TOOTH SIZE AND ARCH DIMENSIONS IN A HYPODONTIA PATIENT GROUP

BY

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Abstract

Aim

To compare the tooth size and arch dimensions of subjects with hypodontia to a non-hypodontia control group and to establish if there are racial differences between White British and South Asian subjects.

Methods

Mesio-distal tooth size and arch dimensions of 186 hypodontia subjects and 62 control subjects were measured. Thirty-one subjects per hypodontia category (mild, moderate, severe) were analysed for each racial group (White British and South Asian) and compared to 31 non-hypodontia control subjects. Mesio-distal tooth size was measured using a Mitutoyo™ digital calliper accurate to 0.01mm. Arch dimensions (intercanine width, intermolar width and arch length) were measured using the ArchMaker 1.1 software program.

Results

Multiple linear regression showed that mean standardised tooth size was 0.69 standard deviations lower in mild hypodontia subjects compared to the control group (C.I. -0.89, -0.49, $p<0.001$). Moderate hypodontia subjects were 1.01 standard deviations smaller (C.I. -1.20, -0.81, $p<0.001$) and severe subjects were 1.59 standard deviations smaller (C.I. -1.79, -1.40, $p<0.001$), respectively. There were no statistically significant differences in tooth size between White British and South Asian subjects ($p=0.165$). Racial group did not influence the effect of hypodontia on tooth size ($p=0.206$). Large individual variation in arch dimensions was observed in hypodontia subjects with an overall tendency for reduced dimensions. No significant differences in arch dimensions existed between White British and South Asian subjects and racial group did not influence the effect of hypodontia on arch dimensions.

Conclusion

Tooth size and arch dimensions are reduced in hypodontia patients with no racial differences between White British and South Asian subjects. The results of this study emphasise the complexity of treating this condition. These factors should be carefully considered in the treatment planning process to ensure an optimal outcome for the patient.

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Chapter 1

Literature Review

1.1 Hypodontia

1.1.1 Introduction

Hypodontia is the term given to describe "the developmental absence of one or more teeth, excluding the third molars" and may affect the deciduous or permanent dentition (Gill and Barker, 2015). It is one of the most prevalent congenital dental conditions (Endo *et al.,* 2006). Treatment usually requires a multi-disciplinary team approach, involving specialists in orthodontics, restorative dentistry, paediatric dentistry and oral surgery. Hypodontia occurs most frequently in the non-syndromic form, but may be a manifestation of an identified syndrome (Cobourne, 2007).

1.1.2 Classification

The severity of hypodontia may be classified according to the number of congenitally missing teeth (Gill and Barker, 2015). Mild hypodontia occurs when 1-2 teeth are absent, moderate when 3-5 teeth are absent and in severe cases there are 6 or more absent teeth. The term "oligodontia" is sometimes used to describe cases of severe hypodontia, where more than 6 teeth fail to develop (Durey *et al.,* 2014). Anodontia is a rare anomaly where the entire dentition fails to form and is frequently associated with an underlying genetic syndrome (Gorlin *et al.,* 1980).

1.1.3 Prevalence

Retrospective studies examining the prevalence of hypodontia report a variety of results, depending on the population studied. The overall global prevalence of hypodontia in the permanent dentition is 6.4% (Khalaf *et al.,* 2014). Hypodontia is much less prevalent in the primary dentition occurring in 0.4 to 0.9% of the population (Arte and Pirinen, 2004).

Racial variation in the prevalence of hypodontia has been described. Rose (1966) found a 4.3% prevalence of hypodontia in British subjects aged between 7 and 14 years of age.

Similar findings were reported by Brook (1974) who observed a 4.5% prevalence of hypodontia in a study of British school children. Globally, a significant range in the prevalence of hypodontia has been reported. A Japanese study found a prevalence of 1.4% (Tsutsui and Yoshida, 1955), which is significantly lower than the results found by O'Dowling and McNamara (1990), who found a prevalence of 11.3% in an Irish population. A recent systematic review outlined the prevalence of hypodontia by continent (Khalaf *et al.,* 2014). Hypodontia was most common in Africa, with a prevalence of 13.4% and was least common in Latin America and the Caribbean with a prevalence of 4.4%. European subjects had a prevalence of 7%, followed by Asian and Australian subjects who both had a 6.3% prevalence, while North Americans had a prevalence of 5%.

Jarvinen and Lehtinen (1981) found no gender differences in the prevalence of hypodontia affecting the deciduous dentition. In contrast, hypodontia of the permanent dentition affects females more than males (Chung *et al.,* 2008; Endo *et al.,* 2006; Maatouk *et al.,* 2008). Brook (1974) observed that females were more affected than males in a British population, reporting a ratio of 3:2. Khalaf *et al.* (2014) in a meta-analysis confirmed the increased prevalence in females, with a combined odds ratio of 1.22.

1.1.4 Tooth predilection

The maxillary and mandibular lateral incisors are most commonly absent in the deciduous dentition (Jarvinen and Lehtinen, 1981). Nik-Hussein and Abdul Majid (1996) found that almost all subjects with hypodontia in the deciduous dentition had hypodontia in the permanent dentition. In the permanent dentition, the third molar is the most commonly absent. Carter and Worthington (2015) in a systematic review, found that the global prevalence of third molar agenesis was 23%, but ranged from 5-56%, depending on the geographic region studied. It was found that the absence of 1 or 2 third molars was most common, with higher rates in females than males.

A meta-analysis of 93 previous studies has identified the most commonly absent teeth worldwide (Khalaf *et al.,* 2014). Excluding the third molar, the mandibular second premolar and the maxillary lateral incisor were most frequently absent, while the first molars and the maxillary central incisors were rarely affected (Table 1.1.4). These findings support the results of studies based on British populations, which also found that the mandibular second premolar was most commonly affected (Brook, 1974; Rose, 1966). Studies of other populations have shown that the maxillary lateral incisor is most commonly missing (Al-Moherat *et al.,* 2009; Fekonja, 2005; Stefania and Elisabeta, 2010). In these studies, congenital absence of the first molars and maxillary central incisor was uncommon and was usually observed in cases of syndromic hypodontia.

A number of researchers have reported that mandibular incisor hypodontia is more frequent in Chinese and Japanese populations (Davis, 1987; Niswander and Sujaku, 1963). Davis (1987) in an epidemiological study of 1093 school children of Southern Chinese origin, found that the mandibular central incisor was the most frequently missing tooth and accounted for 59% of all absent teeth. Niswander and Sujaku (1963) found that the mandibular lateral incisors were most commonly absent in a Japanese population.

Specific Tooth	Distribution of missing teeth by tooth type
Mandibular second premolar	29.9%
Maxillary lateral incisors	24.3%
Maxillary second premolar	13.7%
Mandibular central incisors	6.1%
Mandibular lateral incisor	4.3%
Maxillary first premolar	3.6%
Mandibular first premolar	2.7%
Maxillary canine	2.5%
Mandibular second molar	1.8%
Maxillary second molar	1.5%
Lower canine	1.3%
Maxillary first molar	1.1%
Mandibular first molar	1%
Maxillary central incisor	1%

Table 1.1.4 Adapted from "Prevalence of hypodontia and associated factors: a systematic review and meta-analysis" Khalaf *et al.* 2014

1.1.5 Severity of hypodontia

Khalaf *et al.* (2014) found that mild hypodontia was most frequent, accounting for 82% of all hypodontia cases. Moderate hypodontia accounted for 14% of cases and severe was least common, affecting 3% of the cases, respectively. Although severe hypodontia is least common in the general population, Brook (1974) found that 58% of hypodontia patients treated in a dental hospital setting had severe hypodontia.

1.1.6 Patterns of hypodontia

Most researchers report a predominance of symmetrical hypodontia (Bergström, 1977; Brook, 1974; Endo *et al.,* 1996; Silva Meza, 2003). Others have reported that unilateral hypodontia is most frequent (Davis, 1987; Wisth *et al.,* 1974). Fekonja (2005) found that hypodontia occurred more frequently on the right hand side than on the left, although this was not statistically significant. This concurs with other studies that have failed to show a predilection for one side over the other (Aktan *et al.,* 2010; Endo *et al*., 2006; Sisman *et al.,* 2007).

1.1.7 Aetiology of hypodontia

The aetiology of tooth agenesis has been extensively studied and is yet to be fully understood. Contemporary knowledge would indicate a multifactorial aetiology, involving "complex interactions between genetic, epigenetic and environmental factors during dental development" (Brook, 2009).

Field and Clone Theories

Morphogenetic field and clone theories have been described in an attempt to explain why some teeth are more prone to developmental anomalies than others (Townsend *et al.,* 2009). Butler's Field Theory divided the mammalian dentition into three morphogenetic fields, the incisor, canine and premolar/molar field. The earliest forming tooth in each field is a "key" or stable tooth, with later developing teeth becoming less stable, for example, within the incisor field the central incisor is most stable whereas the lateral incisor is more prone to developmental disturbance (Butler, 1939). Dahlberg (1945) modified Butler's field theory for humans and hypothesised that there were fields for each class of tooth, which included an incisor, canine, premolar and molar field. The most anterior tooth in the field was the "key" tooth and was considered to be most stable with the most distal tooth least stable. Osborn (1978) proposed the clone theory, in which each tooth class (incisor, canine, premolar and molar) develops from a single clone of pre-programmed cells. Each clone induces the dental lamina to initiate tooth development in each class, one tooth at a time, moving in a distal direction. Zones of inhibition surround the clone and block adjacent teeth from forming until the migrating clone has progressed satisfactorily. Any disruption to the clonal cells at a particular point may result in developmental disturbance of teeth distal to the clone position.

Brook (1984) proposed a multifactorial model to demonstrate the relationship between tooth size and number (Fig 1.1.7). It associates hypodontia with microdontia and supernumerary teeth with megadontia. The model consists of normally distributed curves for each gender, to account for the gender dimorphism in tooth size along with the increased prevalence of hypodontia in females and supernumeraries in males. One end of the curve represents the relationship of microdontia and hypodontia and the opposite end represents the association of extra teeth and megadontia. It outlines a threshold for the presence of anomalies in tooth size and number, with polygenetic and environmental factors determining the position of an individual on this scale. This emphasises the multifactorial aetiology of these conditions. Recently this model has been further modified to incorporate abnormalities in shape (Brook *et al.,* 2014).

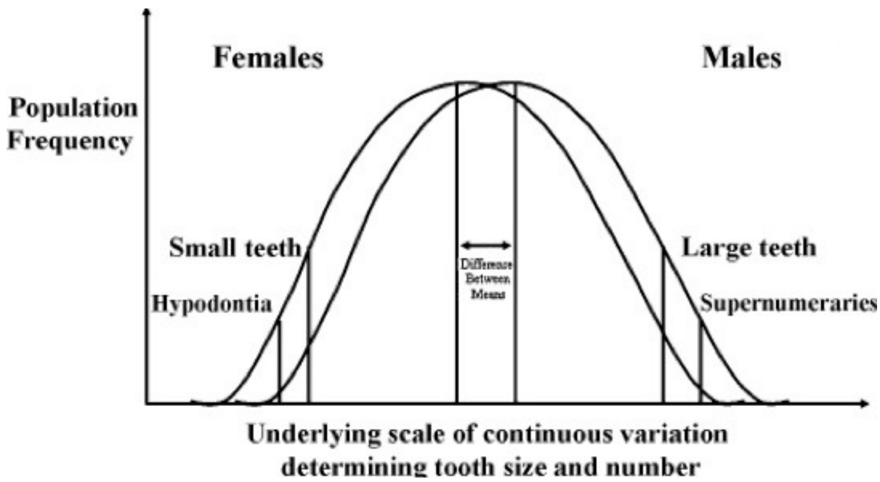

Fig 1.1.7 Brook, (1984) Model to explain the multifactorial aetiology of anomalies in tooth size and number

Environmental Factors

Hypodontia may be acquired following exposure to environmental factors (Riesenfeld, 1970), which result in local or systemic disturbances to the developing tooth germ. Possible environmental factors include (Nunn *et al.,* 2003):

- Irradiation
- Chemotherapy
- Hormonal disturbances
- Metabolic influences
- Maxillofacial trauma
- Osteomyelitis
- Iatrogenic extraction of a tooth germ

Clefting is regarded as an environmental factor in maxillary lateral incisor hypodontia. This is attributed to the close proximity of the maxillary lateral incisor dental lamina to the site of cleft formation, making it susceptible to developmental disturbance. Genetic factors are also involved, as hypodontia of other teeth is more frequent in subjects with cleft lip and palate (Ranta, 1986). Disturbances in maternal health during pregnancy have been identified as an acquired cause of hypodontia by some researchers (Lundström *et al.,* 1962, Keller *et al.,* 1970). Parkin *et al.* (2009) in a cross-sectional study failed to show an association between hypodontia and low birth weight.

