minute 1, 5 and 10 of their EMG activity. The %MVC of minute 1 and 10 were comparable to the 10-minute average in most of the students, but the %MVC of minute 5 was a little increased in most of the students. A similar pattern was also observed with students at baseline and at 3 months.

Left Splenius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 with CSS, whereas the EMG activity slightly decreased from minute 1 to 5 and slightly increased at minute 10 with BSS (Fig. 6-74).

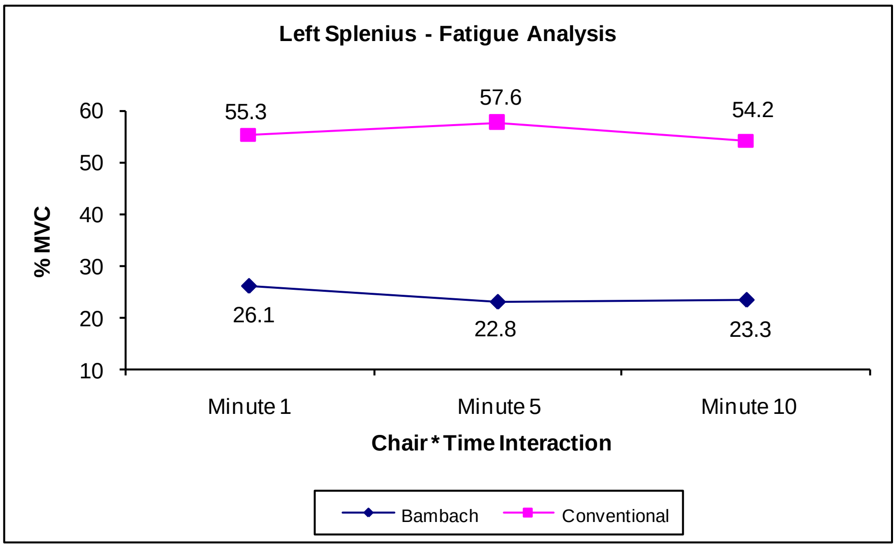


Fig. 6-74. Left Splenius Muscle (Fatigue Analysis of Students 6 Months EMG)

Right Splenius Muscle: The EMG activity gradually decreased from minute 1 to 5 with students in both the groups but at minute 10 the EMG activity slightly increased with BSS and slightly decreased with CSS (Fig. 6-75).

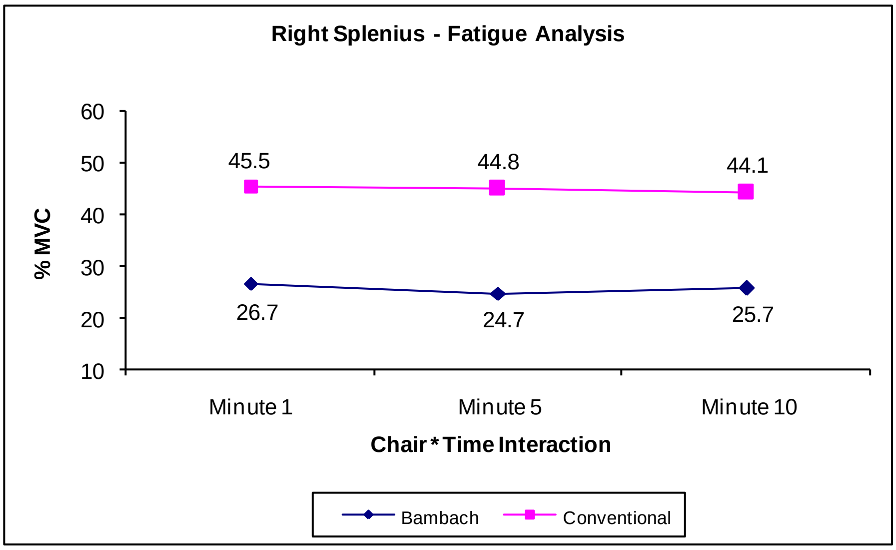


Fig. 6-75. Right Splenius Muscle (Fatigue Analysis of Students 6 Months EMG)

Left Trapezius Muscle: The EMG activity gradually increased from minute 1 to 5 and remained the same at minute 10 in both the groups of students (Fig. 6-76).

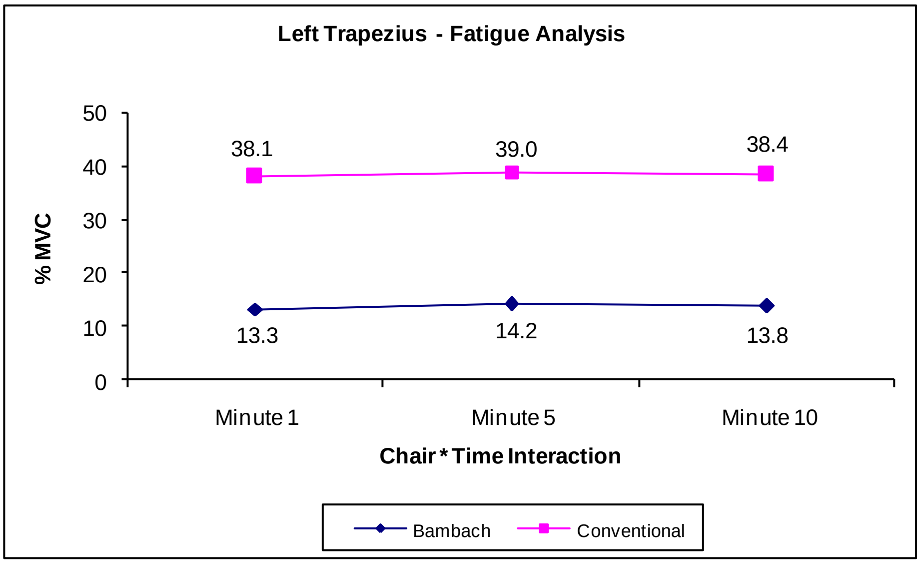


Fig. 6-76. Left Trapezius Muscle (Fatigue Analysis of Students 6 Months EMG)

Right Trapezius Muscle: The EMG activity gradually increased through minute 1, 5 and 10 for the CSS, whereas the opposite occurred with BSS (Fig. 6-77).

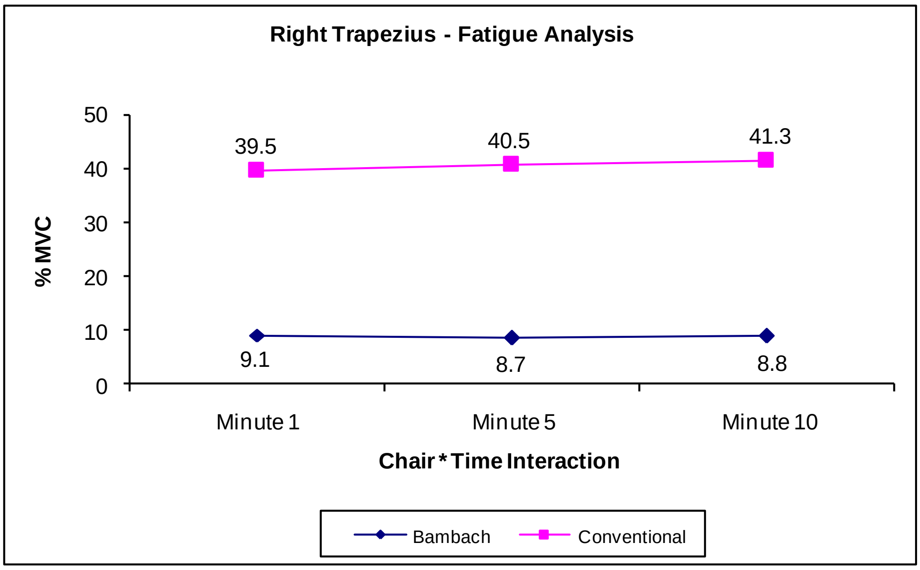


Fig. 6-77. Right Trapezius Muscle (Fatigue Analysis of Students 6 Months EMG)

Left Longissimus Thoracis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in students using both the seats (Fig. 6-78).

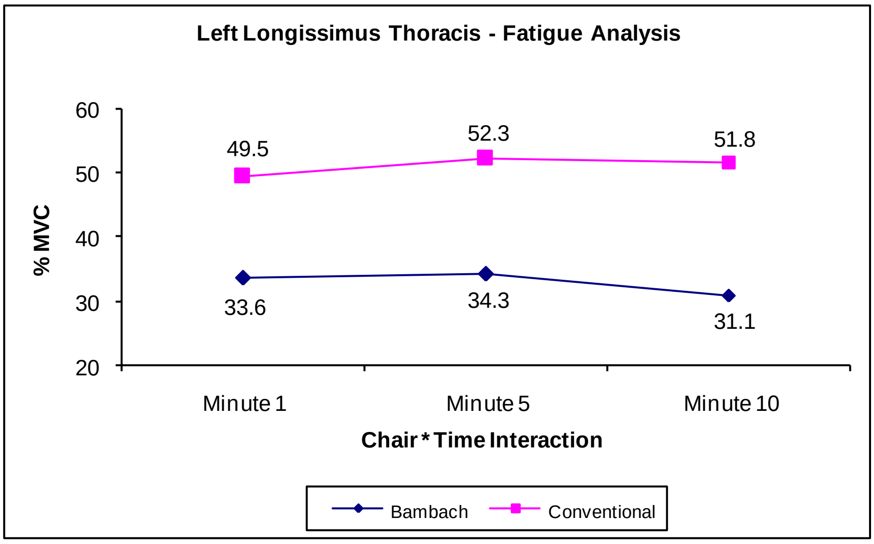


Fig. 6-78. Left Longissimus Thoracis (Fatigue Analysis of Students 6 Months EMG)

Right Longissimus Thoracis Muscle: The EMG activity of BSS slightly increased from minute 1 to 5 and 10, whereas with the CSS the EMG activity slightly increased from minute 1 to 5 but the EMG activity significantly increased from minute 5 to 10 indicative of fatigue (Fig. 6-79).

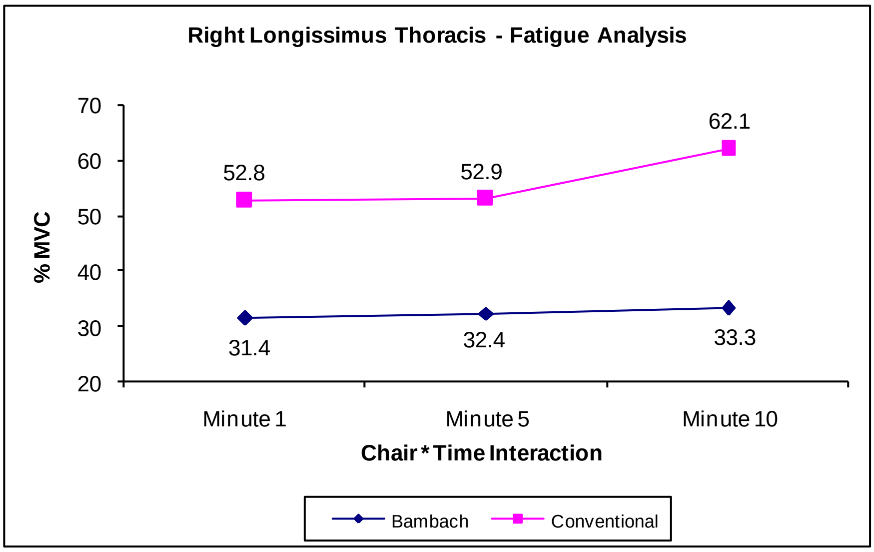


Fig. 6-79. Right Longissimus Thoracis (Fatigue Analysis of Students 6 Months EMG)

Left Multifidus Lumborum Muscle: The EMG activity of BSS slightly increased from minute 1 to 5 and decreased at minute 10, whereas the EMG activity of CSS slightly increased at minute 5 but significantly decreased at minute 10 (Fig. 6-80).

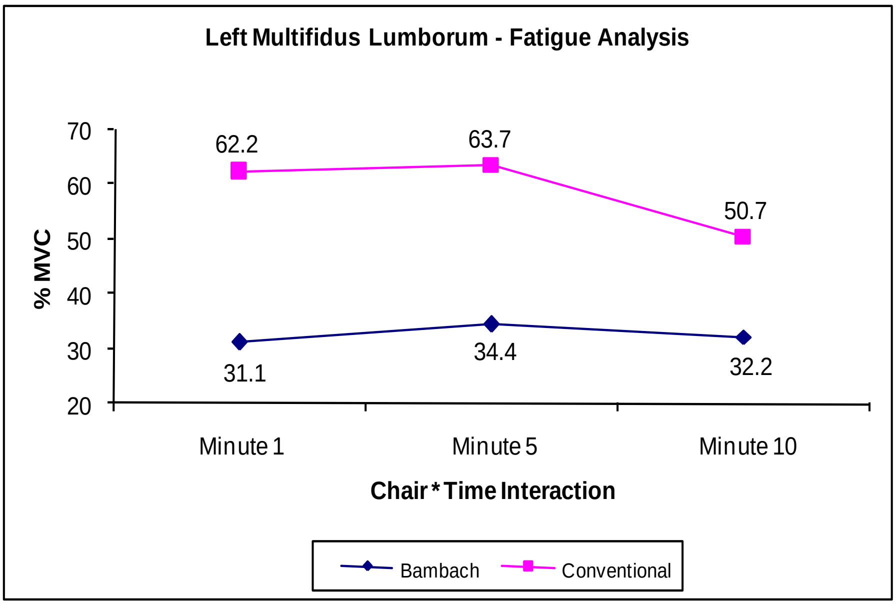


Fig. 6-80. Left Multifidus Lumborum (Fatigue Analysis of Students 6 Months EMG)

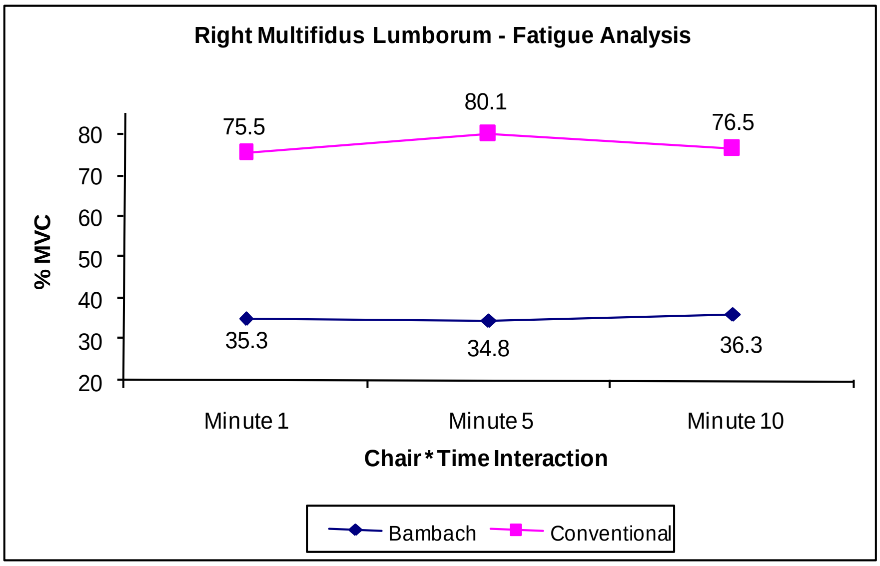


Fig. 6-81. Right Multifidus Lumborum (Fatigue Analysis of Students 6 Months EMG)

Right Multifidus Lumborum Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 with CSS, whereas the EMG activity slightly decreased from minute 1 to 5 and slightly increased at minute 10 with BSS (Fig. 6-81).

Left Extensor Carpi Radialis Muscle: The EMG activity slightly increased from minute 1 to 5 and decreased at minute 10 with CSS, whereas the EMG activity gradually decreased from minute 1 to 5 and remained the same at minute 10 indicating less fatigue when using Bambach seat (Fig. 6-82).

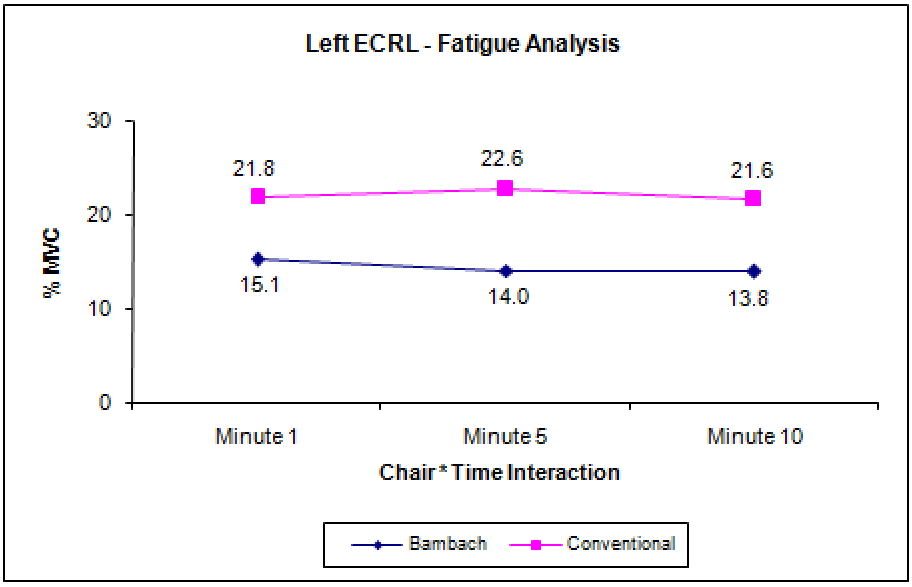
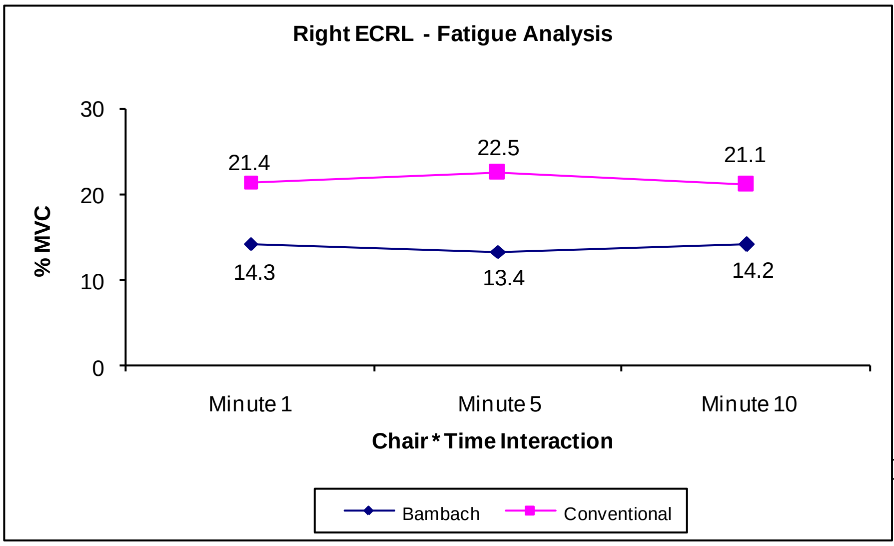


Fig. 6-82. Left ECRL (Fatigue Analysis of Students 6 Months EMG)

Right Extensor Carpi Radialis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 with CSS, whereas the EMG activity slightly decreased from minute 1 to 5 and slightly increased at minute 10 with BSS (Fig. 6-83).



G)

The pattern of fatigue varied with the BSS when compared to the baseline and 3 months EMG i.e. in the muscles observed there is less potential for muscular fatigue when using the BSS. The results were also found to be significant when baseline and 3 months are compared. Overall, the students using Bambach saddle seat recorded significantly lower muscle activity in all the muscles except the ECRL, which may be considered to be more important than the fatigue component during the activity, this being negligible with the Bambach seat students.

6.7.6 Methodology of EMG Study (Dentists):

The EMG study of dentists was undertaken at dental clinics across the West Midlands.

Subjects

The study was introduced to all the dentists who participated in the questionnaire study (Refer to Chapter 2, Section 2.2.4). At the end of the questionnaire they were given information about the EMG study and were asked if they are willing to participate in this further study. If willing, they were asked to complete and return the section at the end of the questionnaire. An information sheet (Appendix XXIX) and a consent form (Appendix XXX) were sent to the dentists who were willing to participate in the EMG study. Twenty-five dentists agreed to participate. The participants were then contacted by phone by the researcher and appointments were arranged. The researcher then visited the dental surgery and data was collected from 12 Bambach seat dentists (BSD) and 10 Conventional seat dentists (CSD).

Apparatus

a. EMG Apparatus
b. Electrodes: Bipolar Electrodes, interfaces and reference electrode
c. A digital camera for taking photographs during the study

Procedure:

Before the study the dentists were asked to complete the consent form that had been sent to them and a consent form for taking photographs (Appendix XVI). The patient undergoing treatment at the time of the data collection was informed of the study and their consent was obtained for photography (Appendix XVII). The procedure and the placement of electrodes were explained to the participating dentists before the commencement of the study. The skin preparation, placement of electrodes, and the method of MVC measurement, were similar to the method used with students (Section 6.7.4). When the dentists were ready the EMG apparatus was switched on and then the dentists were instructed to start the dental procedure (Chapter 3, Section 3.18.1).

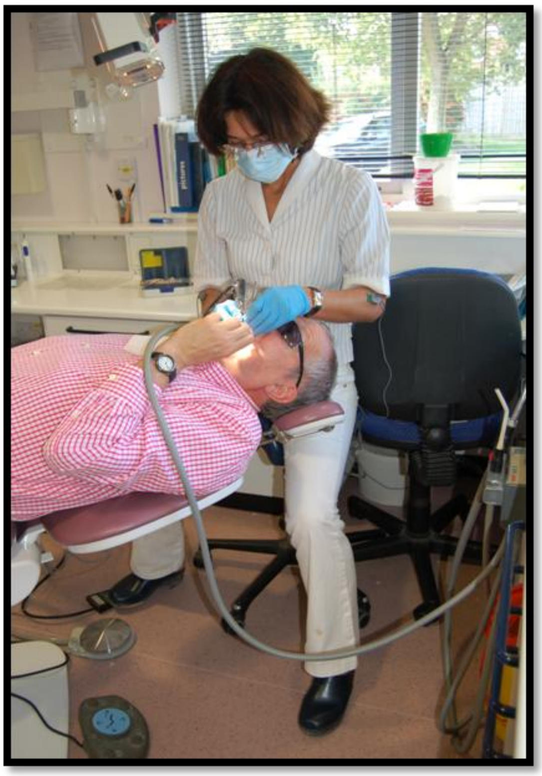


Fig. 6-84. A Dentist seated on a Bambach Saddle Seat

Fig. 6-85. A Dentist seated on a Conventional Seat

During the procedure photos were taken at various angles, which are explained in Chapter 2 (Section 2.14.1). After the ten-minute period the EMG apparatus automatically switches off. The electrodes were removed from by the researcher after the dental procedure was completed and the patient had left the surgery.

6.7.7 Results - Dentists: The results were presented similar to the students.

Results of Minute 1 Average MVC (Dentists):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (p = 0.001).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

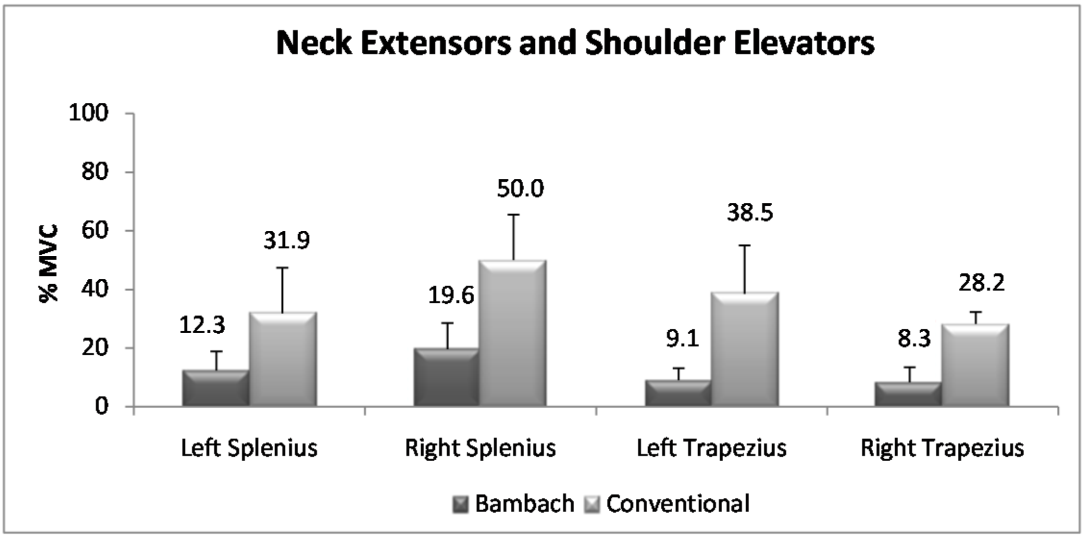


Fig. 6-86. Minute 1 Average of Splenius and Trapezius Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	12	12.33	6.53	1.88	8.17	16.48	5.46	27.58
	Conventional	10	31.85	15.54	4.91	20.73	42.97	13.27	58.14
Right Splenius	Bambach	12	19.61	8.88	2.56	13.96	25.26	2.24	29.60
	Conventional	10	49.98	15.50	4.90	38.89	61.07	27.15	75.12
Left Trapezius	Bambach	12	9.09	4.11	1.18	6.48	11.70	3.02	16.86
	Conventional	10	38.50	16.44	5.20	26.73	50.26	23.47	77.43
Right Trapezius	Bambach	12	8.33	5.24	1.51	5.00	11.67	3.00	19.32
	Conventional	10	28.23	4.17	1.31	25.25	31.22	23.07	34.61

Table. 6-40. Descriptive Statistics (Dentists; Minute 1 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (p = 0.002).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

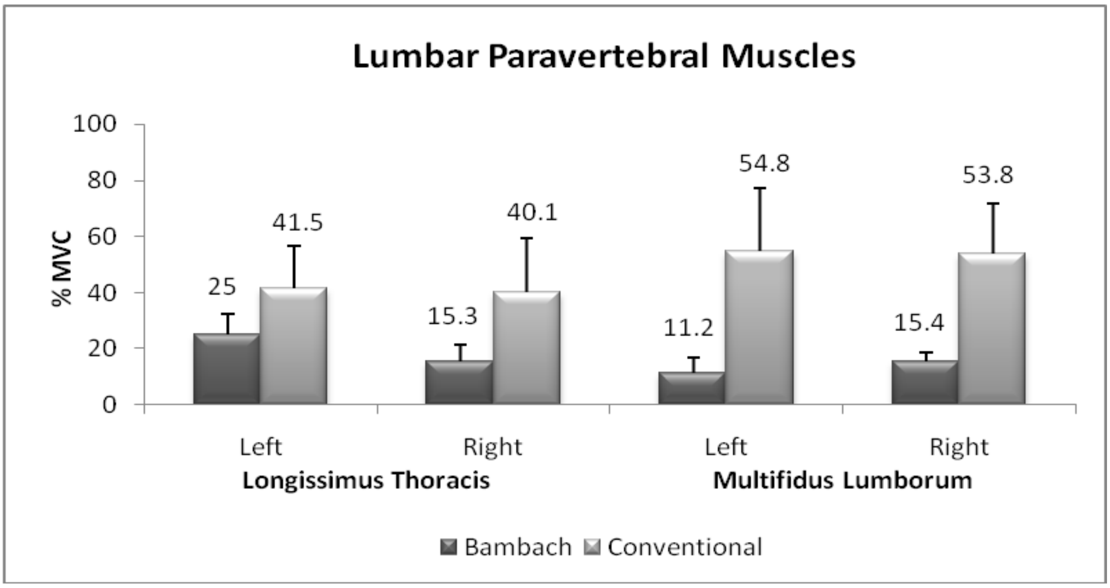


Fig. 6-87. Minute 1 Average of Lumbar Paravertebral Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left Longissimus Thoracis	Bambach	12	25.01	7.30	2.10	20.37	29.65	16.90	41.90
	Conventional	10	41.54	14.05	4.44	31.48	51.59	23.08	61.24
Right Longissimus Thoracis	Bambach	12	15.29	6.50	1.87	11.16	19.42	8.85	30.68
	Conventional	10	40.12	15.15	4.79	29.28	50.96	25.14	66.09
Left Multifidus Lumborum	Bambach	12	11.19	7.67	2.21	6.31	16.07	3.27	28.62
	Conventional	10	54.77	22.34	7.06	38.79	70.76	31.36	98.76
Right Multifidus Lumborum	Bambach	12	15.35	3.14	.90	13.36	17.35	10.66	20.17
	Conventional	10	53.79	16.30	5.15	42.12	65.45	30.28	81.38

Table. 6-41. Descriptive Statistics (Dentists; Minute 1 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (p = 0.380).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.989).

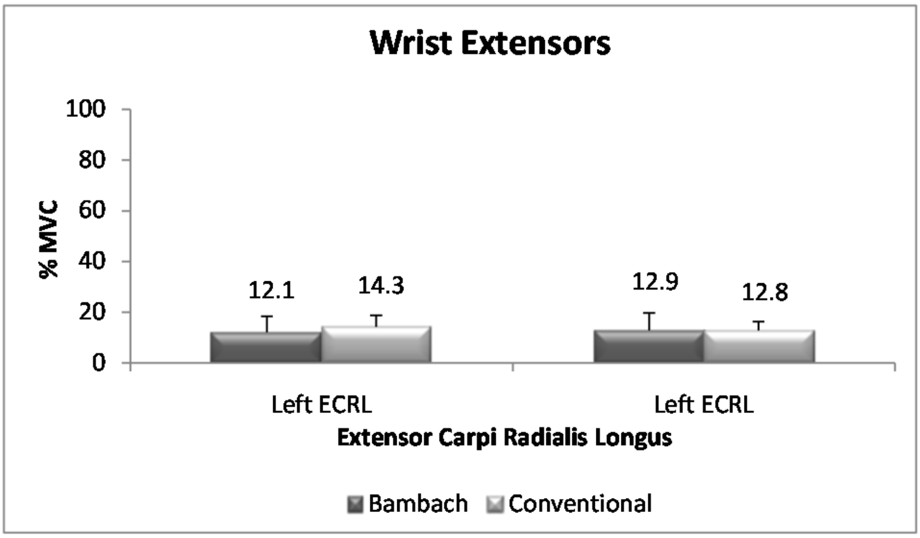


Fig. 6-88. Minute 1 Average of Wrist Extensor Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	12	12.10	6.31	1.82	8.09	16.11	5.66	24.44
	Conventional	10	14.25	4.51	1.42	11.01	17.48	8.59	20.63
Right ECRL	Bambach	12	12.85	6.93	2.00	8.44	17.26	6.62	26.12
	Conventional	10	12.82	3.53	1.11	10.29	15.34	6.52	16.24

Table. 6-42. Descriptive Statistics (Dentists; Minute 1 Average)

Results of Minute 5 Average MVC (Dentists):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles ($p = 0.000$).

Right: The results indicated a significant difference between the two seats for the right splenius muscles ($p = 0.000$).

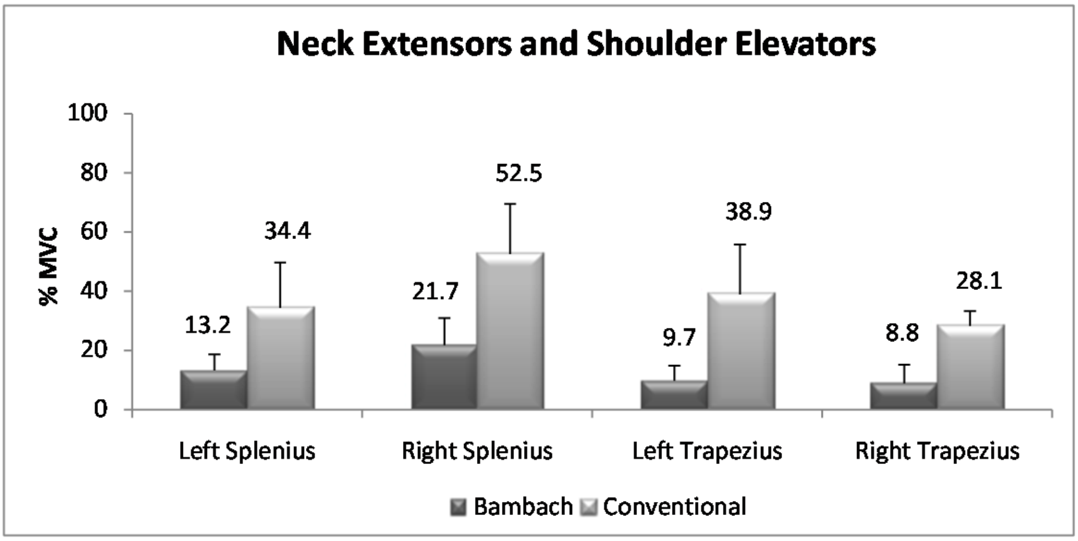


Fig. 6-89. Minute 5 Average of Splenius and Trapezius Muscles (Dentists)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Splenius	Bambach	12	13.17	5.53	1.59	9.66	16.69	6.82	24.77
	Conventional	10	34.36	15.32	4.84	23.40	45.32	14.84	62.92
Right Splenius	Bambach	12	21.65	9.25	2.67	15.76	27.53	2.40	31.41
	Conventional	10	52.54	16.88	5.33	40.46	64.61	27.77	80.73
Left Trapezius	Bambach	12	9.68	5.12	1.47	6.43	12.94	3.41	17.75
	Conventional	10	38.91	16.79	5.30	26.89	50.92	23.49	79.61
Right Trapezius	Bambach	12	8.81	6.28	1.81	4.82	12.80	1.03	21.21
	Conventional	10	28.14	5.08	1.60	24.50	31.77	21.23	34.86

Table. 6-43. Descriptive Statistics (Dentists; Minute 5 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles ($p = 0.000$).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles ($p = 0.000$).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (p = 0.001).

Right: The results indicated a significant difference between the two seats fo the right longissimus thoracis muscles (p = 0.001).

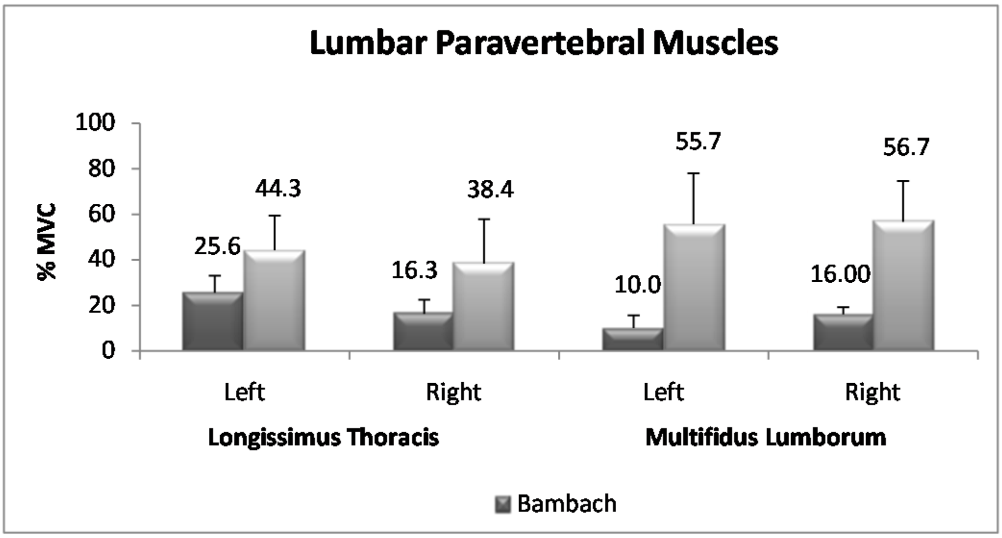


Fig. 6-90. Minute 5 Average of Lumbar Paravertebral Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	12	25.55	7.44	2.14	20.82	30.28	17.64	42.30
	Conventional	10	44.25	15.17	4.79	33.40	55.10	27.59	68.03
Right Longissimus Thoracis	Bambach	12	16.28	6.24	1.80	12.32	20.25	9.52	29.89
	Conventional	10	38.37	19.47	6.15	24.43	52.30	4.08	70.77
Left Multifidus Lumborum	Bambach	12	9.98	5.62	1.62	6.40	13.55	3.41	21.11
	Conventional	10	55.65	22.43	7.09	39.60	71.69	31.31	94.18
Right Multifidus Lumborum	Bambach	12	15.99	3.25	.93	13.93	18.06	9.05	21.29
	Conventional	10	56.68	18.07	5.71	43.75	69.61	32.49	87.48

Table. 6-44. Descriptive Statistics (Dentists; Minute 5 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats fo the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (p = 0.355).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.939).

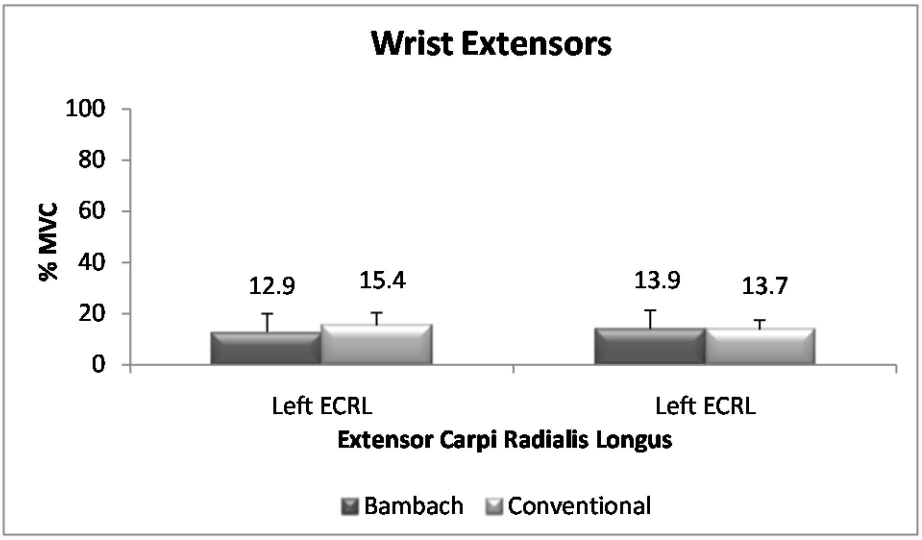


Fig. 6-91. Minute 5 Average of Wrist Extensor Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	12	12.86	7.09	2.04	8.35	17.37	4.20	26.47
	Conventional	10	15.38	4.94	1.56	11.84	18.92	9.21	22.15
Right ECRL	Bambach	12	13.94	7.46	2.15	9.19	18.68	7.11	28.15
	Conventional	10	13.73	3.72	1.17	11.07	16.40	7.02	17.39

Table. 6-45. Descriptive Statistics (Dentists; Minute 5 Average)

Results of Minute 10 Average MVC (Dentists):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

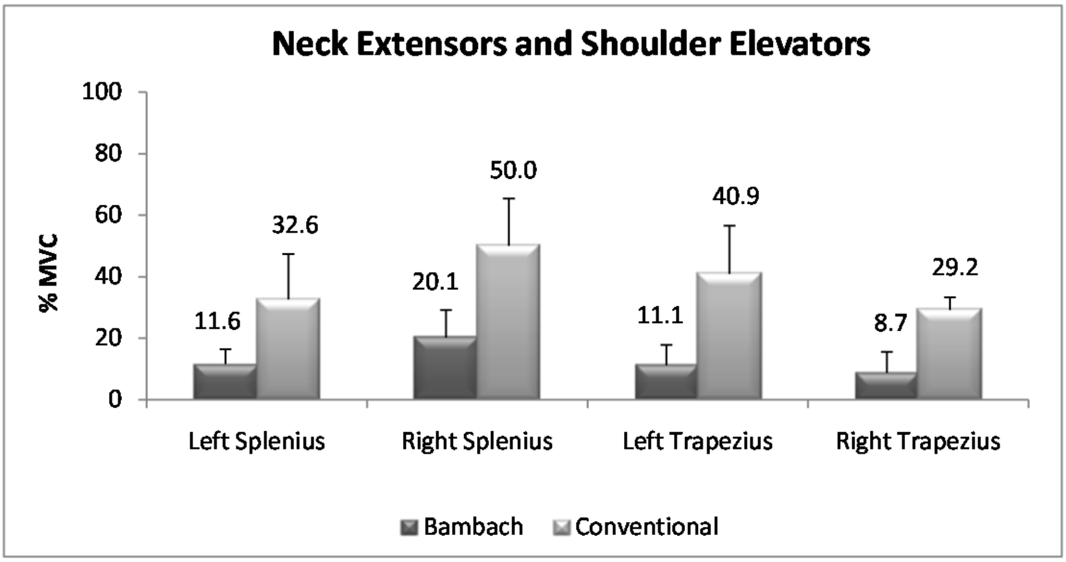


Fig. 6-92. Minute 10 Average of Splenius and Trapezius Muscles (Dentists)

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Left Splenius	Bambach	12	11.56	4.83	1.39	8.49	14.63	2.93	20.39
	Conventional	10	32.58	14.75	4.66	22.03	43.13	14.05	59.50
Right Splenius	Bambach	12	20.14	8.97	2.59	14.43	25.84	2.30	29.64
	Conventional	10	50.00	15.41	4.87	38.97	61.03	27.27	76.32
Left Trapezius	Bambach	12	11.14	6.71	1.93	6.87	15.40	3.78	24.81
	Conventional	10	40.94	15.70	4.96	29.70	52.17	23.00	76.86
Right Trapezius	Bambach	12	8.71	6.82	1.97	4.38	13.05	2.18	24.63
	Conventional	10	29.17	4.15	1.31	26.20	32.14	23.78	36.42

Table. 6-46. Descriptive Statistics (Dentists; Minute 10 Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (p = 0.001).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.000).

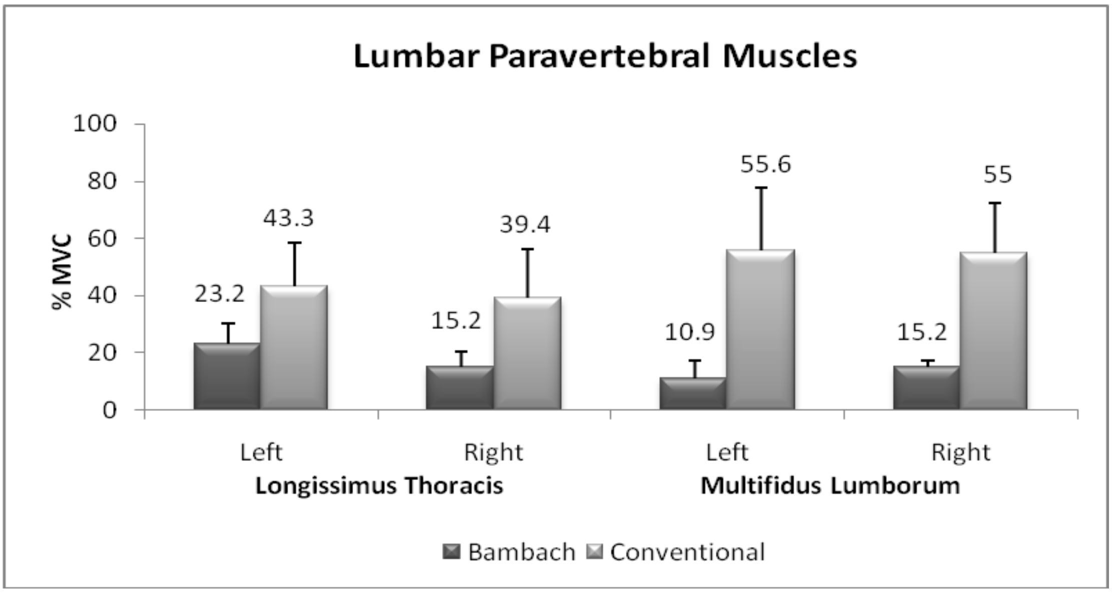


Fig. 6-93. Minute 10 Average of Lumbar Paravertebral Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	12	23.16	7.14	2.06	18.62	27.69	14.90	41.34
	Conventional	10	43.30	15.08	4.77	32.50	54.09	28.02	65.94
Right Longissimus Thoracis	Bambach	12	15.17	5.25	1.51	11.83	18.52	9.23	26.32
	Conventional	10	39.41	16.64	5.26	27.51	51.31	23.32	69.15
Left Multifidus Lumborum	Bambach	12	10.87	6.50	1.87	6.73	15.00	3.06	25.67
	Conventional	10	55.63	22.21	7.02	39.74	71.52	30.19	95.59
Right Multifidus Lumborum	Bambach	12	15.22	2.03	.58	13.93	16.52	12.09	19.22
	Conventional	10	54.96	17.44	5.51	42.47	67.44	33.87	87.74

Table. 6-47. Descriptive Statistics (Dentists; Minute 10 Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats fo the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (p = 0.658).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.946).