Genetic Factors

Genetics play an important role in the aetiology of hypodontia and this has been shown through animal, family and twin studies. Hypodontia is more frequent in subjects who have affected relatives (Arte *et al*., 2001; Brook, 1984; Chosack *et al.,* 1975; Grahnen, 1956). Parkin *et al.* (2009) in a family study showed that up to 29% of the siblings of children with hypodontia are also affected, with 20 - 38% also having a parent with hypodontia. These figures indicate that genetics are an important factor in the aetiology. However, identical twin studies have shown variable expression of hypodontia indicating that other factors are also at play. This reinforces the hypothesis that hypodontia is caused by “complex interactions between genetic, epigenetic and environmental factors” (Brook, 2009).

Familial hypodontia is usually inherited as an autosomal dominant trait but alternatively may be sex-linked or autosomal recessive (Cobourne, 2007). An autosomal dominant pattern of inheritance in hypodontia subjects usually displays incomplete penetrance and variable expressivity (Arte and Pirinen, 2004). Genes that have been associated with familial hypodontia include: MSX1, PAX9, AXIN2, FGR1, TGFA, EDAR, EDA, EDARADD and IRF6 (Cobourne and Sharpe, 2013; Galluccio *et al.,* 2012).

Normal tooth formation is reliant on genes that are responsible for encoding specific signalling molecules and transcription proteins during the initial stages of tooth formation (Zhao *et al.,* 2007). Mice without the transcription factor coding gene MSX 1 demonstrate complete failure of tooth development, cleft palate and deficient alveolar bones (Satokata and Maas, 1994). MSX1 defects have been linked to familial hypodontia and syndromic hypodontia (Vastardis *et al*., 1996). PAX9 gene mutations have been associated with oligodontia and have been mainly linked to missing premolar and molar teeth (Frazier-Bowers *et al*., 2002; Nieminen *et al.,* 2001; Stockton *et al.*, 2000). A PAX9 mutation in a Finnish study has also been linked with hypodontia of incisors, canines and premolars and also with microdontia (Lammi *et al.,* 2003). EDA gene mutations, although usually associated with ectodermal dysplasia have been identified in a study of 15 unrelated Chinese males with familial hypodontia. EDA gene mutations were found in four participants representing 27% of the study sample (Song *et al.,* 2009). Van den Boogaard *et al.* (2012) has associated

WNT10A gene mutations with non-syndromic hypodontia. This study, which included 34 subjects with oligodontia identified WNT10A mutations in 56% of cases. Other gene mutations were less common with MSX1 mutations present in 3% of cases, PAX9 mutations in 9% of cases and AXIN 2 mutations in 3% of cases, respectively.

1.1.8 Syndromes associated with hypodontia

Whilst non-syndromic hypodontia is most prevalent, over 60 syndromic conditions have been identified that include hypodontia in their clinical spectrum. These conditions are listed on the database "On-line Mendelian Inheritance in Man (OMIM)" (Cobourne, 2007). The most common conditions are listed in table 1.1.8.

OMIM	Syndrome	Gene
#190685	Down's Syndrome	Trisomy 21
#305100	Anhidrotic Ectodermal Dysplasia	EDA
#103285	ADULT Syndrome	TP63
#603543	Limb Mammary Syndrome (LMS)	TP63
#225410	Ehlers Danlos (Type VII) Syndrome	ADAMTS2
#308300	Incontentia Pigmenti	NEMO
#180500	Rieger Syndrome	PITX2
#189500	Witkop Syndrome	MSX1

Table 1.1.8 Adapted from "Familial human hypodontia – is it all in the genes?" Cobourne, 2007

Down's Syndome is one of the most well-known syndromes associated with hypodontia. It usually occurs due to trisomy of chromosome 21. Mestrović *et al.* (1998) in an epidemiological study of 112 subjects with Down's syndrome found that hypodontia was present in 39% cases, with the maxillary lateral incisor most commonly affected. Other studies have shown higher prevalences of hypodontia in Downs' syndrome at 56-63% (Kumasaka *et al.,* 1997; Suri *et al.,* 2011).

As previously discussed, an increased prevalence of hypodontia is seen in cleft lip and palate. Laatikainen and Ranta (1994) reported that 64% of patients with cleft lip and palate had hypodontia compared to 17% of subjects without. Maxillary lateral incisor hypodontia is most common in this group. This is attributed to the close proximity of the maxillary lateral incisor dental lamina to the site of cleft formation, making it susceptible to developmental disturbance (Ranta, 1986).

Ectodermal dysplasia is another genetic condition associated with hypodontia. It consists of a group of closely related conditions in which there are over 190 subtypes. All subtypes involve abnormalities of ectodermal structures. It displays either x-linked, autosomal dominant or more rarely an autosomal recessive pattern of inheritance. Its prevalence is 1.6 per 100 000 (Nguyen-Nielsen *et al.,* 2013). EDA, EDAR and EDADD gene mutations have been identified in the aetiology of ectodermal dysplasia (Wright *et al.,* 2014). Structures derived from embryonic ectoderm are affected resulting in hypohydrosis, hypotrichosis, hypodontia along with skin and nail abnormalities. Sweat glands are also affected to varying degrees depending on the subtype. X-linked ectodermal dysplasia may be anhidrotic or hypohidrotic. In the anhidrotic form, the sweat glands are completely absent but are reduced in number in the hypohidrotic form. Hidrotic ectodermal dysplasia occurs when the sweat glands are not affected and this is inherited as an autosomal dominant condition (Nunn *et al.,* 2003). Hypodontia may be the only feature in mildly affected individuals. Ellis-van Crevald and incontinentia pigmenti are classified as variants of ectodermal dysplasia and are also associated with hypodontia (Nunn *et al.,* 2003).

Van der Woude syndrome is an orofacial clefting disorder caused by mutations in the IFR6 gene (Kondo *et al.,* 2002). It is inherited in an autosomal dominant pattern (Nopoulos *et al.,* 2007). Patients present with a cleft lip, with or without cleft palate and lip pits. Up to 81% of patients with Van der Woude syndrome have hypodontia (Rizos and Spyropoulos, 2004). Other features of this condition include hearing loss and abnormalities affecting the limbs, skin, nails, and genitals (Rizos and Spyropoulos, 2004).

Other syndromic conditions associated with hypodontia include ADULT syndrome, Limb Mammary Syndrome, Ehlers Danlos Syndrome and Witkop Syndrome (Cobourne, 2007).

1.1.9 Skeletal features of hypodontia patients

Class I and Class III skeletal patterns, with reduced vertical dimensions are most commonly associated with hypodontia. The prevalence of Class III skeletal profiles rises with severity of hypodontia (Larmour *et al.,* 2005). Acharya *et al.* (2010) in a cephalometric study of 277 hypodontia subjects found that Class III skeletal patterns with reduced vertical dimensions were more common in hypodontia patients than in subjects without hypodontia. This was attributed to maxillary retrusion and mandibular angular prognathism. These finding were only clinically significant in the severe hypodontia group and this pattern has been identified in other studies (Bondarets and McDonald, 2000; Chung *et al.,* 2000; Woodworth *et al.,* 1985). In contrast, other researchers have shown that subjects with hypodontia are more likely to have a Class I skeletal pattern (Dermaut *et al.*, 1986; Yuksel and Ucem, 1997). These differences in skeletal pattern have also been linked to the pattern of hypodontia, with anterior hypodontia having greater effects on the skeletal profile than posterior hypodontia alone (Ben-Bassat and Brin, 2003).

1.1.10 Dental features associated with hypodontia

Khalaf *et al.* (2014) in a systematic review showed that hypodontia subjects had a greater tendency towards a Class III incisor relationship in comparison to the general population. It was found that the combined odds ratio for a Class III incisor relationship was 2.15 (95% CI: 0.78, 5.89) compared to class I or class II. A total of 5 studies were included in the meta-analysis for malocclusion, with 4 of these showing that Class III malocclusion was most common. One study showed that Class II division 2 was most common (Kim, 2011).

The following skeletal and dental characteristics have been reported as being more prevalent in hypodontia subjects (Cobourne, 2007):

Extra-Oral Features

- Bimaxillary retrognathia
- Reduced lower facial height
- Concave facial profile

Intra-oral Features

- Retained deciduous teeth
- Delayed development of permanent teeth
- Delayed eruption of permanent teeth
- Increased overbite
- Microdontia and peg-shaped lateral incisors
- Ectopic eruption of first permanent molars
- Infraocclusion of primary molars
- Ectopic Canines
- Taurodontism
- Dental Rotations

An association between hypodontia and tooth size has long been established and will be discussed in section 1.2. Differences in the dental morphology of patients with hypodontia are also well recognized. Alterations to the maxillary lateral incisor shape have been studied most extensively. Hua *et al.* (2013) reported that in cases of unilateral peg-shaped maxillary lateral incisors, hypodontia of the contra-lateral tooth occurs in 55% of cases. This indicates a higher prevalence of peg-shaped lateral incisors in hypodontia subjects. Alterations in tooth morphology have been shown to affect other teeth in subjects with hypodontia. Recent studies have employed 3D surface imaging to assess these changes. A study which assessed the morphology of the lower left first molar tooth in 120 hypodontia and 40 control subjects found numerous changes in the shape of the molar compared to normal individuals. The changes included a gradual reduction of the clinical crown height at the gingival margin, a less bulbous labial surface, a flatter gingival margin, less defined buccal cusp tips and less tapered proximal surfaces towards the occlusal surface (Al-Shahrani *et al.,* 2014).

Molar taurodontism is seen in greater frequency in hypodontia subjects. A retrospective analysis of 66 hypodontia subjects found that 35% had at least one mandibular first molar with taurodontism compared to 8% of control subjects (Seow and Lai, 1989). Palatally ectopic canines are seen with greater frequency in hypodontia subjects (Peck *et al*., 1996). This may be related to the absence or reduced size of the adjacent lateral incisor, which is thought to assist in guiding the canine into position, according to the canine guidance theory of Becker *et al.* (1984). Alternatively, it may be due to a common genetic aetiology associated with the genetic theory of maxillary canine impaction (Peck *et al.,* 1994). Transposition of maxillary canines is more prevalent in subjects with hypodontia (Peck *et al.,* 1993), along with dental rotations. A retrospective study showed that rotated maxillary lateral incisors and premolars were more common when the contra-tooth was congenitally absent (Bacetti, 1998).

Ectopic eruption of first molars and delays in eruption of teeth are also seen with greater frequency (Bjerklin *et al*., 1992). Delayed development of permanent teeth has been linked to hypodontia. A radiographic study of 135 hypodontia subjects showed delayed dental development compared to age-matched controls, with a mean difference of 1.51 years. The severity of the hypodontia was significantly correlated with the delay (Uslenghi *et al.*, 2006). Deciduous molar infra-occlusion is also associated with hypodontia of premolar teeth. Bjerklin and Bennett (2000) in a longitudinal study which followed 41 subjects with hypodontia of one or both lower second premolars with retained primary molars found that 55% of the retained deciduous molars had infra-occluded by 20 years of age. The authors outlined that there was no predictable pattern for its development. This study also observed that only 2 of the 59 deciduous molars exfoliated naturally over the 8 year follow-up period. If the second deciduous molars survived until 20 years of age, they were deemed to have a good long-term prognosis. Haselden *et al.* (2001) evaluated the prognosis of deciduous teeth based on the degree of root resorption in cases where there was hypodontia of the permanent successor. It was found that the deciduous upper and lower canines had a good prognosis, upper and lower second deciduous molar survival was unpredictable and the survival of first deciduous molars was poor.

1.1.11 Oral Health Related Quality of Life and hypodontia

The Oral Health Related Quality of Life (OHRQoL) of subjects with hypodontia has been investigated in children and adults, often reporting negative psychosocial, functional and emotional impacts (Hobkirk *et al.,* 1994; Kotecha *et al.,* 2013; Meaney *et al.,* 2012; Wong *et al.,* 2006). This may be related to numerous hypodontia related factors including: poor aesthetics, oral symptoms, functional limitations, bullying, prolonged orthodontic/restorative treatment and financial concerns. Locker *et al.* (2010), reported that hypodontia had a greater impact on OHRQoL than dental caries or malocclusion in 36 children with severe hypodontia.