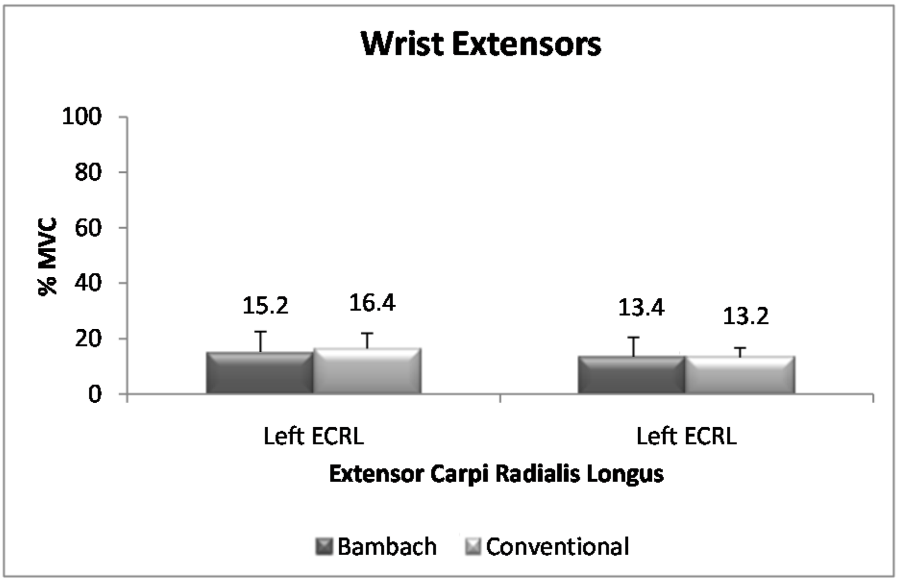


Fig. 6-94. Minute 10 Average of Wrist Extensor Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left ECRL	Bambach	12	15.15	7.40	2.13	10.44	19.86	6.08	28.88
	Conventional	10	16.43	5.56	1.75	12.45	20.41	9.93	23.40
Right ECRL	Bambach	12	13.40	7.11	2.05	8.88	17.92	6.68	26.85
	Conventional	10	13.23	3.44	1.08	10.77	15.70	7.52	16.64

Table. 6-48. Descriptive Statistics (Dentists; Minute 10 Average)

Results of 10-Minutes Average MVC (Dentists):

Splenius Muscles:

Left: The results indicated a significant difference between the two seats for the left splenius muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.000).

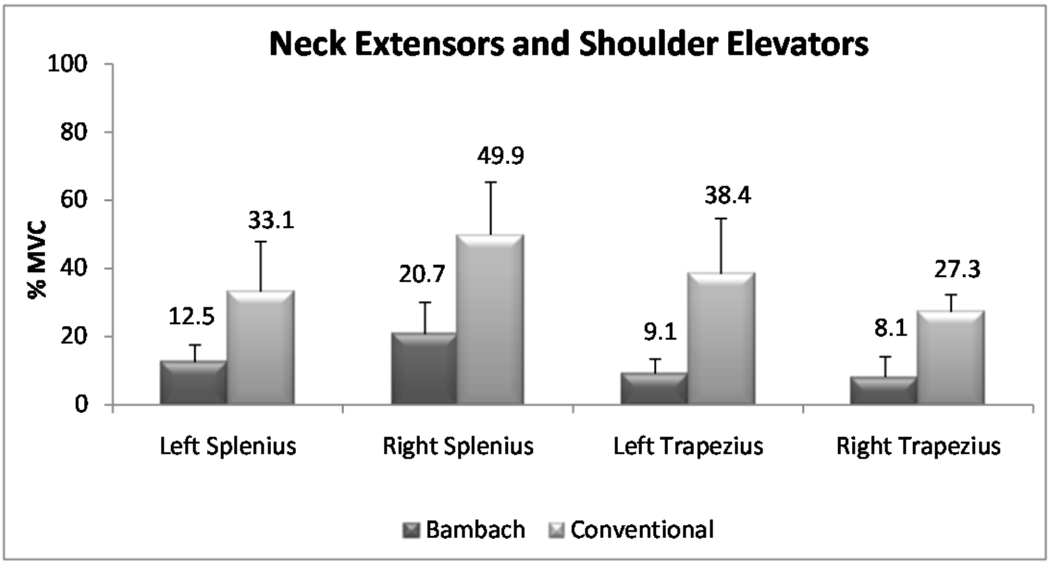


Fig. 6-95. Ten-Minutes Average of Splenius and Trapezius Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	12	12.51	5.02	1.45	9.32	15.71	5.79	22.89
	Conventional	10	33.10	14.74	4.66	22.55	43.64	14.36	59.72
Right Splenius	Bambach	12	20.66	9.41	2.71	14.67	26.64	1.84	31.13
	Conventional	10	49.87	15.5	4.91	38.74	61.00	27.35	76.79
Left Trapezius	Bambach	12	9.08	4.32	1.24	6.33	11.83	3.23	16.77
	Conventional	10	38.35	16.28	5.15	26.69	50.00	23.39	78.12
Right Trapezius	Bambach	12	8.06	5.99	1.73	4.25	11.87	.80	20.02
	Conventional	10	27.26	5.07	1.60	23.62	30.89	20.12	34.66

Table. 6-49. Descriptive Statistics (Dentists; 10 Minutes Average)

Trapezius Muscles:

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.000).

Longissimus Thoracis Muscles (L1 Level):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (p = 0.002).

Right: The results indicated a significant difference between the two seats fo the right longissimus thoracis muscles (p = 0.000).

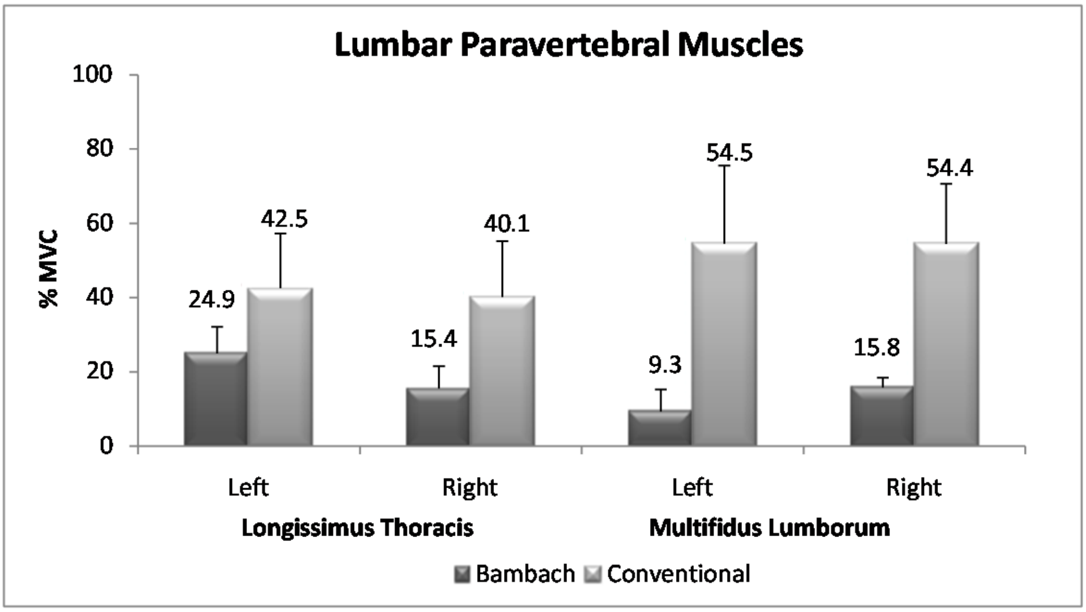


Fig. 6-96. Ten-Minutes Average of Lumbar Paravertebral Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Longissimus Thoracis	Bambach	12	24.93	7.14	2.06	20.39	29.47	16.42	40.81
	Conventional	10	42.47	14.73	4.65	31.93	53.01	25.32	64.53
Right Longissimus Thoracis	Bambach	12	15.44	6.09	1.76	11.57	19.32	9.15	28.98
	Conventional	10	40.09	15.05	4.76	29.32	50.86	25.45	67.29
Left Multifidus Lumborum	Bambach	12	9.30	5.95	1.71	5.52	13.08	3.27	21.12
	Conventional	10	54.45	21.10	6.67	39.35	69.55	31.33	91.56
Right Multifidus Lumborum	Bambach	12	15.75	2.64	.76	14.07	17.43	12.56	20.46
	Conventional	10	54.40	16.27	5.14	42.76	66.04	30.89	83.18

Table. 6-50. Descriptive Statistics (Dentists; 10 Minutes Average)

Multifidus Lumborum Muscles (L5 Level):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles (p = 0.000).

Right: The results indicated a significant difference between the two seats fo the right multifidus lumborum muscles (p = 0.000).

Extensor Carpi Radialis Longus Muscles (ECRL):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (p = 0.334).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.998).

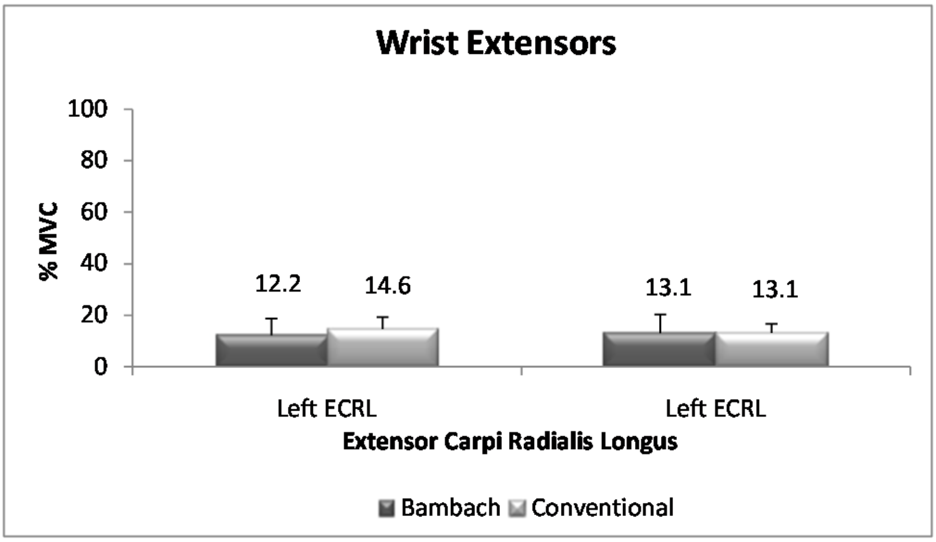


Fig. 6-97. Ten-Minute Average of Wrist Extensor Muscles (Dentists)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	12	12.15	6.56	1.89	7.99	16.32	5.85	25.80
	Conventional	10	14.61	4.70	1.48	11.25	17.97	8.77	21.07
Right ECRL	Bambach	12	13.11	7.28	2.10	8.49	17.74	6.65	26.75
	Conventional	10	13.12	3.59	1.13	10.54	15.69	6.67	16.56

Table. 6-51. Descriptive Statistics (Dentists; 10 Minutes Average)

Fatigue Analysis of Dentists EMG at Minute 1, 5 and 10

A common pattern was observed when comparing minute 1, 5 and 10 of dentists' EMG activity. The %MVC of minute 1 and 10 are comparable to the 10-minute average, but the %MVC of minute 5 is a little increased. A similar pattern was also observed with students. The increase in the EMG activity from minute 1 to 5 indicated a small increase in recruitment and synchronisation of motor unit activity, indicative of fatigue (Cram and Vinitzky, 1995). Further, the observed drop in the EMG activity between minute 5 and 10 occurs as fatigue sets in, where the muscles are no longer capable of meeting the metabolic requirements needed to sustain a contraction. The initial increase in muscular support was followed by a reduction of %MVC (The Failure Point) along with a reduction of EMG activity of muscles.

Left Splenius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in dentists for both the seats (Fig. 6-98).

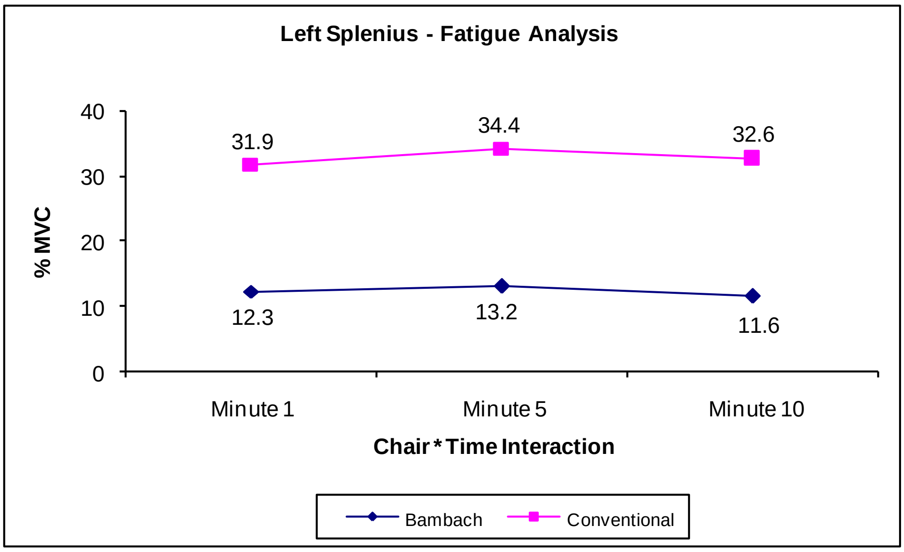


Fig. 6-98. Left Splenius Muscle (Fatigue Analysis of Dentists)

Right Splenius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in dentists for both the seats (Fig. 6-99)

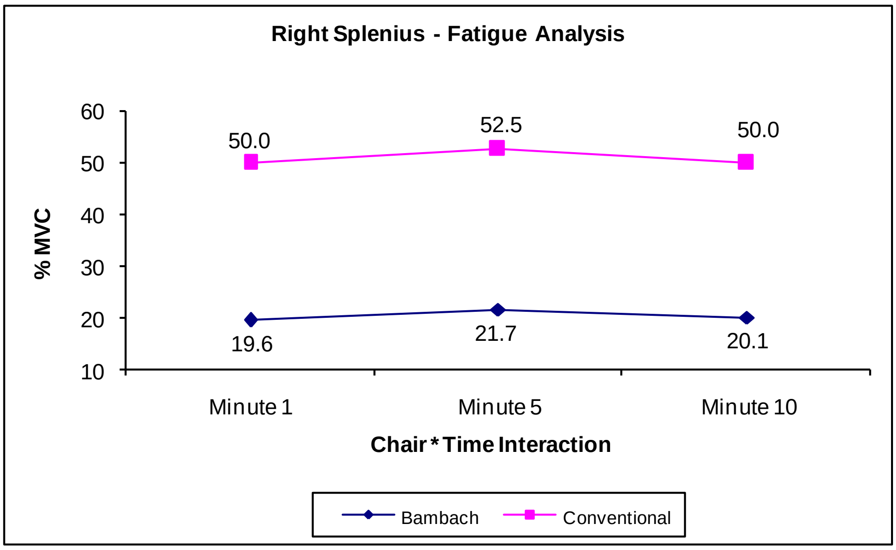


Fig. 6-99. Right Splenius Muscle (Fatigue Analysis of Dentists)

Left Trapezius Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in dentists for both the seats (Fig. 6-100).

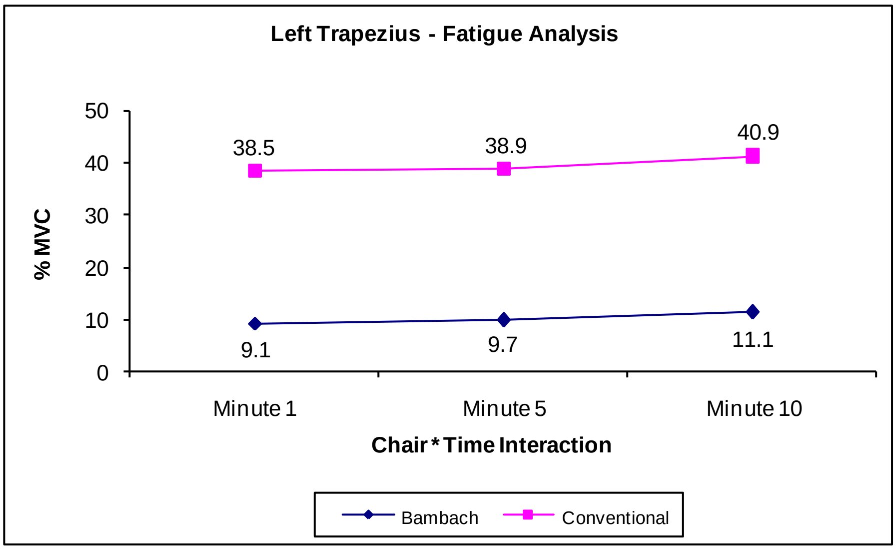


Fig. 6-100. Left Trapezius Muscle (Fatigue Analysis of Dentists)

Right Trapezius Muscle: The results indicated that there is no change in EMG activity at minute 1, 5 and 10, which indicates no sign of fatigue in BSD. The results also indicate an increase in EMG activity at minute 5 for CSD, indicating a small increase in recruitment and synchronisation of motor unit activity, indicative of fatigue in using Conventional Seat (Fig. 6-101)

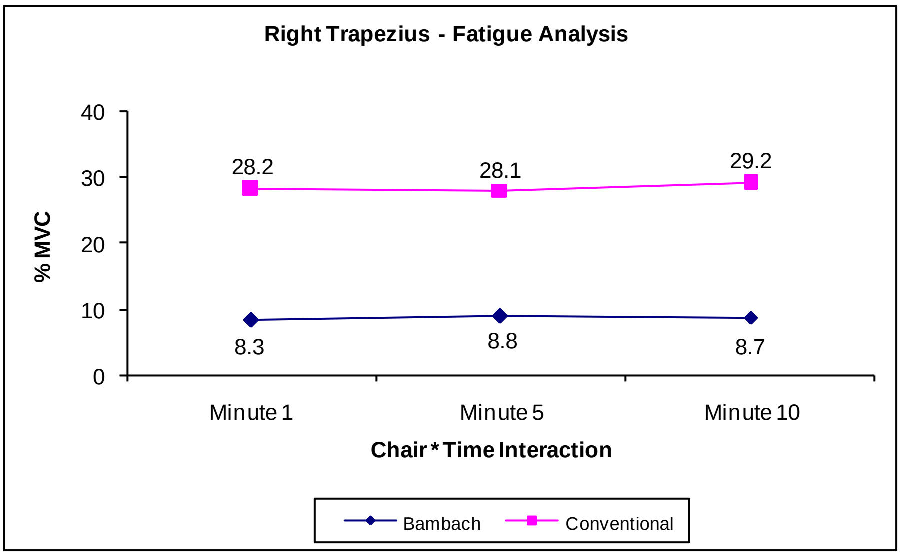


Fig. 6-101. Right Trapezius Muscle (Fatigue Analysis of Dentists)

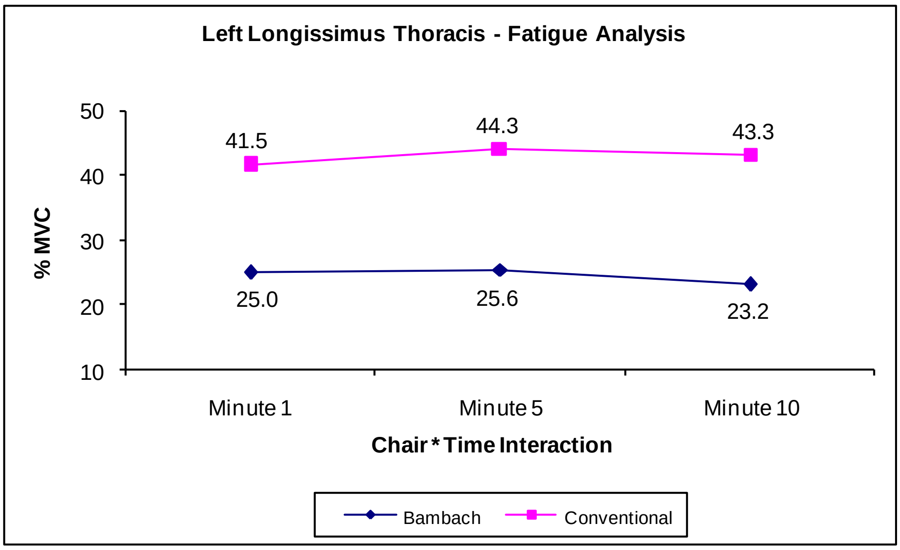


Fig. 6-102. Left Longissimus Thoracis (Fatigue Analysis of Dentists)

Left Longissimus Thoracis Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in dentists for both the seats (Fig. 6-102).

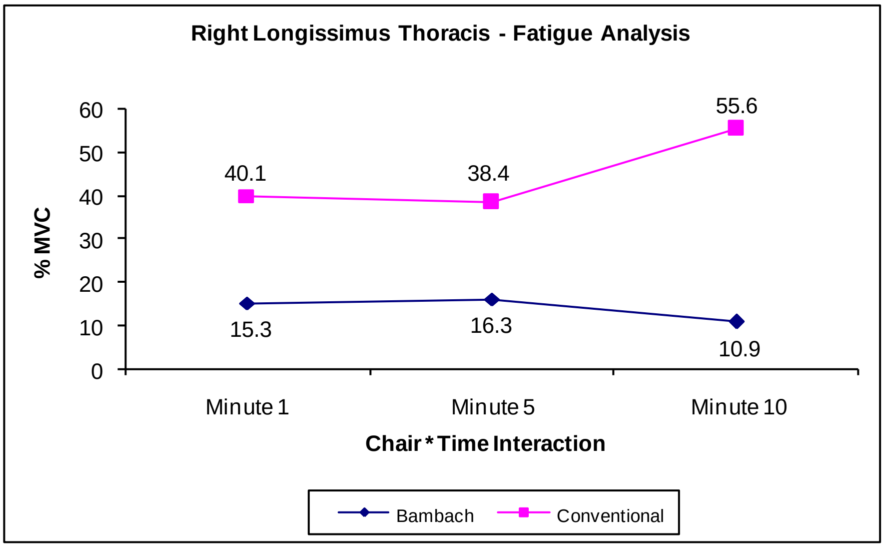


Fig. 6-103. Right Longissimus Thoracis (Fatigue Analysis of Dentists)

Right Longissimus Thoracis Muscle: The EMG activity of BSD slightly increased from minute 1 to 5 but significantly decreased at minute 10 and may indicate fatigue, whereas the opposite occurred in the CSD which also may also indicate fatigue in longer use of the Conventional seat (Fig. 6-103) (Cram and Vinitzky; 1995).

Left Multifidus Lumborum Muscle: The EMG activity of BSD increased from minute 1 to 5 and 10. The EMG activity of CSD increased at minute 5 and decreased at minute 10, indicative of fatigue in CSD (Fig. 6-104) (Cram and Vinitzky; 1995).

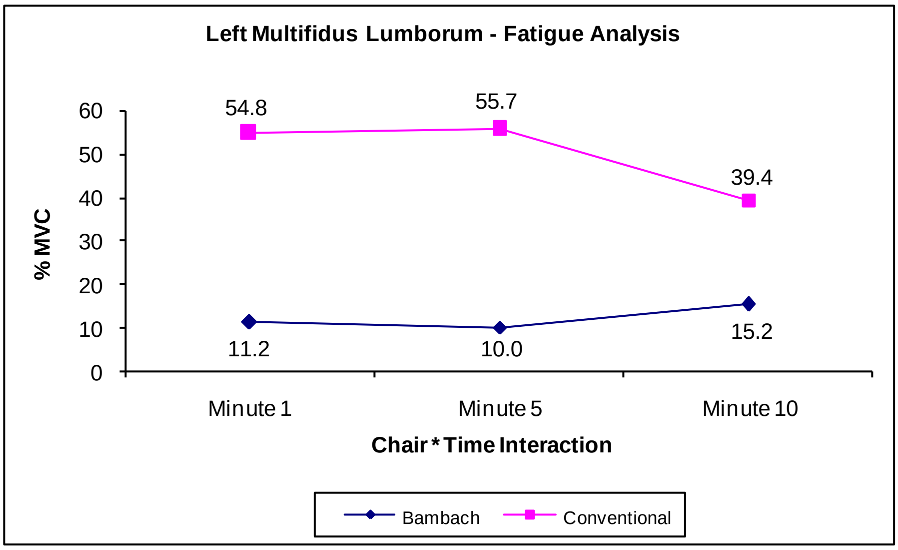


Fig. 6-104. Left Multifidus Lumborum (Fatigue Analysis of Dentists)

Right Multifidus Lumborum Muscle: The EMG activity gradually increased from minute 1 to 5 and decreased in minute 10 in dentists for both the seats (Fig. 6-105).

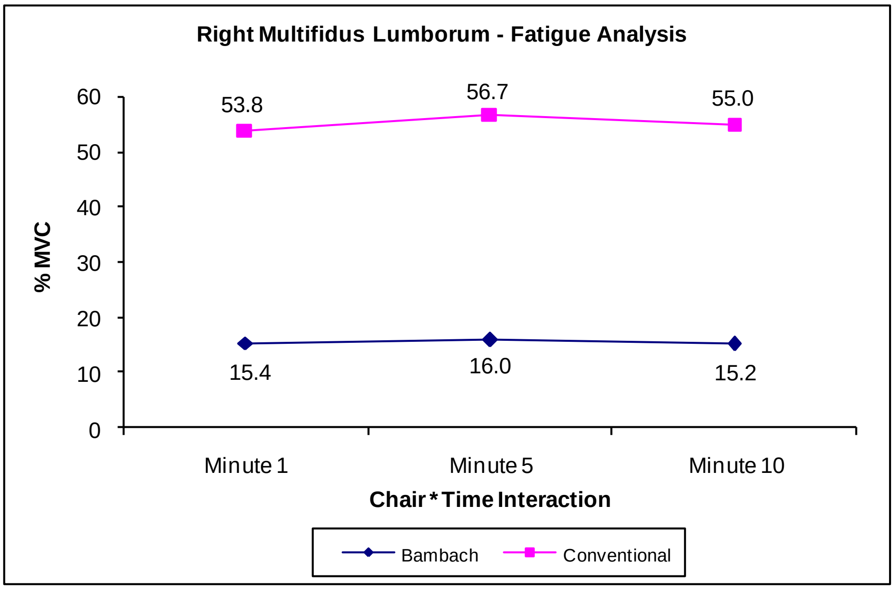


Fig. 6-105. Right Multifidus Lumborum (Fatigue Analysis of Dentists)

Left Extensor Carpi Radialis Muscle: The EMG activity increased slightly from minute 1 to 5 and 10 in dentists for both the seats (Fig. 6-106).

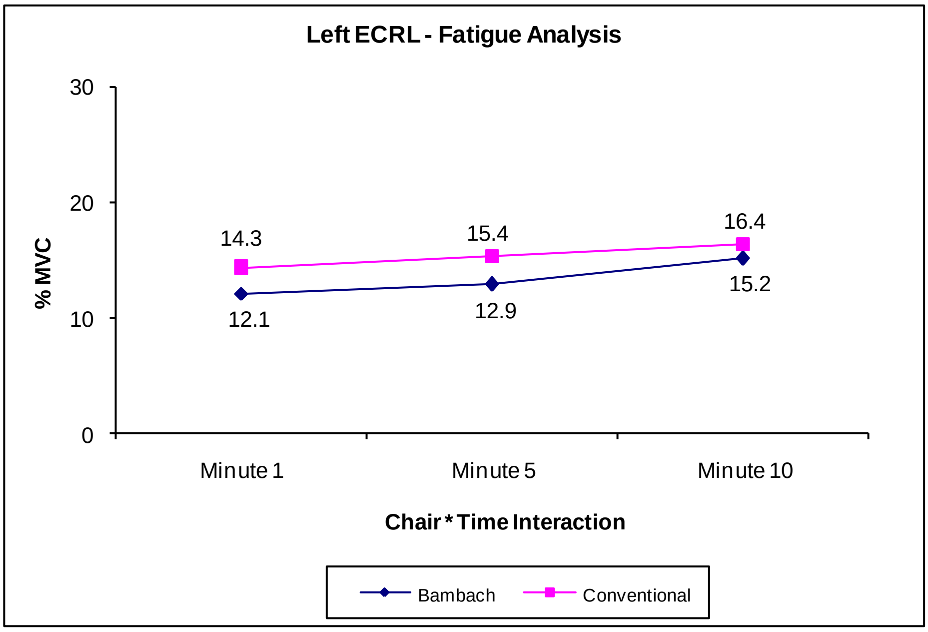


Fig. 6-106. Left ECRL (Fatigue Analysis of Dentists)

Right Extensor Carpi Radialis Muscle: The EMG activity slightly increased from minute 1 to 5 and remained the same at minute 10 in dentists for both the seats (Fig. 6-107).

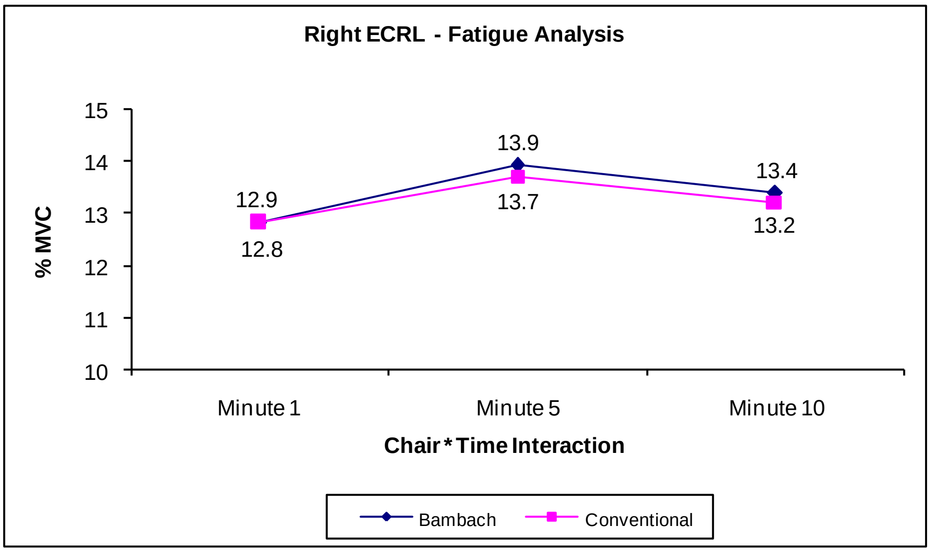


Fig. 6-107. Right ECRL (Fatigue Analysis of Dentists)

Discussion – Fatigue Analysis Students and Dentists

The pattern of fatigue was similar in dentists for both the chairs but there was a significant difference between the seats. Overall the BSD recorded lower muscle activity. The study by Cram and Vinitzky (1995) has shown that there was a significant increase in the EMG activity from minute one to minute five when using an office chair compared to Balans and Back-up chairs; the office chair being similar to the conventional seats used by dentists. The findings in the study suggest that, over time, the CSD must rely more on their back muscles for stabilization and support of the pelvis and back. This will eventually result in fatigue and may predispose to a musculoskeletal disorder. On the contrary, BSD showed lower EMG activity over the 10-minute period, suggesting a reduced chance of fatigue or failure for dentists using the Bambach seat. Overall, the Bambach Seat requires less energy / effort for dentists performing seated work.

The main source of stress and fatigue when sitting for a prolonged period of time is the static activity of the postural / antigravity muscles needed to maintain the various segments of the body in space against gravity (Pheasant 1984; Ostberg, 1984; Coe, 1979; 1983). This is clearly established in this study where CSS showed a common pattern of fatigue in the 6 months EMG, whereas the BSS showed decreased fatigue. Bitterman (1944) defined fatigue as "a reduction in efficiency resulting from continued work and reversible by rest." whereas Goldthwait (1910) reported that when the posture is properly maintained the muscular forces used by the postural muscles would be least and the viscera would be favourably situated for function. This gives the greatest amount of energy for "whatever function the individual may choose or be forced to perform" (Goldthwait, 1910). This was clearly shown with BSS where the pattern of fatigue changed over the 6-month period, which indicates less fatigue when using the Bambach saddle seat. Clark (1954) suggested that a good chair could reduce fatigue by providing proper stabilizing features and reduce the static muscular activity, and thereby relaxing the individual.

6.7.8 Comparative Analysis of Students' EMG over the 6 Months period and Comparing Students 6th Month EMG with Dentists EMG (10 Minutes Average)

The changes in the students EMG over the 6 Month period and the difference in right and left side of the muscles measured were compared using a Doubly Multivariate Mixed Design ANOVA. The results are presented in the following order.

- The changes in the students EMG over the 6 Month Period for each muscle (Right and Left) (Doubly Multivariate Mixed Design ANOVA using SPSS 15.0).
- Comparing the Students 6th Month EMG with Dentists for each muscle (One Way ANOVA using SPSS 15.0).

Splenius Capitis (Neck Extensors): Students' 6 Months Comparison

The results indicate that a significant multivariate within-subject effect for time, i.e. there is a significant effect on both left and right splenius muscle activity as time progresses ($F(4, 92) = 23.25$; $p = 0.000$) in both the groups (Bambach and Conventional). The results also indicate that there is a significant multivariate interaction between time and seat, i.e. there is a significant effect of seat on left and right splenius muscle activity (Bambach and Conventional) as time progresses (F (4, 92) = 6.99; p = 0.000), and this effect varies, depending on the type of seat.

Following the significant multivariate effects, univariate within-subject and interaction effects were examined separately for the left and right splenius muscles. There were significant univariate within-subject effects for time i.e. there was a significant effect of muscle activity as time progressed in both left (F (2, 46) = 22.09; p=0.000) and right splenius muscle (F (2, 46) = 23.41; p = 0.000). The results also indicated that there was a significant univariate interaction between time and seat for the right side (F (2, 46) = 12.87; p = 0.000) and a near significant interaction for the left side (F (2, 46) = 3.07; p = 0.056).

The results indicated that there is a significant difference between groups (Bambach and Conventional) in the use of seat (F (1, 23) = 12.57; p = 0.002) for the left splenius muscle and (F (1, 23) = 5.75; p = 0.025) for the right splenius muscle, collapsed across time. The Bonferonni adjusted pairwise comparisons indicated that muscle activity was significantly lower for the Bambach seat for both the left splenius (p = 0.002) and right splenius (p = 0.025) when compared to the Conventional seat.

Left Splenius Capitis: The results indicated that for both groups of students the muscle activity had significantly reduced over the 6 month period. However the BSS recorded significantly less muscle activity when compared with the CSS. The pattern of decrease in muscle activity was similar in both the groups until 3 months but the effect ceased at 3 months with the CSS and the muscle activity staying almost the same (p= 0.721) (Figure 6-108).

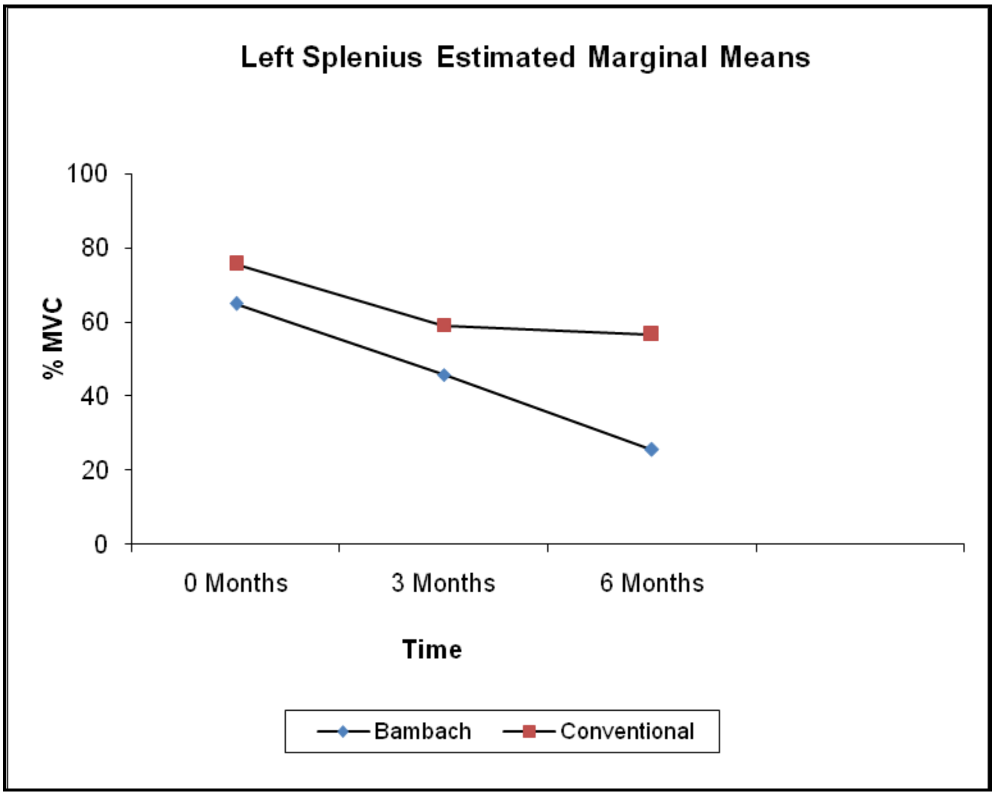


Fig. 6-108. Comparison of Left Splenius Capitis over the 6 Month Period

Right Splenius Capitis: The results indicated that for BSS the muscle activity had significantly reduced over the 6 month period; whereas for the CSS the muscle activity significantly increased at 3 months (p = 0.000) and decreased at 6 months (p = 0.000). The Bambach students recorded significantly less muscle activity when compared with the CSS (p = 0.000). The pattern of reduction of muscle activity for the BSS is similar to the left splenius capitis muscle, whereas the pattern completely changed with the CSS (Figure 6-109).

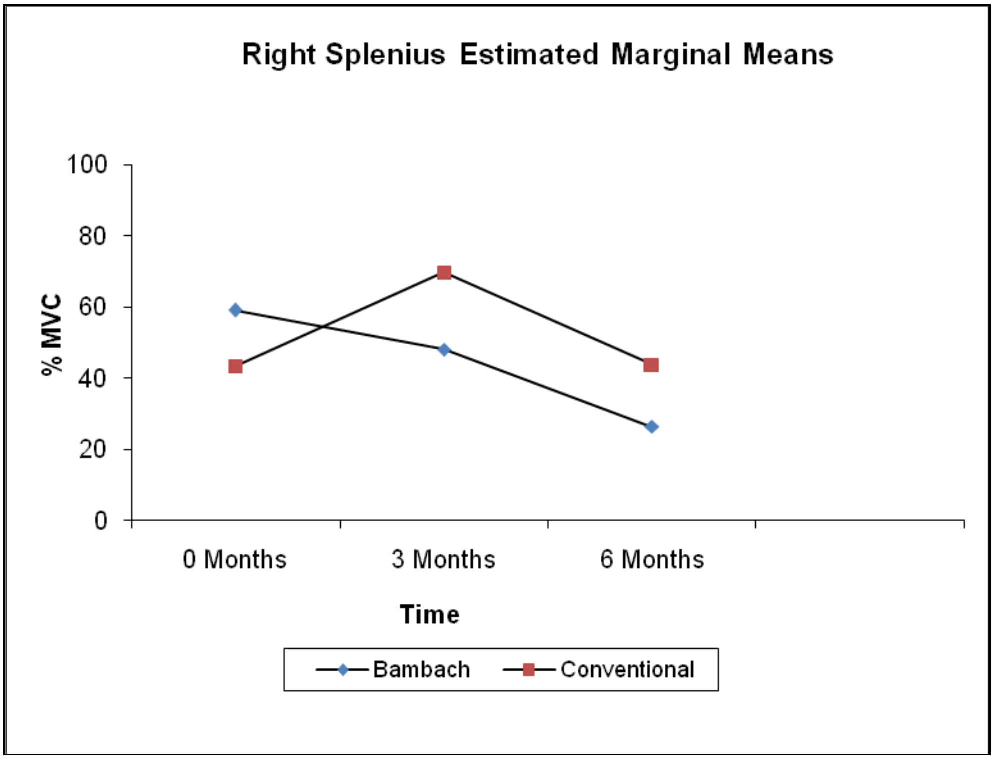


Fig. 6-109. Comparison of Right Splenius Capitis over the 6 Month Period

Splenius Capitis (Neck Extensors): Students 6th Month EMG and Dentists EMG – A Comparative Analysis.

Left Splenius Capitis: The results indicated that there was a significant difference between the students and dentists in both the groups (Bambach ($p = 0.005$) and Conventional ($p = 0.012$)), but the BSS and BSD muscle activity was significantly less, when compared to the CSS and CSD.

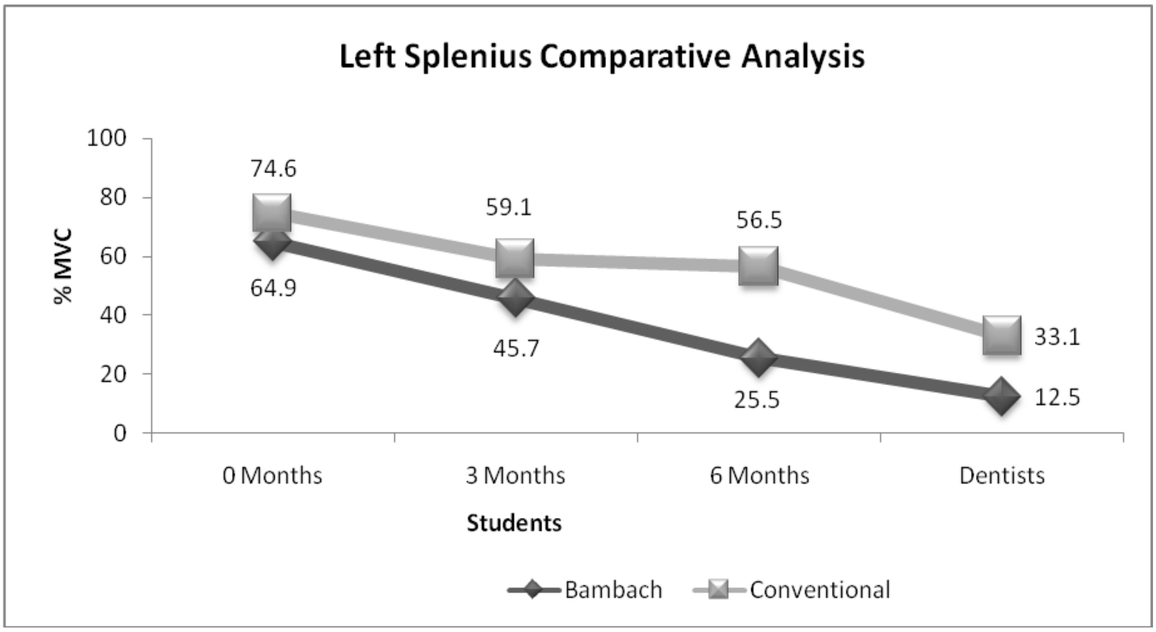


Fig. 6-110. Left Splenius (Neck Extensor) Comparative Analysis

Right Splenius Capitis: The mean muscle activity of BSD was less when compared with the 6th month BSS EMG but there was no significant difference (p = 0.166); whereas the mean muscle activity of CSD was not significantly different (p = 0.363) when compared with the 6th month Conventional student EMG. This indicates that the 6th month students' muscle activity was comparable to that of dentists. The Bambach group recorded significantly less muscle activity with both Students and Dentists when compared with the Conventional group, excluding the baseline recordings (0 months) of students, where the BSS recorded significantly higher muscle activity when compared with CSS. These results may be related to the neck pain reported by dentists in the questionnaire in which only 24.6% (n=15) of BSD reported neck pain, whereas 31.7% (n=19) of CSD reported neck pain. This may be related to posture and increased muscle activity with CSD.

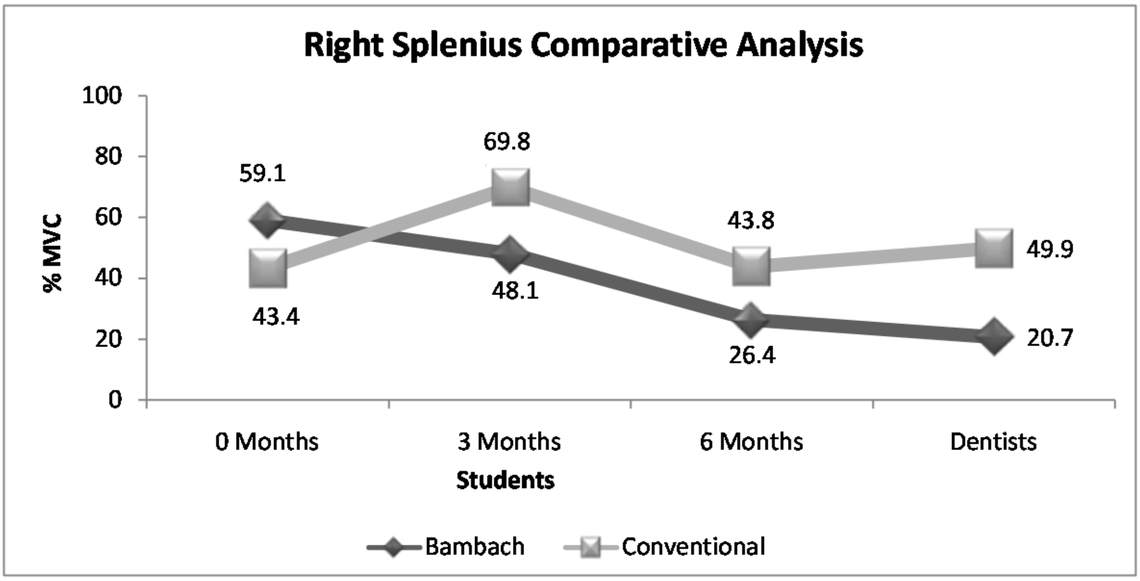


Fig. 6-111. Right Splenius (Neck Extensor) Comparative Analysis

Upper Trapezius (Shoulder Elevators): Students 6 Months Comparison

The results indicated a significant multivariate within-subject effect on time i.e. there was a significant effect on both left and right trapezius muscle activity as time progressed ($F(4, 92) = 11.76$; $p = 0.000$) in both the groups (Bambach and Conventional) which is similar to that of the splenius capitis muscles. The results also indicate that there was a significant multivariate interaction between time and seat, i.e. there is significant effect of seat on left and right trapezius muscle activity (Bambach and Conventional) as the time progressed ($F(4, 92) = 3.25$; $p = 0.048$), and this effect varied depending on the type of seat.

Following the significant multivariate effects, univariate within-subject and interaction effects were examined separately for the left and right trapezius muscles. There were significant univariate within-subject effects time i.e. there was a significant effect of muscle activity as time progress in both left ($F(2, 46) = 38.43$;

p=0.000) and right (F (2, 46) = 17.82; p = 0.000) trapezius muscles. The results also indicated no significant interaction between time and seat for the right side (F (2, 46) = 2.75; p = 0.074) and left (F (2, 46) = .030; p = 0.970).

The results indicated that there was a significant difference between groups (Bambach and Conventional) in the use of seat (F (1, 23) = 91.21; p = 0.000) for the left trapezius muscle and (F (1, 23) = 76.85; p = 0.025) for the right trapezius muscle, collapsed across time. The Bonferonni adjusted pairwise comparisons indicated that muscle activity was significantly lower for both the left trapezius (p = 0.000) and right trapezius (p = 0.000), compared to the Conventional seat.

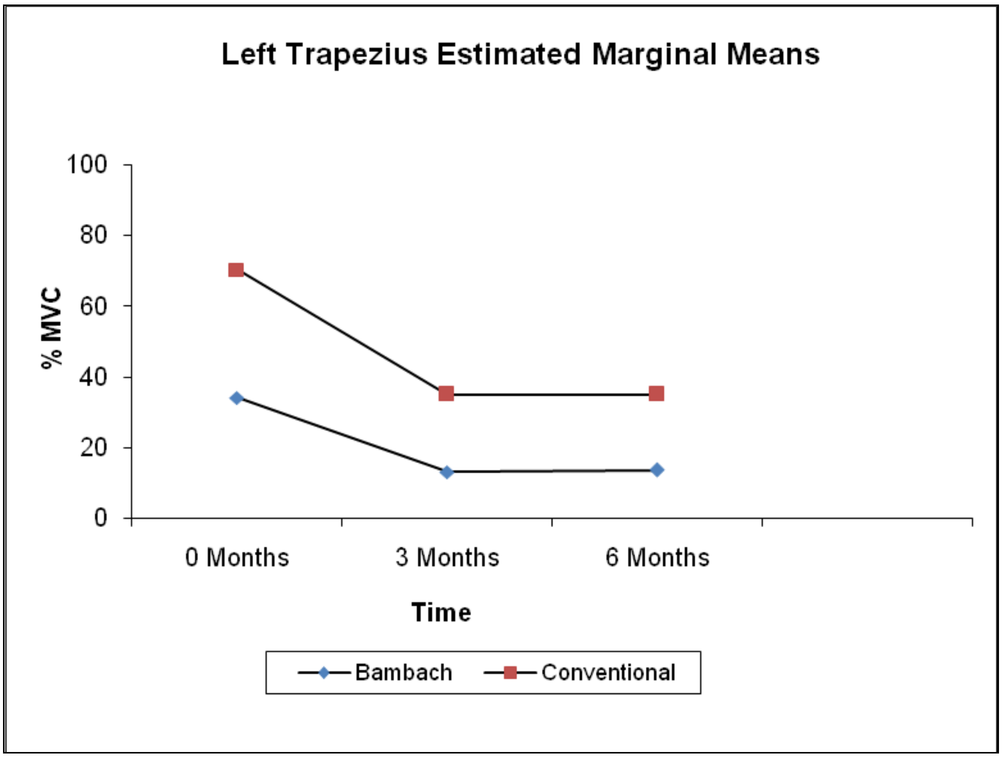


Fig. 6-112. Comparison of Left Trapezius over the 6 Month Period

Left Trapezius: The results indicated that for both groups of students muscle activity had significantly reduced over a 3-month period (P = 0.000 for both the groups) and remained the same over the next 3 months (P = 0.842 for BSS and P = 0.999 for the CSS) (6 Months); but the Bambach students recorded significantly less muscle activity when compared with the Conventional students. The pattern of muscle activity was similar between the groups but the difference is in the amount of muscle activity recorded.

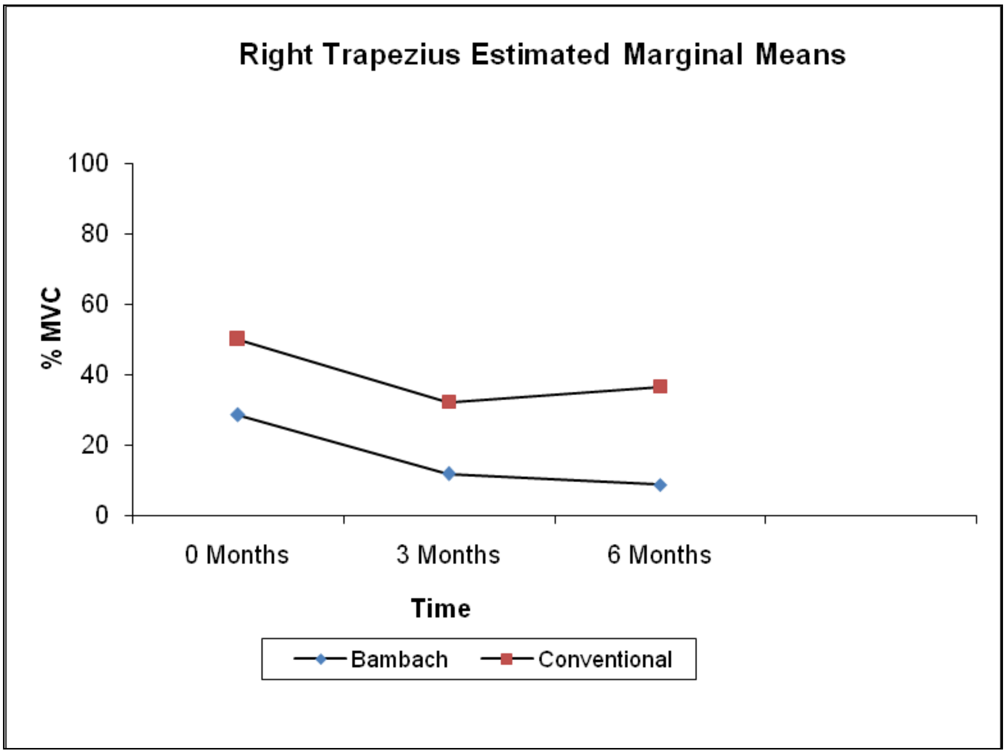


Fig. 6-113. Comparison of Right Trapezius over the 6 Month Period

Right Trapezius: The results indicated that for the BSS muscle activity had significantly reduced over a 6-month period, whereas for the CSS muscle activity significantly reduced at 3-months (p = 0.002) but increased in the next 3-month period (p=0.537). The BSS recorded significantly less muscle activity when compared with the CSS.

Upper Trapezius (Shoulder Elevators): Students 6th Month EMG and Dentists EMG: A Comparative Analysis

Left Trapezius: The BSD recorded decreased muscle activity when compared with the BSS. However there was no significant difference (p = 0.81) in muscle activity. The Bambach seat group recorded significantly less muscle activity in both Students and Dentists, whereas in the Conventional group the CSD recorded increased muscle activity when compared with the 3 and 6 months period of CSS, however there was no significant difference (p=0.666) in muscle activity. The Bambach seat group recorded significantly less muscle activity for both Students and Dentists when compared with the Conventional group (P=0.000).

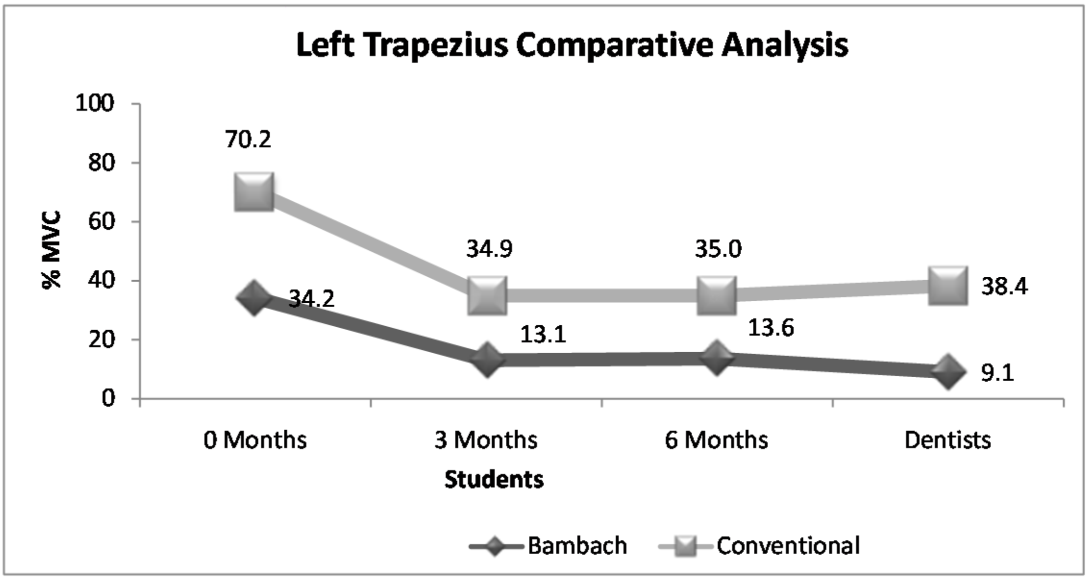


Fig. 6-114. Left Trapezius (Shoulder Elevators) Comparative Analysis

Right Trapezius: The BSD recorded similar muscle activity when compared with BSS, with no significant difference (0.751). A similar pattern was observed with the Conventional seat group with no significant difference between the muscle activity of dentists and students (p = 0.205).

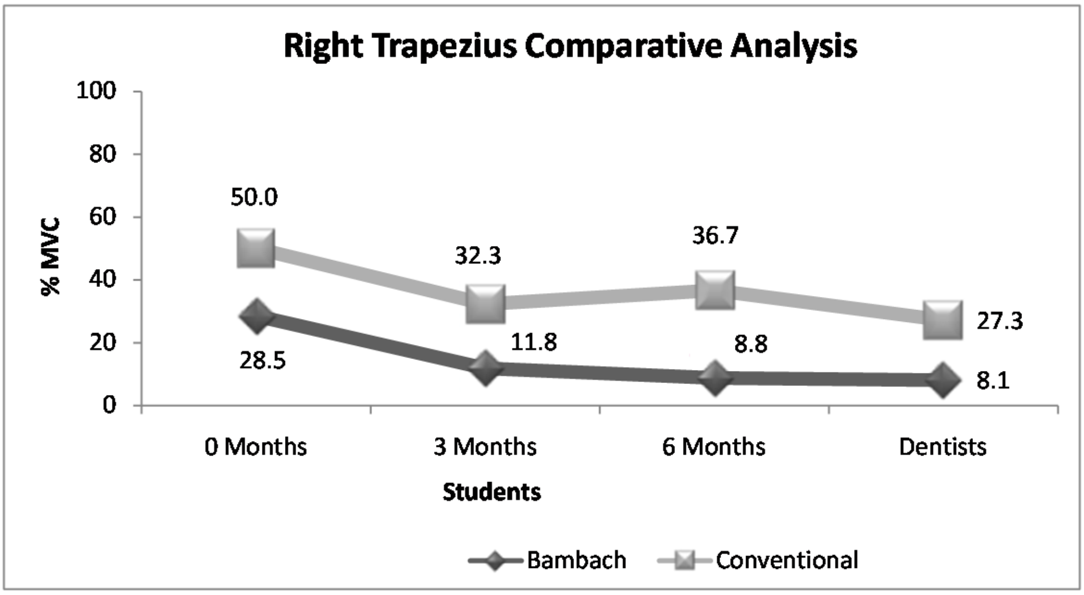


Fig. 6-115. Right Trapezius (Shoulder Elevators) Comparative Analysis

Longissimus Thoracis (Spinal Extensors): Students 6 Months Comparison

The results indicated a significant multivariate within-subject effect on time i.e. there was a significant effect on both left and right longissimus thoracis muscle activity as the time progressed ($F(4, 92) = 6.84$; $p = 0.000$) in both the groups (Bambach and Conventional). The results also indicated that there was a significant multivariate interaction between time and seat i.e. there was a significant effect of seat on left and right longissimus thoracis muscle activity (Bambach and Conventional) as the time progressed ($F(4, 92) = 3.03$; $p = 0.021$), and this effect varied depending on the type of seat.

Following the significant multivariate effects, univariate within-subject and interaction effects were examined separately for the left and right longissimus thoracis muscles. There were significant univariate within-subject effects for time i.e. there was a significant effect of muscle activity as time progressed in both left ($F(2, 46) = 8.81$; $p = 0.001$) and right ($F(2, 46) = 17.40$; $p = 0.000$) longissimus thoracis muscles. The results also indicated that there was a significant univariate interaction between time and seat for right side ($F(2, 46) = 4.59$; $p = 0.015$), and no significant interaction for the left side ($F(2, 46) = 4.59$; $p = 0.146$).

The results indicated that there was a significant difference between groups (Bambach and Conventional) ($F(1, 23) = 4.23$; $p = 0.050$) for the left longissimus thoracis muscle and no significant difference for the right longissimus thoracis muscle ($F(1, 23) = 1.03$; $p = 0.319$), collapsed across time. The Bonferonni adjusted pairwise comparison between subjects indicated that muscle activity was significantly lower for the Bambach seat for the right longissimus thoracis ($p = 0.050$) and that there was no significant difference for the left longissimus thoracis ($p = 0.319$).

Left Longissimus Thoracis: The results indicated that for the BSS the muscle activity increased over the 3-month period and reduced over the 6-month period. The results also indicated that for the CSS the muscle activity had significantly increased over a 6-month period ($P=0.000$). The Bambach group recorded significantly lower muscle activity when compared with the Conventional seat group, excluding the 3 months recording of students in which the Bambach group recorded increased muscle activity.

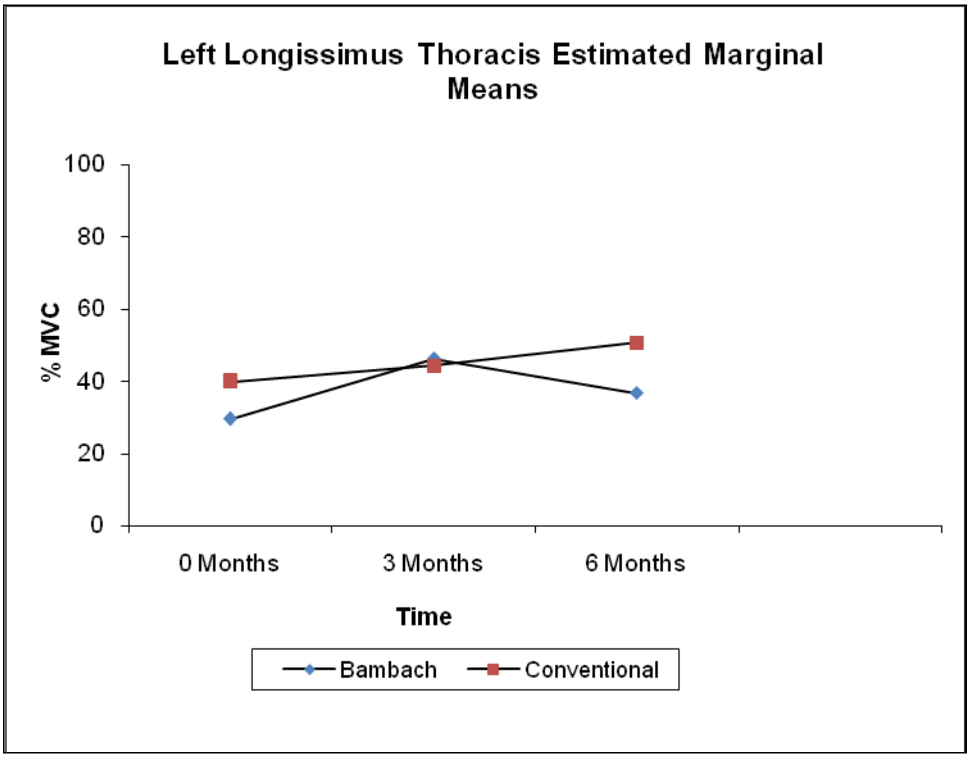


Fig. 6-116. Comparison of Left Longissimus Thoracis over the 6 Month Period

Right Longissimus Thoracis: The results indicated that, for the BSS muscle activity increased over the 3-month period and decreased over the next 3-months. The results also indicated that for the CSS, muscle activity significantly increased over the 6-month period (P=0.000). A similar pattern was also observed with the Left Longissimus Thoracis Muscle. In general, the Bambach seat group recorded significantly less muscle activity when compared with the Conventional seat group.

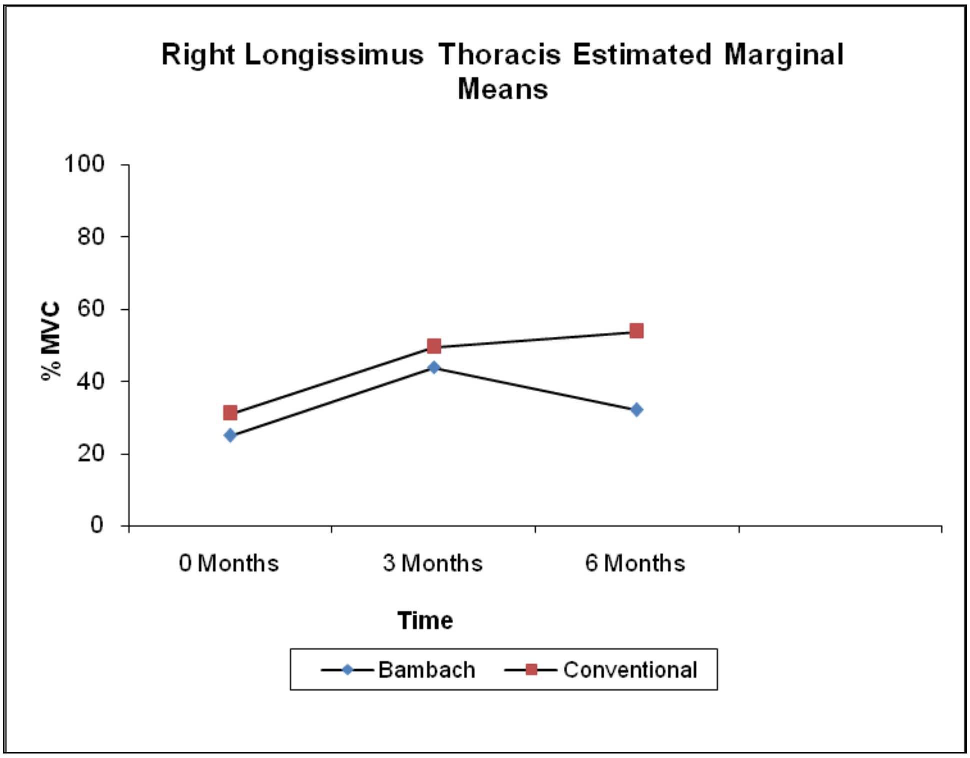


Fig. 6-117. Comparison of Right Longissimus Thoracis over the 6 Month Period

Longissimus Thoracis (Spinal extensors): Students 6th Month EMG and Dentists EMG – A Comparative Analysis

Left Longissimus Thoracis: The BSD recorded significantly decreased muscle activity when compared to BSS (p = .010). The CSD recorded increased muscle activity when compared to the baseline (0 Months) recording in CSS and there was no significant difference in muscle activity when the students 6th month EMG and dentists EMG when compared (p = 0.179).

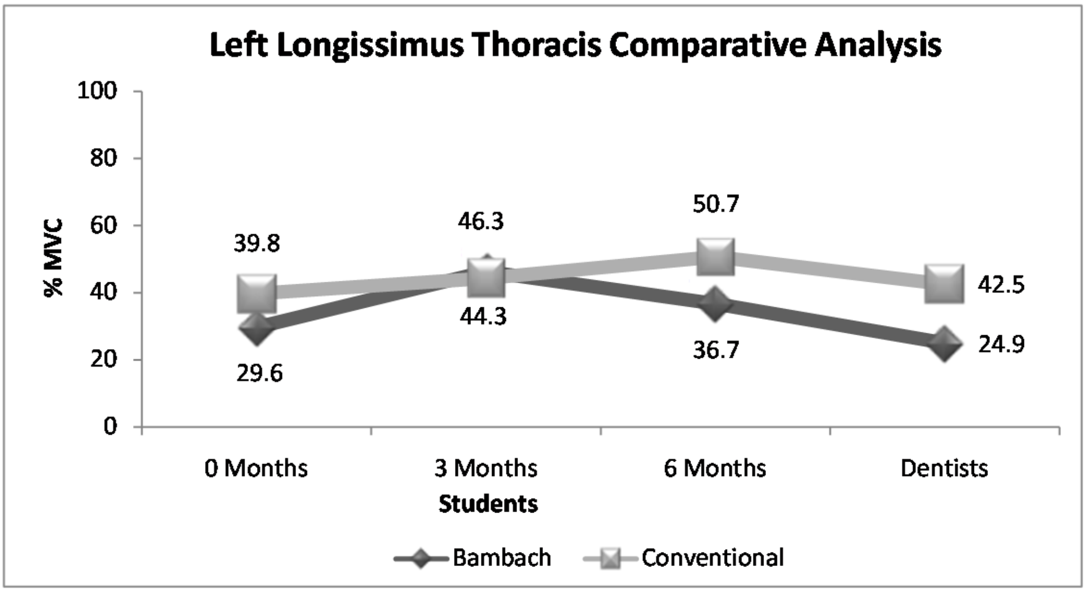


Fig. 6-118. Left Longissimus Thoracis (Spinal Extensor) Comparative Analysis

Right Longissimus Thoracis: The BSD recorded decreased muscle activity when compared to BSS (p = 0.001) a similar pattern to that observed in the left longissimus thoracis muscle. The CSD recorded increased muscle activity when compared to the baseline (0 months) recording in CSS. Comparing the 6^{th} month CSS EMG and CSD EMG indicated a significant difference in muscle activity (p = 0.039).

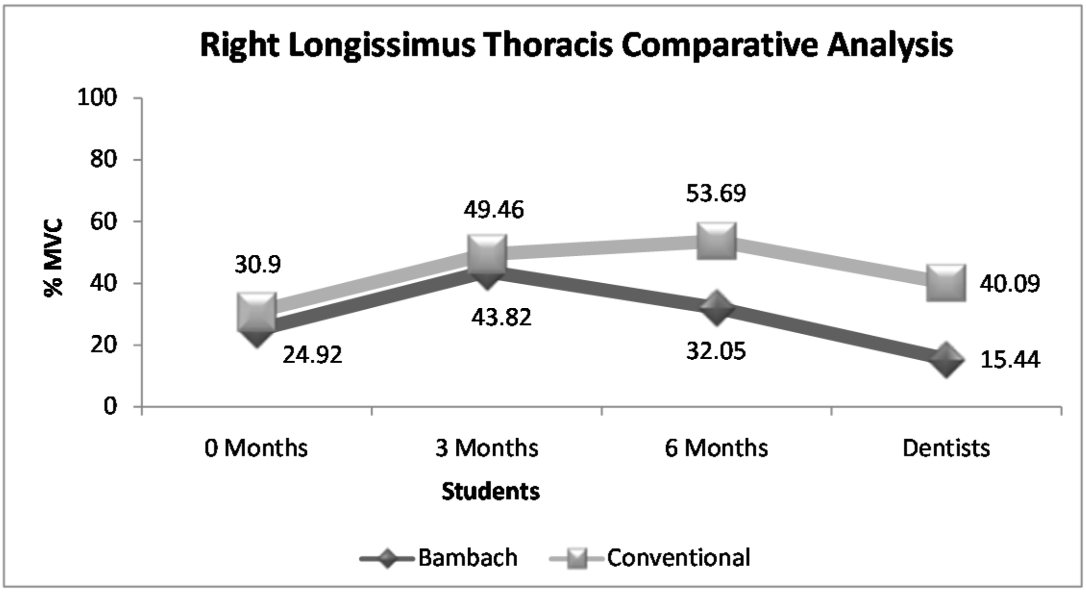


Fig. 6-119. Right Longissimus Thoracis (Spinal Extensor) Comparative Analysis

Multifidus Lumborum (Spinal Extensors): Students 6 Months Comparison

The results indicated no significant multivariate within-subject effect for time i.e. there was no significant effect on both the left and right multifidus lumborum muscle activity as time progressed (F (4, 92) = 1.719; p = 0.152) in both the groups (Bambach and Conventional). The results also indicated that there was a significant multivariate interaction between time and seat i.e. there was a significant effect of seat on right and left multifidus lumborum muscle activity (Bambach and Conventional) as time progressed (F (4, 92) = 8.93; p = 0.000), and this effect varied depending on the type of seat.

Following the significant multivariate effects, univariate within-subject and interaction effects were examined separately for the left and right multifidus lumborum muscles. There was no significant univariate within-subject effect on time i.e. there was no significant effect of muscle activity as time progressed in both left (F (2, 46) = 1.10; p = 0.339) and right (F (2, 46) = 1.40; p = 0.255) multifidus lumborum muscles. The results also indicated that there was a significant univariate interaction between time and seat for left side (F (2, 46) = 8.51; p = 0.001) and the right side (F (2, 46) = 17.71; p = 0.000).

The results indicated that there is significant difference between groups (Bambach Seat and Conventional Seat) (F (1, 23) = 5.60; p = 0.027) for the right multifidus lumborum muscle and no significant difference for the left multifidus lumborum muscle (F (1, 23) = 1.35; p = 0.257), collapsed across time. The Bonferonni adjusted pairwise comparisons indicated that muscle activity was significantly lower for the

BSS for the right longissimus thoracis muscle (p = 0.027) and no significant difference for the left longissimus thoracis muscle (p = 0.257).

Left Multifidus Lumborum: The results indicated that for the BSS the muscle activity increased over the 3-month period and reduced over the 6-month period. The results also indicated that, for the CSS, muscle activity decreased over a 3-month period but significantly increased over the next 3 months (p = 0.000). The Bambach seat group recorded significantly less muscle activity when compared with the Conventional seat group, excluding the 3 months' recording.

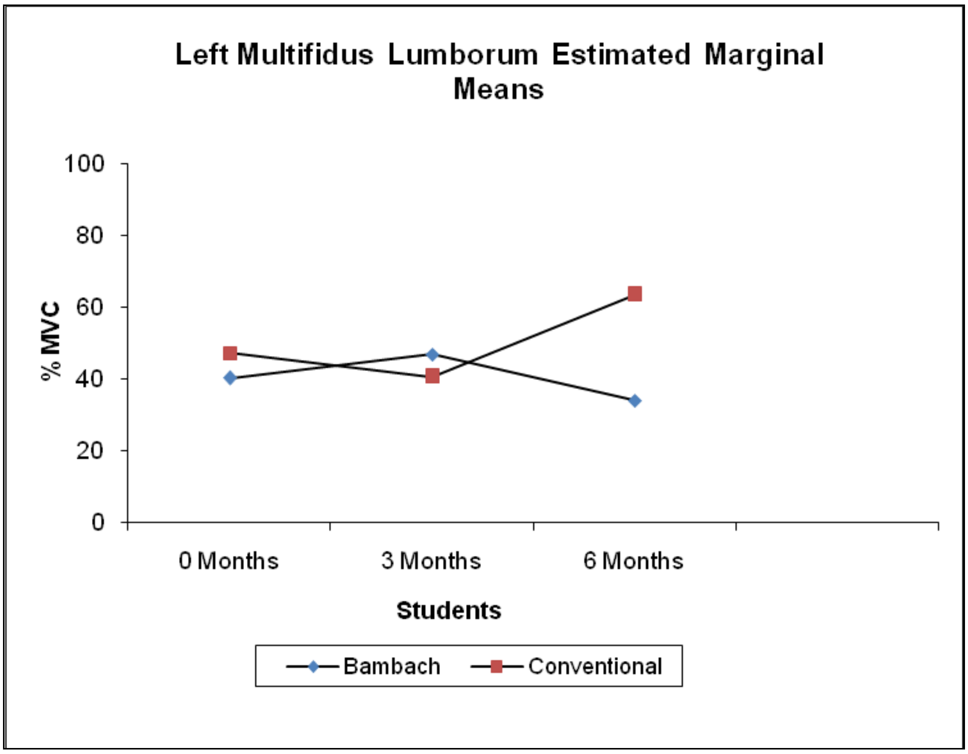


Fig. 6-120. Comparison of Left Multifidus Lumborum over the 6 Month Period

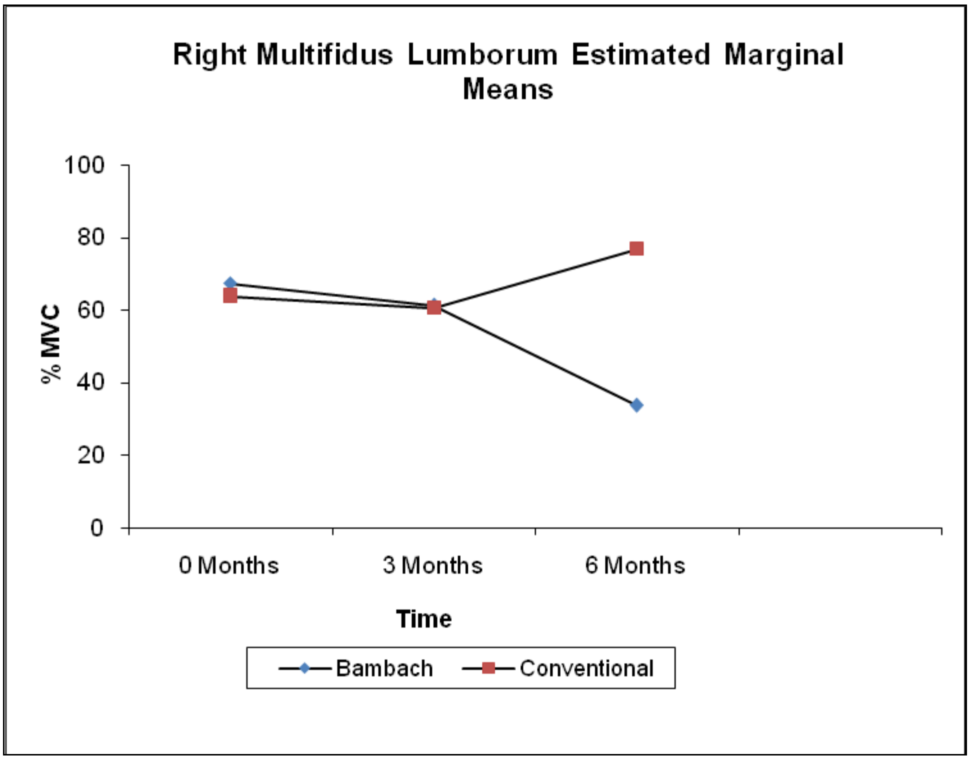


Fig. 6-121. Comparison of Right Multifidus Lumborum over the 6 Month Period

Right Multifidus Lumborum: The results indicated that, for the BSS the muscle activity gradually reduced over the 6-month period. The results also indicated that for the CSS, muscle activity decreased over a 3-month period but significantly increased in the next 3-months (P = 0.000). A similar pattern was also observed in the Left Multifidus Lumborum muscle. The Bambach seat group recorded significantly less muscle activity when compared with the Conventional seat group excluding the baseline (0 months) and 3 months recording of students where there was no significant difference between the groups of students. A similar pattern was observed with the left multifidus lumborum muscle. There was a dramatic decrease of EMG activity with the BSS at the 6th month compared to 0 and 3 months, whereas there is a significant increase with CSS at the 6th Month.

Multifidus Lumborum (Spinal extensors): Students 6th Month EMG and Dentists EMG: A Comparative Analysis

Left Multifidus Lumborum: The BSD recorded significantly decreased muscle activity compared to the BSS (p = 0.000). The CSD recorded increased muscle activity when compared to the baseline (0 Months) and 3 months recording for CSS but there was no significant difference between the 6th month EMG and Dentists' EMG (p = 0.266). The BSS still had a relatively high MVC at 6 months compared to BSD. This is explained because the EMG activity reduces gradually over time when using the Bambach seat, whereas, with the CSS there was a significant increase in EMG activity at 6 months, indicating poor posture.

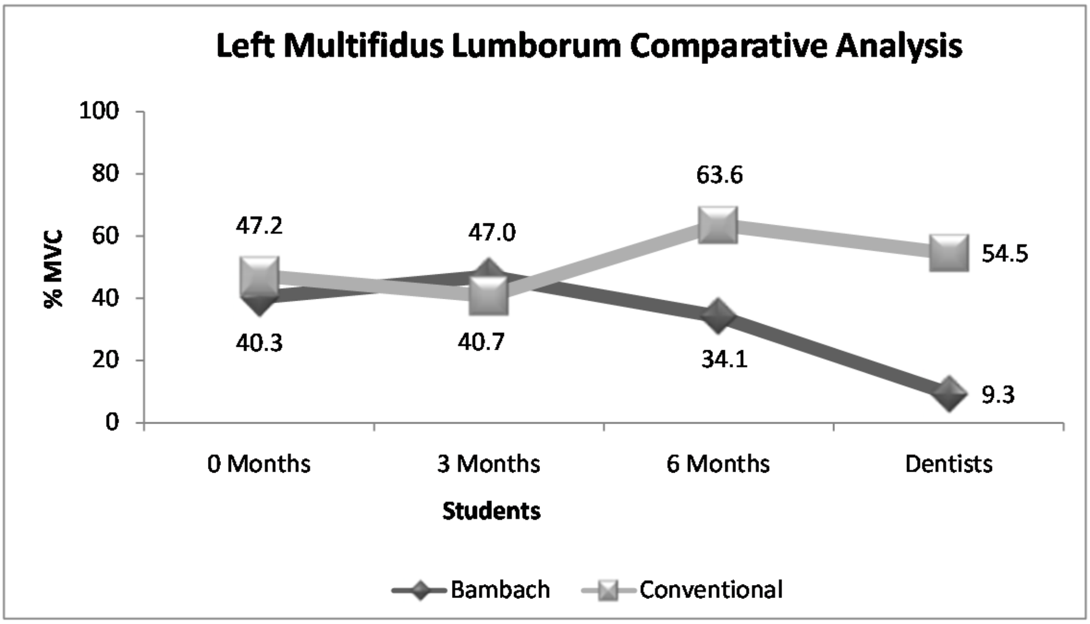


Fig. 6-122. Left Multifidus Lumborum (Spinal Extensor) Comparative Analysis

Right Multifidus Lumborum: The BSD recorded decreased muscle activity on average when compared with 6th month EMG of BSS (p = 0.000). The CSD also recorded decreased muscle activity when compared to the 6th month EMG of CSS (P

= 0.004) the difference being the amount of muscle activity, which is significantly less with the Bambach group.

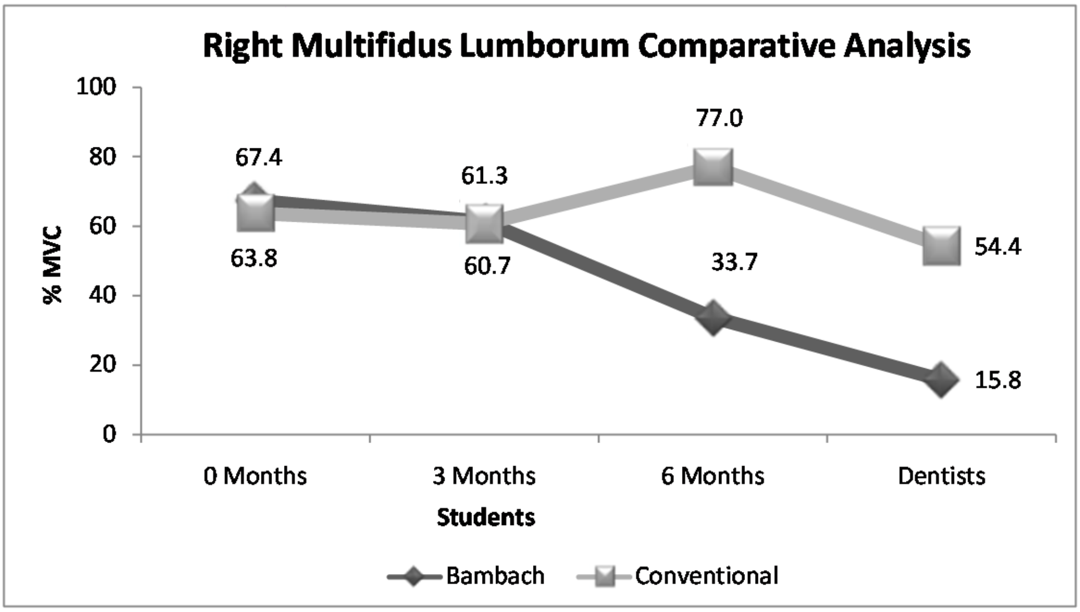


Fig. 6-123. Right Multifidus Lumborum (Spinal Extensor) Comparative Analysis

Extensor Carpi Radialis Longus (Wrist Extensor): Students 6 Month Comparison

The results indicated a significant multivariate within-subject effect on time i.e. there was a significant effect on both right and left ECRL muscle activity as time progressed (F (4, 92) = 7.59; p = 0.000) in both the groups (Bambach seat and Conventional seat). The results also indicated that there was no significant multivariate interaction between time and seat i.e. there was no significant effect of seat on left and right ECRL muscle activity (Bambach and Conventional) as the time progressed (F (4, 92) = 1.17; p = 0.325).

Following the significant multivariate effects, univariate within-subject and interaction effects were examined separately for the left and right ECRL muscles. There was significant univariate within-subject effects for time i.e. there was a significant effect of muscle activity as time progressed in both left ($F(2, 46) = 11.66$; $p = 0.000$) and right ($F(2, 46) = 19.71$; $p = 0.000$) extensor carpi radialis longus muscles. The results also indicated that there was no significant univariate interaction between time and seat for left side ($F(2, 46) = 0.489$; $p = 0.616$) and the right side ($F(2, 46) = 1.058$; $p = 0.355$).

The results indicate that there was a significant difference between groups (Bambach and Conventional) for the right extensor carpi radialis longus muscle ($F(1, 23) = 13.37$; $p = 0.001$) and the left extensor carpi radialis longus muscle ($F(1, 23) = 9.57$; $p = 0.005$), collapsed across time. The Bonferonni adjusted pairwise comparison indicated that muscle activity was significantly lower for the Bambach seat for both the left longissimus thoracis ($p = 0.001$) and right longissimus thoracis ($p = 0.005$), compared to Conventional seat.

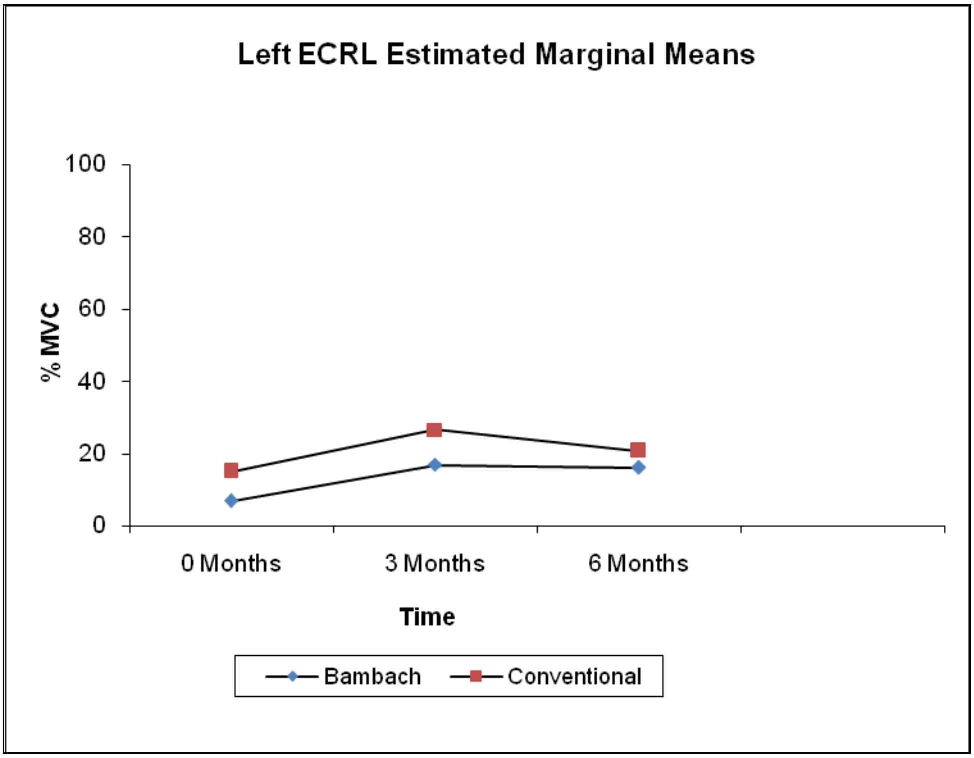


Fig. 6-124. Comparison of Left ECRL over the 6 Month Period

Left ECRL: The results indicated that with the BSS, muscle activity increased in the first three months and remained the same over the next three months. The results also indicated that with the CSS the muscle activity increased in the first three months and decreased in the next three months. However, the Bambach seat group recorded significantly less muscle activity when compared with the Conventional seat group on all three occasions.

Right ECRL: The results indicated that the muscle activity increased in the first three months and remained the same in the next three months for both the groups. However the Bambach seat group recorded less muscle activity when compared with the Conventional seat group on all 3 occasions.

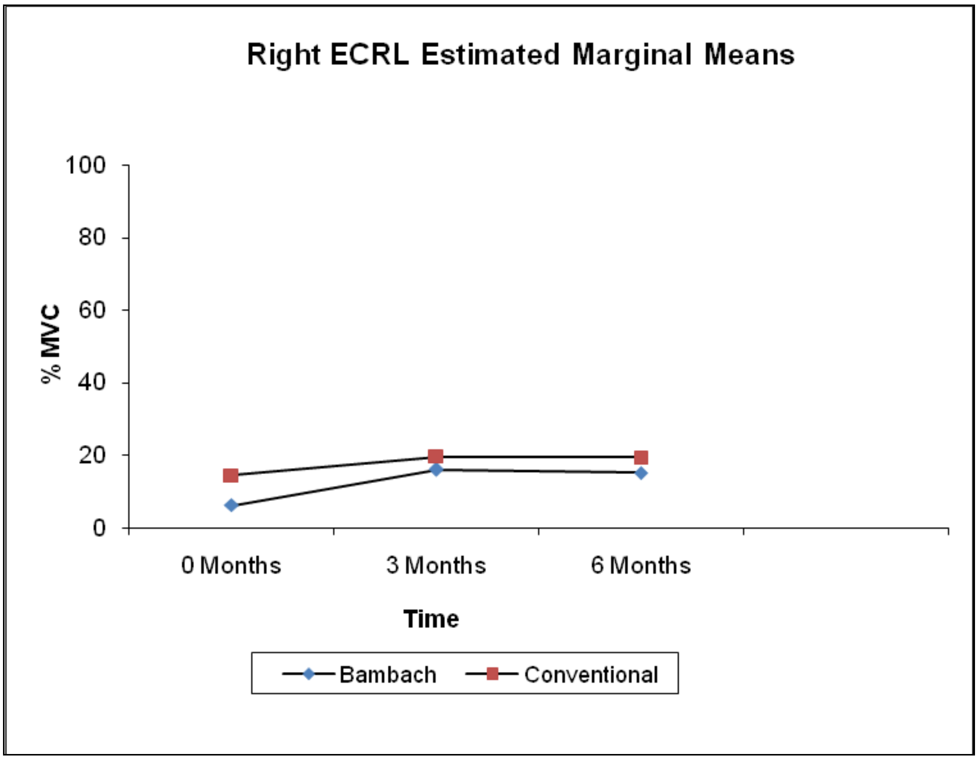


Fig. 6-125. Comparison of Right ECRL over the 6 Month Period

Extensor Carpi Radialis Longus (Wrist Extensors): Students 6th Month EMG and Dentists EMG: A Comparative Analysis

Left ECRL: The BSD recorded decreased muscle activity when compared to 6th month BSS EMG with no significant difference (p = 0.173). CSD recorded significantly decreased muscle activity on average compared with CSS (p = 0.021).