1.1.12 Occlusal indices and hypodontia

The Index of Orthodontic Treatment Need (IOTN) is used in the United Kingdom to determine if patients are eligible for orthodontic treatment provided by the National Health Service (Brook and Shaw, 1989). While an occlusal index specifically for hypodontia has yet to be developed (Shelton *et al.*, 2008), patients are eligible for treatment under two sections of the dental health component of the Index of Orthodontic Treatment Need:

- "4h – Less extensive hypodontia requiring pre-restorative orthodontics or orthodontic space closure to obviate the need for a prosthesis"
- "5h – Extensive hypodontia with restorative implications (more than 1 tooth missing in any quadrant requiring pre-restorative orthodontics"

Other occlusal indices that have been used include the Peer Assessment Rating Index (PAR), the Dental Aesthetic Index (DAI), and Index of Complexity, Outcome and Need (ICON) (Cons *et al.,* 1986; Daniels and Richmond, 2000; Richmond *et al.,* 1992). Overall, these indices indicate a high treatment need for patients with hypodontia.

1.1.13 Management of hypodontia

The treatment of hypodontia, especially in its more severe forms, presents as a complex clinical scenario, requiring a multi-disciplinary team approach from orthodontists, paediatric dentists, restorative specialists, oral surgeons, general dental practitioners and dental therapists (Stevenson *et al.,* 2013). Most dental hospitals in the United Kingdom have established hypodontia clinics with input from all of these specialities to provide comprehensive high quality treatment.

Various options are available for the treatment of hypodontia including acceptance, idealisation or redistribution of space for prosthetic replacement, orthodontic space closure with restorative camouflaging of adjacent teeth or a combination of these options. Many factors should be considered when deciding on the most suitable treatment including the age of the patient, their concerns and motivation, the soft tissue and skeletal pattern, the severity and location of hypodontia, the size, shape and colour of adjacent teeth, residual alveolar ridge width and height, integrity and prognosis of retained deciduous teeth, the presence of crowding or spacing, the incisor classification, the presence of other dental anomalies and overall dental health (Carter *et al.,* 2003; Durey *et al.,* 2014; Hobkirk *et al.,* 1995). Table 1.1.13 outlines the typical management of a patient with severe hypodontia from the deciduous dentition to adulthood (Gill and Barker, 2015).

Orthodontic space closure in hypodontia patients negates the need for prosthetic replacement reducing the restorative burden to the patient. It has also been associated with better long-term stability (Tuverson, 1970). Robertsson and Mohlin (2000) showed that patient satisfaction is greater and periodontal health is better for orthodontic space closure than restorative replacement in subjects with congenitally absent maxillary lateral incisors. Even in space closure cases where canine aesthetics are not ideal, lay people often do not judge this to be less attractive (Rayner *et al.,* 2015). Camouflaging techniques in space closure cases may improve aesthetics and techniques recommended include (Rosa and Zachrisson, 2001):

- Orthodontic bracket alterations
- Crown reshaping
- Composite build-ups
- Tooth whitening
- Gingival surgery
- Indirect restorations

The disadvantages of space closure may include poor aesthetics, especially in cases of asymmetric anterior space closure. Space closure may be slow, with prolonged treatment time and complete space closure may be unachievable. This may be attributed to microdontia or reduced alveolar bone volume. In Class I or Class III cases, it may result in undesirable incisor retraction due to loss of upper anterior anchorage (Carter *et al.,* 2003). Space opening and prosthetic replacement of congenitally missing teeth may be considered when there is an absence of crowding, where space closure would have an adverse effect on the occlusion, in cases of more severe hypodontia or where orthodontic space closure is not possible (Carter *et al.,* 2003). Space opening may confer an occlusal and functional advantage to the patient (Balshi, 1993). Options for prosthetic replacement of missing teeth include (Durey *et al.,* 2014):

- Conventional removable prosthesis
- Conventional and adhesive bridge work
- Implant supported prosthesis with or without bone augmentation

As discussed, hypodontia is often associated with anomalies in size and shape of the remaining teeth (Alvesalo and Portin, 1969; Brook, 2009; Yaqoob *et al.,* 2011). These factors should be considered in the treatment planning process as they may affect the end of treatment aesthetics and occlusion. A Kesling set-up can be used to assist in treatment planning, outlining the possible outcomes to the patient as well as assessing the end of treatment occlusion (Khan *et al.,* 2014). Where microdontia is present and requires correction, orthodontic treatment may be needed to idealise tooth position in order to facilitate restorative build-up (Bello and Jarvis, 1997). Restorative treatment of microdont teeth may be undertaken prior to the start of orthodontic treatment to assist in correct bracket placement and later on in space management (Durey *et al.,* 2014).

Stage	Treatment	Comments
Primary and Early Mixed Dentition	Preventive Advice and Treatments	Dietary analysis, topical fluoride, mouth guards, fissure sealants
	Removable Dentures	May be provided for psychological and functional reasons
	Restorative build-up of retained deciduous or microdont permanent teeth	Consider if high aesthetic concerns
	Interceptive treatment	Consider deciduous extractions to encourage space closure, extraction of deciduous canines if permanent canines ectopic, extraction of infra-occluded deciduous molars
Late Mixed Dentition/early Permanent Dentition	Restorative build-up of retained deciduous or microdont permanent teeth	Consider if high aesthetic concerns
	Interceptive extractions to guide the permanent teeth	e.g. deciduous extractions to encourage space closure, palatal maxillary canines, infraocclusion of deciduous molars
Permanent Dentition (12-16 years)	Orthodontic Treatment	For redistribution of space for prosthetic replacement or space closure Correction of malocclusion Prosthetic teeth may be added to the fixed appliance and to the retainer until ready for restorative phase of treatment
	Resin Bonded Bridges for tooth replacement	Other options to replace missing teeth include retention of the primary tooth, removable dentures, conventional bridges and auto-transplantation
	Restorative build-up of microdont or hypoplastic permanent	Consider if high aesthetic concerns or to assist occlusal fit
	Overdentures	Maybe used in severe hypodontia cases to assist preservation of alveolar bone, improve retention, stability and proprioception
Permanent Dentition (>16 years)	Endosseous Implants	Placed when skeletal growth has completed. This is usually 17-18 years in females and 18-19 years in males. Bone grafting procedures may be required
	Orthognathic Surgery	In patients with severe skeletal discrepancies

Table 1.1.13 Adapted from "The multidisciplinary management of hypodontia: a team approach" Gill and Barker, 2015

1.2 Tooth size

1.2.1 Introduction

Human tooth size has been of interest to clinicians and dental anthropologists since the early 20th century. Variables that have been assessed in relation to tooth size include gender dimorphism, symmetry, racial variation, the effects of malocclusion and anomalies in tooth number. This section of the literature review will explore each variable individually.

1.2.2 Gender dimorphism and tooth size

A substantial number of morphometric studies have shown gender dimorphism in human tooth size (Radlanski *et al.,* 2012). Jensen *et al.* (1957) showed that male subjects had greater tooth dimensions than females. This is in agreement with Garn *et al.* (1967) who proposed that the mean size difference in the permanent dentition was 4%, with the greatest difference in the canines and smallest in the incisors. Potter (1972) reported similar findings and found that the dimensions of the permanent teeth were significantly larger in males, with some exceptions, including the mandibular central incisors, maxillary lateral incisors and mandibular second premolars. Arya *et al.* (1974) analysed the records of 48 males and 47 females and found that all permanent teeth, with the exception for the mandibular central incisor showed gender dimorphism with increased dimensions in male subjects. This concurs with Richardson and Malhotra (1975) who measured the mesio-distal crown dimensions of 162 African American subjects and found significant gender dimorphism for all teeth. Kondo and Townsend (2006) found that regions of individual cusps were significantly larger in male subjects in addition to having an overall larger crown size.

Kerekes-Máthé *et al.* (2015) found that males had larger tooth size measurements than females for each tooth type in a Romanian population with mild hypodontia. The greatest differences were evident in the maxillary canines and maxillary first premolars in females and in the maxillary central and lateral incisors in males. Gungor and Turkkahraman (2013) in a prospective study of 154 hypodontia patients and 50 control subjects found significant gender differences in the bucco-lingual dimension of the mandibular lateral incisor and the mesio-distal dimension of the mandibular first premolar. Other studies have shown few statistically significant differences between male and female tooth size. Khalaf (2016) analysed the models of 120 hypodontia and 40 control subjects and found that although males had larger tooth size measurements, only few of these measurements reached statistical significance. Yaqoob *et al.* (2011) did not find an association between gender and tooth size in a sample of 106 subjects.

1.2.3 Symmetry in tooth size

Asymmetry in tooth size between the left and right side of the dental arches has been reported. Ballard (1944) analysed the study models of 500 subjects with different malocclusions and reported that 90% of subjects showed a left right discrepancy in one or more pairs of teeth. Garn *et al.* (1967) found that asymmetry was present in the bucco-lingual and mesio-distal dimensions of 118 North American subjects of European ancestry. It was found that the most distal tooth in the series was most prone to asymmetry in the bucco-lingual dimension, with more variation in males than females. In contrast, other researchers have failed to find statistically significant differences. Adeyemi and Isiekwe (2004) compared the mesio-distal crown dimensions of 250 secondary school children in Nigeria. They found no significant differences between the left and right sides with the exception of the maxillary second premolars and the female mandibular canine.

1.2.4 Racial variation in tooth size

Racial differences have been reported in tooth dimensions. Lavelle (1972) analysed the mesio-distal crown diameters of three ethnic groups, White, Black and Southeast Asian. Forty models per ethnic group were measured with equal gender distribution. Crown dimensions were greatest in Black subjects, followed by Southeast Asians with White subjects having the smallest dimensions. Yuen *et al.* (1997) found similar results when comparing the dental dimensions of 112 Hong Kong Southern Chinese subjects to Caucasians and Australian Aboriginals. The mesio-distal dimensions of the Hong Kong Southern Chinese sample were larger than Caucasian but smaller than Australian Aboriginals. Mertz *et al.* (1991) confirmed larger tooth dimensions in Black subjects. This study measured the mesio-distal tooth dimensions for each tooth in the lower left quadrant in 51 Black and 50 White subjects. The mean mesio-distal crown dimensions of the canines, premolars and molars were all significantly larger in the Black population. No significant differences existed in the mesio-distal dimensions of the central and lateral incisors.

Despite a large population in South Asia there is a lack of research comparing tooth dimensions of South Asian subjects to other racial groups. A single study was identified in the literature search that compared modern British tooth size to a South Asian population. Radnzic (1987) compared the mesio-distal tooth size of 60 White British males to 60 male immigrants of Pakistani origin in United Kingdom. No statistically significant differences were found between the groups. The author proposed that this may be related to both groups originating from the same Caucasian lineage.

Other populations have been studied, including a study by Axelsson and Kirveskari (1983), who assessed the mesio-distal and bucco-lingual dimensions of 1010 Icelandic school children. The Icelandic population had larger tooth dimensions than Europeans, with only Australian Aborigines and African Americans having larger dimensions. Brook *et al.* (2009a) compared the mesio-distal tooth dimensions between a modern White British group, a White North American, a Southern Chinese group and a Romano-British group. The Romano-British group had the smallest mesio-distal crown dimensions with the Southern Chinese sample having the largest. The authors attributed the different tooth size patterns between the racial groups to the various influences of environmental and genetic factors between the four populations.

1.2.5 Malocclusion and tooth size

The majority of research in relation to tooth size and malocclusion has focused on tooth size discrepancies between the mandibular and maxillary arches using Bolton's ratios. A limited number of studies focus on individual tooth size and malocclusion. Of these, Arya *et al.* (1974) analysed the records of 48 males and 47 females with Class I and Class II malocclusions. No differences in tooth size between the malocclusions were found. Lavelle (1975) compared the dental dimensions of 300 British males aged between 16-18 years with equal numbers of Class I, Class II and Class III malocclusions. Compared to Class I subjects, the mesio-distal and bucco-lingual dimensions were larger for Class II and Class III subjects in the upper arch. Conversely, in the lower arch the measurements were larger for Class I subjects when compared to Class II and Class III. Peck *et al*. (1998) found reduced mesio-distal incisor dimensions in 23 patients with severe Class II division 2 malocclusions and hypothesised that Class II division 2 subjects may have a systematic reduction in tooth size as an associated trait.

Bolton's ratios are a method of identifying tooth size discrepancies between the mandibular and maxillary arches. It consists of an "overall ratio" and an "anterior ratio" (Bolton, 1958). The "overall ratio" consists of the ratio of the combined mesio-distal widths of the twelve mandibular teeth to the corresponding maxillary teeth. The anterior ratio consists of the ratio of the summed mesio-distal widths of the six anterior mandibular teeth to their maxillary counterparts. Different studies investigating Bolton's ratios and malocclusion have shown conflicting results. Araujo and Souki (2003) identified a mandibular excess in subjects with a Class III malocclusion in a Brazilian population. This is in agreement with other studies that also identified a mandibular excess in Class III malocclusion (Alkofide and Hashim, 2002; Sperry *et al.,* 1977; Ta *et al.,* 2001). Other researchers have found no relationship between tooth size discrepancy and type of malocclusion (Crosby and Alexander, 1989; Uysal *et al.*, 2005a).

1.2.6 Tooth size in hypodontia subjects

Research in the 1970's investigated the correlation between hypodontia and tooth size. Lavelle *et al.* (1970) compared the mesio-distal tooth size of subjects with and without third molar agenesis. Study casts from 301 participants aged 18-25 years were analysed. It was found that the tooth dimensions in both males and females were significantly smaller in subjects with third molar agenesis compared to those with complete dentitions. Hypodontia has also been associated with particular patterns of tooth size reduction. In cases of unilateral upper lateral incisor hypodontia, the contra-lateral lateral incisor is often significantly smaller (Rantanen, 1956).

Baum and Cohen (1971) analysed the records of 104 hypodontia subjects and found that there was a significant generalised decrease in mesio-distal tooth dimensions in the hypodontia group compared to normal subjects. Rune and Sarnäs (1974) also found reduced dental dimensions in 91 patients with four or more absent teeth with no gender differences in the amount of reduction. Garn and Lewis (1970) compared the mesio-distal tooth size of two cohorts of patients. One group (n=82) had at least one third molar missing and the remaining group (n=19) had absence of the second premolars and lateral incisors. It was found that both groups had a significant reduction in the mesio-distal tooth dimensions compared to control subjects. This study showed an association between the severity of hypodontia and tooth size. The authors suggested "a gradient for tooth size reduction with varying degrees of hypodontia".

More recent studies have also supported the association between hypodontia and a reduction in tooth size. Mirabella *et al.* (2012) investigated the mesio-distal tooth size of subjects (n=81) with absence of one or both maxillary lateral incisors. The control group consisted of fully dentate patients (n=90). The authors found that maxillary lateral incisor hypodontia predicted a significantly reduced tooth size in the remaining dentition, except for the maxillary first molars. There was no difference in the overall tooth size reduction between subjects with unilateral or bilateral hypodontia and no effect modification by gender. Yaqoob *et al.* 2011 in a similar study design corroborated these results. This study assessed the association between bilateral maxillary lateral incisor hypodontia and anterior tooth width. The anterior mesio-distal tooth dimensions of subjects (n=52) with bilateral maxillary lateral incisor hypodontia were compared to fully dentate controls (n=54). It was found that individual tooth size in both the maxillary and mandibular dentitions was significantly smaller in the hypodontia group compared to the control subjects.

Brook *et al.* (2009b) compared the tooth size of 60 hypodontia patients with 60 control subjects. Hypodontia subjects had a significant reduction in the bucco-lingual and mesio-distal dimensions compared to fully dentate subjects. The differences were greatest in the bucco-lingual dimension. The same study compared tooth size in 60 subjects with supernumerary teeth to the control group and found significantly larger tooth dimensions in this group. These results are supportive of Brook's multifactorial model (Fig 1.1.7) that associates hypodontia with microdontia and supernumerary teeth with megadontia (Brook, 1984). Kerekes-Máthé *et al.* (2015) used a 2D image analysis method to compare tooth dimensions and crown shape of 28 mild hypodontia subjects and 28 control subjects in a Romanian population. All tooth dimensions were smaller in subjects with hypodontia with the mesio-distal dimension most affected in both genders. This study also observed that hypodontia patients presented with less cusp numbers in comparison to the control group.

Numerous researchers have reported an association between the severity of hypodontia and reduction in tooth size. Brook (1984) reported that the greater the number of absent teeth, the larger the reduction in general tooth size, in line with the multifactorial model for tooth number and size. This model has been further developed in recent years to include changes in shape associated with hypodontia (Brook *et al.,* 2014). Gungor and Turkkahraman (2013) in a prospective study of 154 hypodontia patients and 50 control subjects compared the effects of both mild and severe hypodontia on tooth size. A reduction in tooth size was observed in the bucco-lingual and mesio-distal dimensions in the hypodontia groups. In the mesio-distal dimension the percentage reduction ranged from 3.06% to 6.9% in the mild group and from 2.16% to 17.54% in the severe group. The reduction in tooth size was significantly greater in the severe hypodontia group. The tooth most sensitive to change in size in the mesio-distal dimension was the maxillary lateral incisor and the mandibular canine was most affected in the bucco-lingual direction.

Khalaf (2016) investigated the mesio-distal and bucco-lingual tooth dimensions of 120 hypodontia patients divided according to the severity of hypodontia. The subgroups consisted of 40 mild, 40 moderate and 40 severe hypodontia subjects, with equal gender distribution. The control group consisted of 40 fully dentate subjects. Tooth size dimensions were reduced in all subgroups compared to the control group. The greater the severity of hypodontia was associated with a greater reduction in tooth size. The mean reduction in mesio-distal tooth size ranged from 0.16% to 15.32% in the mild group, from 4.91% to 22.47% in the moderate group and from 10.65% to 32.35% in the severe group. The maxillary lateral incisor was most severely affected and the mandibular first molar was least affected. The bucco-lingual dimension was more severely affected in the mild hypodontia group than in the moderate or severe groups. The author suggested that environmental factors could be more influential than genetic factors in the aetiology of mild hypodontia when compared to the moderate and severe forms. As the bucco-lingual dimension develops later compared to the mesiodistal dimension, it makes it makes it more susceptible to environmental insults. Al-Shahrani *et al.* (2014) used a 3D surface imaging technique to compare the lower left first molar size and shape of 120 hypodontia subjects (40 mild, 40 moderate and 40 severe) to 40 control subjects. Eighteen anatomical landmarks were identified and analysed on each subject. The author found significantly smaller dimensions in hypodontia subjects and this size reduction was proportional to the severity of hypodontia.

Smaller tooth dimensions have also been reported in relatives of patients with hypodontia. Schalk-Van Der Weide and Bosman (1996) compared the mesio-distal tooth size of 59 first and second degree relatives of 26 subjects with severe hypodontia. It was found that fully dentate relatives had reduced tooth dimensions compared to a control group. In fully dentate male relatives, the reductions were significant for all teeth except for the lower first molar, upper second premolar, first premolars and upper second molar. In fully dentate female relatives these reductions were significant in all teeth except for the lower molars and second premolars. Similar findings were reported by McKeown *et al.* (2002), who used an image analysis system to compare the dental dimensions of 12 subjects with severe hypodontia and 21 of their relatives without hypodontia to a fully dentate control group. There were statistically significant reductions in tooth dimensions in hypodontia subjects and their fully dentate relatives compared to the control group. The hypodontia group had the greatest reduction and the non-hypodontia relatives were intermediate.

1.3 Dental arch dimensions

1.3.1 Introduction

Research on dental arch dimensions (arch width and arch length) has primarily focused on the development and changes that occur throughout life. Changes to dental arch dimensions as a result of orthodontic treatment have also been of interest to researchers. This section of the literature review will examine the factors that have been shown to influence arch dimensions, as well as examine the available research in relation to arch dimensions in hypodontia subjects.

1.3.2 Development of arch dimensions

Changes in dental arch dimensions occur with growth and may change throughout life. These changes have been investigated in numerous longitudinal studies (Barrow and White, 1952; Bishara *et al.,* 1997; Bishara *et al.,* 1998; DeKock, 1972; Knott, 1961; Sinclair and Little, 1983; Moorrees, 1959; Sillman, 1964; Thilander, 2009).

Sillman (1964) evaluated 65 subjects from birth until 25 years and found that intercanine width increased until 13 years in the maxilla and 12 years in the mandible, with no significant changes up to the end of the study period. The intermolar width increased until 14 years of age and also remained stable. Moorrees (1959) also observed that the intermolar width remained stable after 14 years. DeKock (1972) assessed changes in arch length and intermolar width on 26 subjects from 12 to 26 years and found that arch length decreased with age throughout the period of study, with a mean decrease of 10% in males and 9% in females. There were no changes in female intermolar width in each arch, however small but statistically significant increases in intermolar width were observed in males from 12-15 years of age.

Bishara *et al.* (1997) and Bishara *et al.* (1998) evaluated arch width and arch length changes from 6 weeks to 45 years using subjects from the Iowa facial growth study. Significant increases in anterior arch widths were observed between 6 weeks and 2 years of age. Maxillary and mandibular intercanine widths increased significantly between 3 and 13 years of age, with establishment of the mandibular intercanine width by 8 years of age. Once the permanent dentition was established, there was a small reduction in the intercanine widths up until 45 years of age. In males, intermolar widths also increased significantly from 3 to 13 years of age with no significant changes after 13 years. In contrast, there was a slight reduction in maxillary and mandibular intermolar widths in females between 13 and 26 years. The authors concluded that “after the eruption of the permanent dentition, the clinician should expect no changes or a slight decrease in arch widths”. In relation to arch length, the greatest incremental increase also occurred during the first 2 years of life, with an increase observed in both genders up until 13 years in the maxilla and 8 years in the mandible. However, in contrast to arch width, there was a significant decrease in arch length from 13 to 45 years of age. The mean reduction in the maxilla was 5.7mm in males and 4.6mm in females and the corresponding measurements in the mandible were 7.4mm in males and 8.3mm in females.

Sinclair and Little (1983) reported similar findings when they assessed the arch dimensions of 65 subjects in the mixed dentition, early permanent dentition and early adulthood. A reduction in arch length was observed from the mixed dentition into early adulthood along with a slight decrease in the intercanine width. The reduction in intercanine width was more significant in females than in males aged between 13 and 20 years. Intermolar width was generally stable, although there was some variation by gender. Male subjects displayed a small increase in intermolar width, which was not statistically significant, while female subjects showed a small but statistically significant decrease from 13 to 20 years.

1.3.3 Gender dimorphism in arch dimensions

Bishara *et al.* (1997) found that male subjects had significantly greater arch widths and total arch lengths in both arches than female subjects. This is in agreement with most published studies, which show that dental arch dimensions are consistently larger in males than in females (Al-Khateeb and Abu Alhaija, 2006; Bishara *et al.,* 1997; Burris and Harris*,* 2000; Chang *et al.,* 1986; da Silva Filho *et al.,* 2008; Kuntz *et al.,* 2008; Slaj *et al.,* 2010).

1.3.4 Racial differences in dimensions

Racial differences have been reported in dental arch dimensions, with many different populations studied. Lavelle *et al.* (1971) analysed the arch widths and arch lengths of 5 racial groups in an attempt to identify racial differences in arch dimensions. Modern White British, North American Indian, Black (West African an New Guinean), Australian Aborigine and Anglo-Saxon (16^{th}-18^{th} century British) were compared. Dental arch dimensions were not found to be consistently different in any one group.

In contrast, Mack (1981) found significantly larger arch widths and arch lengths in a Nigerian population compared to White British subjects. Burris and Harris (2000) found similar differences between White and Black subjects. In this study the arch dimensions of 171 African Americans and 159 White American subjects were analysed. African American subjects had larger mean arch lengths and widths than White subjects. The arch widths were 9% larger in men and 11 % larger in women while the arch length was 8% greater overall. More recently, Lombardo *et al.* (2015) confirmed larger arch dimensions in Black subjects when the size and shape of the dental arches of 29 Black African and 37 Caucasian subjects were compared using 3D technology. It confirmed that the maxillary and mandibular dental arches were wider and longer in Black African subjects.