Right ECRL: The BSD recorded decreased muscle activity when compared to 6th month BSS EMG with no significant difference (p = 0.396). CSD recorded significantly decreased muscle activity on average compared with CSS (p = 0.009). A similar pattern was observed in the left ECRL muscles. Comparing the results of the questionnaire for wrist/hand pain indicated that only 9.83% (n=6) of Bambach seat dentists reported wrist/hand pain, whereas 15% (n=9) of CSD reported wrist/hand pain. This may be due to the decreased wrist extensor muscle activity in BSD.

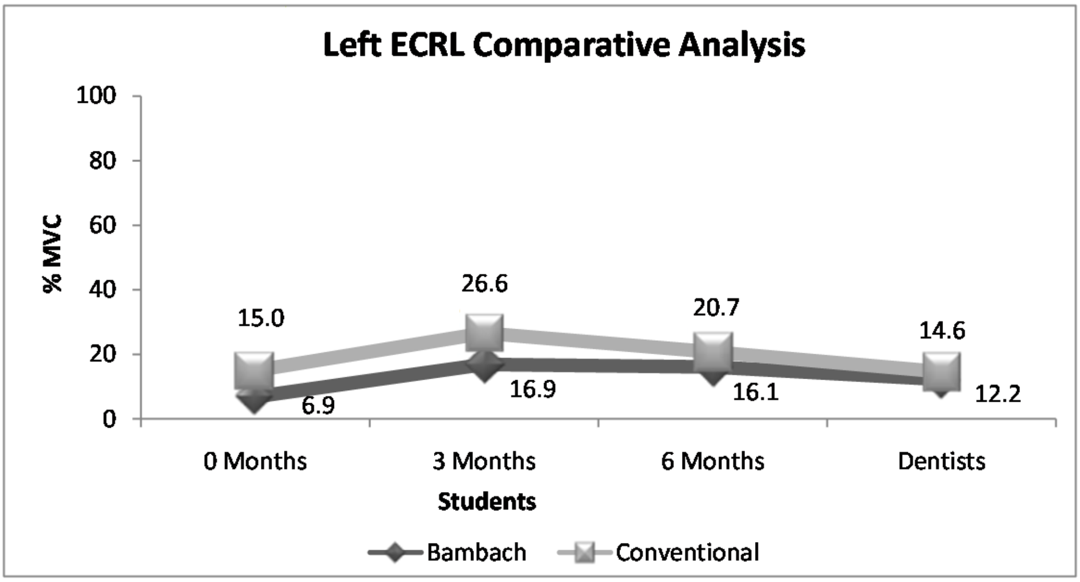


Fig. 6-126. Left Extensor Carpi Radialis Longus (Wrist Extensor) Comparative Analysis

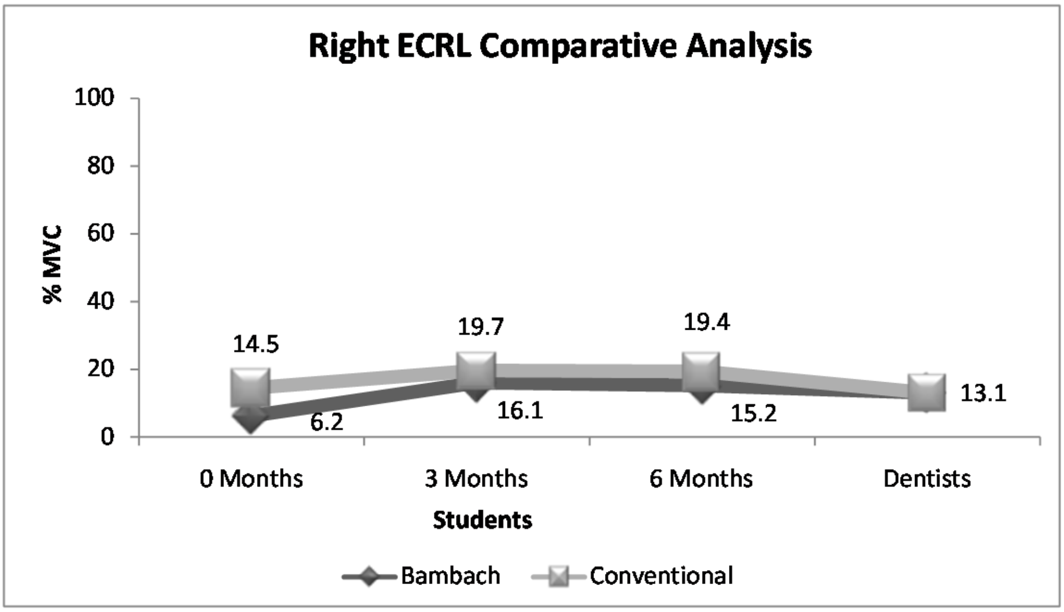


Fig. 6-127. Right Extensor Carpi Radialis Longus (Wrist Extensor) Comparative Analysis

6.7.9 Neck Angle (Neck Flexion) Analysis; their relationship to Neck Muscle activity (Dental Students and Dentists)

The Neck Angle Measurement study was performed to analyse and compare the position of neck and the associated muscle activity of splenius capitis (Neck extensors)

Methodology of Neck Angle Measurement

Dental Students: The photos taken during the EMG study of the dental students were used for Neck angle measurement (Figures 6-128 and 6-129).

Dentists: The photos taken during the EMG study of the dental students were used for neck angle measurement.

Research Design

A between-subject experimental design was selected. The neck flexion in two different seats with different subjects performing the same dental procedure was compared. The neck angles were measured using Adobe Illustrator CS2 (Version 12.0.1), specialised software in which angles may be measured by connecting any two points in a photograph.

Subjects

Dental Students: The study was introduced to all the Year 2 dental students at the Dental School who were attending their first classes in the phantom head laboratory. They were given information sheets (Appendix XIII) and consent forms (Appendix XIV) and asked to return the forms if they were willing to participate in the study.

Photographs of 50 dental students (25 Bambach and 25 Conventional) taken during the final set of EMG data collection at 6 months were selected at random using a random number generator (http://www.segobit.com/rng.htm) and used for analysis.

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Dentists: The study was introduced to all the Dentists who participated in the Questionnaire Study. At the end of the questionnaire they were given information about further study and if they are willing to participate in further study they were asked to complete the bottom portion at the end of the questionnaire. An information sheet (Appendix XXIX) and a consent form (Appendix XXX) were sent to the dentists who were willing to participate in further study. Photographs of 22 dentists (12 Bambach and 10 Conventional) taken during the EMG study of dentists were selected at random using a random number generator (http://www.segobit.com/rng.htm) and used for analysis.

Procedure:

The photos were opened using the Adobe Illustrator CS2. The pen tool was used and a line was drawn connecting the External Occipital Protuberance and C7 Spinous process in the photo. When the line is connected an information palette in the software indicates the angle from the vertical through the photo. This angle was noted: 90 degrees was then subtracted from the measurement to obtain the actual neck flexion angle.

Fig. 6-128. A Year 2 Student working seated on a Bambach Saddle Seat

Fig. 6-129. A Year 2 Student working seated on a Conventional Seat

Note: The angle of neck flexion is indicated thorough blue lines, measured using the Adobe Illustrator CS2.

Data Analysis

An Independent Samples T-Test was used to determine the difference between the angles measured with the subjects using the Bambach Saddle Seat and Conventional Seat. The level of significance used was 0.05.

Results

The results indicated that there was a significant difference between the seats in both the dental students and dentists i.e. the dental students and dentists using the Bambach saddle seat recorded significantly less neck flexion angle compared to the dental students and dentists using the Conventional seat. The mean and standard deviations for the neck flexion in the dental students and dentists are shown in the table below (Table. 6-52). There was a significant difference when compared between the groups (p= .000) for the neck flexion (Table 6-53).

	Type of Seat		Mean	Std. Deviation	Std. Error Mean
Students Neck Angle Measurement	Bambach	25	31.71	9.24	1.84
	Conventional	25	59.43	15.35	3.07
Dentists Neck Angle Measurement	Bambach	12	32.67	7.77	2.24
	Conventional	10	49.45	7.57	2.39

Table. 6-52. Descriptive Statistics

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Students Neck Angle Measurement	Equal variances assumed	17.22	.000	-7.73	48	.000	-27.72	3.58	-34.92	-20.51
	Equal variances not assumed			-7.73	39.39	.000	-27.72	3.58	-34.96	-20.47
Dentists Neck Angle Measurement	Equal variances assumed	.01	.907	-5.09	20	.000	-16.78	3.29	-23.64	-9.91
	Equal variances not assumed			-5.11	19.46	.000	-16.78	3.28	-23.64	-9.91

Table. 6-53. Independent Samples T-Test

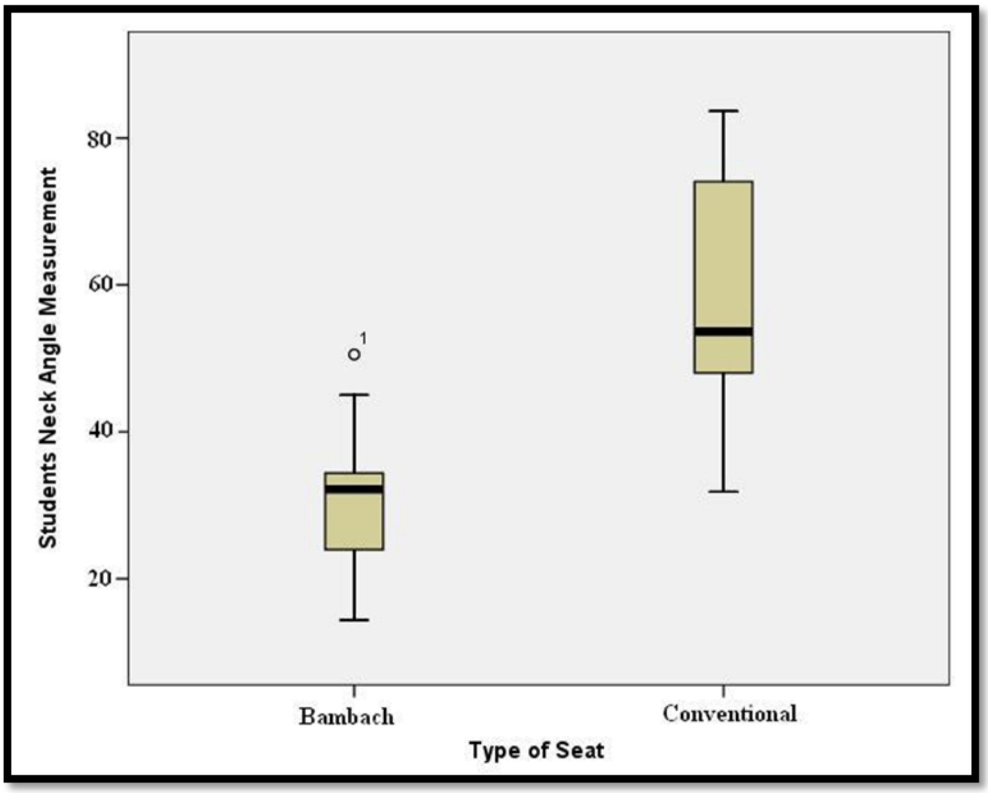

Fig. 6-130. Box Plot – Students' Neck Flexion Angle

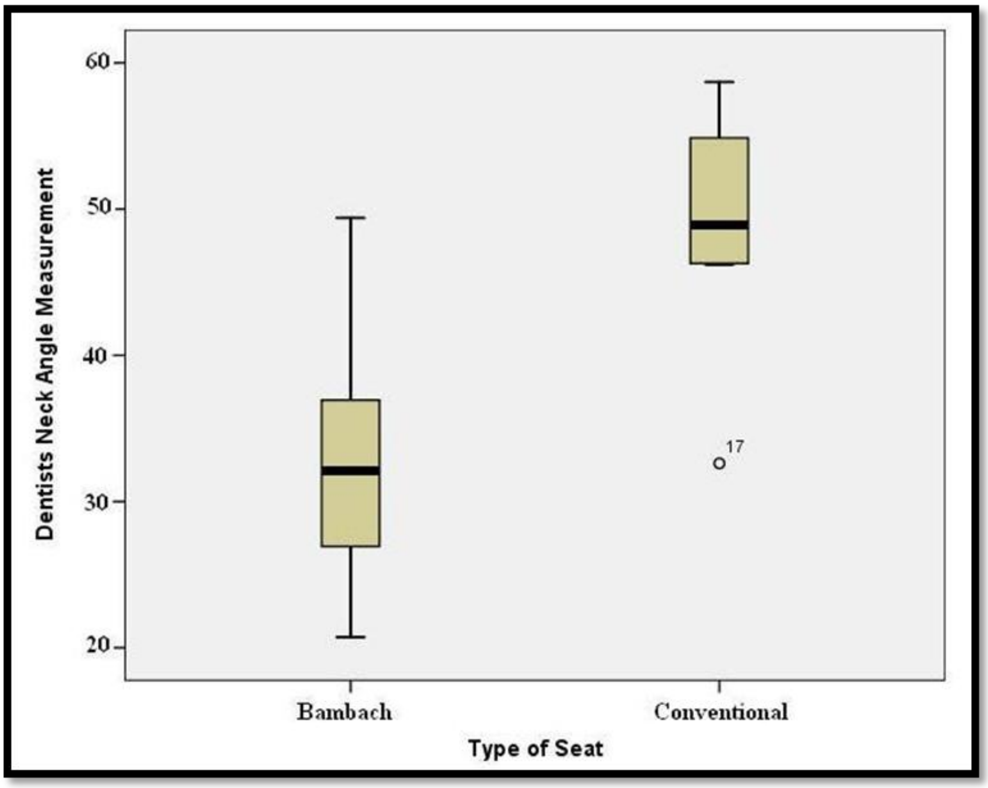

Fig. 6-131. Box Plot – Dentists, Neck Flexion Angle

Discussion

The results indicate that there is a statistically significant difference between the neck flexion angles between the Bambach and Conventional seat students and dentists. Figures 6-130 and 6-131 indicate the mean and standard deviation in box plots. The results of the EMG study also indicate that the students and dentists using the Bambach saddle seat recorded significantly less neck muscle activity compared to students and dentists using the Conventional seat. This may be because of neck flexion; the muscle activity may increase as the angle of neck flexion increases (Seghers et al 2003; Villanueva et al 1997). This means that the loading on the neck extensors increases as the angle of neck flexion increases, because in flexion the neck extensors need to work harder to stabilise the weight of head, but in extreme flexion the neck muscle may fatigue (Smith et al 2002).

Finsen (1999) studied the biomechanical aspects of neck postures during dental work, the aim of the study being to determine the joint movements and muscle activity of the neck (Splenius Capitis) during forward flexion of the cervical spine and to evaluate the load of the neck region. A three dimensional (3-D) video and surface EMG from the splenius muscles were recorded in two common work postures i.e. working in the mouth resulting in hyper-flexion of the neck, and the other handling equipment above the patient which involves moderate flexion of the neck. Seven female dentists took part in the study. The results found no significant difference in muscle activity between hyper-flexed and moderately flexed neck positions (Refer to Chapter 7, Section 7.4.1). This may be because the study compared moderate flexion and extreme flexion; extreme flexion may stretch the muscle, which may lead to fatigue and may decrease the muscle activity. This is not the case in the present study where BSD and BSS with slight to moderate flexion (Mean 31.7 and 32.7 degrees) and CSS and CSD with moderate to severe flexion (Mean 59.4 and 49.5 degrees) were compared; and there may be a difference in muscle activity which is clearly identified in this study. This model is further supported by Bonney and Corlett (2002) who investigated head posture and loading of the cervical spine. They found that, after one hour exposure whilst sitting in a controlled posture, there was significant differences in the shrinkage of spine between the horizontal gaze and the 20° and 40° angles below the horizontal which indicates loading of the cervical spine.

Villanueva et al (1997) investigated neck and shoulder muscle activities at three screen height settings (80, 100 and 120 cm) in ten healthy subjects. The muscles investigated were neck extensors and descending part of the trapezius muscle. They found that an increase in angle of neck flexion increased neck extensor muscle activity. Similarly Seghers et al (2003) investigated prolonged VDT work (89 minutes) at four different screen height settings on head-neck posture, muscle activity and development of muscle fatigue in sixteen subjects (8male and 8 female). The muscles investigated in the study were trapezius, deltoid, splenius capitis and sternocleidomastoid. The results indicated that lowering the screen height increased the viewing angle and increased neck flexion, thereby increasing neck extensor (splenius capitis) muscle activity, which was similar to the findings reported in this study. The results also indicated that there was no significant difference in activity of the other muscles investigated in the study. They also indicated that there were rare occurrences of muscle fatigue.

6.7.10 General Discussion

Neck Extensors (Splenius Muscles):

The results indicated that for the BSS the muscle activity significantly decreased over the 6-month period for both the right and left splenius muscles while using the Bambach seats for their practical sessions. This may be because that the individuals using the Bambach saddle seat are getting used to the normal biomechanical support (Cram & Vinitzky, 1995), which is provided by the Bambach saddle seat in which minimal effort is required to maintain the posture.

In the Conventional seat group a similar pattern was observed but the amount of reduction of % MVC was significantly less compared with the Bambach seat group. This may be because the individuals using the Conventional seat become used to the slumped posture which may be encouraged by the Conventional seat, which provides inadequate biomechanical support where fatigue occurs (Cram & Vinitzky, 1995), the spinal ligaments, joint capsules, the vertebral body and the discs being subjected to excessive strain in this position (Nachemson, 1966) (Chapter 1; Section 1.1.6 and 1.1.7)

Shoulder Elevators (Trapezius Muscles):

The results indicated that for the BSS the muscle activity significantly decreased over the 6-month period for both the right and left upper trapezius muscles while using the Bambach seats for their practical sessions. The reason may be similar to that of splenius muscles in which normal biomechanical support is provided by the Bambach saddle seat. Additionally, the normal spinal and neck posture provided by the

Bambach saddle seat keeps the shoulders in a relaxed position where only minimal activity of the trapezius muscles are required.

In the Conventional seat group a similar pattern was observed but the amount of reduction of % MVC is significantly less compared with Bambach group. The reason may be similar to that of splenius muscles where there is an increased need for trapezius muscle activity in order to maintain the shoulders in position.

Spinal Extensors (Longissimus Thoracis and Multifidus Lumborum)

The results indicated that for the BSS the spinal extensor muscle activity increased in the first three months and decreased in the next three month period (Figure 6-16, 6-17, 6-120 and 6-21). The Bambach saddle seat keeps the spine in its normal 'S' shape during the seated posture. This may require active back muscle contraction to maintain the posture, and may be the reason for the increase in muscle activity in the initial three months (Gandavadi et al, 2005; Keagy et al, 1966). Around 50% of BSS reported low back pain in the DSS at 3 months; this may be correlated with the increased back muscle activity at 3 months. In the next three months the muscle activity was found to be significantly reduced. This may be because the students were becoming accustomed to the biomechanical support provided by the Bambach saddle seat (Cram & Vinitzky, 1995), the posture being maintained by the passive structures of the spine. This is clearly shown with BSD for whom back muscle activity was significantly less when compared with BSS, possibly because BSD were found to have been using the Bambach seat for an average of 3.22 years, whereas the BSS have been using the seat for only 6 months.

EMG and posture analysis using concave shaping under the ischial tuberosities as well as a downward slope of 18% have produced lower overall lumbar muscle activity (Graf & Guggenbuhl, 1993). It would seem that although the Bambach Saddle Seat is not a mechanical aid to control pelvic stability, it utilizes its saddle seat shape to control the pelvis, and the necessary stability for optimal spinal muscle activity is achieved (Verkindere et al 1998). This is supported by earlier studies on the seat, demonstrating that lumbar lordosis can be maintained for longer periods of time than in a standard chair (Gale et al 1989).

In the CSS the spinal extensor muscle activity significantly increased over the 6-month period (Figure 6-132). In a habitually slumped sitting position, an imbalance in the muscle fibres occurs. Instead of the slow oxidative fibres of back muscles the fast twitch muscle fibres may be activated (Cram & Vinitzky, 1995), the implications being that an individual will have the strength to sit upright for short periods of time only, after which fatigue and slump occurs (Garlick, 1998; Cram & Vinitzky, 1995). This would seem increasingly important where it has been identified that lumbar fatigue impairs the ability to sense a change in lumbar position, where this perception of trunk position and motion is essential for correct placement of the trunk with all activity (Taimela et al 1999).

Schuldt et al (1986) analysed the effect of changing the sitting posture on the level of neck and shoulder muscular activity. They found that slumped posture produced a higher level of activity in neck and shoulder muscles than erect posture (Refer to Chapter 1, Section 1.1.12). This is clearly shown with CSD in whom back muscle activity was significantly greater when compared to BSD and was comparable with CSS. In slumped posture the body weight is supported by the passive structures, the ligaments and posterior joint capsules, since the line of gravity falls posterior to the ischial tuberosities. But long-term use of this posture may cause pain and increase the back muscle activity, which was seen in CSS and CSD.

In a study by Cram and Vinitzky (1995), 24 subjects were asked to engage in a seated writing task for ten minutes for each of three special chairs (Balans - Kneeling Chair, Back-Up and Office Chair). The results of the study indicate that Balans chair required significantly higher levels of recruitment to stabilize the pelvis and spine compared to Back-Up or the Office chairs. The results also indicated that the EMG activity from minute one through five was the greatest for the Office chair, suggesting that over time, subjects sitting in the office chair must rely more and more on the Back muscles for stabilization and support of the pelvis which may lead to fatigue. This phenomenon was observed in the CSS and CSD. In reviewing a sitting aid that mechanically stabilized the pelvis in a standard chair, they found that the more one sits in a chair that offers mechanical support to the pelvis and lower spine, the less supplemental muscular effort is required to perform a sitting task. This may be the reason for lower muscle activity recorded among BSS and BSD.

Kuriyama and Ito (2005) investigated EMG functional analysis of the lumbar spinal muscles with low back pain with 22 patients with low back pain and 22 healthy volunteers. Surface EMG was recorded bilaterally from multifidus and longissimus muscles at the L3 level. EMG was recorded in standing resting position, during trunk forward flexion and extension, lateral bending and axial rotation. In standing no muscular activity was observed in both the groups. No muscular activity was observed in full trunk flexion in the control group, whereas continuous muscle activity was observed in the low back pain group. On axial rotation, an intermuscular time lag was observed at the beginning of the motion in the control group, whereas this phenomenon was not observed with low back pain group.

Analysing the spinal extensor muscle activity of the dentists with and without low back pain in both the groups indicate no significant difference between the EMG in both the groups ($P>0.05$). This may be because of the small number of subjects. However the Conventional seat dentists with low back pain (n=5) recorded increased mean muscle activity in both the longissimus thoracis and multifidus lumborum muscles compared to the dentists without low back pain (n=5); whereas the mean muscle activity of the Bambach seat dentists is similar with both the groups with (n=5) and without (n=7) low back pain. This indicates that the dentists who are seated in a slumped posture combined with low back pain recorded increased muscle activity in spinal extensors (Kuriyama and Ito, 2005); whereas even with low back pain the dentists using the Bambach seat recorded similar muscle activity. This may indicate that the Bambach saddle seat may be beneficial in reducing the muscle activity in dentists with or without low back pain.

Figure 6-132 indicates muscle activity (Percentage MVC) of the dental students at 6 months. The colour bright green indicates lower muscle activity and dark red indicates higher muscle activity.

Conventional Seat **Bambach Saddle Seat**

Bright Green	Green	Orange	Red	Dark Red
0 – 20	21 – 40	41 – 60	61 – 80	81 – 100

Fig. 6-132. Percentage MVC of Students at 6 Months (Right and Left Sides)

6.7.11 Case Study of a Dental Student with Back Pain

The study was undertaken at the School of Dentistry – University of Birmingham.

Subject

A 4th year dental student (PH) with severe back pain was investigated using surface EMG. PH was given information sheet (Appendix XXXI) and written consent (Appendix XXVIII) was obtained for the study and for the photographs to be taken during the study (Appendix XV). The student was given a dental ergonomic questionnaire (Appendix XXXII) to note work habits and the level of pain.

Initial Assessment and Surface EMG

A physical examination (Initial Assessment) of the back was performed before the commencement of the study to note the severity of symptoms, regions of pain and the level of pain. The physical examination (Appendix XXXV) revealed severe pain in the right shoulder (posterior), right neck (posterior), and left lumbar region. Severe muscle spasm / tightness was seen in the upper and middle trapezius. The pain level was 10/10 on a VAS Scale. The initial set of EMG was collected during five sessions at the clinics for 10 minutes each during the March and April 2006 (Fig. 6-133). PH was not given any ergonomic interventions or instruction during the initial set of data collection.

Ergonomic Intervention

On completion of the data collection PH was given a BS and was trained for 10 minutes on how to position and use the seat. PH was then instructed to use the BS for the sessions in the clinics at the dental school. PH was also taught general stretching exercises (Appendix XXXVI) and was instructed to perform the exercises twice a day, and was then regularly observed in the clinics and was given appropriate instructions on seating. The feedback received from PH indicated that the symptoms and pain level gradually decreased during 6 months and this was maintained for the following 6 months.

Final Assessment and Surface EMG

Following 12 months use of the BS and at the completion of her studies PH underwent further five sessions of EMG assessment during the clinics (Fig. 6-134). A physical examination (Final Assessment) of the back was performed after the final set of data collection to note any changes in the severity of symptoms, regions of pain and the level of pain compared to the initial assessment.

Apparatus

a. EMG Apparatus
b. Electrodes: Bipolar Electrodes, interfaces and reference electrode
c. A digital camera for taking photographs during the study

Procedure:

Before the commencement of data collection the patients were informed about the study and verbal consent was obtained. The procedure and the placement of electrodes were explained to the student before the study. The skin preparation, placement of electrodes, and the method of MVC measurement, were similar to the procedure explained in Section 6.7.4.3.

When PH was ready the EMG apparatus was switched on and then she was instructed to start the dental procedure and to continue for ten minutes. The EMG apparatus is pre programmed to stop after 10 minutes. The same procedure was repeated for all sets of data collection. During the procedure photos are taken at various angles, which are explained in Section 2.14.1.3.

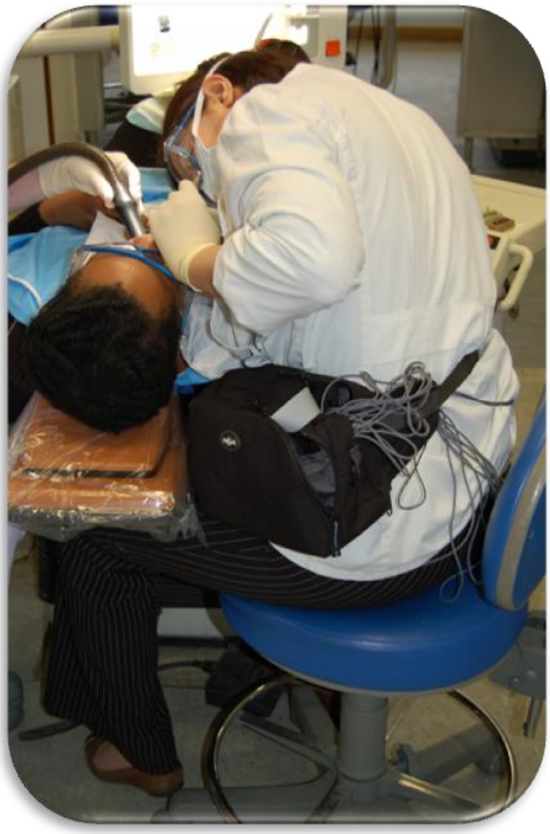

Fig. 6-133. The student working seated on a Conventional Seat

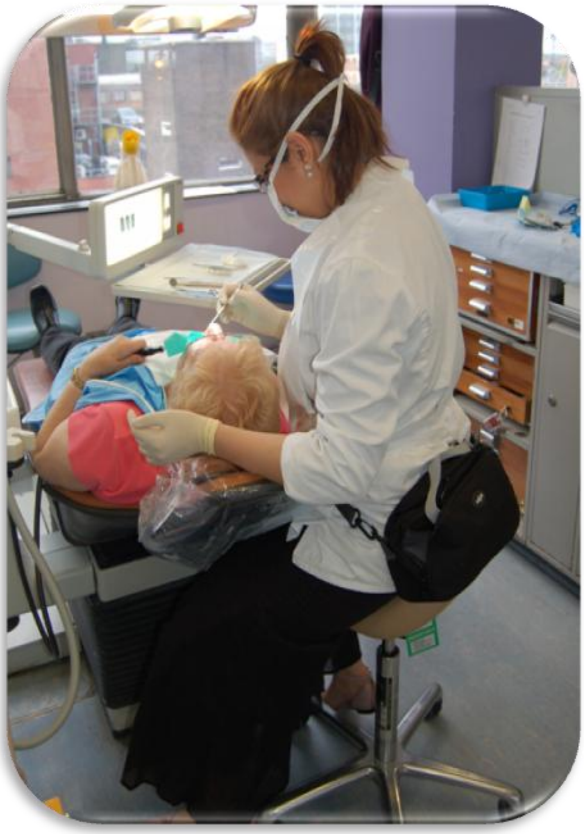

Fig. 6-134. The student working seated on a Bambach Saddle Seat

Data Analysis

The hypotheses are two tailed. Mann-Whitney Test was used to determine the difference between the muscle activity with the subject using the BS Seat and CS. Mann-Whitney Test was used for statistical analysis (n=5) with a level of significance of 0.05..

Results (10 Minutes Average)

The physical examination (Appendix XXXVII) revealed no pain / tightness / muscle spasm in any of the areas previously reported in the initial assessment. The pain level was 0/10 on a VAS Scale. The range of motion of the cervical and lumbar spine had significantly improved. The muscle activities comparing the initial and final recordings are reported below.

Splenius Muscles (Fig 6-135):

Left: The results indicated a significant difference between the two seats for the left splenius muscles (p = 0.008).

Right: The results indicated a significant difference between the two seats for the right splenius muscles (p = 0.032).

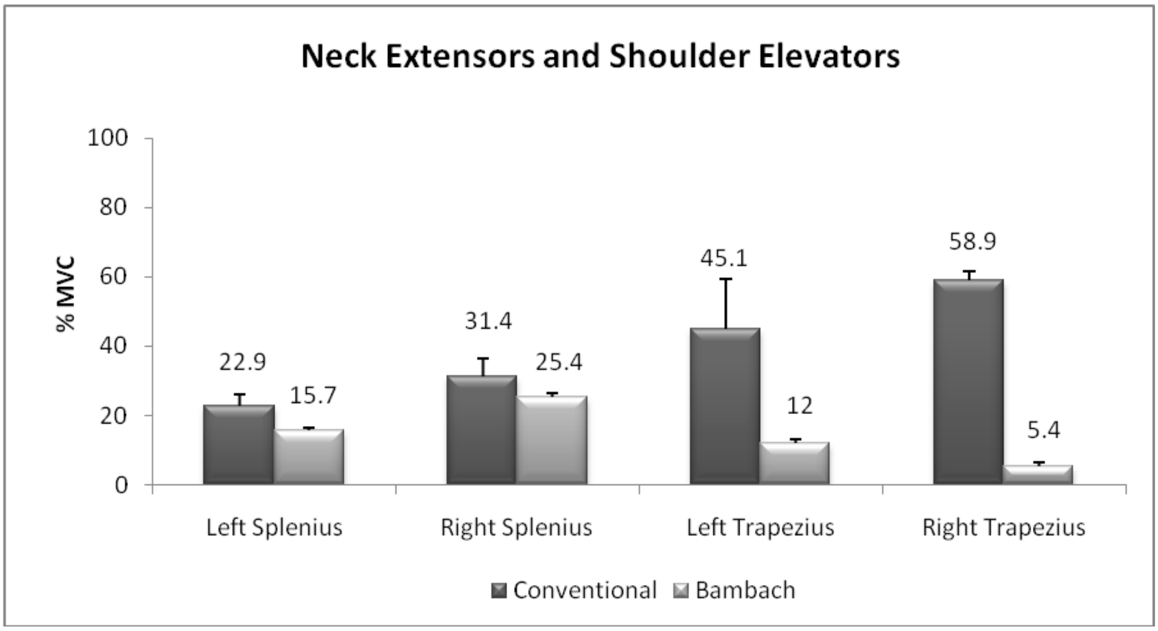

Fig. 6-135. Ten-Minutes Average of Splenius and Trapezius Muscles

Trapezius Muscles (Fig. 6-135):

Left: The results indicated a significant difference between the two seats for the left trapezius muscles (p = 0.008).

Right: The results indicated a significant difference between the two seats for the right trapezius muscles (p = 0.008).

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	Seating					Lower Bound	Upper Bound		
Left Splenius	Bambach	5	15.71	.79	.35	14.72	16.69	15.03	17.07
	Conventional	5	22.88	3.28	1.47	18.80	26.96	18.44	26.85
Right Splenius	Bambach	5	25.38	.90	.40	24.27	26.50	24.71	26.83
	Conventional	5	31.38	5.15	2.30	24.98	37.78	25.60	37.05
Left Trapezius	Bambach	5	11.99	1.28	.57	10.40	13.58	10.75	14.16
	Conventional	5	45.11	14.18	6.34	27.51	62.72	34.99	66.96
Right Trapezius	Bambach	5	5.41	1.16	.52	3.96	6.86	4.37	7.42
	Conventional	5	58.90	2.76	1.23	55.47	62.34	54.60	62.11

Table. 6-54. Descriptive Statistics (10 Minutes Average)

Longissimus Thoracis Muscles (L1 Level) (Fig. 6-136):

Left: The results indicated a significant difference between the two seats for the left longissimus thoracis muscles (p = 0.008).

Right: The results indicated a significant difference between the two seats for the right longissimus thoracis muscles (p = 0.008).

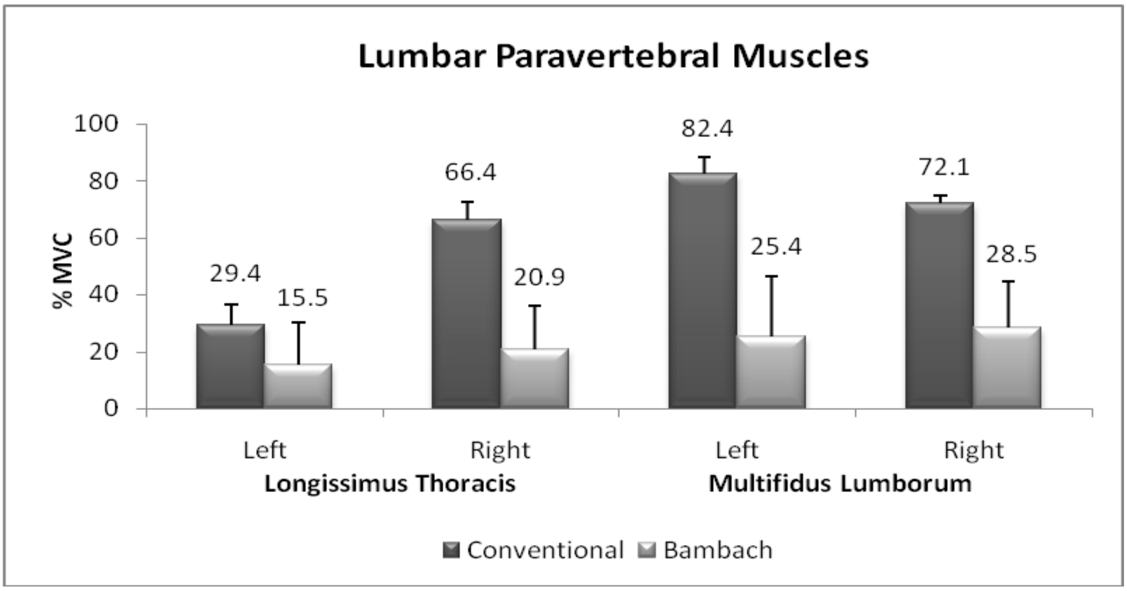

Fig. 6-136. Ten-Minutes Average of Lumbar Paravertebral Muscles

Muscle	Seating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Left Longissimus Thoracis	Bambach	5	15.52	1.33	.59	13.86	17.17	14.19	17.12
	Conventional	5	29.42	8.25	3.69	19.18	39.67	20.53	40.78
Right Longissimus Thoracis	Bambach	5	20.88	3.49	1.56	16.54	25.23	17.12	26.64
	Conventional	5	66.39	20.87	9.33	40.47	92.31	36.49	85.09
Left Multifidus Lumborum	Bambach	5	25.37	1.58	.70	23.40	27.34	23.92	27.71
	Conventional	5	82.37	11.68	5.22	67.86	96.88	63.01	90.24
Right Multifidus Lumborum	Bambach	5	28.52	.72	.32	27.62	29.42	27.75	29.71
	Conventional	5	72.10	9.03	4.04	60.88	83.32	59.14	84.40

Table. 6-55. Descriptive Statistics (10 Minutes Average)

Multifidus Lumborum Muscles (L5 Level) (Fig. 6-136):

Left: The results indicated a significant difference between the two seats for the left multifidus lumborum muscles ($p = 0.008$).

Right: The results indicated a significant difference between the two seats for the right multifidus lumborum muscles ($p = 0.008$).

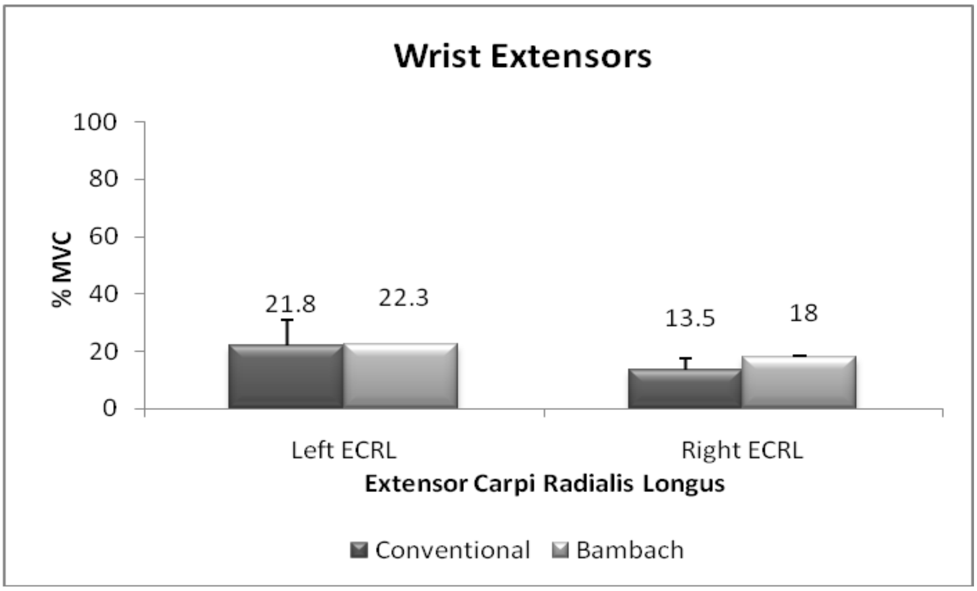

Fig. 6-137. Ten-Minute Average of Wrist Extensor Muscles

Extensor Carpi Radialis Longus Muscles (ECRL) (Fig. 6-137):

Left: The results indicated no significant difference between the two seats for the left ECRL muscles (p = 0.690).

Right: The results indicated no significant difference between the two seats for the right ECRL muscles (p = 0.016).

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
Muscle	**Seating**					**Lower Bound**	**Upper Bound**		
Left ECRL	Bambach	5	22.28	.15	.06	22.09	22.48	22.12	22.46
	Conventional	5	21.82	9.02	4.03	10.62	33.03	9.23	33.35
Right ECRL	Bambach	5	18.02	.56	.25	17.32	18.71	17.42	18.94
	Conventional	5	13.52	4.08	1.82	8.45	18.59	6.64	17.46

Table. 6-56. Descriptive Statistics (10 Minutes Average)

Discussion

PH reported no pain in her back, neck or the upper limbs whilst undertaking dental work after six months use of the BS and this had continued for the remaining 6 months. This was reflected in the lowered EMG recordings indicating the decrease of muscle activity of all the muscles investigated except the left extensor carpi radialis longus where there is no significant difference. Although PH had been given a home exercise program to assist in re education of functional muscle activity she admitted that she had not performed any of the given exercises. This strengthens the impact of the BS as the decrease of pain and muscle activity recorded may solely be due to the use of the chair.

The decreased back muscle activity recorded following 6 months use of the BS may be because the BS keeps the spine in its normal ‘S’ shape during the seated posture, with the pelvis facilitated in an anterior tilted position. PH was able to accept this position and in doing so the over activity of the postural muscles was inhibited and she may become accustomed to the biomechanical support provided by the BS, the posture being maintained by the passive structures of the spine (Milerad et al, 1991).

Graf and Guggenbuhl (1993) measured EMG when using concave shaping under the ischial tuberosities as well as a downward slope of 18%, this position keeps the pelvis in the anterior tilted position and maintains lumbar lordosis, which is similar to the BS. The results indicated that this position produced lower overall lumbar muscle activity. It would seem that although the BS is not a mechanical aid to control pelvic stability, it utilizes its saddle seat shape to control the pelvis, and the necessary stability for optimal spinal muscle activity is achieved (Verkindere et al. 1998). With this level of muscle activity the conditions for development of myalgic pain are avoided. This is supported by earlier studies on the BS, demonstrating that lumbar lordosis can be maintained for longer periods of time than in a standard chair (Gale et al. 1989).

The spinal extensor activity was significantly higher when PH was using the CS and she had adopted a slumped and rotated position for dental work. In a habitually slumped sitting position, an imbalance in the back muscle activity may occur. Instead of the slow oxidative back muscle fibres the fast twitch back muscle fibres may be activated (Cram and Vinitzky, 1995; Kuriyama and Ito, 2005), the implications being that an individual will have the strength to sit upright for short periods of time only, after which fatigue and slump occurs (Cram and Vinitzky, 1995; Garlick, 1998). This phenomenon is further supported by Kuriyama and Ito (Kuriyama and Ito, 2005) where they found continuous muscle activity in patients with low back pain.

The increase in trapezius and splenius muscle activity during dental work has been reported by Finsen et al (1998) and Milerad et al (1991), and this was seen with PH when using the CS. However this activity was significantly reduced with the use of the BS, indicating that the BS influenced upper limb and neck muscle activity by facilitating the spinal position.

The results indicated that the muscle activity of splenius, trapezius, longissimus thoracis and multifidus lumborum have a net decrease over a 12 month period when sitting on a BS. PH's muscle activity could have decreased even when using a CS, however considering the general pattern of muscle activity observed with year 2 dental students and dentists indicate that long-term use of a CS may increase muscle activity. The reduction in muscle activity when using a BS may be an indicator of improved posture and may result in lowering the incidence of musculoskeletal disorders occurring in dental practitioners.

Exercise is considered to be an important aspect in treating low back pain to bring the patient back to fitness. An RCT by Liddle et al (2004) looking at exercise and low back pain has indicated that strengthening exercises of the lumbar spine and lower limbs are considered to be an important component of exercise prescription for low back pain (Rainville et al 1997). Strengthening the spinal extensors along with abdominals are often incorporated to facilitate trunk stabilisation; with elements of flexibility also incorporated in the design. This may be considered important with respect to dentists and dental students as they work predominantly in static postures. A simple structured exercise programme for the patients with chronic low back pain to encourage patients to use their spine normally is also suggested (Moffett, 2002).

Chapter 7

The Ideal Operating Posture of a Dentist

7.0 Introduction:

Dentistry has been considered a demanding profession due to the need for high concentration and precision (Finsen et al 1998) and work-related musculoskeletal disorders, especially of the neck and upper limbs have become common among the dentists (Milerad and Ekenvall, 1990; Osborn et al.1990; Rundcrantz et al.1990; Oberg and Oberg, 1993; Akesson et al. 1995; Finsen, 1995). Most dentists currently work in a sitting position to the side of, or behind, the patient with the patient in a supine position (Finsen et al 1998). Dentists also employ a chair-side assistant, who generally sits on the opposite side of the patient to the dentist (Rundcrantz et al 1990). Because of the narrow work area (the mouth), and the need for dexterity the dentist needs to adopt inflexible work postures which results in static activity of the muscles, often in awkward postures, which resulting in musculoskeletal disorders (Refer to Chapter 1, Section 1.1.11). Shugars et al. (1987) found that low back pain was the most commonly reported symptom by dentists in USA followed by pain in the neck, shoulder, upper back and legs. Lake (1995) reported that dentists who he studied in Canada spent approximately two-thirds of each treatment hour in 19-54º of forward trunk inclination, which increases disc pressures considerably when compared to standing (Nachemson, 1976). The chapter gives details of studies which investigated operating posture in dentistry and then illustrates the 'Ideal Operating posture' recommended for the dentist based on the RULA and EMG study.

7.1 Ideal Operating Posture

There is no 'Ideal Operating Posture', but it is the intention of this part of the chapter to explain the dentist's optimal operating posture, based on previous studies and the EMG study of students and dentists in this study. Dentistry was previously practised with the dentist standing and the patient seated in an upright position. Vision of the oral cavity could only be obtained by bending the trunk and neck of the dentist, producing a distorted and unnatural body posture. When maintained over long hours this may cause strains on the musculature, and resultant physical fatigue. This may give rise to abnormal tensions in joints and ligaments particularly in the sacroiliac joint, zygapophyseal joints of the lumbar and cervical vertebrae and the muscles which maintain these joints. A foot control is used to operate the drill, so with the dentist standing, he/she operates the foot control with one foot and places most of the body weight on the other foot, producing imbalanced limb pressures and consequential altered musculoskeletal dynamics.

Paul (1969) was the first to suggest ways of eliminating stress and fatigue in operative dentistry. He reported that the main physical causes of stress and fatigue were standing with poor posture and with unequal weight bearing on the legs. He explained the positive effects of seated posture.

He explained that the most relaxed seated position is obtained when:

- Both feet are placed firmly on the floor
- The seat is no higher than the knees
- The back is vertical
- Vision is directed to the point of activity. The head will then be slightly tilted to focus the eyes on the hands

He also reported that the least fatiguing position of hand for manual work is within the range of armpit level to 30 cm below this. He reported that these are the positions of minimal stress which should to be adopted for operative dentistry. He also said that the operator's stool should be of correct height with adequate seat area and the point of activity (patient's mouth) should be placed so that the operator can

- Work whilst retaining his seated position
- Maintain his stress-free posture throughout the operation
- Bring all instruments to the patient’s mouth without leaving or changing position

He suggested that the ideal position of the patient is the horizontal lying position with the head as near as possible to the operator.

Paul (1969) suggested discarding the conventional dental chair in order to position the patient in the ideal position and the points of support for the patient’s body being occiput, shoulders, lumbar support, buttocks, legs and feet. The ideal chair should be contoured to follow the natural body curve of the back and support all body joints. There should be no protuberances to interfere with the operator’s thigh and it should have independent tilting of backrest and top, and tilted as far as 10 degrees below horizontal. The backrest of the patient’s chair should be thin, allowing only minimal distance between operator’s thighs and the patient. He also suggested that all instrumentation must be within the reach of seated operator. These elements resulted in changes in the concepts of surgery planning and equipment design. Employment of a chair-side assistant seated near the operator (Four-handed dentistry) was emphasized.

Catovic et al (1991) studied the influence of arm position on the pinch grip strength of female dentists in standing and sitting positions. They investigated the influence of arm positions on manual operations of female dentists, using a gripping device with strain gauges, an impulse amplifier, and a printer in order to record graphically registered deformation. The gripping force, measured in Newtons (N), was measured in the dominant arm at angles (0, 30, 60, 90 and 120 degrees). During the experiment the wrist joint was immobilised in a brace. The same measuring procedure was performed in sitting position. The results indicated that pinch grip forces were higher when the arm was supported both in sitting and standing positions compared with an unsupported arm. They suggested use of standing to perform operations such as taking impressions of the teeth.

Finsen (1999) investigated the biomechanical aspects of neck postures during dental work. He determined joint moments and muscle activity of the neck during forward flexion of the cervical spine and evaluated the load in the neck region. Seven female dentist volunteers were selected for the study. The seven dentists performed dental work sitting with their back upright and forward flexion of the neck. Video (3-D) and bilateral EMG recordings (splenius muscles) were taken during treatment of patients. The dentists changed between two postures during their work with patients. One posture was related to work in the mouth of the patient, resulting in maximal forward flexion on the neck, and the other posture was related to handling dental equipment above the patient resulting in moderate flexion of the neck. The first posture was performed approximately four times more frequently than the second posture, with a movement frequency of 1.5 times per minute (Finsen et al.1998). These typical and non-dynamic working postures were used for biomechanical analyses. No appreciable lateral flexion or rotation was registered in these postures. Because no movements were performed during the recording, one representative video frame was digitized for each of the two neck postures. Additionally, 10 s EMG recordings were analyzed for each posture.

Finsen (1999) then used 3-D analysis and estimated the movements at the atlanto-occipital (A-O) joint and the seventh cervical - first thoracic (C7-T1) joints. Maximal extension moments were estimated from maximal neck extension strength. Extension moments at the C7-T1 joint were significantly higher for a highly flexed position (45% of max) compared to a moderately flexed position (32% of max), but remained unchanged at the A-O joint (40% of max). The mean RMS (Root Mean Square) amplitude was 9% of maximal EMG in both positions (no bilateral differences). This difference between mechanical load and muscle load indicated that EMG may underestimate the total loads of the tissue. Lateral flexion influenced the lateral flexion moment while rotation did not influence the rotation moment. The study demonstrated the importance of quantification of joint loads in occupational risk assessment of the neck. The results of the neck angle measurement study indicated that there was a statistically significant difference between the neck flexion angles between the BS and CS students and dentists, i.e. the BSS and BSD recorded lower neck flexion. The results of the EMG study also indicated that the students and dentists using the BS recorded significantly less neck muscle activity compared to students and dentists using the CS. The results are different to the study by Finsen (1999). This may be because of differences in neck flexion, since muscle activity may increase as the angle of neck flexion increases (Seghers et al 2003; Villanueva et al 1997). This means that the loading on the neck extensors increases as the angle of neck flexion increases, because in flexion the neck extensors need to work harder to stabilise the weight of head, but in extreme flexion the neck muscle may fatigue (Smith et al 2002).

The following are the guidelines for correct operating position for dentists at their work place.

7.2 The Correct Operating Position of the Dentist: The figure below (Fig. 7-1 and 7-2) shows the ideal operating position using the BS and the CS.

Fig. 7-1. Ideal Operating Position (Bambach Seat)

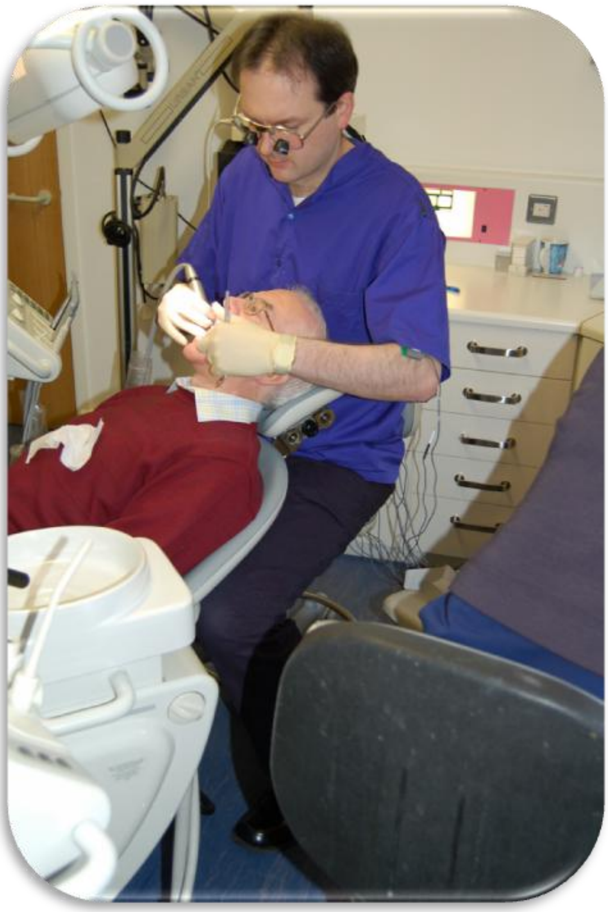

Fig. 7-2. Ideal Operating Position (Conventional Seat)

In general, static postures should be avoided; the concept of a single good posture may be illogical as the human body is designed for movement and changing postures (Lehto et al 1991). Working with prolonged static postures increases exposures to injury due to muscle fatigue, imbalance and ischemia resulting in pain (Valachi and Valachi, 2003a). The literature also supports the concept that the working position is varied as often as possible in order to shift the workload of muscles from one group to other and to replenish the blood supply of the muscles that maintains the posture (Harrison et al 1999; Callaghan and McGill, 2001). The results of this study have indicated that the BSD, in general, worked in an acceptable posture, recording lower muscle activity and decreased level of pain.

7.3 The Correct Position of the Patient: The patient height should be adjusted so that the patient's face is approximately level with the lower sternum of the operator (dentist) (Figure 7-5), or the patient's occiput is approximately level with the operator's elbow (Figure 7-6). This position may avoid unnecessary bending of the operator's neck and upper back and keeps the back in a neutral position. In addition, the patient's head and neck can be rotated in order to get direct vision of the operated tooth. If the operator is working on the patient's upper jaw it may be useful to keep the patient's neck in the extended position to get direct vision of the tooth. Prior to asking the patient to position their head in such positions the dentist should check that the patient has sufficient range of movement and has no history of vertebral artery insufficiency or other contraindications. It is also necessary that the operator changes the position of his/her stool to get better vision of the tooth being treated. Patients should not be positioned too high (Figure 7-3 and 7-4). This may cause elevation and abduction of the operators' shoulders and should be avoided.

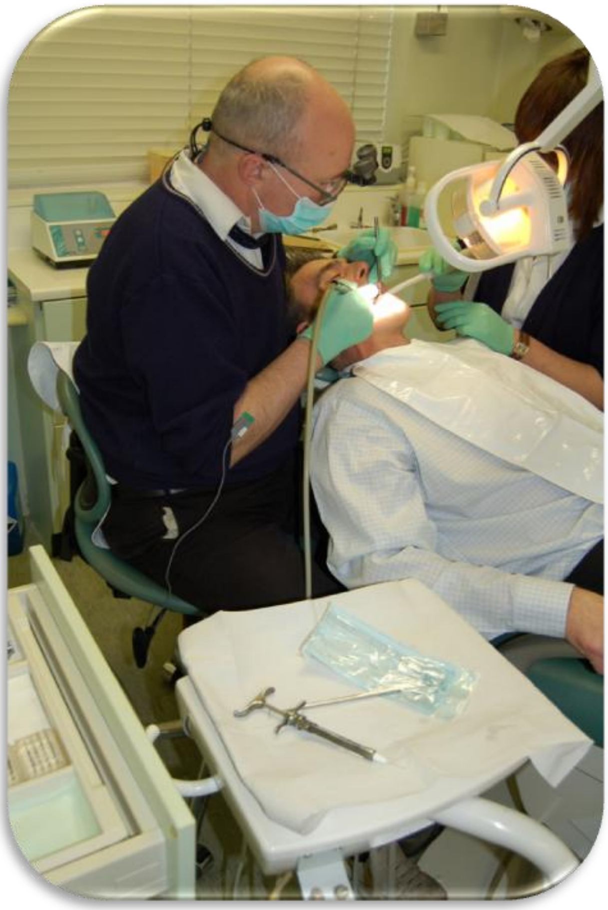

Fig. 7-3. Patient head positioned high (Bambach Seat)

Fig. 7-4. Patient head positioned too high (Conventional Seat)

7.4 The Optimal Position of Various Body Segments

The optimal position of various body segments during dental treatment is explained below in detail, with illustrations.

7.4.1 Neck: The neck should be kept as neutral as possible (Fig 7-5 and 7-6). About 15 to 20° of flexion (bending) may be allowed in the neck. Working with neck postures more than 20° of flexion was found to be associated with neck pain (Ariens et al 2001). In prolonged neck flexion the muscles of the neck and upper back are working continuously to support the weight of the neck and this may lead to discomfort and pain (Hertling and Kessler, 2005; Eriksen, 2004). Use of magnification lenses is emphasized to maintain the neck with less than 20 degrees of flexion (Valachi and Valachi, 2003b). The results of the present study indicated that the CSS and CSD recorded significantly increased neck flexion angles compared to BSS and BSD who had recorded optimal neck flexion angles, which is a significant factor in preventing neck pain. Any side flexion (side bending) should be avoided. Instead of side flexion during work, the position of the patients' head may be changed or the position of the operator may be varied in order to get direct vision of the tooth operated. If the height of the dental chair is optimally adjusted the tooth being operated upon may appear within the focal distance of the eye without a need for increased flexion in the neck.

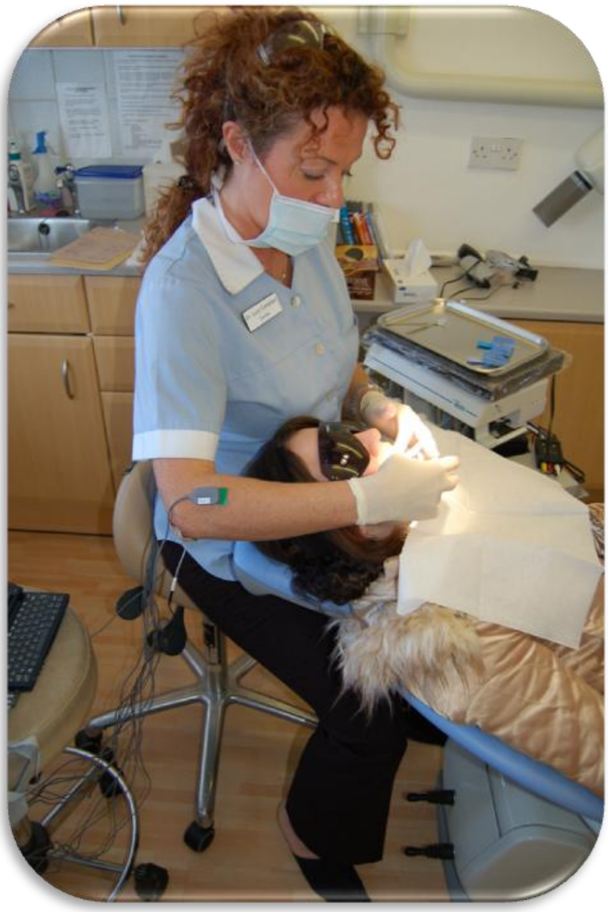

Fig. 7-5. Ideal Position of Neck and Upper Back (Bambach Seat)

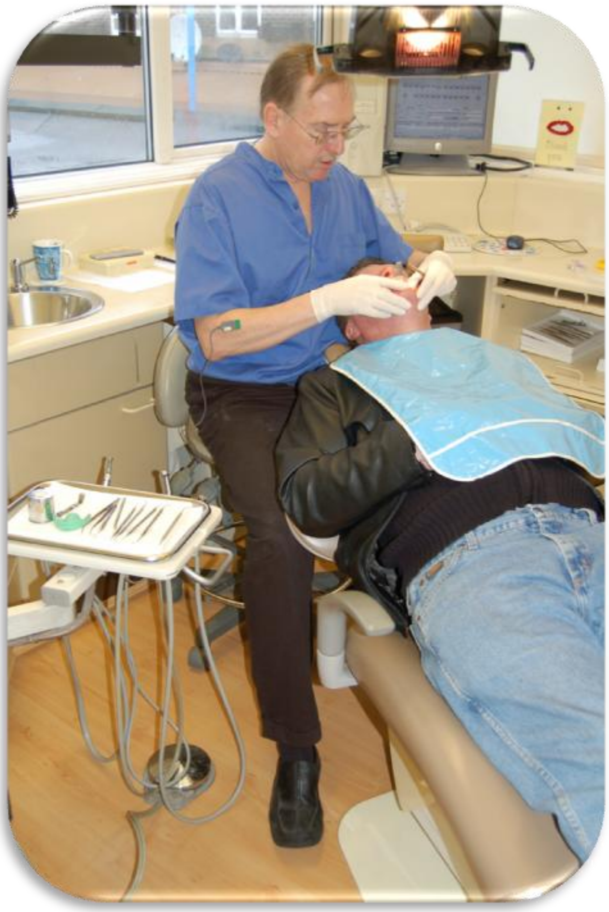

Fig. 7-6. Ideal Position of Neck and Upper Back (Conventional Seat)

7.4.2 Upper Back: The position of the upper back depends on the position of the neck. If the neck is hyper-flexed (excessive bending) the upper back also tends to be flexed. This may lead to discomfort or pain (Hertling and Kessler, 2005). The figures 7-5 and 7-6 show the ideal upper back position.

7.4.3 Shoulders: The shoulders should be kept in a relaxed position. It is common among dentists to work with raised shoulders and be avoided where possible (Refer to Chapter 3, Section 3.18). The results of the present study have indicated that this position increases the activity of upper trapezius muscles and may result in discomfort and pain. This may be due to the incorrect positioning of the patients' couch or the operators' stool. This may be avoided by simply positioning the patient at the correct height (Fig. 7-7).

The other common problem in the shoulder is the abduction of shoulders while working. This may increase the activity of upper trapezius, deltoid and neck muscles. This may easily be avoided if the dentist changes the position of the operators' stool. For example, to get direct vision of the upper tooth the dentist can work from the side of the patient instead of working from behind (Fig. 7-7). It is always necessary to keep the elbows near the trunk where possible. This may avoid unnecessary muscle activity in the shoulder, neck and upper back (Refer to Chapter 3, Section 3.18).

7.4.4 Elbows and Wrists: The elbows should be positioned around 100° to 110° of flexion and with the wrists in neutral or in slight extension in order to get a good grip of the instruments used. The functional position of the wrist is slight extension with slight flexion of fingers in the inter-phalangeal joints with the thumb at the side of the index finger. This position allows good gripping of the instruments. It is also necessary to use the pencil grip of the instruments when working with patients as this is ideal grip for the wrist. Figure 7-7 shows the ideal position of elbows (approx 100° of flexion), wrist (Slight Extension) and the fingers with pencil grip of instruments.

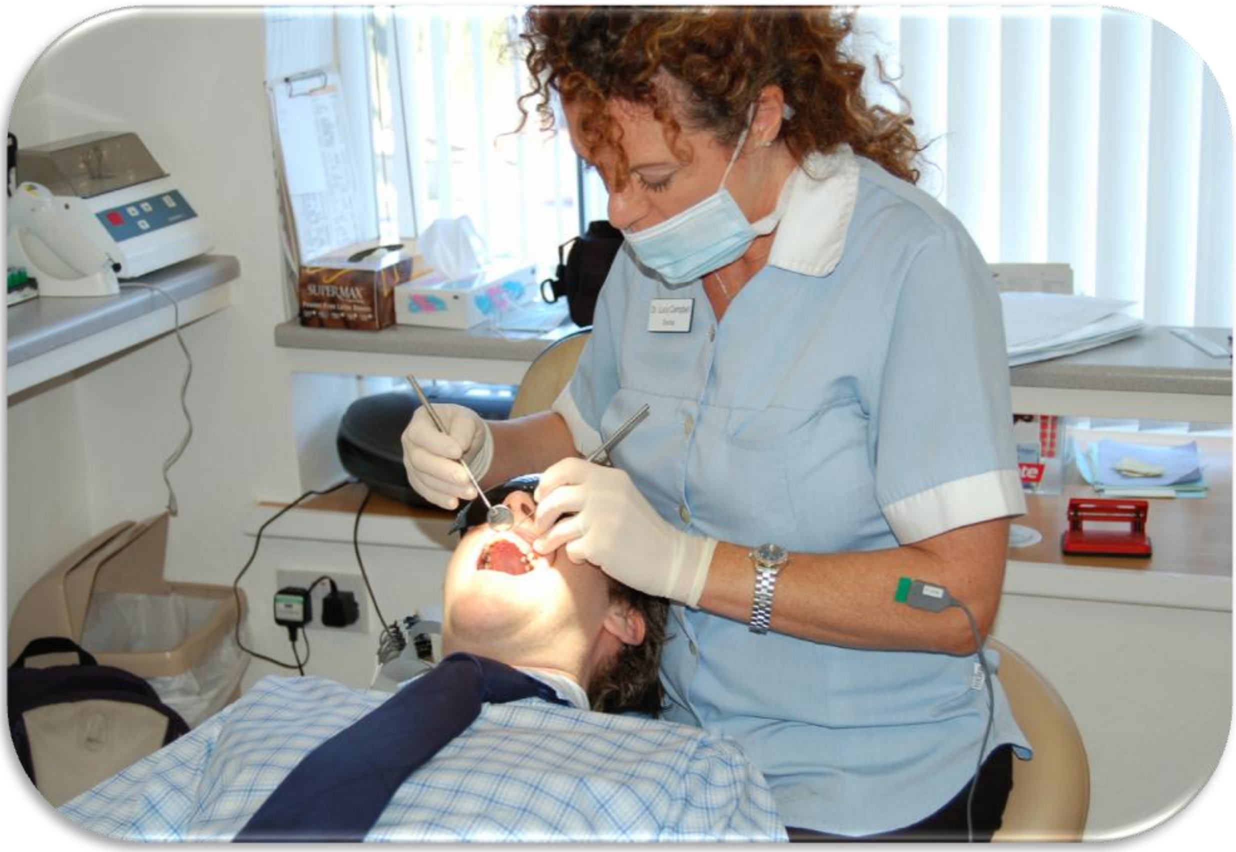

Fig. 7-7. The Ideal Position of Shoulders, Elbows and wrists (Bambach Seat)

7.4.5 Lower back: The position of the lower back depends on the position of the neck, upper back and the seat angle (Chaffin et al 2006). If the neck and upper back is hyper-flexed or the operator’s stool is flat or posteriorly tilted the lower back tends to slump. This slumped posture, added to repeated leaning towards a patient when working, can cause strain over the lower back extensors and may contribute to low back pain (Granata et al 2005). The transversus abdominus muscles are slack in this position and may become weak, this being an important factor for low back pain (Hodges and Richardson, 1996; Hides et al 1996) (Refer to Chapter 1, Section 1.1.17). Positioning the patient and adjusting the operators' stool may overcome this problem. The results of this study indicated that the BSS and BSD recorded significantly lower back muscle activity compared to CSS and CSD. Figure 7-8 shows the ideal lower back position with lumbar lordosis. Tilting the seat anteriorly to 15 degrees may increase lumbar lordosis (Chaffin et al 2006), the lumbar lordosis being necessary to maintain the normal s-shape of spine. The use of the saddle seat promotes the natural low back curve by increasing the hip angle (Valachi and Valachi, 2003b) which enables sitting close to the patient and positioning the knees under the dental chair (Fig. 7-8).

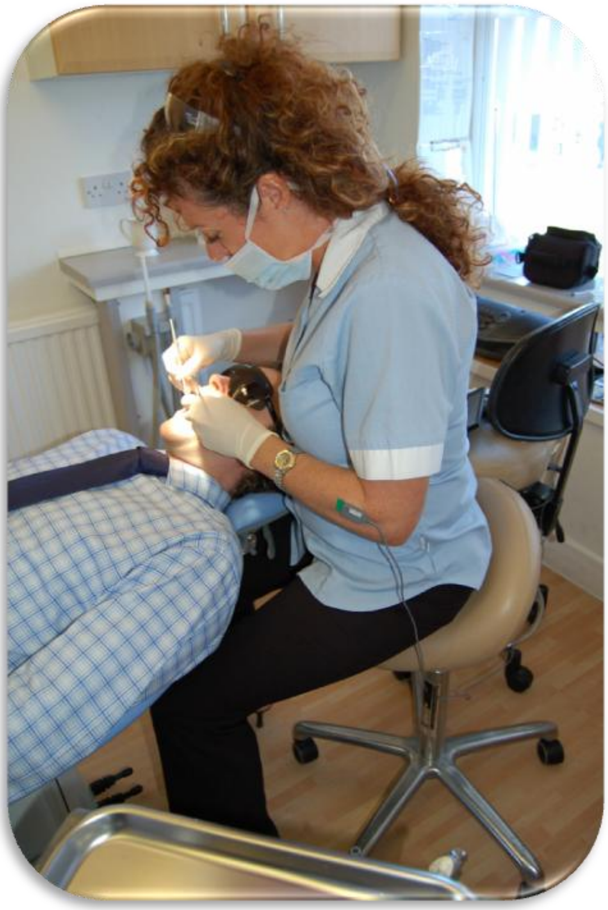

Fig. 7-8. Ideal position of Lower Back pelvis and Hips (Bambach Seat)

7.4.6 Pelvis and Hips: The position of the pelvis and hips are important to preserve the normal s-shape of the spine. The pelvis, when anteriorly tilted with the hips around 110° to 120° (obtuse angle), maintains the normal lordosis of the lumbar spine (Fig 7-8). This, in turn, will comfortably place the spine in the normal s-shape normally seen in standing. To maintain this position the height and seat tilt of the operator stool has to be adjusted and the patient to be positioned in correct height. The height has to be adjusted until the hip angle falls to approximately 110º to 120º. The seat has to be anteriorly tilted (around 15° as mentioned before) until some body weight is felt passing through the legs, with a slight lumbar lordosis. If seat tilt is not possible in the operators' stool, the height of the stool should be increased. Sitting at the edge of the stool (or) fitting the seat with a wedge shaped cushion may allow a degree of anterior tilt in pelvis.

Fig. 7-9. Ideal position for the knees and feet (Bambach Seat).

Note: The neck is over flexed, this should be avoided

7.4.7 Knees: The position of the knee depends on the height of the seat and angle of hips. If the hips are kept in a position as mentioned above the knee rests comfortably in an angle of 110° to 130°, which is similar to the angle of hips (Figs 7-1 and 7-9). The knees should be positioned under the dental chair if possible, and if this positioning causes shoulder elevation and abduction, a different position should be assumed (Valachi and Valachi, 2003b).

7.4.8 Feet: The feet should always be kept flat on the floor. This allows part of the body weight to be transferred through the legs. This reduces active loading on the back muscles. This position simulates standing, which is functionally a stable position for the spine. Changes in the position of feet can shift the loading of low back muscles and may help replenish blood supply of these muscles (Valachi and Valachi, 2003b). Keeping the legs behind, placing them on the foot ring, or using only one leg for support has to be avoided (Fig.7-10). When using the foot switch to activate the drill the dentist needs to make sure that part of the legs are supported on the floor (Figs. 7-1, 7-3 and 7-9).

7.5 Examples of Poor Posture:

7.5.1 Slumped Back Posture: The figures 7-10 and 7-11 show dentists with a slumped back, due to the improper positioning of the operator's stool and the patient. Figure 7-10 also shows the right foot not supported on the floor. Figure 7-11 shows hyper-flexion of the neck. Slumped back position in associated with increased back muscle activity as observed in CSS and CSD in this study. The slumped posture places excess load on the passive structures of the spine, namely, the ligaments, discs and the vertebral body and lengthens the muscles of the back. The flexed neck posture increases the activity of the neck musculature in order to support the weight of the head as observed in this study.

Solution: The operator's stool should be adjusted for height, seat angle adjusted to anterior tilt and the feet properly supported on the floor. With these adjustments, if the height of the dental chair is increased, the neck may return to the near neutral position of 10º to 20º of flexion. If still direct vision is a problem, the dentist should work from the side of the patient and this may improve the visibility of the tooth operated. Alternatively, the dentist should ask the patient to rotate the head.

Fig. 7-10. Slumped back with improper leg Support (Conventional Seat)

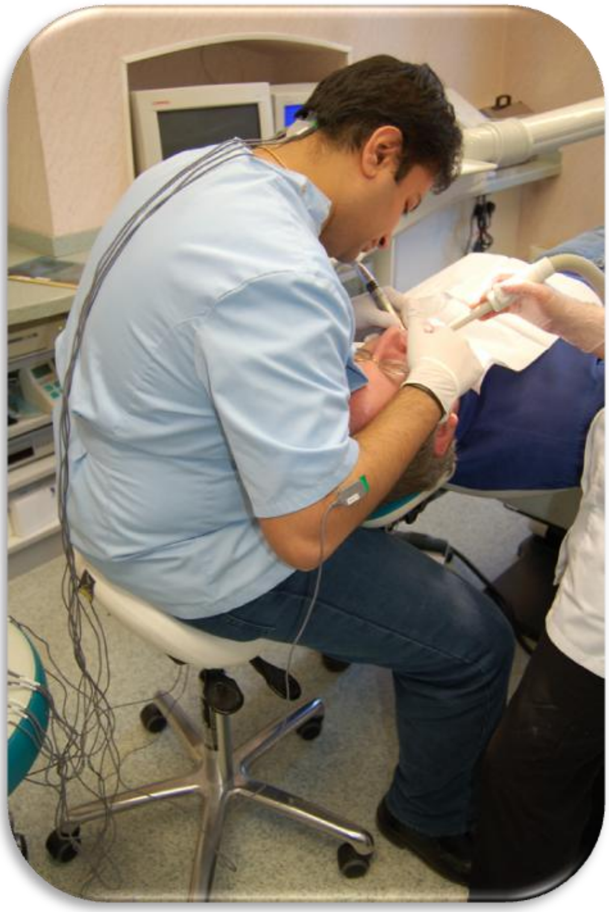

Fig. 7-11. Slumped back, hyper-flexion of neck (Bambach Seat)

7.5.2 Raised Shoulders, Twisted Neck and Trunk Posture: Figure 7-12 and 7-13 show dentists working with a raised left shoulder. Figure 7-12 shows the dentist working with his trunk flexed to one side. Figure 7-13 shows the dentist working with a side-flexed and twisted trunk, and a flexed, side-flexed and twisted neck. This twisted posture, if maintained for long periods, may lead to muscular imbalances around the neck and trunk, and uneven loading on the passive structures of the spine, as mentioned above.

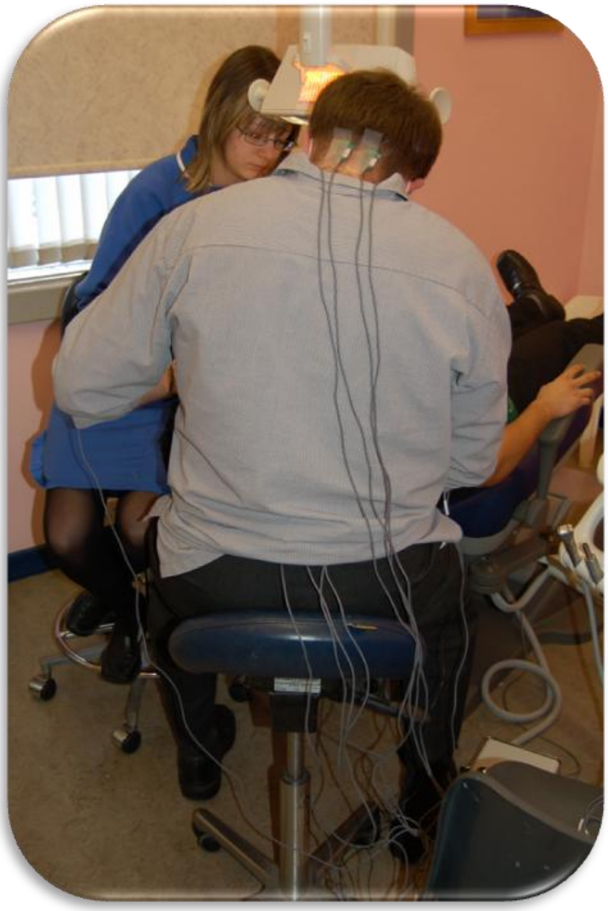

Fig. 7-12. Side-Flexed Trunk and Neck (Bambach Seat)

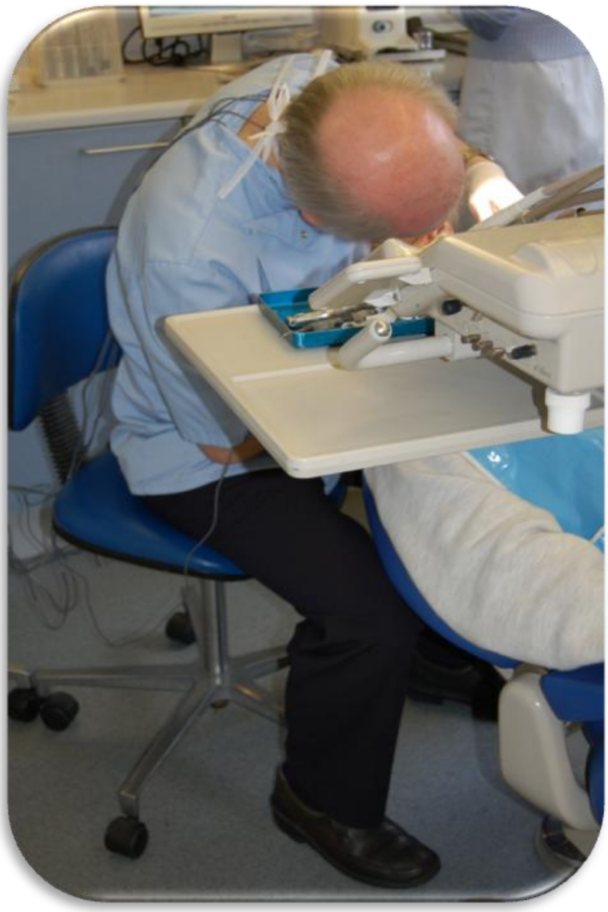

Fig. 7-13. Twisted, Side-Flexed and Flexed Neck and Trunk (Conventional Seat)

Solution: The dentists in figures 7-12 and 7-13 are trying to get a direct visual of the tooth which they are treating, with the dentist in figure 7-13 trying to work on the upper jaw. This posture can easily be avoided by positioning the patients' neck in extension or the dentist may work from the side of the patient where direct vision is possible without bending or twisting the neck or trunk. If the dental chair height is adjusted properly the shoulders will drop and loading on the trapezius muscles may be reduced.

7.6 Conclusion: Despite improved equipment, and the practice of four-handed dentistry, the results indicate that the incidence of back pain has not decreased over the last 15 yrs (Bassett, 1983). Research is needed to determine the specific factors related to back pain, so that effective preventive measures may be developed. Dental students should be taught correct operating posture and relaxation techniques, and they should be aware of the dangers of poor body posture. It would be hoped that such measures would reduce the incidence of musculoskeletal disorders in future generations of dentists.

Chapter 8

General Discussion, Conclusion, Recommendations, Limitations of the Study and Future Work

8.1. General Discussion

This thesis has investigated the relationship between posture, seating, and muscle activity in dentists and dental students. The results indicated that, in general, dentists work in poor posture for long hours without having any rest breaks, which may be the principal reason for the reported increase in prevalence of musculoskeletal disorders among dentists. However, some of the dentists surveyed in the present study reported no pain, even while working for long hours. Even when using a CS 40% of the dentists had not developed myalgia, possibly because they may have adapted a good working posture. However more CSD (31.7%) reported moderate to extreme pain which affected their dental work when compared with BSD (21.3%) who reported moderate to extreme pain.

An interesting pattern was observed with the dentists. The number of BSD reporting pain reduced as the number of hours worked increased, whereas the opposite occurred with the CSD, with the number of dentists reporting pain increasing as the number of hours they worked increased. This may be because the BSD become accustomed to the use of the seat, as their posture is predominantly maintained by the passive structures of their spine (Refer to Chapter 1, Section 1.1.8). The concept is further supported by the RULA study where BSD and BSS recorded decreased risk scores compared to CSD and CSS. Investigating the health problems reported by dentists in the present study indicated that a quarter of dentists suffer from musculoskeletal problems. This supports the findings by Burke and Freeman (1997) where they reported that musculoskeletal disorders are the major reason for early retirement among dentists.

Investigating the physical demands involved in dental work indicated that 30% of dentists found difficulty in working the required number of hours, difficulty in doing work without extra breaks, and reported difficulty in working fast enough some of the time, thus indicating a strong physical association between dental work and the development of a musculoskeletal disorder. The concept is illustrated in figure 8-1.

Attitude towards dental work serves as an important factor in relating stress and psychological association with dental work. Investigation of the psychosocial aspects of dental work in this study indicated a general pattern among dentists, with two thirds of the responding dentists reporting a positive attitude towards their work. On the other hand, 25% of dentists reported difficulty in sticking to their schedule and 30% of dentists reported difficulty in handling their workload some of the time. Around 35% to 40% of dentists reported difficulty in feeling a sense of accomplishment; with these dentists reporting more pain in the questionnaire. This may be due to a negative attitude towards dental work. This, combined with stress, may be the principal reason for the development of a musculoskeletal disorder. The dentists strongly agreed that dentistry requires working hard and fast, with 35% to 45% of dentists agreeing that they are asked to do excessive amounts of work, and around 40% to 45% of dentists considering that they don't have enough time to get their job done. This would appear to indicate that stress and physical demands are placed on dentists in their work.

Prolonged Static Posture and the Development of a Musculoskeletal Disorder

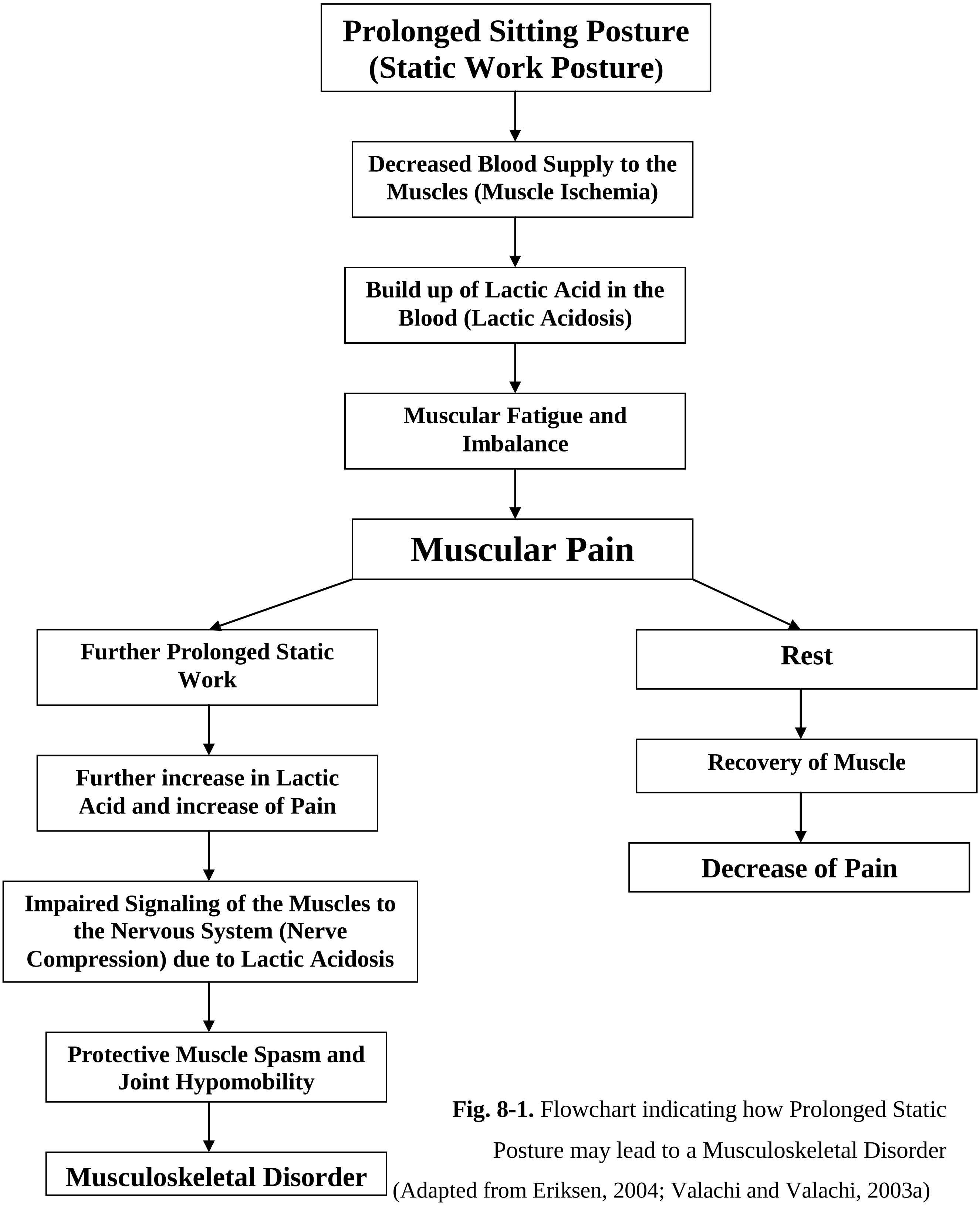

Fig. 8-1. Flowchart indicating how Prolonged Static Posture may lead to a Musculoskeletal Disorder (Adapted from Eriksen, 2004; Valachi and Valachi, 2003a)

The results of this study appear to indicate that a vicious cycle exists among dental students and dentists practicing in the community (Fig. 8-2). This pattern was observed among CSS and CSD investigated in this study. However the pattern was completely reversed with BSS and BSD investigated in this study. The relationships between the different aspects of this study indicated in figure 8-2 are discussed in light of the reasons for developing a musculoskeletal disorder and, finally, a model on decreasing the development of a musculoskeletal disorder is presented (Fig. 8-3).

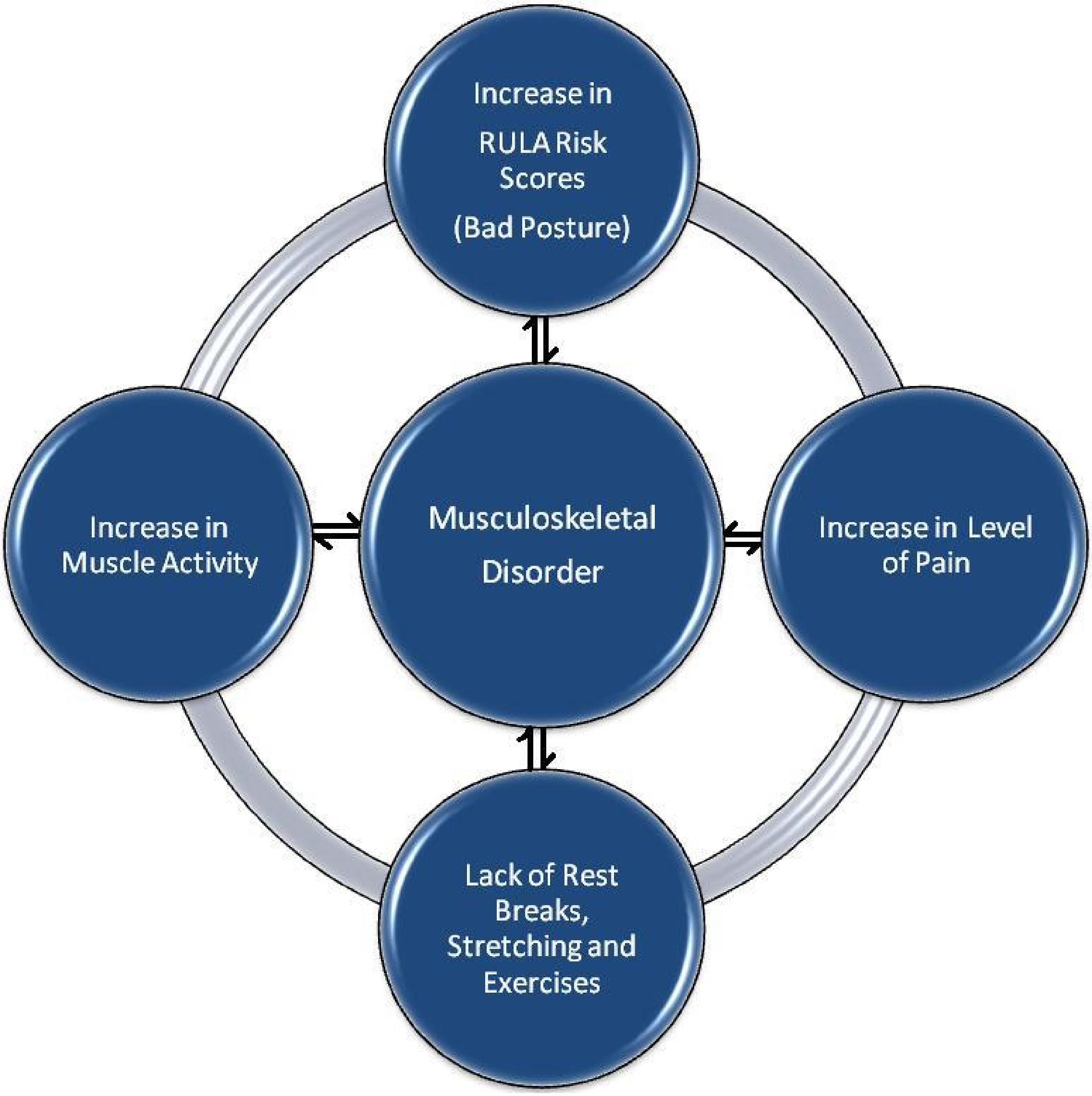

Fig. 8-2. Cycle leading to a musculoskeletal disorder

Relationship between Working Posture and Pain

A unique pattern was observed when comparing the RULA scores of years 3, 4 and 5 dental students; the RULA scores gradually increased from year 3 to 4 and to 5. This may indicate that the working postures of students are gradually getting worse, since the posture of year 3 students is better when compared to year 5. This phenomenon is supported by the study by Rising et al (2005) in which body pain was investigated among dental students. They found that the frequency and duration of worst pain were found to be higher in the third year compared to first year. This may be because the year 5 students work on more complex dental procedures (e.g. crowns and bridges); they also work for longer hours and spend more time in clinics when compared to the Year 3 and 4 students. Rising et al (2005) reported the occurrence of chronic musculoskeletal pain at an early stage in dental careers, with 70% of dental students reporting pain by their third year in dental school. This finding was further supported by the study by Thornton et al (2004) in which the investigation of physical and psychosocial exposures in US dental schools indicated that exposure to physical stressors began in dental school and may be exacerbated by the psychological stress experienced by dental students.