No differences have been found in the arch dimensions of British subjects and a Pakistani population. Radnzic (1987) compared the arch dimensions of 60 White British males to 60 male immigrants of Pakistani origin in United Kingdom. The interincisor width (maximum difference between the lateral incisors), intermolar width and arch length were assessed. No statistically significant differences were found between both racial groups. This is the only study identified in the literature search that compared the arch dimensions of White European subjects to a South Asian population.

Comparisons of arch dimensions have been made of subjects from Southeast Asia with other racial groups. Nojima *et al.* (2001) compared the arch dimensions of 110 Caucasian subjects with 110 Japanese subjects and found that the Caucasian population had significantly decreased arch widths and arch lengths compared to the Japanese. Diwan and Elahi (1990) investigated the arch dimensions of 91 adults from the Philippines with Egyptian and Saudi Arabian subjects. Egyptian subjects showed wider posterior arch dimensions with shorter arch lengths compared to the Filipino subjects. Saudi Arabian subjects showed narrower intercanine widths with longer arch lengths compared to subjects from the Philippines.

1.3.5 Arch dimensions and malocclusion

Differences in arch dimensions associated with different malocclusion types have been investigated. These studies are often retrospective, study different populations and have differences in methodology and design, which may account for the conflicting results reported.

Class II division 1 malocclusion subjects have been found to have the equivalent or narrower arch widths than subjects with a Class I malocclusion. Staley *et al.* (1985) reported narrower arch dimensions in Class II division 1 when comparing the arch dimensions of Class I (n=36) and Class II division 1 subjects (n=39). Maxillary intermolar and intercanine widths were greater in Class I subjects with no difference in the mandibular intercanine width. Male subjects in the Class II Division 1 group had reduced mandibular intermolar widths compared to Class I individuals. Sayin and Turkkahraman (2004) also observed that the maxillary intermolar width was reduced in a study of female Class II division 1 subjects. In contrast to the previous study, it was found that the mandibular intercanine width was significantly larger in Class II division 1 subjects, with no difference in the maxillary intercanine width. Bishara *et al.* (1996) compared the arch width dimensions of Class II division 1 subjects (n=37) with Class I subjects (n=55) and found that although the intermolar width was reduced in both genders, this was only statistically significant in male subjects.

Other researchers have not found significant differences in the arch dimensions of Class II division 1 subjects. Fröhlich (1961) found no differences in the intercanine and intermolar widths of 51 Class II Division 1 subjects when compared to a Class I control group. The author concluded that absolute arch length and width of Class II division 1 subjects does not significantly differ from subjects with a Class I occlusion.

The position and inclination of the teeth have also been shown to influence the measurements. Uysal *et al.* (2005b) observed that the maxillary intermolar width was increased in Class II division 1 subjects (n=106) compared to Class I controls (n=150). This increase in intermolar width was associated with a reduction in maxillary intermolar alveolar width. The authors hypothesised that the maxillary molar teeth may be buccally inclined to compensate for an insufficient alveolar base. Shu *et al.* (2013) found no significant differences in the maxillary intermolar widths between Class I (n=45) and Class II division 1 subjects (n=45). This study also measured the bucco-lingual inclination of the posterior teeth for all subjects. In contrast to the hypothesis of the previous study (Uysal *et al.,* 2005b), it was found that maxillary posterior teeth were significantly more lingually inclined in Class II division 1 subjects.

The arch dimensions of Class II division 2 subjects have also been evaluated. Moorees *et al.* (1969) compared untreated Class II division 2 malocclusions to a control group and observed that the intercanine width was increased in both arches in the Class II division 2 group, with no statistically significant differences in the intermolar widths. Uysal *et al.* (2005b) found that Class II division 2 subjects (n=108) displayed no differences in the maxillary intercanine and intermolar widths but had wider mandibular intermolar and intercanine widths than Class I subjects (n=150). In contrast, Herren and Jordi-Guilloud (1973) found narrower maxillary intermolar widths in Class II division 2 subjects compared to subjects with a normal occlusion, with no differences in mandibular intercanine and intermolar widths.

Walkow and Peck (2002) reported some differences in the transverse dimensions of Class II division 2 subjects. While no differences were observed in the intermolar widths or in the maxillary intercanine width, the mandibular intercanine width was significantly smaller in Class II division 2 subjects. This was attributed to lower incisor retroclination often associated with this incisor relationship. Buschang *et al.* (1994) in a study of 386 female subjects, found reduced mandibular transverse dimensions in Class II division 2 subjects compared to Class II division 1 and Class I subjects. The Class II division 2 subjects also had greater maxillary arch dimensions compared to Class II division 1 subjects.

Differences in the arch dimensions of subjects with a Class III malocclusion have been reported. Uysal *et al.* (2005c) compared arch dimensions of class III subjects (n=100) with a control group (n=150). Narrower maxillary dimensions were found in Class III subjects, with reduced intermolar and interpremolar widths. Conversely, the mandibular arch had wider dimensions with increased intercanine and intermolar widths. In contrast, Herren and Jordi-Guilloud (1973) found that the only difference in arch dimensions between Class III subjects (n=30) and control subjects (n=30) was a reduction in the maxillary intermolar width. No significant difference in mandibular arch width was found. Kuntz *et al.* (2008) found similar results when the arch dimensions of Class III subjects were compared to Class I controls. In this study of 119 subjects, it was found that the maxillary intermolar width was smaller in the Class III malocclusion group when compared to an ideal occlusion. There were no significant differences in the mandibular arch widths. Al-Khateeb and Abu Alhaija (2006) failed find a single difference between the maxillary and mandibular arch dimensions of Jordanian subjects, aged between 13 and 15 years when Class III and Class I subjects were compared. This study contrasted to other studies in that the Class I control subjects had crowding which may have resulted in smaller arch dimensions.

1.3.6 Arch dimensions and dental crowding

Smaller dental arch dimensions have been reported when dental crowding is present. Mills (1964) compared the arch dimensions of young adult males (n=230) and found that arch widths were significantly smaller in crowded arches than in well-aligned arches. There were no significant differences in arch length between the two groups. Radnzic (1988) found that arch dimensions were reduced in crowded arches when comparing the arch dimensions of 120 adolescent male subjects of British and Pakistani origin. The differences in interincisor width, intermolar width, arch perimeter and arch length were statistically significant in both the maxilla and mandible for British subjects. In subjects from Pakistan, all maxillary arch dimensions were significantly reduced, however in the mandible only the lower interincisor width and arch perimeter showed statistically significant differences in crowded subjects. Howe *et al.* (1983) found similar results when 50 crowded arches were compared to 54 non-crowded dentitions.

Chang *et al.* (1986) showed gender dimorphism in the differences in arch dimensions when comparing 74 crowded arches with 89 well-aligned arches in a Chinese population. Whilst the maxillary and mandibular intermolar widths were significantly reduced in the crowded groups for both genders, the intercanine widths showed gender differences. There were no differences in the maxillary intercanine widths in male subjects but female subjects with crowding had reduced dimensions compared to female subjects with well-aligned arches. Conversely, the mandibular intercanine widths showed no differences in females but males had narrower dimensions in the crowded group.

1.3.7 Arch dimensions and hypodontia

There have only been a small number of studies that have compared the arch dimensions of hypodontia subjects to non-hypodontia control groups. Early studies focused on subjects with mild to moderate hypodontia and failed to find significant differences in the arch dimensions of these patients with non-hypodontia controls (Bailit *et al.,* 1968; Wisth *et al.,* 1974). Woodworth *et al.* (1985) found no differences in the arch dimensions of 43 subjects of Northwest European origin with hypodontia of the maxillary lateral incisors. Other retrospective studies have shown a tendency towards reduced arch dimensions in hypodontia subjects. Le Bot and Salmon (1977) reported significantly reduced maxillary arch widths and arch lengths in subjects with hypodontia of one or both maxillary lateral incisors when compared to non-hypodontia control subjects.

More recent studies have examined subjects with more severe forms of hypodontia and have found a significant reduction in the arch dimensions. Bu *et al.* (2008) compared the arch dimensions of 50 oligodontia subjects with 50 control subjects. Both groups were matched by age and gender with all control group subjects having an ideal occlusion, including Class I canines, Class I molars and anterior crowding of less than 2mm. The mean number of absent teeth was 11 but ranged from 6 to 20. All arch dimension measurements were significantly smaller in the oligodontia group. Greater differences were seen in the maxillary arch than in the mandibular arch for all dimensions. The mean reduction in maxillary arch length was 4.40mm compared to 2.80 mm in the mandibular arch when compared to the control group. The mean reduction in maxillary intercanine width was 2.82mm and 2.70 mm in the mandible. Intermolar widths were 3.40mm narrower in the maxilla and 1.80mm narrower in the mandible. Despite a greater reduction in maxillary arch dimensions compared to mandibular measurements, the authors did not find an increased prevalence of posterior crossbites in oligodontia subjects. It was proposed that the mean difference between the maxillary and mandibular intermolar width was not large enough to create a crossbite and that unequal mesial movement of the posterior teeth between the maxilla and mandible may have modified the antero-posterior and transverse relationship.

These findings are in broad agreement with a retrospective study which compared the transverse arch dimensions of 55 hypodontia subjects with 55 control subjects (Fekonja, 2013). In this study intercanine width and intermolar widths were measured using a digital calliper. No reference was made to the severity of hypodontia in this study and the mean number of missing teeth was not reported. Maxillary intercanine width was most severely affected with a mean reduction of 3.05mm in male subjects and 3.12mm in female subjects. The authors postulated that this reduction is most likely related to mesial movement of the maxillary canines in cases of congenitally absent lateral incisors. The reduction in the mandibular intercanine widths was 2.41mm in males and 2.99mm in females. Maxillary intermolar widths were also more affected than in the mandible. The mean reduction in maxillary intermolar width was 2.46mm in males and 3.13mm in females whereas the corresponding measurements in the mandible were 1.95mm and 2.03mm, respectively. Less reduction in mandibular dimensions was attributed to the retention of the second deciduous molar in subjects with congenital absence of lower second premolars.

1.3.8 Clinical relevance of arch dimensions

As previously discussed, age related changes in arch dimensions occur throughout life and there is a tendency for a reduction in measurements (Bishara *et al*., 1997; Bishara *et al*., 1998; DeKock, 1972; Sinclair and Little, 1983; Sillman, 1964; Thilander, 2009). These changes may result in changes to dental alignment and in the development or exacerbation of a malocclusion.

Expansion of the mandibular arch form during orthodontic treatment is not recommended in most circumstances as such changes are regarded as unstable. Felton *et al.* (1987) compared the arch dimensions of subjects with normal occlusions with Class I and Class II non-extraction orthodontic patients. The authors found that 70% of cases that had arch form modification during treatment returned to their pre-treatment shape. It was recommended that the arch form should be customised to the original shape of the arch during orthodontic treatment. De la Cruz *et al.* (1995) found similar results when comparing the arch form of Class I and Class II subjects 10 years post orthodontic treatment involving first premolar extractions. The greater the magnitude of change resulted in a greater susceptibility for relapse. The authors emphasised that although it was good clinical practice to customise the final working archwire to the pre-treatment arch form, it did not guarantee long-term stability and individual variation exists. Burke *et al.* (1998) in a meta-analysis of 26 studies found that a 1-2mm expansion of the mandibular intercanine width occured during orthodontic treatment regardless of whether the treatment involved extractions or not. It was found that these changes relapsed post treatment but that changes in intermolar width were more stable longterm.

Although preservation of the mandibular archform is good clinical practice in orthodontics, there is no guarantee of stability as the aetiology of orthodontic relapse is multi-factorial (Little *et al.,* 1981; Little *et al.,* 1988). There are some clinical situations where changes to the mandibular archform may be acceptable including Class II division 2 cases with retroclined lower incisors, Class II division 2 with mild crowding, mild Class III cases, bimaxillary proclination and digit sucking habits (Keating, 1985; Selwyn-Barnett, 1991; Shapiro, 1974; Walkow and Peck., 2002).

1.4 Methods for measuring tooth size and arch dimensions

Traditional methods to measure tooth size and arch dimensions include a dial calliper, Vernier calliper or digital calliper. Direct measurement on the dental casts using a digital calliper is regarded as the gold standard (Naidu *et al.,* 2009; Quimby *et al.,* 2004; Stevens *et al.,* 2006). Digital callipers have been developed which directly input the data measured on dental casts on to computer programs. An example includes the Hamilton Arch Tooth System™ (GAC International, Central Islip, NY) which inputs each tooth size measurement directly from a digitial calliper to a computer software program and performs a Bolton's analysis. This system has been shown to be more efficient than conventional measurement methods (Othman and Harradine, 2007; Tomassetti *et al.,* 2001) and provides additional accuracy by eliminating the manual transfer of data (Ho and Freer, 1999).