Investigating body pain among year 2 dental students using the daily symptom survey revealed that the BSS recorded lower levels of pain and discomfort on workdays over a week, compared with the CSS. It is interesting to note that only after only eleven weeks of using the seats, even at the beginning of the day, the number of BSS reporting pain was less when compared to the CSS. However some students have reported body pain due to reasons other than dentistry, these being excluded from the pain analysis. The reasons include bike riding, driving for long hours, sitting in the car for long hours, working at a computer for long hours, walking for long hours, playing tennis, playing football, swimming, attending a lecture session, use of high heels, painting shelves, carrying boxes, and rowing in gym. Interestingly, four students specified use of conventional seat at home as a reason for their pain. These extraneous reasons need to be carefully considered while analysing the pain and these may have an impact on clinical practice.

Relationship between Working Posture and Muscle Activity

The results also indicated that the CSS recorded higher RULA risk scores when compared to the CSD; whereas the BSS recorded RULA risk scores comparable to that of BSD (Gandavadi et al. 2007). This may indicate that CSS develop poor postural habits during their undergraduate study i.e. at an earlier stage of dental career (Thornton et.al 2004; Wegman, 1983; Rising et al 2005). Due to pain and discomfort the CSD may need to adapt their posture to a comfortable position, this may be the reason for the decreased RULA scores recorded among CSD compared to CSS. On the other hand, the BSS appear to develop healthy postural habits at an earlier stage of dental career i.e. in just 6 months of the use of the Bambach seat during their undergraduate study. This good posture maintained by BSS and BSD were also found to be associated with decreased muscle activity, which has been clearly established in the EMG study.

Relationships between Working Posture, Pain and Muscle Activity

The results also indicated that with the BSS the muscle activity significantly decreased over the 6-month period in all the muscles investigated. This may be because the individuals using the BS are getting accustomed to the normal biomechanical support (Cram & Vinitzky, 1995), which is provided by the BS in which minimal effort is required to maintain the posture. A similar pattern was also observed with the CSS, but not for all the muscles investigated. However, the amount of reduction of muscle activity over the 6-month period was significantly less when compared with BSS. This may be because the individuals using the CS were getting accustomed to the slumped posture which may be encouraged by CS which may be considered to provide inadequate biomechanical support, resulting in fatigue (Cram & Vinitzky, 1995). The spinal ligaments, joint capsules, the vertebral body and the discs are being subjected to excessive strain in this position (Nachemson, 1966).

A unique pattern of spinal extensor muscle activity was observed with the BSS, where the muscle activity increased in the first three months and decreased in the next three months. The increased muscle activity in the first three months may be because BS keeps the spine in its optimal 'S' shape during the seated posture and may require active back muscle contraction to maintain spinal posture. This may be the reason for the increase in muscle activity in the initial three months (Gandavadi et al 2005). Also, around 50% of BSS reported low back pain in the DSS at three months; this may be correlated with the increased back muscle activity at three months. In the next three months the muscle activity significantly reduced; this may be because the posture is predominantly maintained by the passive structures of the spine or it may be due to sufficient training. This was clearly indicated with BSD where the back muscle activity was significantly less compared with BSS. This may be because BSD have been using the Bambach seat for an average of 3.2 years, whereas the BSS have been using the seat for only 6 months.

With the CSS the spinal extensor muscle activity significantly increased over the 6-month period. This may be because, in the habitually slumped sitting position, an imbalance in the muscle fibres occurs. Instead of slow oxidative fibres of back muscles the fast twitch muscle fibres may be activated (Cram & Vinitzky, 1995), the implications being that an individual will have the strength to sit upright for short periods of time only, after which fatigue and slump occurs (Garlick, 1998; Cram & Vinitzky, 1995). Schuldt et al (1986) found that slumped posture produced a higher level of activity in neck and shoulder muscles than erect posture. This is clearly observed with CSD in which the back muscle activity was significantly increased when compared to BSD and was comparable with CSS.

The muscle activity among BSS, BSD, CSS, and CSD can be associated with the RULA risk scores reported in this study. Both BSS at 6 months and BSD recorded lower muscle activity at 6 months and also recorded lower RULA risk scores, whereas the CSS at 6 months and CSD recorded higher muscle activity and higher RULA risk scores. This may imply that good/acceptable work postures may be associated with lower muscle activity, and poor work postures may be associated with higher muscle activity and may be associated with pain as reported by CSD in the questionnaire and CSS in the DSS. However the results of the DSS of the students were not greatly comparable to that of the dentists with respect to the regions and level of pain. This may be because of the low number of respondents in the DSS of dentists. However, low back pain was the most commonly reported area of pain in both dentists and dental students. The levels of pain reported by BSD were comparable to that of BSS, whereas the levels of pain reported by CSD were higher compared to CSS. This may imply that long-term use of CS may increase the pain experienced by dentists and may lead to a musculoskeletal disorder. However, the results may vary with a larger sample size of dentists.

Relationship between Low Back Pain and Muscle Activity

The results indicated that the dentists who are seated in a slumped posture (CSD) who had low back pain recorded increased muscle activity in spinal extensors (Kuriyama and Ito, 2005), whereas, even with low back pain, the BSD recorded similar muscle activity compared to the BSD without low back pain. This may indicate that the BS may be beneficial in reducing muscle activity in dentists with or without low back pain. This is further supported by the case study (PH) with severe back pain investigated in this study. The initial EMG recording of PH when using the CS indicated lower splenius muscle activity and higher trapezius muscle activity compared to the six months EMG activity of the Year 2 CSS. This may be due to pain experienced by PH in the trapezius region further reinforced by poor posture. However PH initial back muscle activity was comparable to that of the six months EMG activity of the Year 2 CSS which was very high. The splenius and trapezius muscle activity of PH at one year (BS) was comparable to the six months EMG activity of the year 2 BSS. Whereas PH recorded lower back muscle activity at one year compared to BSS. This may be because PH was using the BS for 12 months but the year 2 students were using the BS for only 6 months, which may imply that long-term use of the BS may decrease back muscle activity.

Relationship between Percentage MVC, Fatigue and Rest Breaks

Chaffin (1973) described a neuromuscular theory for fatigue mechanisms: a sustained contraction of a muscle can result in the fibres losing their tension producing capacity, additional motor units are then needed to maintain the total tension state of the muscle. This sustained muscle contraction may then lead to myalgia due to mechanisms explained in figure 8-1. Rohmert (1973) found that no reduction in maximum strength occurred if the holding force is limited to 15% MVC, which is observed with BSD; however the investigation was only based on investigation for 10 to 25 minutes. Studies investigating holding times of more than one hour have found that the endurance limit for muscles may only be 8% MVC (Jonsson, 1988). Sjogaard et al (1986); cited in Jonsson, 1988) showed that muscle fatigue may occur at 5% MVC sustained for one hour and others have suggested that forces greater than 10% MVC cannot be sustained for greater than 10 to 15 minutes without perception of fatigue (Swanson et al 1989). Sustained forces of 6% and 20% MVC have been reported in keyboard tasks (Swanson et al 1989); these forces are much higher with dental work as the dentists work with awkward and static postures. Analysing the muscle fatigue with dentists and dental students has revealed that, even with 10 minutes of dental activity, there is an increase in occurrence of fatigue with CSS and CSD, whereas the occurrence of fatigue was negligible with BSS and BSD.

The period of rest time has been investigated in relation to percentage MVC by various researchers. Hagberg (1981) found that with intermittent static contractions (2 seconds work, 2 seconds rest) the MVC can be maintained for longer periods of time. However this is not possible with dental work and the work activity may become repetitive. It was suggested that even 2 seconds of rest may be adequate to facilitate blood flow and for the removal of contraction-inhibiting metabolic waste products, thereby reducing the development of pain and increasing endurance. Bystrom et al (1991) found that the maximal endurance time was 43% longer when exercise was performed with pauses rather than continuous exercise. The subjects, when performing exercises with pauses, were also able to return to their normal MVC level rapidly. It may be hypothesised that if the BSD work with around 15% MVC with regular rest breaks (2-10 seconds) every 10-20 minutes, they may prolong or evade the occurrence of muscle fatigue and back pain. However if the work involves maintenance of higher percentage MVC the frequency and duration of the rest breaks may need to be increased in order to reverse the muscle to its original state.

In the questionnaire study 30.6% of dentists have reported that they had not taken any rest breaks during dental work and 63.6% of dentists reported that they have never rested their hands during a typical workday. This may be a reason for the prevalence for musculoskeletal disorders among dentists. However, the dentists may consider rest breaks as not performing any work at all, whereas the rest breaks may be considered as just a change from one posture to the other. The examples may include

- A dentist stretching to pick up a dental instrument.
- Moving around the patient and changing positions.
- Performing office work (Data Entry).
- Walking up to the reception to greet and call the next patient.

Educating dental students and practising dentists about work habits may play an important role in the prevention of work related musculoskeletal disorders associated with dentistry.

Ergonomic Intervention, Training and Musculoskeletal Disorders

The results of the questionnaire study of UK dental schools on dental student posture indicate that the training which the students receive on operating posture, is minimal. Formal training therefore needs to be incorporated in order to reduce the incidence of musculoskeletal disorders associated with dentistry. The results of also indicate that ergonomic training, and the use of an ergonomic aid such as a dental operator stool (BS) (Smith et al 2002), combined with healthy work habits and awareness about posture, may be beneficial in reducing muscle activity, pain, and discomfort and ultimately the development of musculoskeletal disorders among dental students and dentists. This is illustrated in figure 8-3.

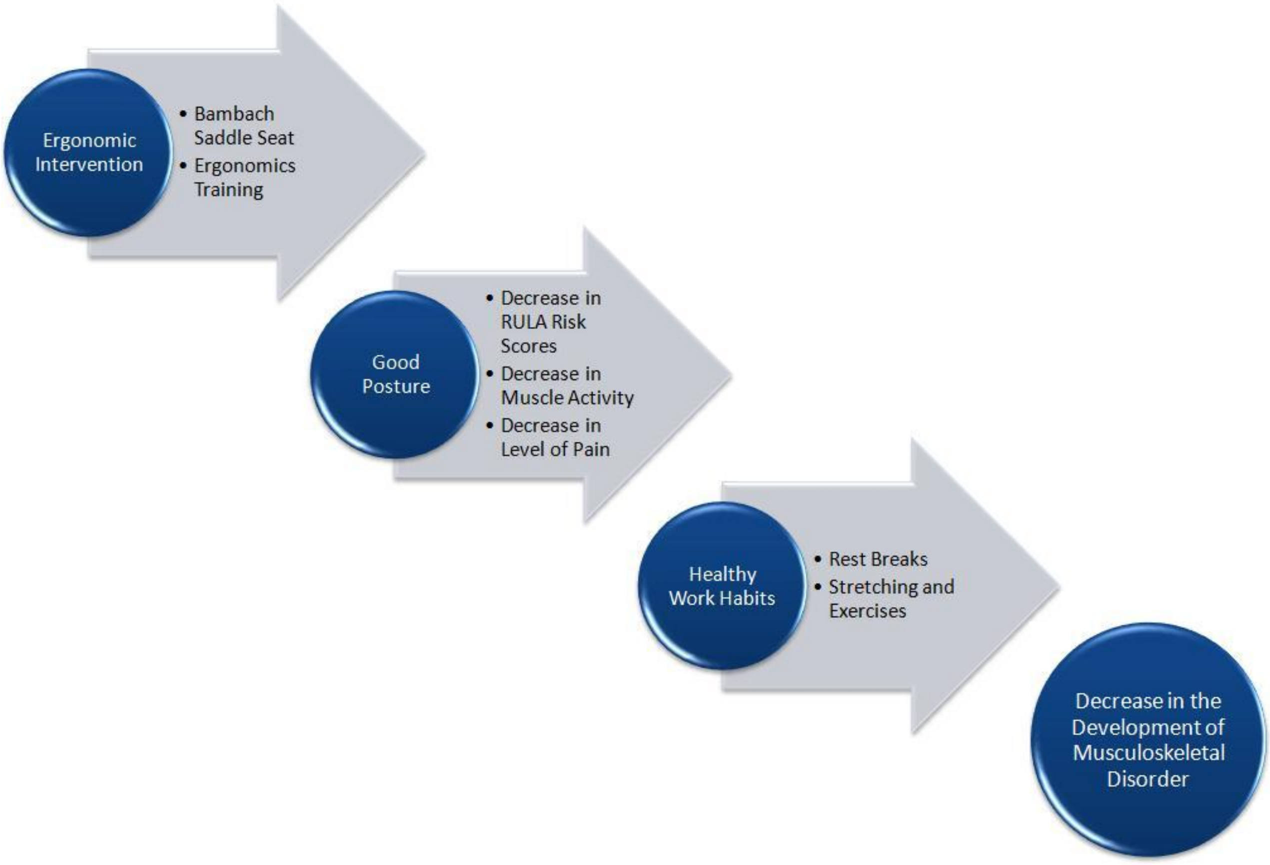

Fig. 8-3. Ergonomic Intervention and Musculoskeletal Disorder

8.2. Recommendations

The Occupational Safety and Health Administration (OSHA) and American Dental Association (ADA) have been working together since 2004 to encourage a culture of prevention, while sharing technical knowledge in the area of ergonomics and promoting safe and healthy working conditions for dental employees working in the USA. The ADA added ergonomics information, including information on the OSHA and ADA Alliance and the Alliance Program, to the handouts and materials distributed to ADA members and others in the dental profession who attend the ADA's Success Seminar Series. The seminars focus on business topics related to dental practice management. The ADA worked with 58 dental schools, 280 hygiene programs and 260 dental assistance programs to assess the status of the schools existing ergonomics programs, number of hours of training provided and attitudes on the topic. As a result, the ADA made recommendations to enhance ergonomic training at dental schools and other programs. A similar program needs to be implemented in the UK, since most of the dental schools are interested in including ergonomics training in their curriculum. Increasing the awareness about ergonomics in the work place among practising dentists in the UK and a dedicated module in the syllabus of undergraduate dentists on ergonomics, including correct working posture, chair-side exercises and four-handed dentistry is suggested.

8.3. Limitations of the Study and Future Work

Questionnaire Study

The initial response rate of dentists (18.5%) was low and was a main limitation of the questionnaire study. However a response rate of 60.5% was achieved after the follow up. The questionnaire study was also performed with the dental students in year 3, 4 and 5. Due to the low response rate from the students the results were not considered in this thesis. If the students' data had achieved a good response rate the results would have presented an idea of work habits and pain among dental student population.

Rapid Upper Limb Assessment

Blinding was not used for postural assessment using photographs and postural assessment using live assessment and there was a possibility of bias in the study. However these problems were addressed by performing inter-rater and intra-rater reliability by using photographs and live assessment for postural analysis with the researcher as one of the raters. The results indicated a high level of reliability in both intra-rater and inter-rater reliability and the postural assessment by the researcher can be considered unbiased. Future work may consider using single or double blinding in the assessment of posture to avoid the possibility of bias.

Daily Symptom Survey

The DSS charts were distributed to 30 dentists, but only 10 dentists replied to the survey. This was a potential limitation and the results may have been different with larger sample size. However a larger sample size was achieved with the DSS of students (n=30).

The DSS of students were performed after 3 months of the use of chair and was not performed at the beginning of the study or after 6 months of the use of chair. The DSS at 6months would have given us an idea about the level of pain since there was a significant difference between the muscle activities of dental students at 6 months.

EMG Study

The muscles used in the EMG study, the lumbar paravertebral muscles and the splenius muscles are deep muscles. Needle EMG or fine wire EMG may have been appropriate for these muscles, to avoid cross talk among muscles when using surface EMG. However surface EMG were used for these muscles in the various studies reported here. Finsen et al (1996) used Splenius Capitis and Upper Trapezius muscles observing dentists, and Schuldt et al (1987) and Christensen (1986) used Upper Trapezius muscles observing assembly plant employees. Milerad et al (1991) used Upper Trapezius and Extensor Carpi Radialis Longus muscles observing dentists. Hardage et al (1983) used Longissimus thoracis and Multifidus lumborum muscles observing dentists and Kramer et al (2005) and Stokes et al (2003) used these muscles to analyse EMG in low back pain.

The potential problem of the EMG study of dental students was poor compliance among the students participating in this study. The EMG study of year 2 dental students was planned to be completed in 2005 with 30 dental students, however due to low response rate the study was repeated in 2006 and the numbers were increased. The students dropped out of the study for the following reasons:

- Two students failed in the exams and fell a year behind.
- Three students dropped out of their course. The reasons included marriage, could not cope with the course, repeatedly failed in their exams.
- Four students allocated to the conventional seat group for the sessions in their clinics preferred to use the BS and were not happy to participate in the study.
- Two students had back and neck pain and did not want to participate in the study.
- Four students dropped out of the study for unknown reasons.

A baseline measure in 2005 will have increased the numbers and may have given better results.

The procedures used in the EMG study of dentists were not standardized since the dentists were working on real patients and this was a potential limitation. However, the jaw operated on and the procedures used were collected during the study and these were found to be similar with both groups of dentists. Future work should consider investigating the effect of different types of dental work, other stools and the use of magnifying loupes on posture.

In the EMG study of dentists the sample was not standardized for age, sex or height. The results may have been slightly different if the subjects had been age matched. However the muscle activity of the students using the Bambach Saddle Seat at 6 months was comparable to the muscle activity of the dentists using the Bambach Saddle Seat. This may indicate that the results may have been similar even if the sample size had been age matched.

Blinding was not used in this study, but this may not be a potential issue with EMG recording as the results would be similar if the same electrode positions were used. However the blinding may be used for analysis of the EMG data. Due to funding and time constraints on training, the use of another person for the data collection and analysis blinding was not possible.

Future studies should consider measuring the abdominal muscle activity during different seated postures in order to determine the recruitment patterns of the muscles responsible for core stability of the trunk.

8.4. Conclusion

The thesis has reported the relationship between posture, seating and muscle activity among dentists and dental students. The dentists and the students using the CS have followed a similar pattern and are reported here:

- Poor posture increasing the RULA risk scores
- Increase in level of pain through the workday, especially the back, neck and shoulders.
- Increase in muscle activity (percentage MVC) during dental work
- Increased neck flexion angles during dental work contributing to neck pain

The dentists and dental students using the Bambach Saddle Seat followed a pattern opposite to the dentists and dental students using the conventional seat, namely:

- Good posture decreasing the RULA risk scores
- Decrease in level of pain through the workday
- Lower muscle activity (percentage MVC) during dental work
- Neutral neck flexion angles during dental work resulting in lower incidence of neck pain

This thesis has established the relationship between posture, seating and muscle activity and indicates that use of an ergonomic aid (dental operator stool) may improve posture, decrease pain and muscle activity and may decrease the development of musculoskeletal disorders among dental students and dentists.

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- The Right Way to Do Sit-Ups 30/01/2007

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Appendices

Appendix I: The Dental Ergonomic Questionnaire

Please read each question. Indicate your answer by circling / filling in the space provided.

1. Please state the year of your graduation: **2. Please state your age:**

3. Are you male or female: **4. Number of Children:**

5. Is your Practice City or Town Centre Suburban Rural

6. Are you:

Practice Owner or Partner Associate Assistant Salaried Other

7. Is your Practice Single Handed Partnership/group

8. Is Your Practice Private Private/NHS NHS

9. Is your practice a specialist practice? Yes No

If yes, please specify specialty ______________________

10. How many restorations do you place in an average month?

0 – 10 11 – 20 21 – 30 >30

11. In a typical day in the past week, how many hours did you: (Please tick)	0 Hours	1-2 Hours	3-4 Hours	5-6 Hours	7-8 Hours	9+ Hours
a. Spend sitting in your Operator's Stool?						
b. Spend sitting in another chair at your work place?						
c. Spend treating patients?						
d. Spend sitting and working at a computer on a weekday?						
e. Spend sitting and working on a computer on a weekend?						

12. In the past week, did you take any rest breaks (1 - 5 Minutes) from dental procedures?

Yes No

If yes, on how many days did this apply: ________ Days

13. During a typical day, how frequently do you get up and leave your patient treatment area to go do other work, take a break, talk to your colleagues, etc.? (Select one):

Never
About once a day
About once every 2-3 hours
About once every hour
About once every half hour
About once every 15 minutes
About once every 5 minutes

14. During a typical day, how frequently do you need to rest your hands? (Select one)

Every	**Every**	
5 Minutes	1-2 Hours	Never
15 Minutes	2-3 Hours	
30 Minutes	More than 3 hours	

15. In general, would you say your health is: Please circle

Excellent Very Good Good Fair Poor

16. Do you have a health problem or medical condition that you would like to tell us about? Please indicate it below

17. Do you use glasses or contact lenses when treating patients?

Yes No

18. Do you use magnifying loupes?

Yes No If Yes please state make __________________

Percentage	All of the Patients (100%)	Most of the Patients	Half of the Patients (50%)	Some of the Patients	None of the Patients (0%)
For what percentage of patients do you use the magnifying loupes? (Please Tick)					

19. Have you received any training in correct operating position? Yes No

If yes, as Undergraduate or Postgraduate

20. How much force do you have to use with your hands and wrists during the following procedures

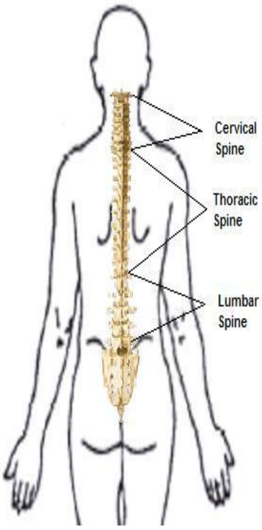
Dental Procedure		Indicate force with wrists and hands	
a. Dental Examination	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
b. Scaling and Polishing	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
c. Direct placement restorations	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
d. Orthodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
e. Crown and Bridge work	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
f. Removable Prosthodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
g. Endodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
h. Tooth Extraction	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists

21. Please indicate the frequency of the following dental procedures used in a typical day at your surgery

Dental Procedure (Please Tick)	Most Frequently Used	Frequently Used	Less Frequently Used	Not Used
a. Dental Examination				
b. Scaling and Polishing				
c. Direct placement restorations				
d. Orthodontics				
e. Crown and Bridge work				
f. Removable Prosthodontics				
g. Endodontics				
h. Tooth Extraction				

22. Think about how you have used your Operator's Stool __in the past 4 weeks__. Please mark how much you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Neither Agree or Disagree	Dis-agree	Strongly Disagree	N/A
a. When I am seated in my stool, my lumbar spine is supported against the seat back						
b. My chair provides comfortable seat (bottom) support						
c. When I sit in my stool, my arms rest comfortably at my side						
d. When I am sitting in my stool, my legs and feet are in a comfortable position						
e. When I am sitting in my stool, my neck is in a comfortable position						
f. Overall, the Operator's Stool is comfortable						
g. I am satisfied with my Operator's Stool						



23. Because some Operator's Stools may not be suitable for all body types, we would like to know your height and weight:

Height: Feet ______ Inches ______ (or) Meters ______

Weight: ______ in Kg (or) Stones ______ Lbs ______

24 a. What is the make of your Operator's Stool? ________________________

b. If the make is not known - Is it Flat Seat (or) Saddle Seat

25. What is the approximate age of your Operator's Stool? ______________

26. We would be grateful if you would tell us about the adjustable features of your Operator's Stool

	1. Do you have the following feature?		2. Do you know how to adjust it?		3. Have you adjusted it in the last month?	
Chair Feature	Yes	No	Yes	No	Yes	No
a. Height adjustment						
b. Seat angle adjustment						
c. Lumbar (lower back) support adjustment						
d. Arm rest adjustment						
e. Arm rest angle (pivot) adjustment						

27. Overall, how easy is it for you to adjust your Operator's Stool? (Select one:)

Easy Difficult There are no adjustable features in my chair

28. Have you received any training, information, or assistance on how to adjust your Operator's Stool?

Yes No

29. Have you had any pain in the past 4 weeks?

Yes No (If no go to Q.35)

30. If Yes where did you feel the pain?

Head Neck Shoulders Upper Back Lower Back
Upper Limbs Lower Limbs Hands Hip Knees

Ankles Feet

Other Area – Please Specify ____________________

31. During the past 4 weeks, how much did pain interfere with your dental work?

Not at all A Little Bit Moderately Quite a Bit Extremely

32. In general how much pain did you feel (Please mark a cross on the line)

No Pain |―――――――――――――――――――――――――― Intense Pain

0 10

33. What medications have you used during <u>the past 4 weeks</u> for your pain?

Have you	Yes	No
a. Taken any over-the-counter medicines such as Aspirin, Neurofen, Ibuprufen, or Paracetamol?		
b. Taken any prescription pain medications such as prescription Co-Proximol, Codeine etc?		
c. Taken very strong prescription pain medications such as Tramadol , DF118 (Dihydrocodeine), Gabapentin , Voltoral (Diclofenac)		

34. Have you consulted any of the following people in reference to your pain? Please Circle

GP Physiotherapist Osteopath Chiropractor Complementary Therapist

35. In the <u>past 4 weeks</u> how <u>difficult</u> was it for you to do the following?

It was DIFFICULT to	All of the time it was difficult to (100%)	Most of the time it was difficult to	Half of the time it was difficult to (50%)	Some of the time it was difficult to	None of the time it was difficult to (0%)	Does Not Apply To My Job
a. Work the required number of hours						
b. Get going easily at the beginning of the work day						
c. Start on my job as soon as you arrived at work						
d. Do my work without stopping to take extra breaks or rests						
e. Stick to a routine or schedule						
f. Handle the workload						
g. Work fast enough						
h. Finish work on time						
i. Feel a sense of accomplishment in your work						
j. Feel you have done what you are capable of doing						

36. Do you do exercises during the workday to prevent or relieve your pain or discomfort?

Yes No

37. Think about a typical day on your job and mark how much you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree	N/A
a. My job requires that I learn new things						
b. My job involves a lot of repetitive work						
c. My job requires me to be creative						
d. My job allows me to make a lot of decisions on my own						
e. My job requires a high level of skill						
f. On my job, I have very little freedom to decide how I do my work						
g. I get to do a variety of different things on my job						
h. I have a lot of say about what happens on my job						
i. I have an opportunity to develop my own special abilities						
j. My job requires working very fast						
k. My job requires working very hard						
l. I am **not** asked to do an excessive amount of work						
m. I have enough time to get the job done						
n. I am free from conflicting demands that others make						
o. The people I work with are helpful in getting the job done						

38. Which of the following best describes your racial or ethnic background?

1. Asian	3. Black or	5. Chinese	7. White or Caucasian
2. Asian British	4. African British	6. Chinese British	8. Other – Please State ____________

MANY THANKS FOR COMPLETING THIS QUESTIONNAIRE

Comments:

We would be grateful for your help in two ways: (This Portion will be detached)

1. Completion of a daily symptom form over 5 days
2. Participation in a study examining dentists posture and muscle activity in the surgery

----

Results & Further Study: Please tick the box and fill in your name and address in the space below or attach your practice card if

☐ You would like to be informed of the results of this questionnaire

☐ You would like to participate in further study

We look forward working with you in future

Appendix II: Posturegram assessment form (Adapted from Priel 1974)

POSTUREGRAM	Serial No………………………
Company's Name: ________________________ Department: ________________________ Task/Operation: ________________________ Operator(s): ________________________ Analyst: ________________________ Date recorded: ________________________ Reviewed on: ________________________ Reason: ________________________	Sketch:

	Reference Planes	Inclined towards	Approximate angles
	BODY'S FRONTAL PLANE	R.H. / L.H.	0 5 10 20 30 45 60 75 90
	BODY'S LATERAL PLANE	Front / Back	0 5 10 20 30 45 60 75 90

Circle approximate indications	LEFT HAND SIDE			RIGHT HAND SIDE
	Located at level number above (+) or below (-)	Levels of joints At 'zero position'		Located at level number Above (+) or below (-)
	+ - 1 2 3 4 5 6 7 8 9 0	9 Above head	9	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	8 Neck	8	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	7 Shoulder	7	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	6 Elbow	6	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	5 Wrist	5	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	4 Hips	4	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	3 Knees	3	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	2 Ankles	2	+ - 1 2 3 4 5 6 7 8 9 0
	+ - 1 2 3 4 5 6 7 8 9 0	1 Toes	1	+ - 1 2 3 4 5 6 7 8 9 0

Record angle and direction + or -	In reference planes			Direction + or – and angle of inclination of limbs	In reference planes		
	Frontal	Lateral	Horizontal		Frontal	Lateral	Horizontal
	________	________	________	Head	________	________	________
	________	________	________	Shoulders	________	________	________
	________	________	________	Arms	________	________	________
	________	________	________	Forearms	________	________	________
	________	________	________	Hands	________	________	________
	________	________	________	Trunk	________	________	________
	________	________	________	Thighs	________	________	________
	________	________	________	Legs	________	________	________
	________	________	________	Foot	________	________	________

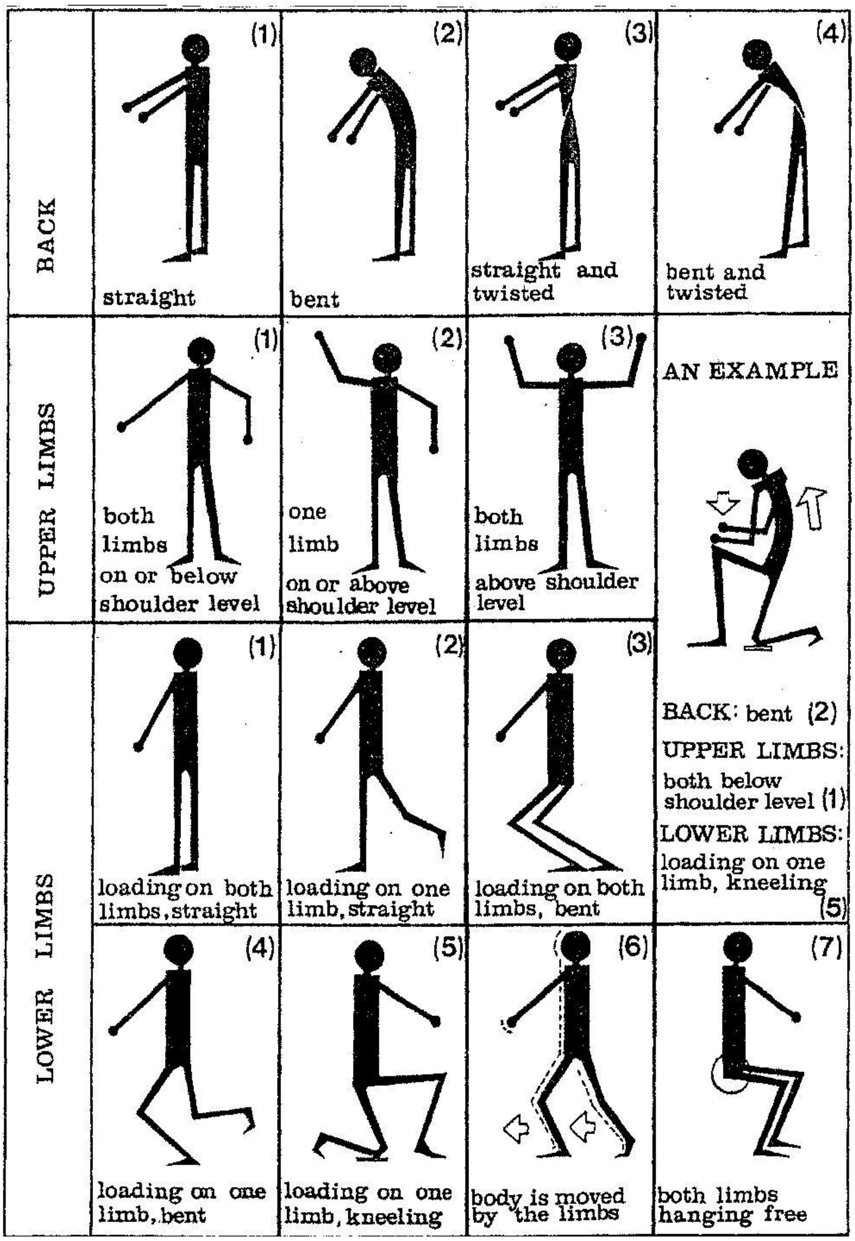
Brief verbal definition of posture: ____

____

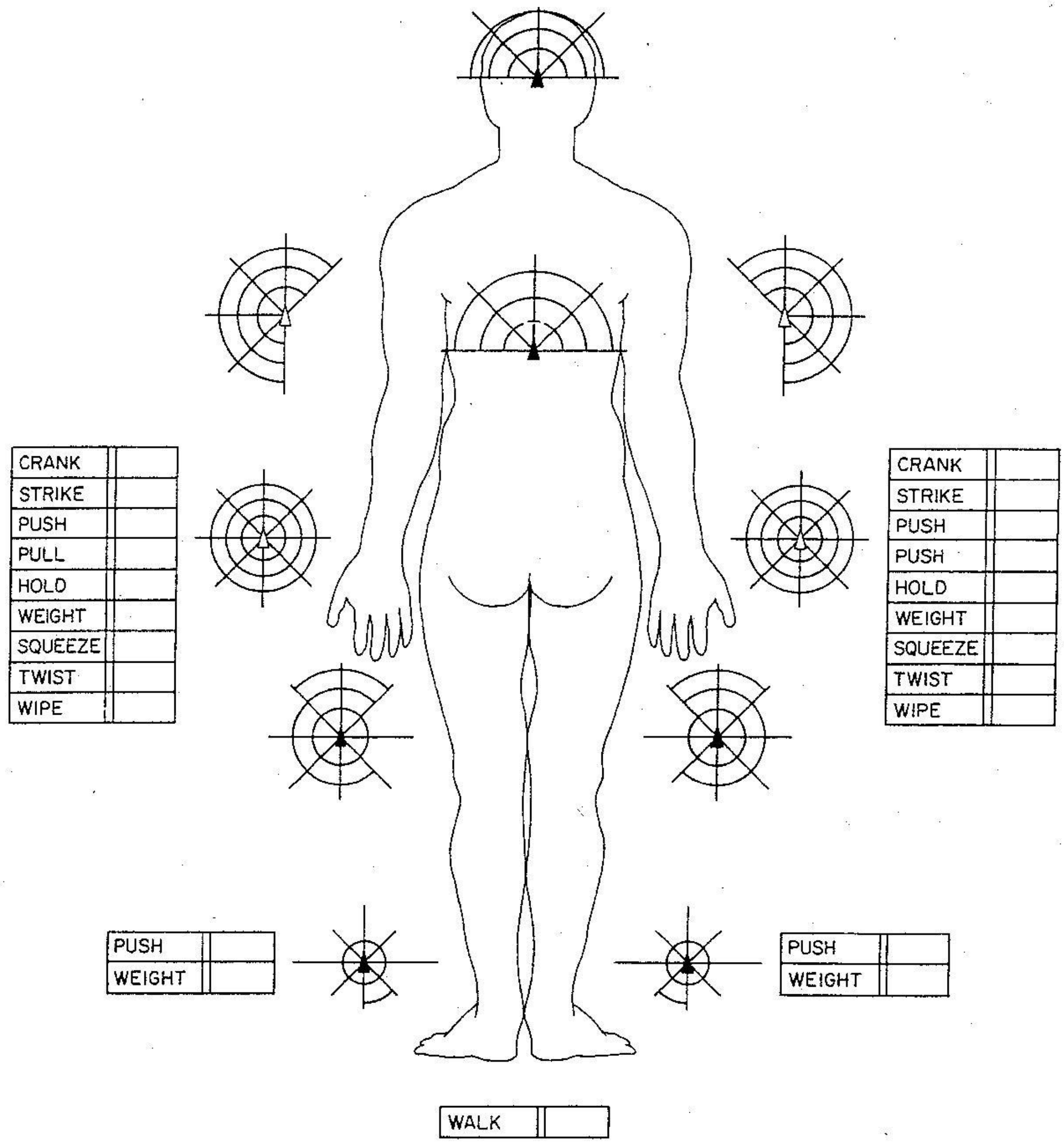
Explanatory remarks: ____

____

Appendix III: List of items classified by OWAS (Karhu, Kansi & Kuorinka 1977)

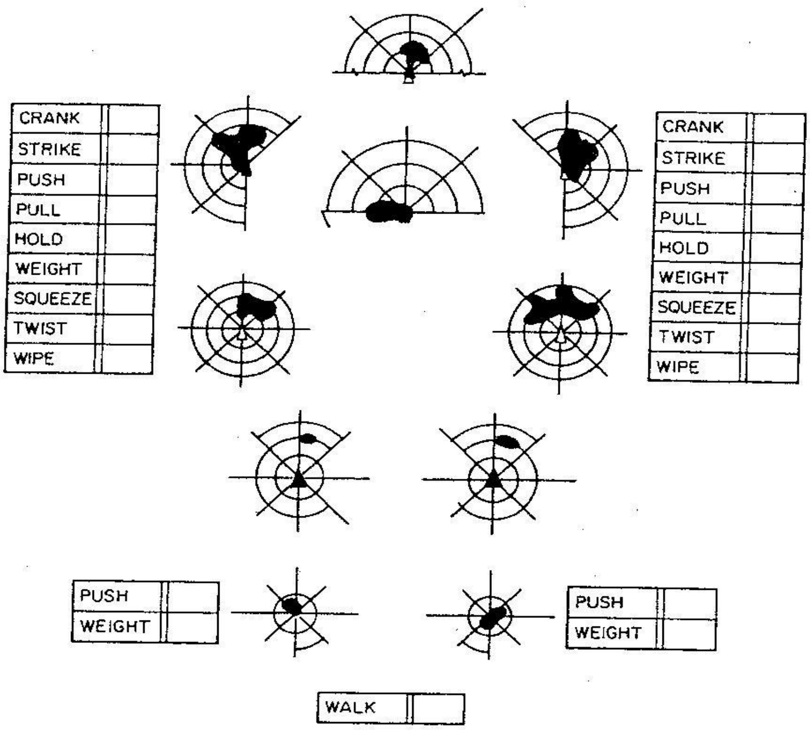


Appendix IV: Body Chart showing targets adjacent to its associated body part. (Reproduced from Corlett et al (1979))



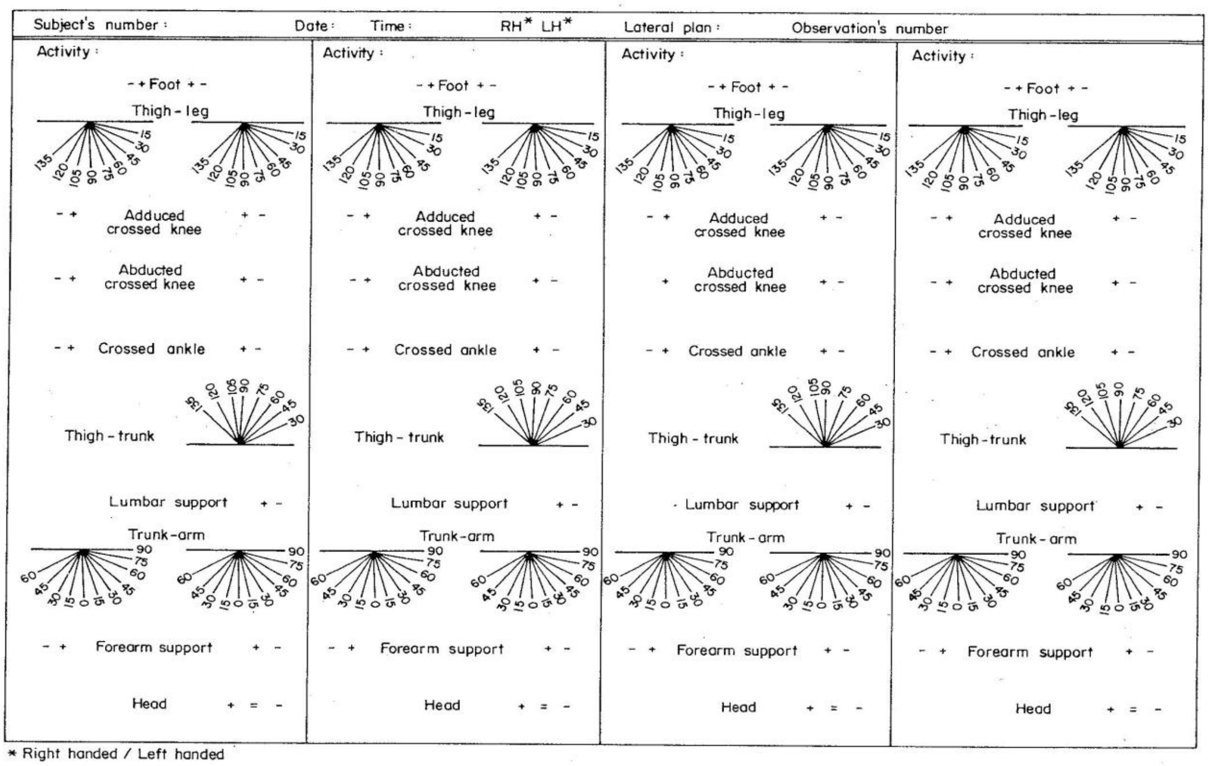
Appendix V: The range of movements of a worker has been blocked in the diagram.

(Reproduced from Corlett et al 1979)



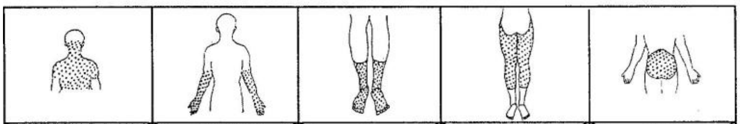
Appendix VI: Posture Recording: Sitting Posture Registering Card

(Reproduced from Gil and Tunes 1989)



Appendix VII: PLIBEL Recording Chart

Method for the identification of musculo-skeletal stress factors which may have injurious effects-PLIBEL



Kemmlert, K. Kilbom, Å. (1986) National Board of Occupational Safety and Health, Research Department, Work Physiology Unit, 171 84 Solna, Sweden

neck/shoulders, upper part of back	elbows, forearms hands	feet	knees and hips	low back	
		1.	1.	1.	1. Is the walking surface uneven, sloping, slippery or nonresilient?
2.	2.	2.	2.	2.	2. Is the space too limited for work movements or work materials?
3.	3.	3.	3.	3.	3. Are tools and equipment unsuitably designed for the worker or the task?
4.				4.	4. Is the working height incorrectly adjusted?
5.				5.	5. Is the working chair poorly designed or incorrectly adjusted?
		6.	6.	6.	6. (If the work is performed whilst standing): Is there no possibility to sit and rest?
		7.	7.		7. Is fatiguing foot-pedal work performed?
		8. a ______ b ______ c ______	8. a ______ b ______ c ______	8. a ______ b ______ c ______	8. Is fatiguing leg work peformed eg: a) repeated stepping up on stool, step etc.? b) repeated jumps, prolonged squatting or kneeling? c) one leg being used more often in supporting the body?
9. a ______ b ______ c ______ d ______				9. a ______ b ______ c ______ d ______	9. Is repeated or sustained work performed when the back is: a) mildly flexed forward? b) severely flexed forward? c) bent sideways or mildly twisted? d) severely twisted?
10. a ______ b ______ c ______ d ______					10. Is repeated or sustained work performed when the neck is: a) flexed forward? b) bent sideways or mildly twisted? c) severely twisted,? d) extended backwards?
11. a ___ e ___ b ___ f ___ c ___ g ___ d ___				11. a ___ e ___ b ___ f ___ c ___ g ___ d ___	11. Are loads lifted manually? Notice factors of importance as: a) periods of repetitive lifting b) weight of load c) awkward grasping of load d) awkward location of load at onset or end of lifting e) handling beyond forearm length f) handling below knee height g) handling above shoulder height
12.	12.			12.	12. Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?
13.					13. Is sustained work performed when one arm reaches forward or to the side without support?
14. a ______ b ______	14. a ______ b ______				14. Is there repetition of: a) similar work movements? b) similar work movements beyond comfortable reaching distance?
15. a ______ b ______	15. a ______ b ______				15. Is repeated or sustained manual work performed? Notice factors of importance as: a) weight of working materials or tools b) awkward grasping of working materials or tools
16.					16. Are there high demands on visual capacity?
	17. a ___ c ___ b ___ d ___				17. Is repeated work, with forearm and hand, performed with: a) twisting movements? b) forceful movements? c) uncomfortable hand positions? d) switches or keyboards?

Method of application.

* Find the injured body region
* Follow white fields to the right
* Do the work tasks contain any of the factors discribed?
* If so, tick where appropriate

Also take these factors into consideration:

a) the possibility to take breaks and pauses
b) the possibility to choose order and type of work tasks or pace of work
c) if the job is performed under time demands or psychological stress
d) if the work can have unusual or unexpected situations
e) presence of cold, heat, draught, noice or troublesome visual conditions
f) presence of jerks, shakes or vibrations

Appendix VIII: Quick Exposure Checklist for Work-related Musculoskeletal Disorders (Li and Buckle 1998)

Job title: **Task:** **Assessment conducted by:** **Worker's name:** **Date:** **Time:**

Back

- *When performing the task, is the back*

A1: almost neutral?
A2: moderately flexed or twisted or side bent?
A3: excessively flexed or twisted or side bent?

- **For manual handling tasks only**: *Is the movement of the back* -

B1: infrequent? (Around 3 times per minute or less)
B2: frequent? (Around 8 times per minute)
B3: very frequent? (Around 12 times per minute or more)

- **Other tasks**: Is the task performed in static postures most of the time? *(either seated or standing)*

B4: No. B5: Yes.

Shoulder/arm

- *Is the task performed*

C1: at or below waist height?
C2: at about chest height?
C3: at or above shoulder height?

- *Is the arm movement repeated*

D1: infrequently? (Some intermittent arm movement)
D2: frequently? (Regular arm movement with some pauses)
D3: very frequently? (Almost continuous arm movement)

Wrist/Hand

- *Is the task performed*

E1: with almost a straight wrist?
E2: with a deviated or bent wrist position?

- *Is the task performed with similar repeated motion patterns*

F1: 10 times per minute or less?
F2: 11 to 20 times per minute?
F3: More than 20 times per minute?

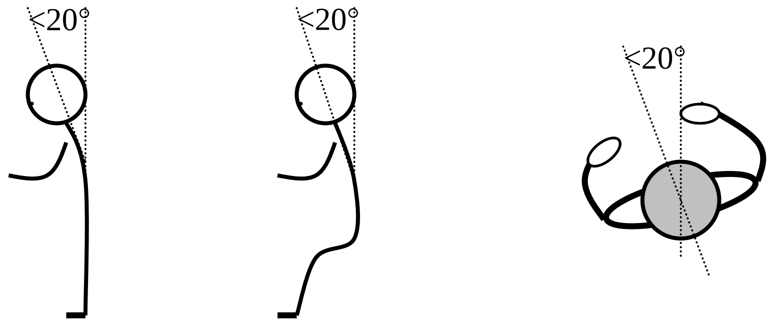
Neck

- *When performing the task, is the head/neck bent or twisted excessively?*

G1: No
G2: Yes, occasionally
G3: Yes, continuously

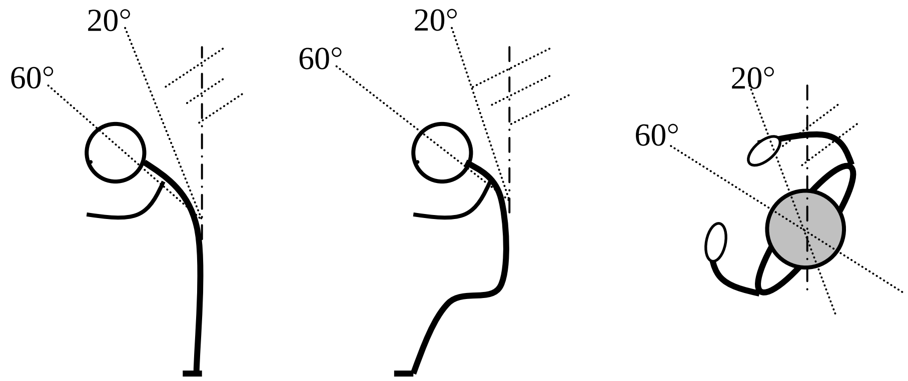
Appendix IX: Guide to use the QEC exposure assessment tool

Exposure assessment of the Back



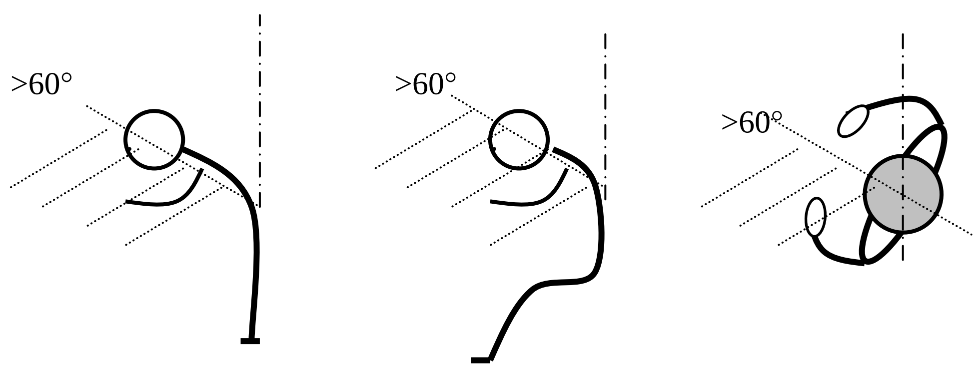
Standing **Sitting** **Twisting**

The back is 'almost neutral' (http://www.geocities.com/qecuk/)



Standing **Sitting** **Twisting**

The back is 'flexed or twisted' (http://www.geocities.com/qecuk/)



Standing **Sitting** **Twisting**

The back is 'excessively flexed or twisted' (http://www.geocities.com/qecuk/)

Appendix X: Worker's assessment of the task assessed. (Li and Buckle 1998)

Name: Job title: Date:

What is the maximum weight handled in this task?
a1: Light (5 kg or less)
a2: Moderate (6 to 10 kg)
a3: Heavy (11 to 20 kg)
a4: Very heavy (More than 20 kg)

How much time on average do you spend per day doing this task?
b1: less than 2 hours
b2: 2 to 4 hours
b3: more than 4 hours

When performing this task (single or double handed), what is the maximum force level exerted by one hand?
c1: Low (e.g. Less than 1 kg)
c2: Medium (e.g. 1 to 4 kg)
c3: High (e.g. More than 4 kg)

Do you experience any vibration during work?
d1: Low (or no)
d2: Medium
d3: High

Is the visual demand of this task -
e1: Low? (There is almost no need to view fine details)
e2: High? (There is a need to view some fine details)

Do you have difficulty keeping up with this work?
f1: Never
f2: Sometimes
f3: Often

How stressful do you find this work?
g1: Not at all
g2: Low
g3: Medium
g4: High

Appendix XI: Score Table to calculate QEC total exposure scores (Li and Buckle 1998)

Exposure to the **Back**

	A1	A2	A3	Score 1	B1	B2	B3	Score 2	b1	b2	b3	Score 3
a1	2	4	6		2	4	6		2	4	6	
a2	4	6	8		4	6	8		4	6	8	
a3	6	8	10		6	8	10		6	8	10	
a4	8	10	12		8	10	12		8	10	12	

				Score 4				B4	B5	Score 5	Total score for the back = Sum of scores 1 to 5
b1	2	4	6		2	4	6	2	4		
b2	4	6	8		4	6	8	4	6		
b3	6	8	10		6	8	10	6	8		

Exposure to the **Shoulder/arm**

	C1	C2	C3	Score 1	D1	D2	D3	Score 2	b1	b2	b3	Score 3
a1	2	4	6		2	4	6		2	4	6	
a2	4	6	8		4	6	8		4	6	8	
a3	6	8	10		6	8	10		6	8	10	
a4	8	10	12		8	10	12		8	10	12	

				Score 4				Score 5	Total score for shoulder/arm = Sum of scores 1 to 5
b1	2	4	6		2	4	6		
b2	4	6	8		4	6	8		
b3	6	8	10		6	8	10		

Exposure to the **Wrist/hand**

	F1	F2	F3	Score 1	E1	E2	Score 2	b1	b2	b3	Score 3
c1	2	4	6		2	4		2	4	6	
c2	4	6	8		4	6		4	6	8	
c3	6	8	10		6	8		6	8	10	

				Score 4			Score 5	Total score for the wrist/hand = Sum of scores 1 to 5
b1	2	4	6		2	4		
b2	4	6	8		4	6		
b3	6	8	10		6	8		

Exposure to the **Neck**

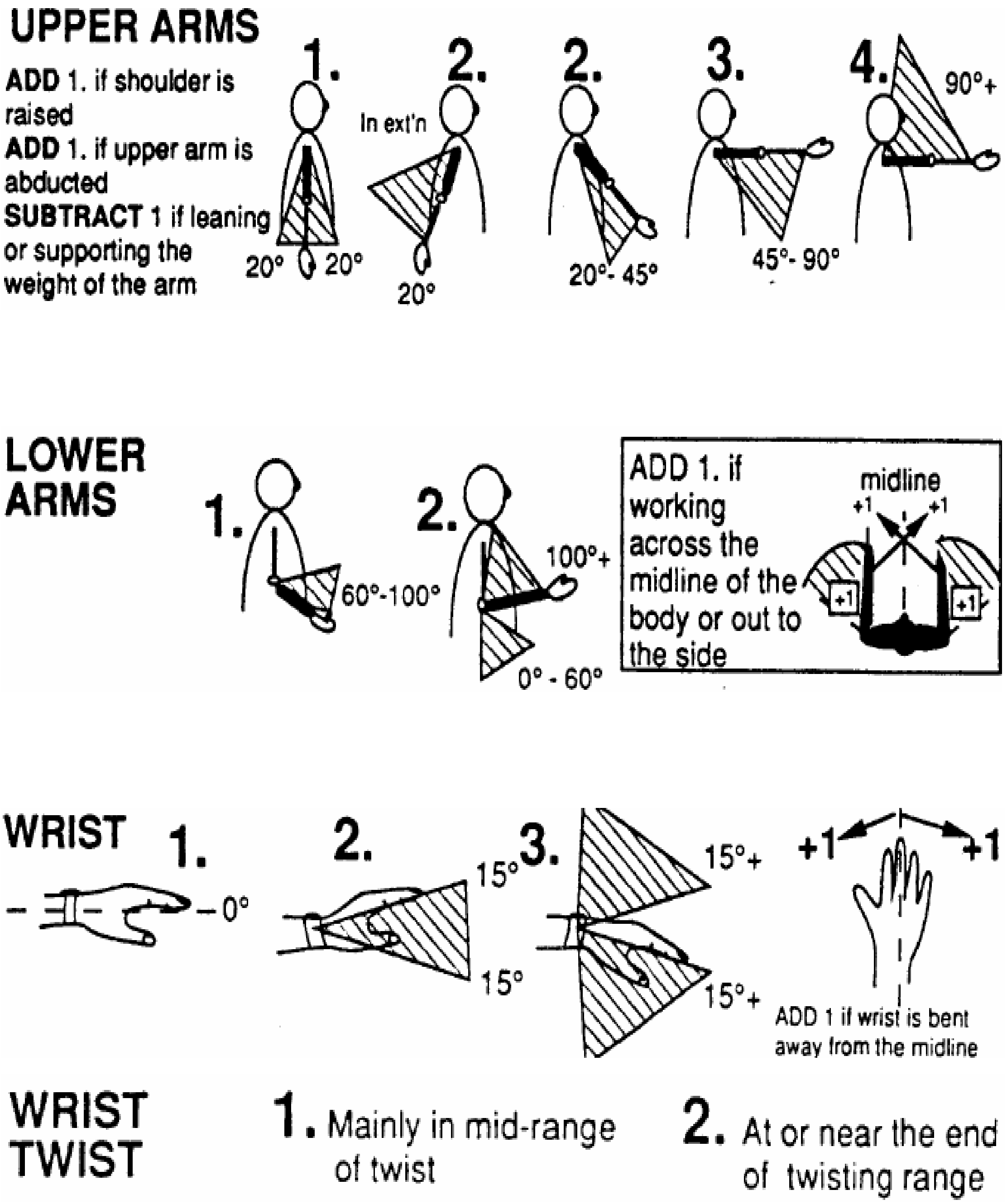
	G1	G2	G3	Score 1	e1	e2	Score 2	Total score for the neck = Scores 1+ 2
b1	2	4	6		2	4		
b2	4	6	8		4	6		
b3	6	8	10		6	8		

Worker's evaluations

d1	d2	d3	f1	f2	f3	g1	g2	g3	g4	(Worker's evaluation) **Total**
1	4	9	1	4	9	1	4	9	16	

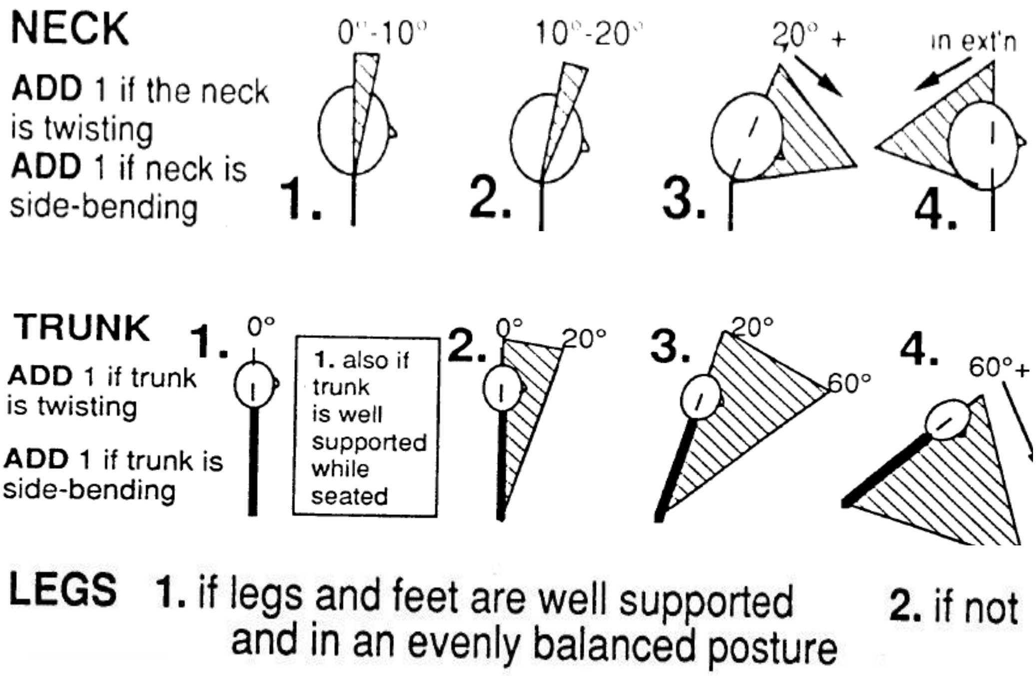
Back: ________ Shoulder/arm: _________ Wrist/hand: _________ Neck: _________

Appendix XII: RULA Arm and Wrist Analysis



(Adapted from McAtamney & Corlett; 1993)

RULA Neck, Trunk and Leg Analysis



(Adapted from McAtamney & Corlett; 1993)

Appendix XIII: Tables for calculating Posture Score

Table A: Upper Limb Posture Score

UPPER ARM	LOWER ARM	WRIST							
		1		2		3		4	
		WRIST TWIST		WRIST TWIST		WRIST TWIST		WRIST TWIST	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	2	3	3	3	4	4
2	1	2	2	2	3	3	3	4	4
	2	2	2	2	3	3	3	4	4
	3	2	3	3	3	3	4	4	5
3	1	2	3	3	3	4	4	5	5
	2	2	3	3	3	4	4	5	5
	3	2	3	3	4	4	4	5	5
4	1	3	4	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	3	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	7	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

RULA Source: McAtamney, L. and Corlett, E.N. (1993) Applied Ergonomics, 24 (2), 91-9.

Table B: Neck, Trunk, Legs Posture Score

NECK POSTURE SCORE	TRUNK POSTURE SCORE											
	1		2		3		4		5		6	
	LEGS		LEGS		LEGS		LEGS		LEGS		LEGS	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	2	1	2	2	3	3	4	4	4	4	4
2	1	2	2	2	3	4	4	5	5	5	5	5
3	2	2	2	3	3	4	4	5	5	5	6	6
4	2	3	2	3	3	4	4	5	5	6	6	6
5	3	4	4	4	4	5	5	6	6	6	6	6

RULA Source: McAtamney, L. and Corlett, E.N. (1993) Applied Ergonomics, 24 (2), 91-9.

RULA Score Sheet

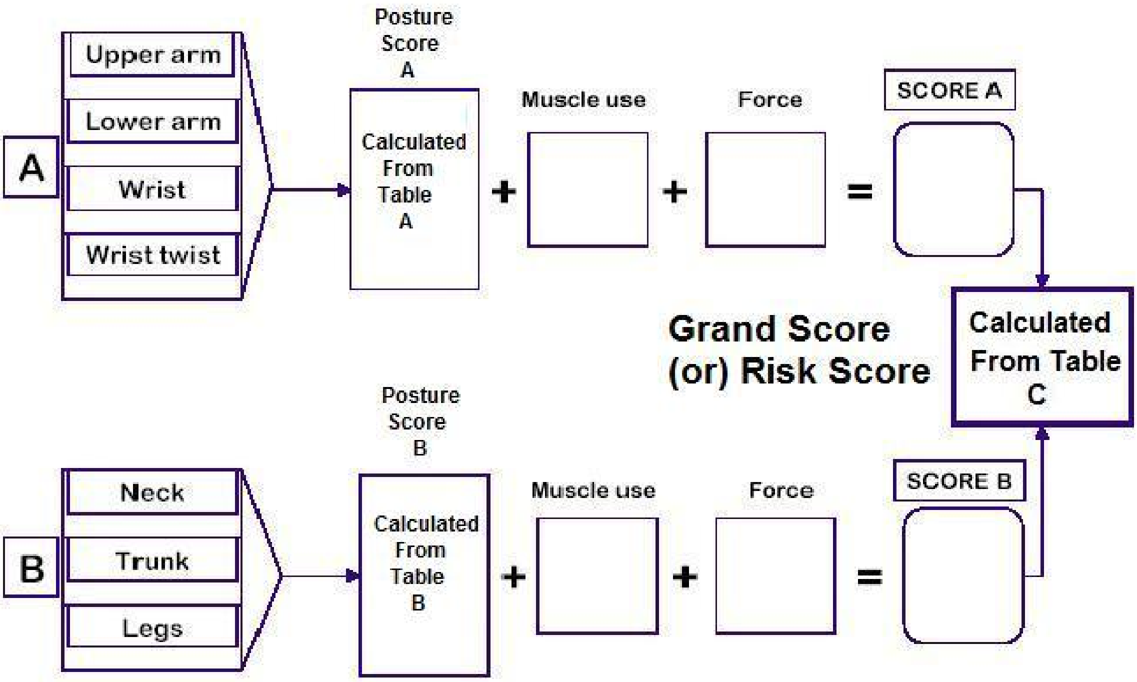


Table C: Grand Score Table

TABLE C		FINAL SCORE B (NECK, TRUNK, LEG)						
		1	2	3	4	5	6	7
FINAL SCORE B (UPPER LIMB SCORE)	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Action level	Score	Action
1	1 or 2	Acceptable posture.
2	3 or 4	Further investigation needed; changes may be required.
3	5 or 6	Investigation and changes needed soon.
4	7	Investigation and changes required immediately.

RULA Source: McAtamney, L. and Corlett, E.N. (1993) Applied Ergonomics, 24 (2), 91-9.

Appendix XIV: Information Sheet (Dental Students)

Information Sheet Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

The purpose of this study: Using two commercially available dental seats (one a standard seat and the other an ergonomically designed saddle seat), the study will investigate how the back, shoulder and neck muscles work while the dentist is sitting working.

The procedures

- All participants will be asked to complete a work, environment and health questionnaire to investigate the functional demands required to undertake the common dental tasks. (5 minutes to complete)
- Year 2 dental students participating in the study will be asked to complete a short daily symptom survey for 5 days to record levels of discomfort during the working day (5 minutes per day for 5 days).
- Year 2 dental students participating in the study will be randomly allocated to either a standard seat or a saddle seat to use for all practical skills session in the phantom head laboratory.
- Photographs of participants will be taken in the phantom head laboratory to analyse common dental activities and identify common postures adopted during these activities.
- Surface electromyography will be used to record the muscle activity of the back and upper limbs occurring during common dental activities and to see if there is a difference between the two dental seats. 30 participants will be randomly selected (30 minutes to complete).

What will the information be used for? The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information? Any information that is obtained will remain completely confidential and seen only by the research team. All questionnaires will be coded and the code held secure within the School of Health Sciences University of Birmingham.

The Risks There are no risks associated with this activity. Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system

If you decide not to take part, your decision will be respected without question.
You are free to withdraw from the study at any time without giving a reason.
Participating or withdrawal from the study will have no effect on your degree programme.

Any Complaints regarding the study should be made to the Research Administrator, School of Health Sciences. (Audrey Smith E-Mail: a.smith.2@bham.ac.uk Tel: 0121 4143865)

Appendix XV: CONSENT FORM (Dental Students)

Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

Have you read and understood the information sheet containing details of the research study?…… Yes / No

Have you had an opportunity to ask questions and discuss this study?………………… ………Yes / No

Have you received satisfactory answers to all your questions?……………………………………… Yes / No

Have you received enough information about the study?... Yes / No

Have you been told that any information used will remain anonymous?……………………… Yes / No

Do you understand that you are free to withdraw from the study at any time, without giving a reason …….Yes / No

Who explained the details of this study to you?..

I agree to take part in this study ....Yes / No

Signature of subject……………………………… ....Date……………………… …………

Printed full name of subject ....
(Block Capitals)

University E-Mail address……

Signature of researcher ……………………………………………………………………………………Date……………………….

Printed full name of researcher……………………………………………………………………………………………………

Thank you very much for taking the time to complete this form.

This consent form will be stored in the School of Health Sciences in accordance with the Data Protection Act (1998)

Appendix XVI

UNIVERSITY OF BIRMINGHAM

SCHOOL OF HEALTH SCIENCES & SCHOOL OF DENTISTRY

CONSENT FORM – USE OF PHOTOGRAPHS

Thank you for consenting to take part in the study. This consent form is for the photographs to be taken at the phantom head laboratory and in the Clinics.

I, ______________________________, freely and voluntarily agree to participate in a research project (Working Postures in Dentists: The relationship between seating, muscle activity and musculoskeletal disorders) under the direction of Prof Burke, Dr. Jill Ramsay and Amar Gandavadi, to be conducted at the University of Birmingham (School of Dentistry)

In agreeing to participate in this study, I understand that I will be observed while I perform dental procedures during lab work and clinics. Photographs will be taken during observing.

I understand that the photographs are taken with my permission and may be reproduced in dissemination of the research project by the sponsors and in academic publications. The photographs will also be used in assisting and developing research questions relating dentists posture and seating. I have read and understood the contents of this form.

Participant Date: Researcher Date:

Appendix XVII

UNIVERSITY OF BIRMINGHAM

SCHOOL OF HEALTH SCIENCES & SCHOOL OF DENTISTRY

CONSENT FORM – USE OF PHOTOGRAPHS

Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

This consent form is for the photographs to be taken in the dental surgery.

I, ______________________________, freely and voluntarily consent for photographs to be taken during the study.

The purpose of this study is to record the muscle activity of a dentist during common dental activities using surface electromyography.

I understand that the photographs are taken with my permission and may be reproduced in dissemination of the research project by the sponsors and in academic publications. Where my face is within the photo it will be obscured in any publication. The photographs will also be used in assisting and developing research questions relating dentists posture and seating. I have read and understood the contents of this form.

Signature (Participant)	Date:	Signature (Researcher)	Date:

Appendix XVIII

UNIVERSITY OF BIRMINGHAM

SCHOOL OF HEALTH SCIENCES & SCHOOL OF DENTISTRY

CONSENT FORM – USE OF PHOTOGRAPHS

Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

This consent form is for the photographs to be taken in the dental surgery.

I, ________________________________, freely and voluntarily consent for photographs to be taken during my dental treatment.

The purpose of this study is to record the muscle activity of a dentist during common dental activities using surface electromyography.

I understand that photographs will be taken of the dentist when performing dental procedures in the surgery and that may include part of my face. Where my face is within the photo it will be obscured in any publication. I understand that the study is interested in the posture of the dentist and not the patient.

The photographs are taken with my permission and may be reproduced in dissemination of the research project by the sponsors and in academic publications. The photographs will also be used in assisting and developing research questions relating dentists posture and seating. I have read and understood the contents of this form.

Signature Date:
(Participant)

Signature Date:
(Researcher)

Appendix XIX

RULA - Information Sheet

- I have enclosed photos of 20 dental students and RULA assessment forms in this file for you to assess.
- For each person there will be 1, 2 or 3 photos. Most of the photos will have the posterior view and side view of the student. In the posterior view the positions of the lower arm and wrist are not visible, to enable viewing of this, side view / front view of the person is included as the second photo.
- The photos and the assessment forms are given specific numbers. Please match the correct photo/s with the form before analysing. You may need to see 2 or 3 photos in different views to get an idea of the person's posture before analysing.
- Please complete the RULA assessment sheet. Give separate scores for right and left upper limb.
- You do not need to find and fill in the final arm and wrist score, neck trunk & leg final score and the grand score. I will calculate and fill in the final scores.

Note:

Muscle Use Score: The posture of the students when observed was held for more than a minute (or) the action repeatedly occurred more than 4 times per minute. So all the students were given a muscle use score of 1 and it is already been filled in the form.

Force / Load Score: The force / load score may not apply for the students. Their clinics were only for 3 hours in a day. So I have filled in 'NIL' in the form.

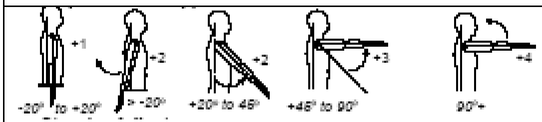
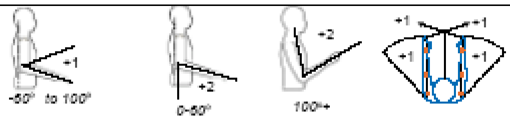
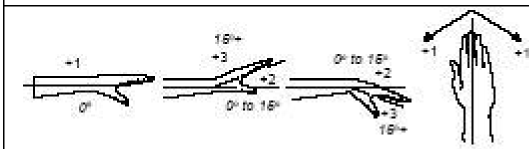
Thank you for helping with my research.
Amar Gandavadi

Appendix XX: Rapid Upper Limb Assessment of Dental Students (Modified)

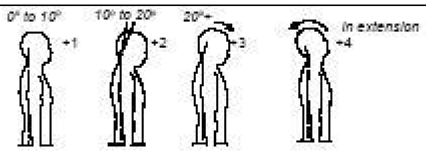
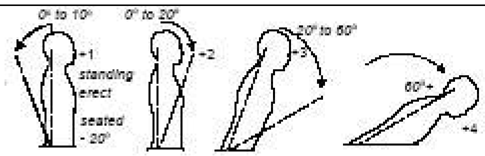
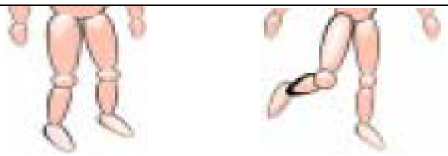
Number of Photo:

Name of Analyser:

Arm and Wrist Analysis

<table>
<tr><th rowspan="2">Upper Arm Position</th><th colspan="3">Right</th><th colspan="3">Left</th></tr>
<tr><th>Position</th><th>Score</th><th>Total Score</th><th>Position</th><th>Score</th><th>Total Score</th></tr>
<tr><td>
1 2 3 4 5
If shoulder is raised: +1
If Upper arm is Abducted: +1
If arm is supported or person is Leaning: -1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th rowspan="2">Lower Arm Position</th><th colspan="3">Right</th><th colspan="3">Left</th></tr>
<tr><th>Position</th><th>Score</th><th>Total Score</th><th>Position</th><th>Score</th><th>Total Score</th></tr>
<tr><td>
1 2 3 4
If arm is working across midline of the body: +1
If arm out to side of the body: +1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th rowspan="2">Wrist Position</th><th colspan="3">Right</th><th colspan="3">Left</th></tr>
<tr><th>Position</th><th>Score</th><th>Total Score</th><th>Position</th><th>Score</th><th>Total Score</th></tr>
<tr><td>
1 2 3 4
If wrist is bent from midline: +1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>Wrist Twist</th><th>Position</th><th>Score</th><th>Total Score</th><th>Position</th><th>Score</th><th>Total Score</th></tr>
<tr><td>If wrist is twisted mainly in midrange: +1
If twist at or near end of twisting range: +2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Muscle Use Score If posture mainly static (i.e. held for longer than one minute) or; If action repeatedly occurs 4 times per minute or more: +1	**Right**	**Left**
	1	1
Final Arm and Wrist Score	**Right**	**Left**

Neck Analysis	**Neck**		
	Position	**Score**	**Total Score**
 1 2 3 4 If neck is twisted: +1 If neck is side-flexion: +1			
Trunk Analysis	**Trunk**		
	Position	**Score**	**Total Score**
 1 2 3 4 If trunk is twisted: +1 If trunk is side-flexed: +1			
Leg Analysis	**Leg**		
	Position	**Score**	**Total Score**
 1 2 If legs and feet supported and balanced: +1 If legs and feet supported and person is in seated position: +1 If legs and feet are not evenly balanced and supported: +2 (Unstable Posture)			
Muscle Use Score If posture mainly static (i.e. held for longer than one minute) or; If action repeatedly occurs 4 times per minute or more: +1	1		
Neck, Trunk and Leg Final Score	**Final Score**		
Force / Load Score Total hr / day treating patient From 4 to 6 hours: +1 More than 6hours / day: +2	NIL		
RULA Grand Score Arm and Wrist + Neck Trunk and Leg	**Grand Score**		

Appendix XXI: RULA for Dental Students (Modified)

Name of Student: **Sex:** **Age:** **Year:** **Clinic:** **Date:**

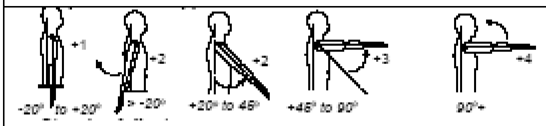
Procedure Undertaken: **Time Observed:**

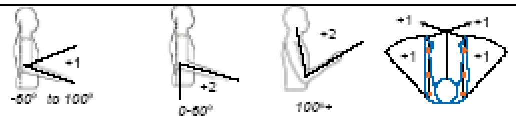
Tooth Operated:

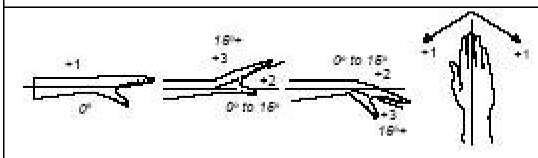
UR	UL
8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8
LR	**LL**
8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8

Mirror Use:		**Yes**	**No**
Dominant Hand:	**R**	**L**	
Height Adjusted:	**OS**	**Yes**	**No**
	DC	**Yes**	**No**

Arm and Wrist Analysis

Upper Arm Position	**Right**			**Left**		
	Position	**Score**	**Time in Position**	**Position**	**Score**	**Time in Position**
 1 2 3 4 5 If shoulder is raised: +1 If Upper arm is Abducted: +1 If arm is supported or person is Leaning: -1						

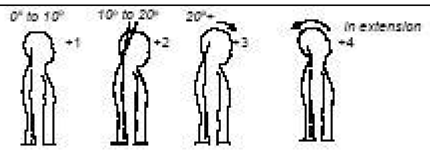
Lower Arm Position	**Right**			**Left**		
	Position	**Score**	**Time in Position**	**Position**	**Score**	**Time in Position**
 1 2 3 4 If arm is working across midline of the body: +1 If arm out to side of the body: +1						

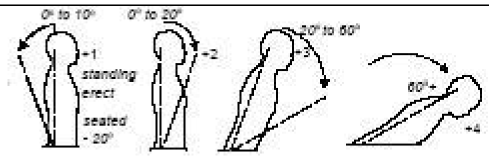
Wrist Position	**Right**			**Left**		
	Position	**Score**	**Time in Position**	**Position**	**Score**	**Time in Position**
 1 2 3 4 If wrist is bent from midline: +1						

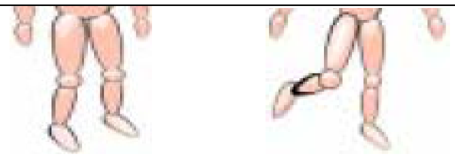
Wrist Twist	**Position**	**Score**	**Time in Position**	**Position**	**Score**	**Time in Position**
If wrist is twisted mainly in midrange: +1 If twist at or near end of twisting range: +2						

Muscle Use Score If posture mainly static (i.e. held for longer than one minute) or; If action repeatedly occurs 4 times per minute or more: +1	Right	Left

Final Arm and Wrist Score	Right	Left

Neck Analysis	Neck		
	Position	Score	Total Score
 1 2 3 4 If neck is twisted: +1 If neck is side-flexion: +1			

Trunk Analysis	Trunk		
	Position	Score	Total Score
 1 2 3 4 If trunk is twisted: +1 If trunk is side-flexed: +1			

Leg Analysis	Leg		
	Position	Score	Total Score
 1 2 If legs and feet supported and balanced: +1 If legs and feet supported and person is in seated position: +1 If legs and feet are not evenly balanced and supported: +2 (Unstable Posture)			

Muscle Use Score If posture mainly static (i.e. held for longer than one minute) or; If action repeatedly occurs 4 times per minute or more: +1	
	1

Neck, Trunk and Leg Final Score	Final Score
Force / Load Score Total hr / day treating patient From 4 to 6 hours: +1 More than 6hours / day: +2	NIL
RULA Grand Score Arm and Wrist + Neck Trunk and Leg	**Grand Score**

Appendix XXII: **QUESTIONNAIRE ON DENTAL STUDENTS' POSTURE**

This questionnaire has been sent to the Dean/Director of your dental school, and (s)he has identified you as the person most involved in the organisation and teaching of dental ergonomics/ foundation clinical skills. We very much appreciate your help in completing this questionnaire.

(Please fill in / circle or tick your responses for the following questions)

1.. Please state the number of undergraduate students in the first year

____

2. Do your students receive training in the use of correct operating posture?

Yes ☐ No ☐

If yes, please continue to question 4.

If no, please state if you are considering introducing this in the future

Yes ☐ No ☐

and continue to question 8.

3. For how many years have you been responsible for the teaching of operating posture? _________

4. At what stage in the curriculum are students introduced to the concept of operating posture?. Year_______ Term_______________

Does this include:

a. Dentist positioning
b. Patient positioning
c. Both

5. Please state which of the following are used to teach operating posture

a. Lectures
b. Seminars
c. Practical demonstrations by a dentist
d. Practical demonstrations by a physiotherapist
e. Chairside instruction
f. Other, please state

____

6. Other than chairside instruction, please state the approximate number of hours of teaching which are devoted to the teaching of operating posture ________ hrs

7. In your memory, have any students had to stop studying dentistry because of musculoskeletal problems.

Yes ☐ No ☐

If yes, how many ________ in ______ years

8. Are common types of musculoskeletal disorders (MSD) included in the curriculum?

Yes ☐ No ☐

9. Are contributing factors to MSD included in the curriculum

Yes ☐ No ☐

If yes, are these

a. Work related
b. Non-Work related
c. Combination of both

10. Is the use of stretching and exercising included in the curriculum?

Yes ☐ No ☐

11. Is the use of magnification included in the curriculum ?

Yes ☐ No ☐

If yes, the use of which of following are included?

a. Loupes
b. Operating microscope
c. Other magnification

12. Is 4-handed dentistry included in the curriculum ?

Yes ☐ No ☐

If yes, please state which of the following are used to teach this

a. Lectures
b. Seminars
c. Practical demonstrations
d. Chairside instruction
e. Other, please state

____

13. In your opinion, how important is the teaching of operating posture in the curriculum?

a. Very important
b. Somewhat important
c. Somewhat unimportant
d. Not important

14. Are there any research studies presently being carried out in your school on dentists posture / musculoskeletal problems?

Yes ☐ No ☐

If yes, please indicate name of researcher

____

Please also indicate (if possible) a brief description of the research undertaken

____

____

____

____

15. In your opinion, is the funding for the teaching of operating posture in the curriculum adequate?

a. Adequate
b. Somewhat inadequate
c. Very inadequate
d. Not applicable

16. Please indicate your programme's future plans regarding the length of time allocated to the teaching of operating posture

a. Will be increased
b. Will stay the same
c. Will be reduced
d. Don't know

If a (will be increased), please elaborate on your future plans

____

____

____

if c (will be reduced), please elaborate

____

____

____

17. Please give your position in the school

____

Any other comments?

____

____

____

____

____

____

Thank you for your help

Appendix XXIII: Daily Symptom Chart (Students)

Date: Time: (Please Circle One) Morning Afternoon Evening

Activity

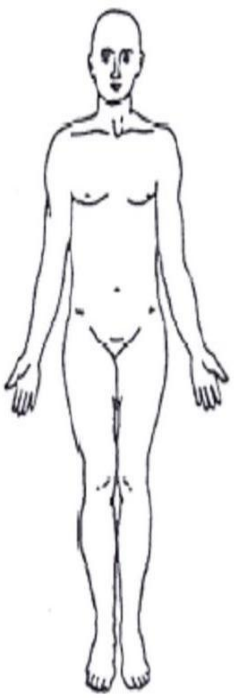
Beginning of the day
Following lecture session
Following practical session

Seat

Conventional seat
Saddle seat

Please mark your current level of discomfort or pain for the different areas of your body, where zero (at the far left) represents <u>no</u> pain or discomfort, 10 (at the far right) indicates <u>severe</u> pain or discomfort. Please also indicate the exact area of pain by an X in the body chart given below.

Anterior



Posterior

Part of the body	**Discomfort or Pain level**										
	None				Moderate						Severe
Neck	0	1	2	3	4	5	6	7	8	9	10
Shoulders	0	1	2	3	4	5	6	7	8	9	10
Upper back	0	1	2	3	4	5	6	7	8	9	10
Elbow	0	1	2	3	4	5	6	7	8	9	10
Lower back	0	1	2	3	4	5	6	7	8	9	10
Lower arm/wrist/ Hand	0	1	2	3	4	5	6	7	8	9	10
Buttocks/thighs	0	1	2	3	4	5	6	7	8	9	10
Knees	0	1	2	3	4	5	6	7	8	9	10
Lower legs/ankles/ feet	0	1	2	3	4	5	6	7	8	9	10

Have you undertaken any activity today that may be the cause of this/these pain(s)?
(If yes please indicate the activity)

Appendix XXIV: INFORMATION SHEET – Daily Symptom Survey of Students:

The purpose of the survey
To record the variation in symptoms and changes in areas of symptoms over a period of 5 days in dental students

The procedure

- Fifteen daily symptom charts are enclosed with this sheet.
- You need to fill in one form at the Morning (Beginning of the day), one in the afternoon (Middle of the day) and one in the evening (End of the day).
- You need to fill in the date and circle the time (Morning / Afternoon / Evening)
- You need to circle one of the activity (Beginning of the day / Following a Lecture Session / Following a Practical Session)
- Please also circle the type of seat used if it was a practical session (Conventional/Saddle)
- Follow the instructions and fill in the rest of the form.
- For each day you need to complete 3 of the enclosed forms and for 5 days.

What will the information be used for?
The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information?
Any information that is obtained will remain completely confidential and seen only by the research team. All information will be coded and the code held secure within the School of Health Sciences University of Birmingham.

The Risks
There are no risks associated with this activity.
Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits
The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system

If you decide not to take part, your decision will be respected without question.
You are free to withdraw from the study at any time without giving a reason. Participating or withdrawal from the study will have no effect on your degree programme.

Appendix XXV: Daily Symptom Chart (Dentists)

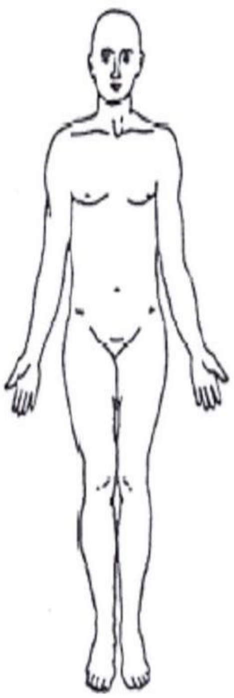
Date: Time: (Please Circle One) Morning Afternoon Evening

Activity

Beginning of the day
Middle of the Day
End of the Day

Please mark your current level of discomfort or pain for the different areas of your body, where zero (at the far left) represents no pain or discomfort, 10 (at the far right) indicates severe pain or discomfort. Please also indicate the exact area of pain by an X in the body chart given below.

Anterior **Posterior**



Part of the body	**Discomfort or Pain level**										
	None				Moderate						Severe
Neck	0	1	2	3	4	5	6	7	8	9	10
Shoulders	0	1	2	3	4	5	6	7	8	9	10
Upper back	0	1	2	3	4	5	6	7	8	9	10
Elbow	0	1	2	3	4	5	6	7	8	9	10
Lower back	0	1	2	3	4	5	6	7	8	9	10
Lower arm/wrist/ Hand	0	1	2	3	4	5	6	7	8	9	10
Buttocks/thighs	0	1	2	3	4	5	6	7	8	9	10
Knees	0	1	2	3	4	5	6	7	8	9	10
Lower legs/ankles/ feet	0	1	2	3	4	5	6	7	8	9	10

Have you undertaken any activity today that may be the cause of this/these pain(s)?
(If yes please indicate the activity)

Appendix XXVI: INFORMATION SHEET – Daily Symptom Survey of Dentists:

The purpose of the survey

To record the variation in symptoms and changes in areas of symptoms over a period of 5 days in dental students

The procedure

- Fifteen daily symptom charts are enclosed with this sheet.
- You need to fill in one form at the Morning (Beginning of the day), one in the afternoon (Middle of the day) and one in the evening (End of the day).
- You need to fill in the date and circle the time (Morning / Afternoon / Evening)
- You need to circle one of the activity (Beginning of the day / Middle of the Day / End of the Day)
- Follow the instructions and fill in the rest of the form.
- For each day you need to complete 3 of the enclosed forms and for 5 days.

What will the information be used for?

The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information?

Any information that is obtained will remain completely confidential and seen only by the research team. All information will be coded and the code held secure within the School of Health Sciences University of Birmingham.

The Risks

There are no risks associated with this activity.

Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits

The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system

If you decide not to take part, your decision will be respected without question.

You are free to withdraw from the study at any time without giving a reason. Participating or withdrawal from the study will have no effect on your degree programme.

Appendix XXVII: Information Sheet (Dental Students)

INFORMATION SHEET – Electromyographic (EMG) Study:

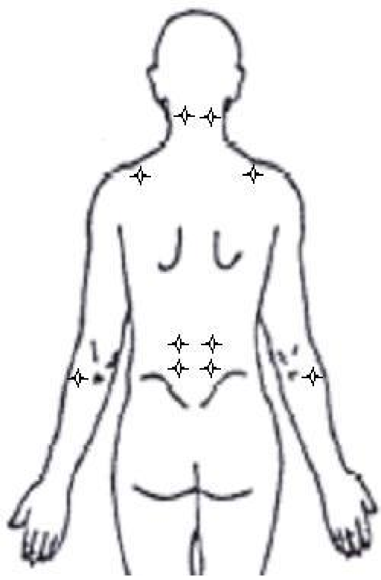
The purpose of this study
To record the muscle activity of the back and upper limbs occurring during common dental activities using surface electromyography and to see if there is a difference between the two dental seats. The study takes approximately 30 minutes to complete.

The procedures

- The participants will be allocated an individual time for the study in the phantom head laboratory.
- The Participants need to use the same dental chair, which was allocated for use in the phantom head laboratory.
- The participants need to do a dental procedure (E.g. Filling in a tooth) during the time of the study.
- EMG from the following muscles will be measured during the study

  Upper Trapezius (Right and Left)
  Neck Extensors (Right and Left)
  Wrist Extensors (Right and Left)
  Lumbar Paravertebrals (Right and Left)

  The figure shows approximate areas of electrode placement
  (✧ are the electrode placement areas)



- Skin Preparation: Skin will be prepared with alcohol wipe before electrode placement.
- Video recording of the procedure will be done for the entire time of the study.

What will the information be used for?
The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information?
Any information that is obtained will remain completely confidential and seen only by the research team. All information will be coded and held secure within the School of Health Sciences University of Birmingham.

The Risks
There are no risks associated with this activity. Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits
The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system

If you decide not to take part, your decision will be respected without question.
You are free to withdraw from the study at any time without giving a reason.
Participating or withdrawal from the study will have no effect on your degree programme.

Appendix XXVIII: <u>CONSENT FORM</u> (Dental Students)

Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

Have you read and understood the information sheet containing details of the research study?…… Yes / No

Have you had an opportunity to ask questions and discuss this study?…………………………Yes / No

Have you received satisfactory answers to all your questions?……………………………………. Yes / No

Have you received enough information about the study?.. Yes / No

Have you been told that any information used will remain anonymous?……………………… Yes / No

Do you understand that you are free to withdraw from the study at any time, without giving a reason ……Yes / No

Who explained the details of this study to you?..…………

I agree to take part in this EMG study ....……Yes / No

Signature of subject…………………………. ....Date.......................…………

Printed full name of subject ....…………………………………………………………………..

Signature of researcher ………………………………………………………………………………………Date……………………….

Printed full name of researcher……………………………………………………………………………………………………

Thank you very much for taking the time to complete this form.

This consent form will be stored in the School of Health Sciences in accordance with the Data Protection Act (1998)

Appendix XXIX: Information Sheet (Dentists)

INFORMATION SHEET – Electromyographic (EMG) Study:

The purpose of this study

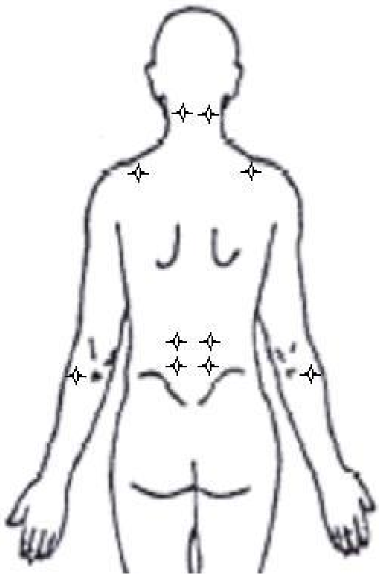
To record the muscle activity of the back and upper limbs occurring during common dental activities using surface electromyography and to see if there is a difference between the two dental seats. The study takes approximately 30 minutes to complete.