More recently with the introduction of digital study models and CBCT models, 3D imaging has been utilised in odontometrics. Examples of systems include eModels™(GeoDigm, Clanhassen, MN,USA), OrthoCad™ (Cadent, Carlstadt, NJ, USA) and Digimodel™ (Orthoproof, Albuquerque, NM, USA). Studies have focused on comparing the validity of such systems to conventional plaster models. Quimby *et al.* (2004) compared the validity and reproducibility of mesio-distal tooth size measurements and dental arch dimensions using OrthoCad™ (Cadent, Carlstadt, NJ, USA) and conventional plaster models. It was found that measurements from the computer-based models were as reliable as the measurements taken directly from plaster models. Other researchers have reported similar findings (Leifert *et al.,* 2009; Mullen *et al.,* 2007; Santoro *et al.,* 2003; Stevens *et al.,* 2006).

Fleming *et al.* (2011) in a systematic review of 17 studies found that mean differences in tooth size and arch dimensions measured on digital models compared to plaster models were not significant. Rossini *et al.* (2016) in an update to this systematic review, evaluated a greater number of studies with lower risk of bias. Measurements of tooth size, Bolton's ratio, arch dimensions, interarch occlusal features and occlusal indices were compared. It concluded “that digital models are as reliable and accurate as plaster models and could be considered the new gold standard in current practice”.

1.5 Summary of the literature

Hypodontia describes the “developmental absence of one or more teeth, excluding the third molars” and may affect the deciduous or secondary dentition (Gill and Barker, 2015). Mild hypodontia occurs when 1-2 teeth are absent, moderate has 3-5 absent teeth and in severe cases, there are 6 or more missing teeth. The overall global prevalence of hypodontia is 6.4% (Khalaf *et al.,* 2014) and affects females more than males (Endo *et al.,* 2006; Maatouk *et al.,* 2008; Chung *et al.,* 2008). Hypodontia occurs most frequently in the non-syndromic form, but may be a manifestation of an identified syndrome (Cobourne, 2007). Contemporary knowledge would indicate a multifactorial aetiology, involving a complex interplay “between genetic, epigenetic and environmental factors during the early stages of tooth formation” (Brook, 2009).

The association between hypodontia and a reduction in tooth size has long been established (Baum and Cohen, 1972; Lavelle, 1970). More recent studies have shown that this association is influenced by the severity of hypodontia (Brook, 1984; Gungor and Turkkahraman, 2013; Khalaf, 2016). Brook (1984) proposed a single model relating tooth size and number. Recently, this model has been further modified to incorporate abnormalities in shape (Brook *et al.,* 2014). While the effect of hypodontia on tooth size has been studied in different populations, studies have not compared the effects on different racial groups.

Dental arch dimensions can change throughout life and these changes have been investigated in numerous longitudinal studies (Bishara *et al.,* 1997; Bishara *et al.,* 1998; DeKock, 1972; Knott, 1961; Sinclair and Little, 1983). Differences in arch dimensions have been reported between genders, racial groups and malocclusions. A small number of studies have compared the arch dimensions of hypodontia subjects to fully dentate controls. While early studies show no significant differences in hypodontia, more recent studies suggest a reduction in dimensions (Bu *et al.,* 2008; Fekonja, 2013; Le Bot and Salmon, 1977; Wisth, 1974; Woodworth, 1985).

1.6 Aims of the study

The literature review revealed an established association between hypodontia and tooth size in different populations, however there is a paucity of research comparing these differences between racial groups. While studies have shown a greater reduction in tooth size with the severity of hypodontia, there are only a limited number of studies that have used the most common classification (mild, moderate and severe). Few studies have analysed the arch dimensions of hypodontia patients and controversy exists as to whether there are significant differences compared to a fully dentate control group.

Birmingham Dental Hospital is the main treatment centre for specialist dental services in the West Midlands region. It serves an ethnically diverse area with a large South Asian population. A study comparing the tooth size and arch dimensions of both White British and South Asian hypodontia subjects would improve our knowledge in this field, which in turn may assist in the management of this patient group. The aim of this study was therefore to compare the tooth size and arch dimensions of subjects with hypodontia to a fully dentate control group and to investigate if there were racial differences in these measurements, between White British and South Asian subjects.

The null hypotheses were:

1. There is no difference in tooth size between subjects with hypodontia and subjects without hypodontia.
2. There are no differences in the arch dimensions between subjects with hypodontia and subjects without hypodontia.
3. There is no difference in tooth size between White British and South Asian subjects with hypodontia.
4. There are no differences in the arch dimensions between White British and South Asian subjects with hypodontia.

Chapter 2

Materials and Method

2.1 Sampling

Dental study models of 186 hypodontia subjects and 62 control subjects were analysed retrospectively. These subjects were identified through the hypodontia multi-disciplinary database and from the “ODTP” database of patients treated in the Orthodontic Department at Birmingham Dental Hospital.

2.2 Ethical approval

Ethical approval was obtained through the National Research Ethics Service Committee, East of Scotland (Reference number: 15/ES/0090, IRAS Project ID: 169068).

Local NHS Research and Development approval was obtained from Birmingham Community Healthcare NHS Trust.

2.3 Sample size calculation

Altmans nomogram (Altman, 1991) was used to determine the sample size for the study. The power was set at 0.8 (80%) with α=0.05. The standard deviation (sd) of tooth size (0.5mm) and arch dimensions (2mm) was determined from previously published studies (Bishara *et al.,* 1997; Brook *et al.,* 2009b; Mirabella *et al.,* 2012). The clinically relevant difference (crd) was set at 0.5mm for tooth size and 2mm for arch dimensions. The standardised difference was therefore 1.0 for both groups (standardised difference = crd/sd). The nomogram indicated that a sample size of 31 was required to give a power of 0.8 with α=0.05. Thirty-one casts per hypodontia category (mild, moderate, severe) were required for each racial group.

2.4 Selection criteria

Inclusion criteria for hypodontia group

- Orthodontic patients aged between 12-20 years of age
- Hypodontia of one or more permanent teeth
- The presence of the permanent canines and the first molars in at least the maxilla or the mandible
- Good quality pre-treatment study models

Exclusion criteria for hypodontia group

- Subjects with congenital clefts, or have suspected or identifiable syndromes.
- Previous orthodontic treatment
- Previous dental extractions
- Previous restorative treatment
- Poor quality study models

Inclusion criteria for control group

- Orthodontic patients aged between 12-20 years of age
- The presence of all permanent teeth excluding third molars
- Good quality pre-treatment study models

Exclusion criteria for control group

- Subjects with congenital clefts, or have suspected or identifiable syndromes.
- Previous orthodontic treatment
- Previous dental extractions
- Previous restorative treatment
- Poor quality study models

2.5 Subject selection

The study models of 186 hypodontia subjects and 62 control subjects were required for analysis. Subjects were selected from the study models of hypodontia patients who were either assessed or treated at Birmingham Dental Hospital between 2000-2015. Potential subjects were identified from the hypodontia multi-disciplinary database and from the ODTP database of patients treated in the Orthodontic Department. The variables assessed for inclusion were racial group, severity of hypodontia, gender and malocclusion. The control subjects were identified from the ODTP database of patients treated in the Orthodontic Department. The variables assessed for the control group included racial group, gender and malocclusion. Successive cases were selected that met the inclusion criteria until the sample size was reached.

Racial group

The racial groups studied were White British and South Asian. South Asian subjects included those of Indian, Pakistani or Bangladeshi origin. Subjects from any other racial group were excluded. The racial group was determined by searching the “patient demographic” section on the patient administration system (iPM). Subjects were suitable for inclusion if they were registered as belonging to one of the following racial groups on iPM:

- White British
- Asian/Asian British – Indian
- Asian/Asian British – Bangladeshi
- Asian/Asian British – Pakistani

Severity of hypodontia

The number of missing teeth and severity of hypodontia was recorded. This was determined using the pre-treatment radiographs. The severity of hypodontia was recorded as mild if there were 1-2 missing teeth, moderate if there were 3, 4 or 5 missing teeth and severe if there were 6 or more absent teeth. The dental records were checked to ensure that no teeth were missing due to extraction.

Gender

Gender was determined from the patients demographic section on iPM, the hospitals patient administration system. An equal number of males and females were selected for each hypodontia group and control group.

Malocclusion

The British Standards Institute's Incisor Classification (1983) was used to classify the malocclusion of subjects as Class I, Class II division 1, Class II division 2 and Class III. The malocclusion was initially determined from the ODTP database or, if not stated from the intra-oral clinical photographs. The malocclusion was confirmed using the subjects study models at data collection. Equal numbers of each malocclusion were selected for the control group. The hypodontia groups were matched as closely as possible.

Study model quality

The study models of each subject were assessed prior to measurements to confirm that they were of acceptable quality. Any subjects with damaged models were excluded and replaced with alternative suitable subjects.

2.6 Model measurement

All measurements were carried out by the same operator (S.H.).

Arch dimensions

Arch dimensions were measured indirectly using the ArchMaker 1.1 software program. An image of each study model was imported to the program by scanning the model using a flatbed scanner. This method was used by Rice (2003) in an unpublished thesis carried out at the University of Birmingham. The author showed that the ArchMarker 1.1 program was a valid and reproducible method of measuring dental arch dimensions, with greater accuracy compared to direct measurement with a digital calliper. Three dimensions per arch were measured. Intercanine width was measured as the distance between the canine cusp tips. The intermolar width was measured as the distance between the mesio-buccal cusp tips of the first molars. Arch length was measured as the perpendicular distance between the line connecting the distal surfaces of the first molars and the contact point of the central incisors. In hypodontia cases where the central incisors were absent, the most labial aspect of the alveolar ridge was chosen as an alternative landmark.

Prior to scanning, the occlusal dental landmarks were identified and marked with an ink dot on each study model. A 10 cm ruler was fixed and scanned with each model to allow the program to calibrate for potential magnification errors encountered during the scanning process. Once scanned, each image was imported into the ArchMaker 1.1 programme. The dental landmarks on the study model and the calibration ruler were digitised on-screen with the aid of a mouse. The program then constructed lines that represented each dimension and calculated the values for each measurement in millimetres (Fig 2.6.1). The values for each subject were recorded on a Microsoft Excel (2010) spreadsheet.

Tooth size

The mesio-distal tooth size was measured directly on the study model for all permanent teeth using a Mitutoyo™ digital calliper accurate to 0.01mm (Fig 2.6.2). The measurements were made from mesial contact point to distal contact point. Rotated teeth were measured from the mesial and distal contact points in their de-rotated position. In cases where the adjacent tooth was absent measurements were made from the points where the missing tooth would normally contact. The values for each measurement were manually recorded on a Microsoft Excel (2010) spreadsheet.

2.7 Data analysis

The measurements for tooth size and arch dimensions were recorded on a Microsoft Excel (2010) spreadsheet. The statistical analysis was completed using Stata Statistical Software: Release 14 (College Station, TX: Statacorp LP). The following analyses were completed:

- Intraclass correlation to assess intra-examiner reliability. This was following the re-measurement of tooth size and arch dimensions of 20 control subject study models, two months after the initial measurements were made.
- Graphical evaluation of normality of distribution using Q-Q plots.
- Standardisation of mean tooth size using a mean of zero and a standard deviation of one. This permitted the combination of the tooth size measurements giving a single value per subject. This assisted in analysing the overall effect of hypodontia on tooth size.
- Multiple linear regression analysis to investigate the association between mean standardised tooth size (dependent variable) and severity of hypodontia, gender, racial group and malocclusion.
- Multiple linear regression analysis to investigate the association between arch dimensions (dependent variable) and severity of hypodontia, racial group and malocclusion.
- Fractional polynomial regression analysis to investigate the association between the number of missing teeth and tooth size, adjusting for gender, racial group and malocclusion. Interaction terms were used to assess if the association between tooth size and hypodontia is modified by gender, racial group or malocclusion (effect modification).
- Fractional polynomial regression analysis to investigate the relationship between the number of missing teeth and arch dimensions, adjusting for gender, racial group and malocclusion. Interaction terms were used to assess if the association between arch dimensions and hypodontia is modified by gender, racial group or malocclusion (effect modification).

- All estimates are presented with two-sided 95% confidence intervals and all statistical tests were two-sided at a significance level $\alpha=0.05$.

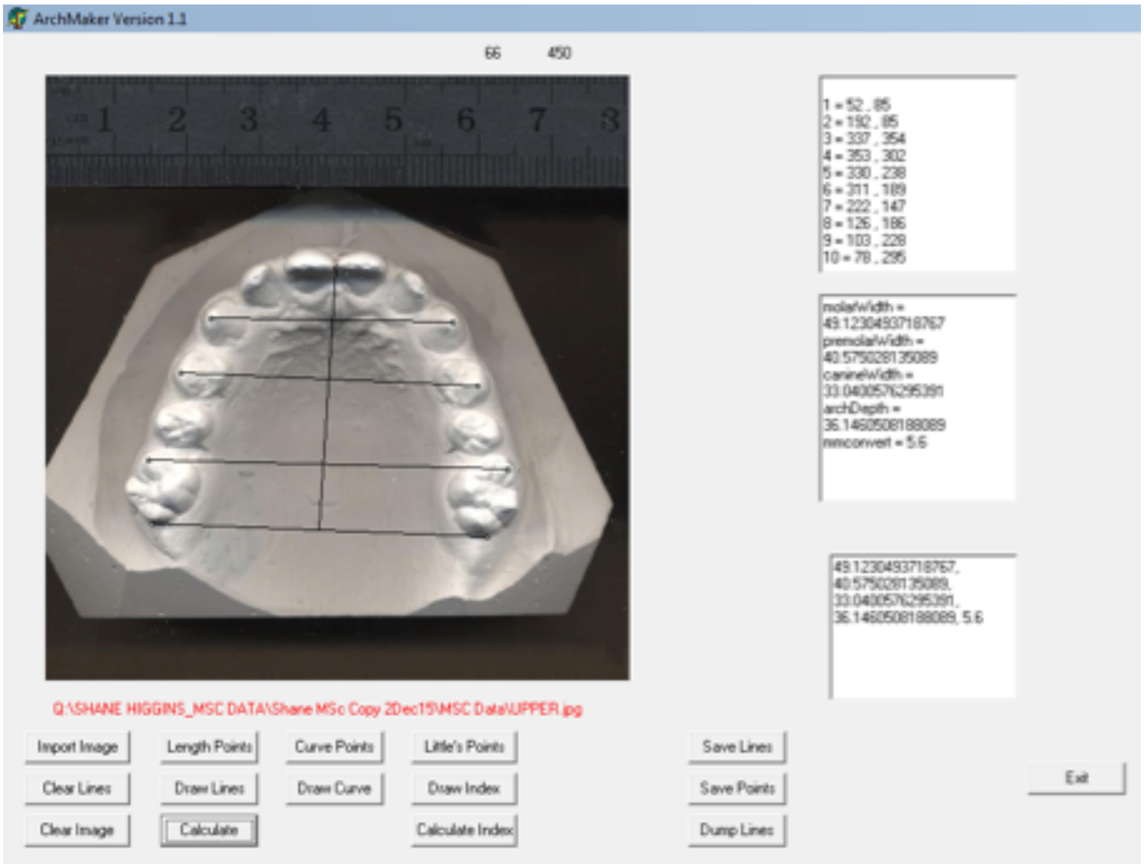

Fig 2.6.1 The ArchMaker 1.1 program

Fig 2.6.2 Mitutoyo™ digital calliper (Mitutoyo Corporation, Kawaskai, Japan)

Chapter 3

Results

3.1 Characteristic of Sample

	Control	Mild Hypodontia	Moderate Hypodontia	Severe Hypodontia
Male	15	15	16	15
Female	16	16	15	16
Mean no of Missing teeth	0	1.51	4.32	9.79
Class I	8	9	8	7
Class II Div 1	8	7	6	5
Class II Div 2	7	8	8	9
Class III	8	7	9	10

Table 3.1.1 Characteristic of sample White British subjects

	Control	Mild Hypodontia	Moderate Hypodontia	Severe Hypodontia
Male	16	15	15	15
Female	15	16	16	16
Mean no of missing teeth	0	1.64	3.90	8.90
Class I	8	8	10	8
Class II Div 1	8	8	8	6
Class II Div 2	8	6	7	7
Class III	7	7	6	10

Table 3.1.2 Characteristic of sample - South Asian subjects

3.2 Reproducibility testing

Intra-examiner reliability was tested using intraclass correlation coefficients (ICC). ICC values ranged from 0.77 to 0.99 (Table 3.2.1). This indicates excellent reliability for tooth size and arch dimension measurements.

Measurement	ICC
UR1, UL1	0.98, 0.97
UR2, UL2	0.97, 0.96
UR3, UL3	0.95, 0.95
UR4, UL4	0.96, 0.94
UR5, UL5	0.92, 0.76
UR6, UL6	0.97, 0.95
UR7, UL7	0.98, 0.98
LR1, LL1	0.91, 0.93
LR2, LL2	0.97, 0.96
LR3, LL3	0.94, 0.93
LR4, LL4	0.97, 0.97
LR5, LL5	0.95, 0.96
LR6, LL6	0.98, 0.97
LR7, LL7	0.96, 0.98
Maxillary Intercanine Width	0.99
Maxillary Intermolar Width	0.99
Maxillary Arch Length	0.99
Mandibular Intercanine Width	0.99
Mandibular Intermolar Width	0.99
Mandibular Arch Length	0.99

Table 3.2.1 Intraclass correlations of the measurements

3.3 Tooth size measurements

Tooth	Control Group		Mild Hypodontia		Moderate Hypodontia		Severe Hypodontia	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
U1	8.92	(0.44)	8.57	(0.53)	8.22	(0.65)	7.95	(0.57)
U2	6.99	(0.49)	6.25	(0.87)	5.93	(0.89)	5.59	(0.74)
U3	8.03	(0.42)	7.56	(0.56)	7.45	(0.49)	7.02	(0.60)
U4	7.32	(0.36)	6.99	(0.40)	6.72	(0.50)	6.25	(0.42)
U5	7.15	(0.33)	6.80	(0.39)	6.54	(0.51)	6.12	(0.51)
U6	10.78	(0.44)	10.48	(0.54)	10.33	(0.56)	9.70	(0.75)
U7	10.42	(0.51)	9.87	(0.57)	9.70	(0.84)	9.48	(0.63)
L1	5.63	(0.30)	5.43	(0.33)	5.19	(0.55)	5.06	(0.33)
L2	6.10	(0.38)	5.76	(0.44)	5.51	(0.41)	5.30	(0.42)
L3	7.16	(0.39)	6.71	(0.42)	6.52	(0.42)	6.30	(0.47)
L4	7.43	(0.39)	7.02	(0.43)	6.90	(0.47)	6.55	(0.39)
L5	7.53	(0.38)	7.18	(0.50)	6.94	(0.42)	6.55	(0.59)
L6	11.39	(0.52)	10.74	(0.60)	10.66	(0.57)	10.43	(0.64)
L7	10.74	(0.50)	10.29	(0.52)	10.08	(0.48)	9.76	(0.62)

Table 3.3.1 Mesio-distal tooth dimensions (mm)

Tooth	Mild Hypodontia (%)	Moderate Hypodontia (%)	Severe Hypodontia (%)
U1	-3.92	-7.84	-10.87
U2	-10.58	-15.16	-20.02
U3	-5.85	-7.22	-12.57
U4	-4.51	-8.19	-14.61
U5	-4.89	-8.53	-14.40
U6	-2.78	-4.17	-10.01
U7	-5.27	-6.91	-9.02
L1	-3.55	-7.80	-10.12
L2	-5.57	-9.67	-13.11
L3	-6.28	-8.93	-12.01
L4	-5.51	-7.13	-11.84
L5	-4.64	-7.83	-13.01
L6	-5.70	-6.40	-8.43
L7	-4.18	-6.14	-9.12

Table 3.3.2 Mean reduction in tooth size from control group %

Group	Mean Standardised Tooth Size	S.D.
Control	0.74	0.49
Mild Hypodontia	0.06	0.61
Moderate Hypodontia	-0.26	0.64
Severe Hypodontia	-0.85	0.68

Table 3.3.3 Mean standardised tooth size per group (Mean = 0, S.D. = 1)

3.4 Normality testing

Q-Q plots confirmed that tooth size and arch dimension measurements were normally distributed.

3.5 Statistical analysis of tooth size

Independent Variable	Coefficient (mm)	95% CI	P Value
Mild Hypodontia	-0.69	-0.89 - -0.49	**<0.001**
Moderate Hypodontia	-1.01	-1.20 - -0.81	**<0.001**
Severe Hypodontia	-1.59	-1.79 - -1.40	**<0.001**
Gender	-0.41	-0.54 - -0.26	**<0.001**
Racial Group	0.09	-0.04 - 0.24	0.165
Class II Division 1	0.22	0.02 - 0.41	**0.029**
Class II Division 2	-0.05	-0.25 - 0.15	0.628
Class III	0.06	-0.14 - 0.26	0.557

Table 3.5.1 Multiple linear regression of mean standardised tooth size adjusted for severity of hypodontia, gender, racial group and malocclusion

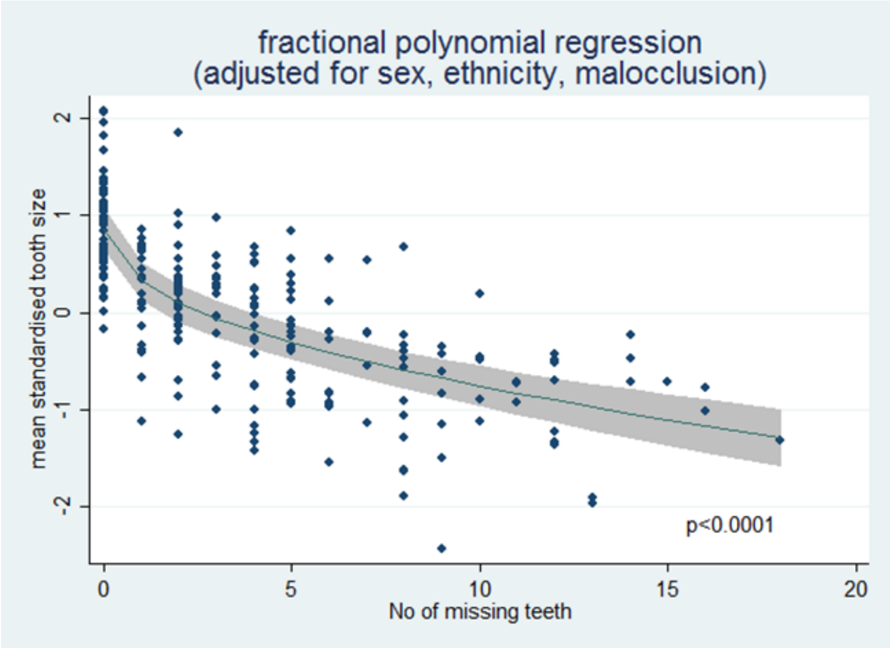

Fig 3.5.1 Fractional polynomial regression of mean standardised tooth size and number of missing teeth, adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.5.1) showed that there was a significant association between mean standardised tooth size and hypodontia. Tooth size in subjects with mild hypodontia was 0.69 standard deviations lower than subjects without hypodontia (C.I. -0.89, -0.49, $p<0.001$). Moderate hypodontia subjects were 1.01 standard deviations smaller (C.I. -1.20, -0.81, $p<0.001$) and severe subjects were 1.59 standard deviations smaller (C.I. -1.79, -1.40, $p<0.001$), respectively.

Gender dimorphism existed, with female tooth size 0.41 standard deviations lower than the male value (C.I. -0.54, -0.26, $p<0.001$). There was no association between racial group and tooth size ($p=0.165$). Significant differences between different malocclusions only existed in the Class II Division 1 group, with the mean tooth size 0.22 standard deviations larger than the Class I group (C.I. 0.02, 0.41, $p=0.029$). Fractional polynomial regression (Fig. 3.5.1) confirmed a significant non-linear association between tooth size and number of missing teeth independent of gender, racial group and malocclusion ($p<0.0001$). Furthermore, the addition of interaction terms showed that there was no effect modification by gender ($p=0.140$), racial group ($p=0.206$) or malocclusion ($p=0.1004$) on the relationship.