The procedure

- The procedure involves recording the electrical activity of the muscles using surface electromyography. It is a non-invasive procedure and is not painful.
- The electrical activity of the muscles will be recorded for ten minutes during a dental procedure (E.g. Filling in a tooth). It will take around 10 minutes to set up the equipment and apply the electrodes.
- EMG from the following muscles will be measured during the study

  Upper Trapezius (Right and Left)
  Neck Extensors (Right and Left)
  Wrist Extensors (Right and Left)
  Lumbar Paravertebrals (Right and Left)

  The figure shows approximate areas of electrode placement (✧ are the electrode placement areas)



- Skin Preparation: Skin will be prepared with alcohol wipe before electrode placement.

What will the information be used for?

The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information?

Any information that is obtained will remain completely confidential and seen only by the research team. All information will be coded and held secure within the School of Health Sciences University of Birmingham.

The Risks

There are no risks associated with this activity. Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits

The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system

If you decide not to take part, your decision will be respected without question.
You are free to withdraw from the study at any time without giving a reason.

Appendix XXX: **<u>CONSENT FORM</u>** **(Dentists)**

Working postures in dentists: The relationship between seating, muscle activity and musculoskeletal disorders in dentists

Have you read and understood the information sheet containing details of the research study?…… Yes / No

Have you had an opportunity to ask questions and discuss this study?…………………………Yes / No

Have you received satisfactory answers to all your questions?……………………………………. Yes / No

Have you received enough information about the study?... Yes / No

Have you been told that any information used will remain anonymous?……………………… Yes / No

Do you understand that you are free to withdraw from the study at any time, without giving a reason ……Yes / No

Who explained the details of this study to you?.......................……………………………………………

I agree to take part in this EMG study ....……Yes / No

Signature of subject..............……………………………………………………………….........Date.......................…………………

Printed full name of subject ....………………………………………………………………………………………….

Signature of researcher ……………………………………………………………………………………Date……………………….

Printed full name of researcher……………………………………………………………………………………………………

Thank you very much for taking the time to complete this form.

This consent form will be stored in the School of Health Sciences in accordance with the Data Protection Act (1998)

Appendix XXXI: Information Sheet (EMG Case Study)

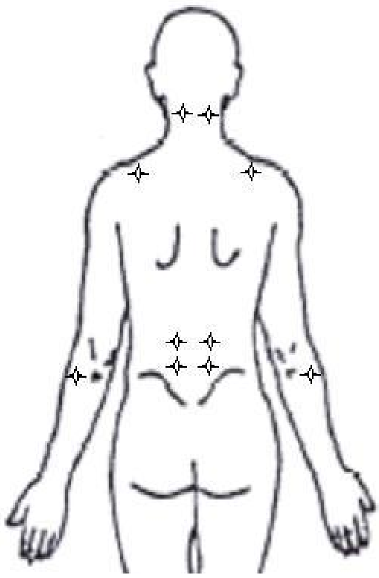
The purpose of this study
To record the muscle activity of the back and upper limbs occurring during common dental activities using surface electromyography and to see if there is a difference between the two dental seats. The study takes approximately 30 minutes to complete.

The procedures

- The procedure involves recording the electrical activity of the muscles using surface electromyography. It is a non-invasive procedure and is not painful.
- The electrical activity of the muscles will be recorded for ten to 30 minutes during a dental procedure (E.g. Filling in a tooth). It will take around 10 minutes to set up the equipment and apply the electrodes.
- EMG from the following muscles will be measured during the study

  Upper Trapezius (Right and Left)
  Neck Extensors (Right and Left)
  Wrist Extensors (Right and Left)
  Lumbar Paravertebrals (Right and Left)

  The figure shows approximate areas of electrode placement (✧ are the electrode placement areas)



- Skin Preparation: Skin will be prepared with alcohol wipe before electrode placement.

What will the information be used for?
The results of the study used assist in planning ergonomic advice for dental practitioners to help reduce musculoskeletal discomfort due to the demands of dental practice. The results may be reproduced in dissemination of the research project by the sponsors and in academic publications and may also be used in assisting and developing research questions relating dentists posture and seating.

Will anyone have access to my personal information?
Any information that is obtained will remain completely confidential and seen only by the research team. All information will be coded and held secure within the School of Health Sciences University of Birmingham.

The Risks
There are no risks associated with this activity. Participants will be advised to seek professional help should they identify a persistent musculoskeletal problem.

The Benefits
The benefits of the study will be in understanding the demands of dental work imposed upon the musculoskeletal system
If you decide not to take part, your decision will be respected without question.
You are free to withdraw from the study at any time without giving a reason.
Participating or withdrawal from the study will have no effect on your degree programme.

Appendix XXXII: Dental Ergonomic Questionnaire (Students)

Please read each question. Indicate your answer by circling / filling in the space provided.

1. **Please state your age:** 2. **Are you:** Male or Female

3. **Year of Study:**

4. In a typical day in the past week, how many hours did you:	0 Hours	1-2 Hours	3-4 Hours	5-6 Hours	7-8 Hours	9+ Hours
a. Spend sitting in your Operator's Stool?						
b. Spend sitting in another chair at your clinic?						
c. Spend treating patients?						
d. Spend sitting and working at a computer on a weekday?						
e. Spend sitting and working on a computer on a weekend?						

5. In the past week, did you take any rest breaks (1 - 5 Minutes) from dental procedures?

Yes No

If yes, on how many days did this apply: ________ Days

6. During a typical day, how frequently do you get up and leave your patient treatment area to go do other work, take a break, talk to your classmates etc.? (Select one):

Never
About once a day
About once every 2-3 hours
About once every hour
About once every half hour
About once every 15 minutes
About once every 5 minutes

7. During a typical day, how frequently do you need to rest your hands? (Select one)

Every
5 Minutes
15 Minutes
30 Minutes

Every
1-2 Hours
2-3 Hours
More than 3 hours

Never

8. In general, would you say your health is: Please circle

Excellent Very Good Good Fair Poor

9. Do you have a health problem or medical condition that you would like to tell us about?
Please indicate it below

10. Do you use glasses or contact lenses when treating patients?

Yes No

11. Do you use magnifying loupes?

Yes No If Yes please state make ________________

Percentage	All of the Patients (100%)	Most of the Patients	Half of the Patients (50%)	Some of the Patients	None of the Patients (0%)
For what percentage of patients do you use the magnifying loupes? (Please Tick)					

12. Have you received any training in correct operating position?

Yes No

13. How much force do you have to use with your hands and wrists during the following procedures

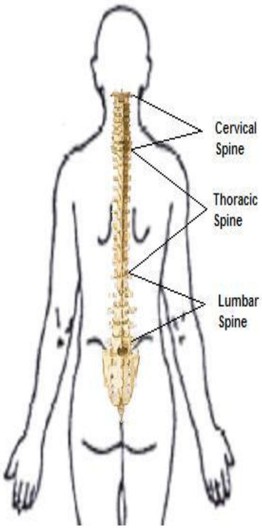
Dental Procedure		Indicate force with wrists and hands	
a. Dental Examination	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
b. Scaling and Polishing	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
c. Direct placement restorations	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
d. Orthodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
e. Crown and Bridge work	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
f. Removable Prosthodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
g. Endodontics	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists
h. Tooth Extraction	No force with hands and wrists	1 2 3 4 5 6 7	Extremely high force with hands and wrists

14. Please indicate the frequency of the following dental procedures used in a typical day at your clinics

Dental Procedure	Most Frequently Used	Frequently Used	Less Frequently Used	Not Used
a. Dental Examination				
b. Scaling and Polishing				
c. Direct placement restorations				
d. Orthodontics				
e. Crown and Bridge work				
f. Removable Prosthodontics				
g. Endodontics				
h. Tooth Extraction				

15. Think about how you have used your Operator's Stool in the past 4 weeks. Please mark how much you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Neither Agree or Disagree	Dis-agree	Strongly Disagree	N/A
a. When I am seated in my stool, my lumbar spine is supported against the seat back						
b. My chair provides comfortable seat (bottom) support						
c. When I sit in my stool, my arms rest comfortably at my side						
d. When I am sitting in my stool, my legs and feet are in a comfortable position						
e. When I am sitting in my stool, my neck is in a comfortable position						
f. Overall, the Operator's Stool is comfortable						
g. I am satisfied with my Operator's Stool						



16. Because some Operator's Stools may not be suitable for all body types, we would like to know your height and weight:

Height: Feet ______ Inches ______ (or) Meters ______

Weight: ______ in Kg (or) Stones ______ Lbs ______

17. Have you received any training, information, or assistance on how to adjust your Operator's Stool?

Yes No

18. Overall, how easy is it for you to adjust your Operator's Stool? (Select one:)

Easy Difficult There are no adjustable features in my chair

19. Have you felt pain in the past 4 weeks?

Yes   No   (If no go to Q.25)

20. If Yes where did you feel the pain?

Head   Neck   Shoulders   Upper Back   Lower Back
Upper Limbs   Lower Limbs   Hands   Hip   Knees

Ankles   Feet

Other Area – Please Specify________________________

21. During the past 4 weeks, how much did pain interfere with your dental work?

Not at all   A Little Bit   Moderately   Quite a Bit   Extremely

22. In general how much pain did you feel (Please mark a cross on the line)

No Pain |————————————————————— Intense Pain

1   10

23. What medications have you used during <u>the past 4 weeks</u> for your pain?

Have you	Yes	No
a. Taken any over-the-counter medicines such as Aspirin, Neurofen, Ibuprufen, or Paracetamol?		
b. Taken any prescription pain medications such as prescription Co-Proximol, Codeine etc?		
c. Taken very strong prescription pain medications such as Tramadol , DF118 (Dihydrocodeine), Gabapentin , Voltoral (Diclofenac)		

24. Have you consulted any of the following people in reference to your pain? Please Circle

GP   Physiotherapist   Osteopath   Chiropractor   Complementary Therapist

25. Do you do exercises during the workday to relieve your pain or discomfort?

Yes   No

26. Think about a typical day on your job and mark how much you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree	N/A
a. My job requires that I learn new things						
b. My job involves a lot of repetitive work						
c. My job requires me to be creative						
d. My job allows me to make a lot of decisions on my own						
e. My job requires a high level of skill						
f. On my job, I have very little freedom to decide how I do my work						
g. I get to do a variety of different things on my job						
h. I have a lot of say about what happens on my job						
i. I have an opportunity to develop my own special abilities						
j. My job requires working very fast						
k. My job requires working very hard						
l. I am **not** asked to do an excessive amount of work						
m. I have enough time to get the job done						
n. I am free from conflicting demands that others make						
o. The people I work with are helpful in getting the job done						

27. In the past 4 weeks how difficult was it for you to do the following?

It was DIFFICULT to	All of the Time (100%)	Most of the Time	Half of the Time (50%)	Some of the Time	None of the Time (0%)	Does Not Apply To My Job
a. Work the required number of hours						
b. Get going easily at the beginning of the work day						
c. Start on my job as soon as you arrived at work						
d. Do my work without stopping to take extra breaks or rests						
e. Stick to a routine or schedule						
f. Handle the workload						
g. Work fast enough						
h. Finish work on time						
i. Feel a sense of accomplishment in your work						
j. Feel you have done what you are capable of doing						

28. Which of the following best describes your racial or ethnic background?

1. Asian
2. Asian British
3. Black or
4. African British
5. Chinese
6. Chinese British
7. White or Caucasian
8. Other – Please State ____________

MANY THANKS FOR COMPLETING THIS QUESTIONNAIRE

Comments:

Appendix XXXIII: EMG Results (Students)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2091.374	1	2091.374	5.711	.025
Right Splenius	1019.776	1	1019.776	36.794	.000
Left Trapezius	7435.827	1	7435.827	131.385	.000
Right Trapezius	2728.661	1	2728.661	67.837	.000

Between Groups One Way ANOVA (Baseline Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	812.135	1	812.135	17.476	.000
Right Longissimus Thoracis	169.205	1	169.205	1.534	.228
Left Multifidus Lumborum	10173.919	1	10173.919	1.467	.238
Right Multifidus Lumborum	10.642	1	10.642	.035	.853

Between Groups One Way ANOVA (Baseline Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	438.793	1	438.793	29.325	.000
Right ECRL	455.045	1	455.045	32.956	.000

Between Groups One Way ANOVA (Baseline Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2807.510	1	2807.510	6.904	.015
Right Splenius	931.881	1	931.881	30.060	.000
Left Trapezius	7916.027	1	7916.027	172.212	.000
Right Trapezius	3181.360	1	3181.360	114.145	.000

Between Groups One Way ANOVA (Baseline Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	996.424	1	996.424	24.286	.000
Right Longissimus Thoracis	158.625	1	158.625	1.210	.283
Left Multifidus Lumborum	219.497	1	219.497	.712	.407
Right Multifidus Lumborum	15.077	1	15.077	.048	.829

Between Groups One Way ANOVA (Baseline Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	403.842	1	403.842	22.831	.000
Right ECRL	428.404	1	428.404	26.896	.000

Between Groups One Way ANOVA (Baseline Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	1711.633	1	1711.633	4.056	.056
Right Splenius	677.263	1	677.263	24.602	.000
Left Trapezius	7444.743	1	7444.743	127.542	.000
Right Trapezius	2938.984	1	2938.984	75.228	.000

Between Groups One Way ANOVA (Baseline Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	871.508	1	871.508	20.178	.000
Right Longissimus Thoracis	161.665	1	161.665	1.507	.232
Left Multifidus Lumborum	424.936	1	424.936	1.403	.248
Right Multifidus Lumborum	37.176	1	37.176	.118	.734

Between Groups One Way ANOVA (Baseline Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	487.330	1	487.330	31.943	.000
Right ECRL	406.643	1	406.643	26.422	.000

Between Groups One Way ANOVA (Baseline Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	577.682	1	577.682	2.778	.109
Right Splenius	1515.997	1	1515.997	39.705	.000
Left Trapezius	8002.131	1	8002.131	191.450	.000
Right Trapezius	2837.168	1	2837.168	72.246	.000

Between Groups One Way ANOVA (Baseline Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	638.239	1	638.239	10.144	.004
Right Longissimus Thoracis	220.267	1	220.267	2.896	.102
Left Multifidus Lumborum	297.254	1	297.254	.999	.328
Right Multifidus Lumborum	82.244	1	82.244	.244	.626

Between Groups One Way ANOVA (Baseline Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	404.465	1	404.465	25.156	.000
Right ECRL	421.070	1	421.070	28.751	.000

Between Groups One Way ANOVA (Baseline Students; 10 Minute Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	1563.076	1	1563.076	9.341	.004
Right Splenius	5243.795	1	5243.795	16.292	.000
Left Trapezius	4392.749	1	4392.749	26.425	.000
Right Trapezius	3704.923	1	3704.923	26.440	.000

Between Groups One Way ANOVA (3 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	3.789	1	3.789	.006	.937
Right Longissimus Thoracis	358.253	1	358.253	.719	.402
Left Multifidus Lumborum	54.034	1	54.034	.113	.739
Right Multifidus Lumborum	.152	1	.152	.000	.982

Between Groups One Way ANOVA (3 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	791.988	1	791.988	5.620	.023
Right ECRL	148.061	1	148.061	1.967	.170

Between Groups One Way ANOVA (3 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	1421.264	1	1421.264	7.575	.009
Right Splenius	6070.256	1	6070.256	18.271	.000
Left Trapezius	4567.895	1	4567.895	22.905	.000
Right Trapezius	4103.432	1	4103.432	24.886	.000

Between Groups One Way ANOVA (3 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	97.984	1	97.984	.143	.707
Right Longissimus Thoracis	376.489	1	376.489	.649	.426
Left Multifidus Lumborum	110.767	1	110.767	.194	.663
Right Multifidus Lumborum	1.608	1	1.608	.005	.945

Between Groups One Way ANOVA (3 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	907.500	1	907.500	5.274	.028
Right ECRL	137.898	1	137.898	1.503	.228

Between Groups One Way ANOVA (3 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	1475.188	1	1475.188	7.428	.010
Right Splenius	4867.395	1	4867.395	14.668	.001
Left Trapezius	3870.113	1	3870.113	24.436	.000
Right Trapezius	3835.968	1	3835.968	26.076	.000

Between Groups One Way ANOVA (3 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	.151	1	.151	.000	.988
Right Longissimus Thoracis	260.791	1	260.791	.497	.485
Left Multifidus Lumborum	16525.334	1	16525.334	.961	.334
Right Multifidus Lumborum	.145	1	.145	.000	.983

Between Groups One Way ANOVA (3 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	912.705	1	912.705	5.957	.020
Right ECRL	153.331	1	153.331	1.954	.171

Between Groups One Way ANOVA (3 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	1625.272	1	1625.272	8.774	.005
Right Splenius	4264.783	1	4264.783	12.689	.001
Left Trapezius	4318.585	1	4318.585	27.457	.000
Right Trapezius	3814.439	1	3814.439	25.946	.000

Between Groups One Way ANOVA (3 Months Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	35.687	1	35.687	.052	.821
Right Longissimus Thoracis	288.396	1	288.396	.562	.458
Left Multifidus Lumborum	363.569	1	363.569	.758	.390
Right Multifidus Lumborum	3.254	1	3.254	.010	.920

Between Groups One Way ANOVA (3 Months Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	850.485	1	850.485	5.411	.026
Right ECRL	120.417	1	120.417	1.450	.237

Between Groups One Way ANOVA (3 Months Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	6905.732	1	6905.732	19.504	.000
Right Splenius	2869.579	1	2869.579	15.557	.000
Left Trapezius	4953.983	1	4953.983	33.920	.000
Right Trapezius	7442.552	1	7442.552	39.157	.000

Between Groups One Way ANOVA (6 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	2043.048	1	2043.048	12.505	.001
Right Longissimus Thoracis	3694.057	1	3694.057	20.521	.000
Left Multifidus Lumborum	7824.749	1	7824.749	46.362	.000
Right Multifidus Lumborum	13005.534	1	13005.534	44.210	.000

Between Groups One Way ANOVA (6 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	360.491	1	360.491	6.950	.013
Right ECRL	409.676	1	409.676	9.769	.004

Between Groups One Way ANOVA (6 Months Students; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	9753.616	1	9753.616	28.394	.000
Right Splenius	3249.657	1	3249.657	18.517	.000
Left Trapezius	4949.843	1	4949.843	24.591	.000
Right Trapezius	7883.155	1	7883.155	36.458	.000

Between Groups One Way ANOVA (6 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	2614.183	1	2614.183	19.680	.000
Right Longissimus Thoracis	3409.779	1	3409.779	15.786	.000
Left Multifidus Lumborum	6947.132	1	6947.132	28.242	.000
Right Multifidus Lumborum	16550.225	1	16550.225	79.813	.000

Between Groups One Way ANOVA (6 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	587.372	1	587.372	13.958	.001
Right ECRL	679.327	1	679.327	16.597	.000

Between Groups One Way ANOVA (6 Months Students; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	7718.814	1	7718.814	23.152	.000
Right Splenius	2733.846	1	2733.846	16.610	.000
Left Trapezius	5693.251	1	5693.251	35.869	.000
Right Trapezius	8484.384	1	8484.384	50.678	.000

Between Groups One Way ANOVA (6 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	3465.327	1	3465.327	22.924	.000
Right Longissimus Thoracis	2748.378	1	2748.378	12.505	.001
Left Multifidus Lumborum	6668.334	1	6668.334	26.455	.000
Right Multifidus Lumborum	13014.398	1	13014.398	55.957	.000

Between Groups One Way ANOVA (6 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	487.531	1	487.531	11.842	.002
Right ECRL	381.275	1	381.275	9.939	.004

Between Groups One Way ANOVA (6 Months Students; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	7770.939	1	7770.939	21.697	.000
Right Splenius	2454.312	1	2454.312	13.191	.001
Left Trapezius	3659.531	1	3659.531	17.447	.000
Right Trapezius	6249.531	1	6249.531	27.095	.000

Between Groups One Way ANOVA (6 Months Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	1575.378	1	1575.378	8.231	.007
Right Longissimus Thoracis	3777.811	1	3777.811	18.531	.000
Left Multifidus Lumborum	7010.479	1	7010.479	32.059	.000
Right Multifidus Lumborum	15100.594	1	15100.594	71.908	.000

Between Groups One Way ANOVA (6 Months Students; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	170.634	1	170.634	2.928	.097
Right ECRL	143.170	1	143.170	3.719	.063

Between Groups One Way ANOVA (6 Months Students; 10 Minutes Average)

Appendix XXXIV: EMG Results (Dentists)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2078.034	1	2078.034	15.713	.001
Right Splenius	5030.081	1	5030.081	33.177	.000
Left Trapezius	4717.529	1	4717.529	36.005	.000
Right Trapezius	2159.045	1	2159.045	93.935	.000

Between Groups One Way ANOVA (Dentists; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	1490.034	1	1490.034	12.600	.002
Right Longissimus Thoracis	3362.383	1	3362.383	26.552	.000
Left Multifidus Lumborum	10359.597	1	10359.597	40.298	.000
Right Multifidus Lumborum	8056.735	1	8056.735	64.402	.000

Between Groups One Way ANOVA (Dentists; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	25.071	1	25.071	.805	.380
Right ECRL	.007	1	.007	.000	.989

Between Groups One Way ANOVA (Dentists; Minute 1 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2448.584	1	2448.584	19.985	.000
Right Splenius	5204.538	1	5204.538	29.671	.000
Left Trapezius	4657.869	1	4657.869	32.960	.000
Right Trapezius	2037.283	1	2037.283	61.118	.000

Between Groups One Way ANOVA (Dentists; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	1906.463	1	1906.463	14.222	.001
Right Longissimus Thoracis	2659.549	1	2659.549	13.839	.001
Left Multifidus Lumborum	11375.234	1	11375.234	46.641	.000
Right Multifidus Lumborum	9028.924	1	9028.924	59.060	.000

Between Groups One Way ANOVA (Dentists; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	**34.684**	**1**	**34.684**	**.895**	**.355**
Right ECRL	**.224**	**1**	**.224**	**.006**	**.939**

Between Groups One Way ANOVA (Dentists; Minute 5 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2409.618	1	2409.618	21.750	.000
Right Splenius	4863.266	1	4863.266	32.137	.000
Left Trapezius	4843.781	1	4843.781	35.669	.000
Right Trapezius	2282.638	1	2282.638	68.335	.000

Between Groups One Way ANOVA (Dentists; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	2212.763	1	2212.763	16.958	.001
Right Longissimus Thoracis	3203.434	1	3203.434	22.911	.000
Left Multifidus Lumborum	10928.831	1	10928.831	44.541	.000
Right Multifidus Lumborum	8610.077	1	8610.077	61.823	.000

Between Groups One Way ANOVA (Dentists; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	8.884	1	8.884	.201	.658
Right ECRL	.155	1	.155	.005	.946

Between Groups One Way ANOVA (Dentists; Minute 10 Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Splenius	2311.125	1	2311.125	20.685	.000
Right Splenius	4655.307	1	4655.307	29.523	.000
Left Trapezius	4672.262	1	4672.262	36.037	.000
Right Trapezius	2010.094	1	2010.094	64.077	.000

Between Groups One Way ANOVA (Dentists; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left Longissimus Thoracis	1678.075	1	1678.075	13.337	.002
Right Longissimus Thoracis	3314.696	1	3314.696	27.064	.000
Left Multifidus Lumborum	11117.767	1	11117.767	50.559	.000
Right Multifidus Lumborum	8150.741	1	8150.741	66.274	.000

Between Groups One Way ANOVA (Dentists; 10 Minutes Average)

Between Groups ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Left ECRL	32.923	1	32.923	.979	.334
Right ECRL	.000	1	.000	.000	.998

Table. 6-99. Between Groups One Way ANOVA (Dentists; 10 Minutes Average)

Appendix XXXV:

Case Study – Physical Examination

Name: PH

Age:	22	D.O.B:	29/06/1983
Sex:	Female	Occupation:	Dental Student (Year 4)

PAST HISTORY:

- Onset of pain around 5 weeks ago (1st/2nd week of February)
- Sudden onset of pain on the right shoulder (**P**A) when performing a RCT (Root Canal Therapy).
- The pain started in the right shoulder (**P**A) then spread to the right side of the neck (PB) and then in two weeks pain was also on the Left Lumbar region (**P**C)

Precipitating Factors:

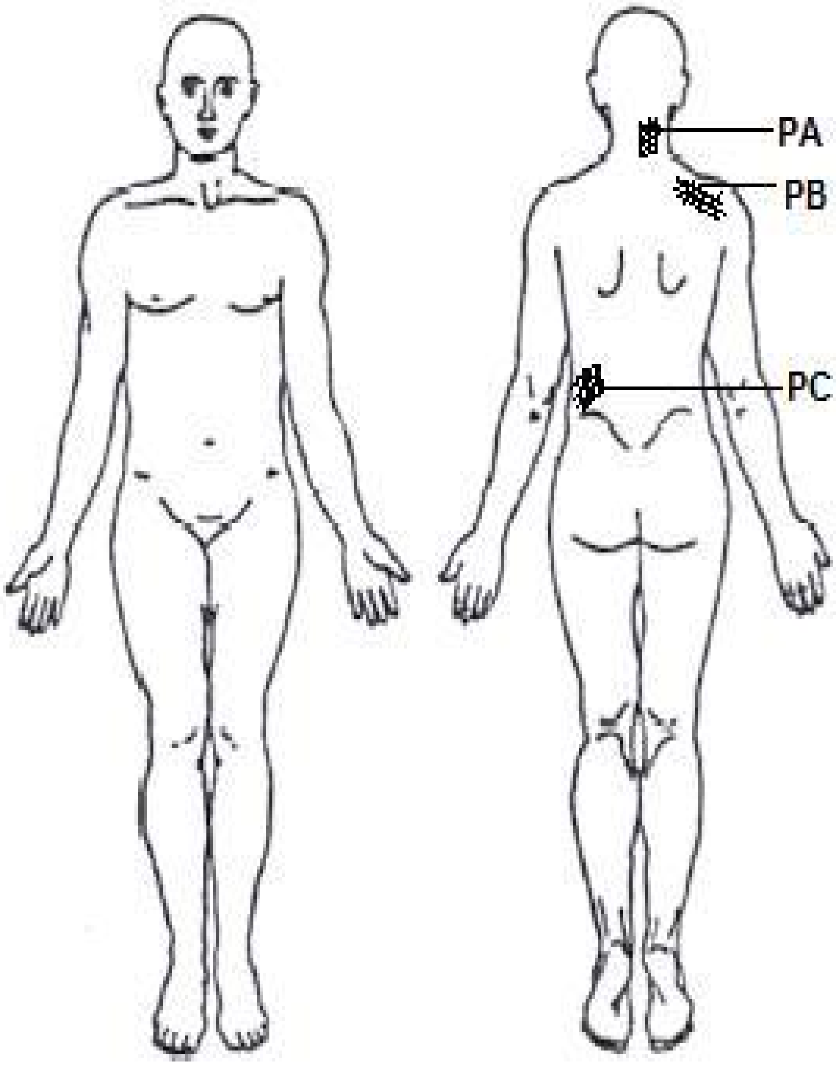
- Performing treatment procedure (E.g. RCT – Root Canal Therapy)
- Poor Sitting / Working Posture

Investigations:

None

PRESENT HISTORY:

Symptom Chart:



	PA	PB
Description of Pain	Throbbing	Throbbing
VAS	10/10	10/10
Depth of Pain:	Deep	Deep

Intermittent / Unremitting: Pain starts after the activity and is constant and takes hours to ease.

Behaviour Of Symptoms:

Aggravating Factors:

- Performing treatment procedures (E.g. RCT – Root Canal Therapy) P_A, P_B & P_C
- Use of Computer at home sitting on a office chair (Can work only for 20 minutes)
- When the subject is in pain rotation aggravates pain (P_c)
- Palpation of the upper and middle trapezius muscles, caused P_A and P_B to appear.

  PA (Postero-anterior) movement of the cervical spine increased P_A and P_B.
- Side Flexion of the Lumbar Spine to the left increased (P_c)

Relieving Factors:

- Lying down flat
- Exercise
- Cervical Distraction during examination relieved pain

Effect of Certain Positions / Movement:

- Side flexion towards the left side increases pain (P_C).
- Sitting in front of computer increases P_A, P_B & P_C

Latency of Pain: (How long does it take for the pain to reach it's peak)

- Pain immediate onset on certain activity (E.g. Performing treatment procedures)

Past Medical History:

General Health and Fitness:

Good

Social History:

Hobbies:

None

Ergonomics:

- Working Posture needs to be changed
- Correct working / sitting posture is to be emphasized.

Drug History:

- Taken Neurofen to ease pain

Special Questions:

Cough / Sneeze (Response of pain)

Negative

History of Present Condition:

Onset:

- Pain starts immediately when starting to treat patients
- Sitting in front of computer on a office chair
- Pain in the begging of the day when getting up from bed

Investigations:

None

Planning the Physical Examination:

Severity:

P_A Moderate to Severe

P_B Moderate to Severe

P_C Moderate

Irritability:

P_A Moderate to Severe

P_B Moderate to Severe

P_C Moderate

- Does any aspect of the patient history indicate caution?

- What are your decisions regarding movement?

  Caution should be taken in attempting movements such as side flexion of the back, which increases pain. The ROM should be assesses till the pain free range if any movement shoots pain

- Can you predict the comparable signs? (E.g. Radiating Pain)

  $P_B \longrightarrow P_A$ (Radiating / Referred Pain) P_B might be due to P_A

  $P_C \longrightarrow P_B$ P_C might be due to P_B (Involvement of the Lattismus Dorsi may have caused P_B & P_C

- What is the relationship between pain and resistance? (E.g. Pain > Resistance)

  Pain > Resistance

- Nature of Presentation:

  Neurogenic: 30% Myogenic: 70%

Physical Examination:

Active Movements:

Lumbar Spine: (Standing)

Flexion (Bending): Movement was restricted by **PC** (ROM – 51 cm from floor to tip of middle finger)

Right Side Flexion: Movement was restricted by pain **PC** (ROM - 48 cm from floor to tip of middle finger

Left Side Flexion: Movement was restricted by pain **PC** (ROM - 53 cm from floor to tip of middle finger

Neck: (Sitting)

Left Rotation:	ROM 11cm from tip of chin to tip of shoulder
Right Rotation:	ROM 11cm from tip of chin to tip of shoulder
Flexion:	ROM 2 finger width from chin to chest

Shoulder: (Lying)

Flexion:	Full ROM, End of flexion range increases **PC**
Abduction:	Full ROM
Internal Rotation:	Full ROM
External Rotation:	Full ROM

Neurological Examination:

Sensation: Normal

Referred Pain:

PB ⟶ **PA** (Radiating / Referred Pain) PB might be due to PA

Knee Jerk :

Passive Movements:

Special Tests: (E.g. SLR / Crossed SLR / Tension Sign)

- SLR (Lasegue Test): Negative on both left and right sides
- Bragard Test (L4/L5/S1 Nerve root pain): Negative

  The patient had hamstring tightness and had stretching pain behind the knee.

Sensitizing Additions to SLR (Lasegue Test):

Hip adduction and Internal Rotation (Sciatic Nerve): Negative

Ankle Dorsiflexion (Sciatic Nerve): Negative

Dorsiflexion/Eversion (Tibial Nerve): Negative (localised ankle pain)

Dorsiflexion/Inversion (Sural Nerve): Negative with (localised ankle pain)

Plantar Flexion/Inversion (Peroneal Nerve): Negative

Supine Lying: (Movement of Hips / Knees and the response to pain)

- Hip and Knee: Full ROM and no pain reported.

Inter-vertebral Tests by Palpation:

Soft tissue Changes: (E.g. Tightness/Spasm)

Tightness / Protective Spasm of the upper and middle trapezius are seen.

Palpation of these muscles increased the P_A and P_B

Skin – Sweat / Temperature: Normal.

Palpation: (Local Spinal Palpation – E.g. Note Tenderness / Increase of Pain)

- Cervical Spine:

  PA movement of the cervical vertebrae increased P_A and P_B

- Lumbar Spine:

  PA movement of the lumbar vertebrae was normal

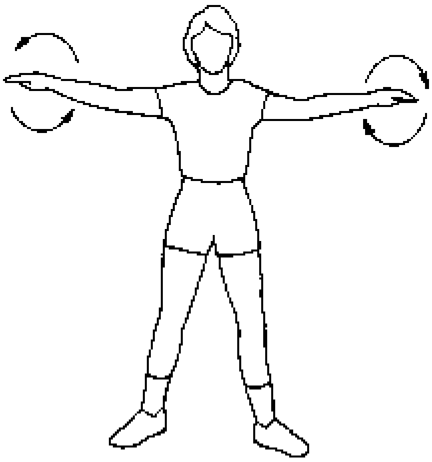
Impression / Hypothesis: Posture related pain.

Appendix XXXVI: Stretching Exercises

Arms and Shoulders

- Stand with back straight and feet a shoulder width apart. Extend arms outward to shoulder height.
- Rotate shoulders forward and make large circular motion with arms.
- Repeat in opposite direction.

Do three times in each direction.

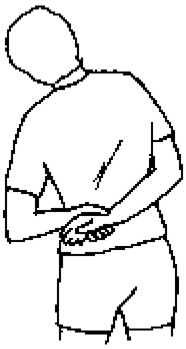


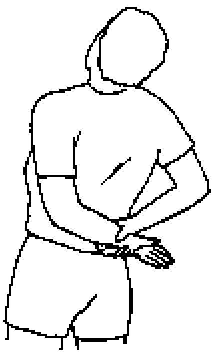
Neck and Shoulders

Stretches the sternocleidomastoid , pectoralismajor, and deltoid muscles.

- Stand with feet a shoulder width apart and arms behind body.
- Grasp left wrist with right hand. Pull left arm down and to right. Tilt head to the right. Hold this position for 10 to 15 seconds.

Repeat with right wrist, pulling right arm down and to left. Tilt head to left.



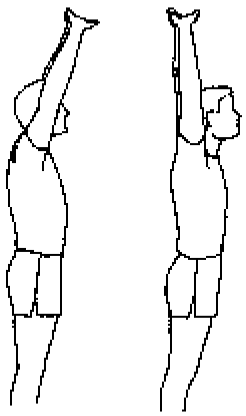


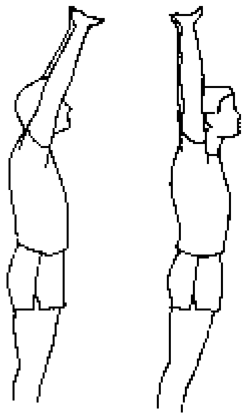
Abdomen

Stretches abdominals, obliques, latissimus dorsi, and biceps.

- Stand and extend arms upward and over head.
- Interlace fingers with palms turned upward.
- Stretch arms up and slightly back. Hold this position for 10 to 15 seconds.

Variation: To stretch rectus abdominis muscles. Stretch to one side, then other. Return to starting position.



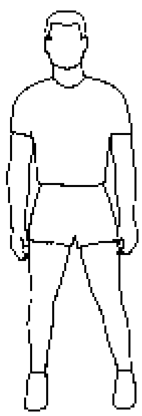


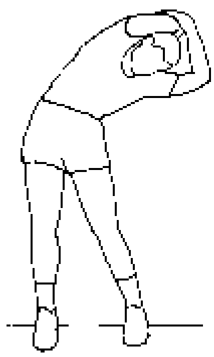
Overhead Arms Pull

Stretches external and internal obliques, latissimus dorsi, and triceps.

- Stand with feet a shoulder width apart. Raise right arm, bending right elbow. and touching right hand to back of neck.
- Grab right elbow with left hand and pull to left. Hold this position for 10 to 15 seconds.
- Return to starting position.

Do the same stretch with left arm.



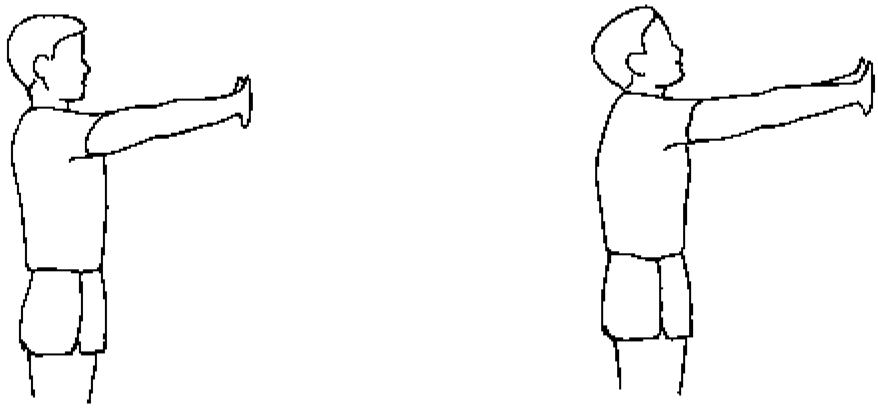


Upper Back

Stretches lower trapezius and posterior deltoid muscles of upper back.

- Stand with arms extended to front at shoulder height with fingers interlaced and palms facing outward.
- Extend arms and shoulders forward. Hold this position for 10 to 15 seconds.

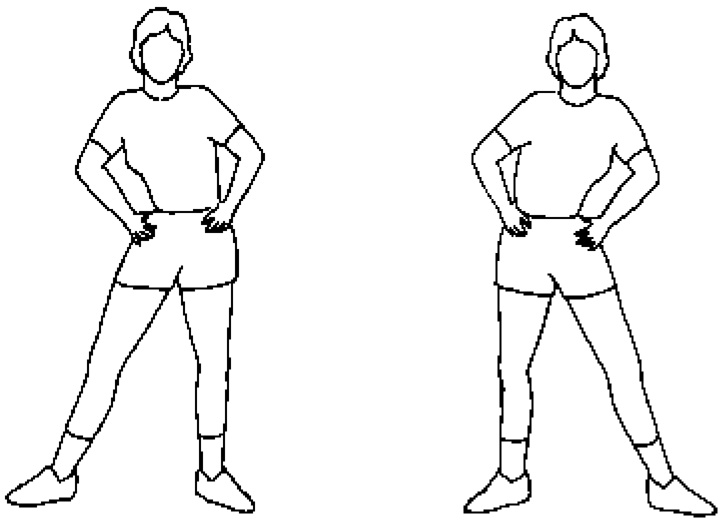
Return to starting position.



Hips

- Stand with back straight and a feet shoulder width apart.
- Rotate hips clockwise while keeping back straight.
- Repeat in counterclockwise direction.

Do three times in each direction.



Appendix XXXVII:

Case Study – Physical Examination (Review)

Name: PH

Age:	24	D.O.B:	20/06/1983
Sex:	Female	Occupation:	Dental Student (Year 5)

PAST HISTORY & CONDITION:

- The pain (P_A, P_B and P_C) reduced after 1 month of the use of chair
- Had neck / shoulder pain once in the past year while performing endodontics

Ergonomics:

Has been using the Bambach Saddle seat for the past one year.

History of Present Condition:

- Currently no pain at any areas of the body.

Physical Examination:

Active Movements:

Lumbar Spine: (Standing)

Flexion (Bending): Full ROM (The patient was able to touch the floor)

Right Side Flexion: ROM - 45 cm from floor to tip of middle finger (3 cm improvement)

Left Side Flexion: ROM - 47 cm from floor to tip of middle finger (6 cm Improvement)

Neck: (Sitting)

Left Rotation: ROM 9.5cm from tip of chin to tip of shoulder (1.5 cm improvement)

Right Rotation: ROM 9cm from tip of chin to tip of shoulder (2 cm improvement)

Flexion: Full ROM

Shoulder: (Lying)

Flexion: Full ROM

Abduction: Full ROM

Internal Rotation: Full ROM

External Rotation: Full ROM

Passive Movements:

Special Tests: (E.g. SLR / Crossed SLR / Tension Sign)

- SLR (Lasegue Test): Negative on both left and right sides
- Bragard Test (L4/L5/S1 Nerve root pain): Negative

The patient had hamstring tightness and had stretching pain behind the knee.

Sensitizing Additions to SLR (Lasegue Test):

Hip adduction and Internal Rotation (Sciatic Nerve): Negative

Ankle Dorsiflexion (Sciatic Nerve): Negative

Dorsiflexion/Eversion (Tibial Nerve): Negative (localised ankle pain)

Dorsiflexion/Inversion (Sural Nerve): Negative with (localised ankle pain)

Plantar Flexion/Inversion (Peroneal Nerve): Negative

Supine Lying: (Movement of Hips / Knees and the response to pain)

- Hip and Knee: Full ROM and no pain reported.

Inter-vertebral Tests by Palpation:

Soft tissue Changes: (E.g. Tightness/Spasm)

No tightness or spasm was observed.

Skin – Sweat / Temperature: Normal

Palpation: (Local Spinal Palpation – E.g. Note Tenderness / Increase of Pain)

- Cervical Spine:

  PA movement caused localised tenderness in the cervical spine.

- Thoracic Spine:

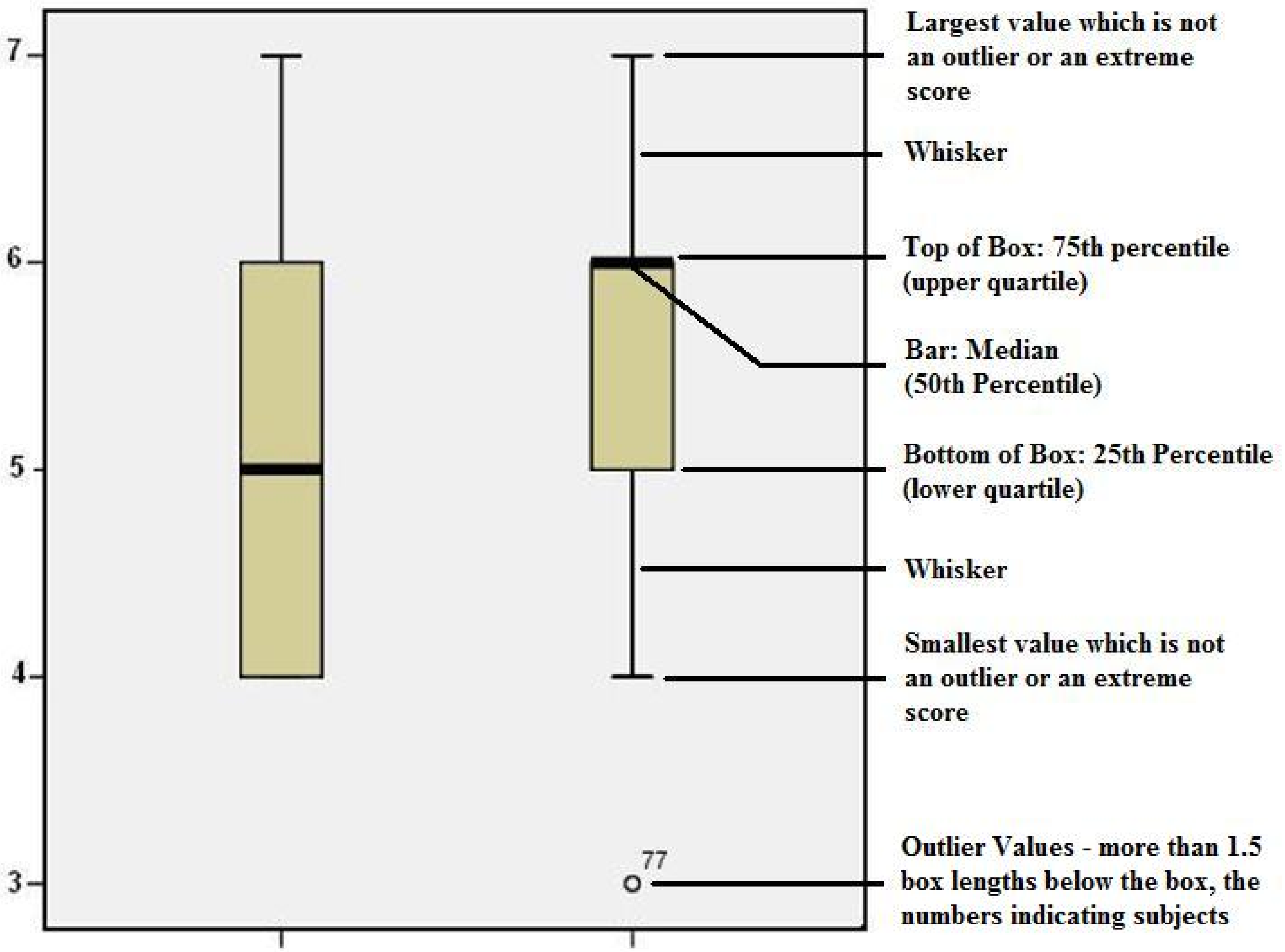
  PA movement revealed stiffness on the thoracic spine.

- Lumbar Spine:

  PA movement of the lumbar vertebrae was normal without any tenderness

Impression / Hypothesis:

Appendix XXXVIII: **Structure of a Box Plot**



Adapted from Kinnear and Gray (2008)

Appendix XXXIX:

British Dental Journal Article
VOLUME 203 NO. 10 NOV 24 2007 pp 601-605

Assessment of Dental Student Posture in Two Seating Conditions using RULA methodology: A Pilot Study

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