3.6 Arch dimensions

Hypodontia Group	Maxillary Intercanine Width Mean (SD)	Maxillary Intermolar Width Mean (SD)	Maxillary Arch Length Mean (SD)	Mandibular Intercanine Width Mean (SD)	Mandibular Intermolar Width Mean (SD)	Mandibular Arch Length Mean (SD)
Control	32.88 (2.30)	49.22 (3.19)	39.06 (2.72)	26.53 (1.94)	45.17 (2.21)	34.28 (2.50)
Mild	31.69 (3.26)	48.67 (3.54)	36.91 (3.14)	25.45 (1.85)	44.22 (2.67)	34.37 (2.73)
Moderate	31.98 (3.08)	48.24 (3.18)	35.37 (2.67)	25.19 (2.97)	44.21 (2.48)	32.40 (2.39)
Severe	31.68 (3.11)	45.93 (3.50)	33.51 (3.61)	24.58 (3.41)	44.97 (3.03)	31.98 (2.97)

Table 3.6.1 Mean arch dimension measurements per group (mm)

Hypodontia Group	Maxillary Intercanine Width	Maxillary Intermolar Width	Maxillary Arch Length	Mandibular Intercanine Width	Mandibular Intermolar Width	Mandibular Arch Length
Mild	-1.19	-0.55	-2.15	-1.08	-0.95	0.09
Moderate	-0.90	-0.98	-3.69	-1.34	-0.96	-1.88
Severe	-1.20	-3.29	-5.56	-1.95	-0.20	-2.30

Table 3.6.2 Mean difference in arch dimensions from control group (mm)

3.7 Statistical analysis of maxillary intercanine width

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	-1.22	-2.21 - -0.24	**0.015**
Mod Hypodontia	-0.92	-1.91 - 0.06	0.065
Severe Hypodontia	-1.19	-2.18 - -0.21	**0.017**
Gender	-1.57	-2.27 - -0.87	**<0.001**
Racial Group	0.02	-0.69 - 0.70	0.95
Class II Div 1	0.13	-0.83 - 1.10	0.788
Class II Div 2	0.50	-0.49 - 1.49	0.319
Class III	-0.17	-1.15 - 0.81	0.731

Table 3.7.1 Multiple linear regression of maxillary intercanine width adjusted for severity of hypodontia, gender, racial group and malocclusion

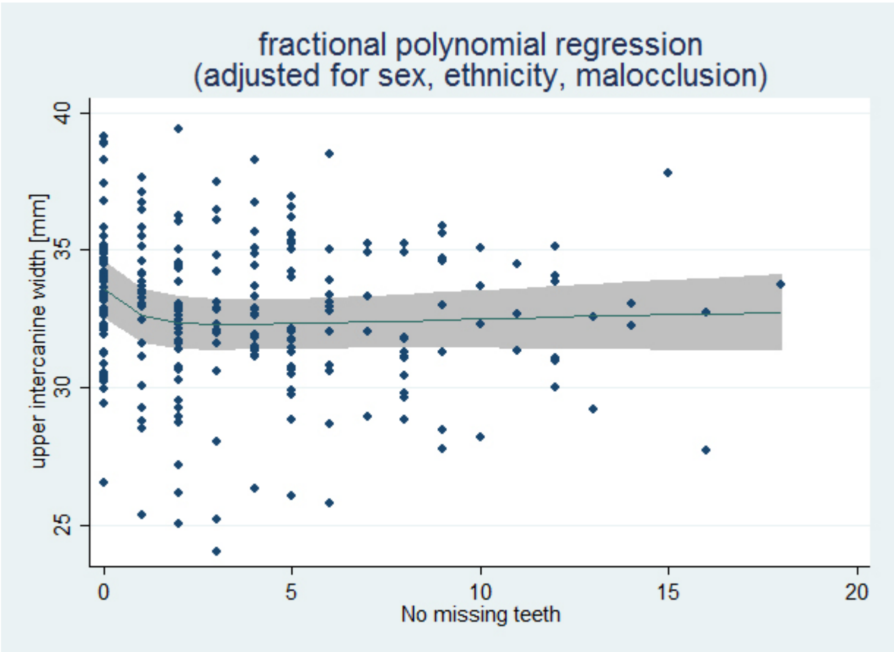

Fig 3.7.1 Fractional polynomial regression of maxillary intercanine width and number of missing teeth adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.7.1) showed an association between maxillary intercanine width and hypodontia. Differences were statistically significant for mild and severe hypodontia and approached statistical significance for moderate hypodontia. Maxillary intercanine width was 1.22 mm narrower in the mild hypodontia group compared to the non-hypodontia control group (C.I. -2.21, -0.24, $p=0.015$). Moderate hypodontia subjects were 0.92mm smaller (C.I. -1.91, 0.06, $p=0.065$) and severe hypodontia subjects were 1.19mm smaller (C.I. -2.18, -0.21, $p=0.017$) than the control group, respectively.

Female subjects had smaller dimensions (-1.57mm) than male subjects (C.I. -2.27, -0.87, $p<0.001$). There were no statistically significant differences between racial groups ($p=0.95$) or between the different types of malocclusion (Class II division 1 $p=0.788$, Class II division 2 $p=0.319$, Class III $p= 0.731$).

Fractional polynomial regression (Fig 3.7.1) confirmed there was a significant linear association between maxillary intercanine width and number of missing teeth, independent of gender, racial group and malocclusion ($p=0.048$). Furthermore, the addition of interaction terms showed that there was no effect modification by gender ($p=0.548$), racial group ($p=0.17$) or malocclusion ($p=0.509$) on the relationship.

3.8 Statistical analysis of maxillary intermolar width

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	-0.57	-1.72 - 0.56	0.319
Mod Hypodontia	-1.01	-2.15 - 0.12	0.082
Severe Hypodontia	-3.27	-4.42 - -2.13	**<0.001**
Gender	-1.60	-2.41 - -0.79	**<0.001**
Racial group	-0.23	-1.04 - 0.57	0.572
Class II Div 1	-0.90	-2.03 - 0.22	0.113
Class II Div 2	-0.39	-1.54 - 0.75	0.501
Class III	-1.53	-2.67 - -0.38	**0.009**

Table 3.8.1 Multiple linear regression of maxillary intermolar width adjusted for severity of hypodontia, gender, racial group and malocclusion

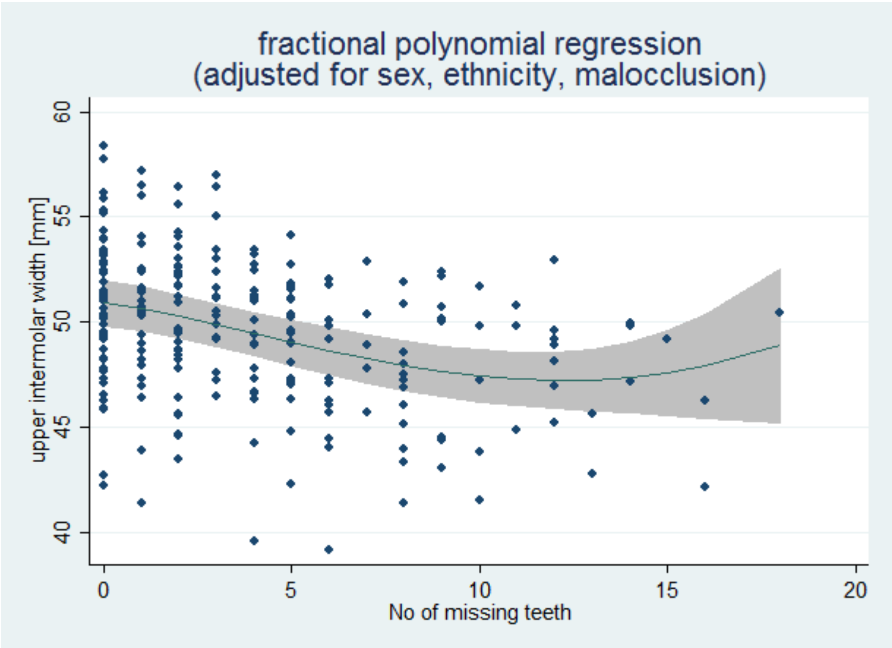

Fig 3.8.1 Fractional polynomial regression of maxillary intermolar width and number of missing teeth, adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.8.1) showed an association between maxillary intermolar width and hypodontia. These differences were only statistically significant for subjects with severe hypodontia. Maxillary intermolar width was 0.57mm narrower in mild hypodontia subjects compared to the non-hypodontia control group (C.I. -1.72, 0.56, $p=0.319$). In subjects with moderate hypodontia, it was reduced by 1.01 mm (C.I. -2.15, 0.12, $p=0.082$) and by 3.27mm (C.I. -4.42, -2.13, $p<0.001$) in the severe hypodontia group.

Gender dimorphism existed, with females having smaller dimensions (-1.60mm) than male subjects (C.I. -2.41, -0.79, $p<0.001$). There was no association between racial group and maxillary intermolar width ($p=0.572$). A significant association between maxillary intermolar width and malocclusion only existed in Class III subjects who had narrower maxillary intermolar widths (-1.53mm, C.I. -2.67, -0.38, $p=0.009$) compared to Class I subjects.

Fractional polynomial regression (Fig 3.8.1) confirmed there was a significant linear association between maxillary intermolar width and number of missing teeth independent of gender, racial group and malocclusion ($p<0.0001$). Furthermore, the addition of interaction terms showed that there was no effect modification by gender ($p=0.941$), racial group ($p=0.828$) or malocclusion ($p=0.478$) on the relationship.

3.9 Statistical analysis of maxillary arch length

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	-2.17	-3.33 - -1.03	**<0.001**
Mod Hypodontia	-3.71	-4.87 - -2.57	**<0.001**
Severe Hypodontia	-5.54	-6.69 - -4.39	**<0.001**
Gender	-1.77	-2.59 - -0.96	**<0.001**
Racial Group	0.43	-0.38 - 1.24	0.296
Class II Div 1	1.90	0.78 - 3.03	**<0.001**
Class II Div 2	-0.44	-1.61 - 0.71	0.447
Class III	-1.12	-2.27 - -0.03	**0.046**

Table 3.9.1 Multiple linear regression of maxillary arch length adjusted for severity of hypodontia, gender, racial group and malocclusion

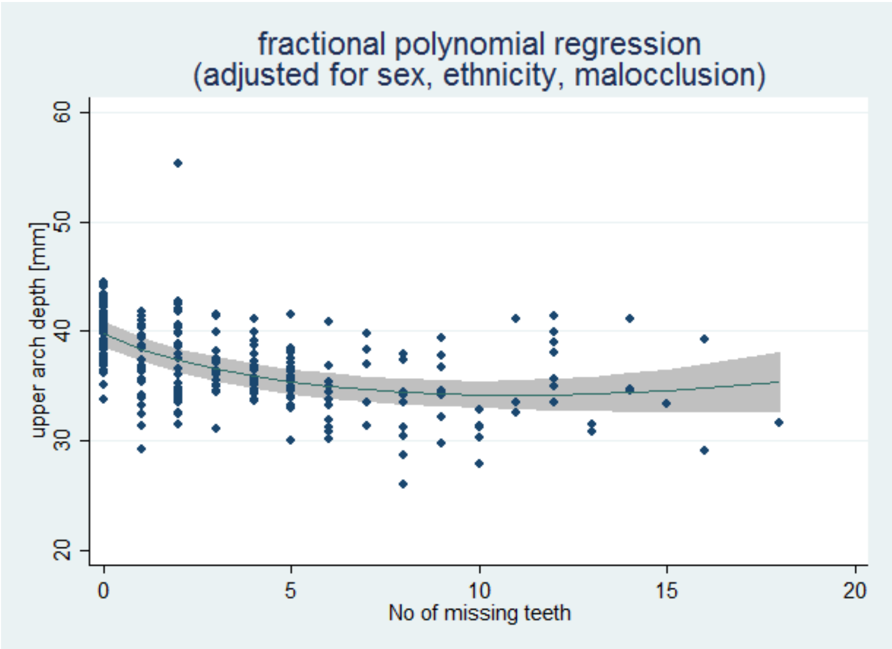

Fig 3.9.1 Fractional polynomial regression of maxillary arch length and number of missing teeth adjusted for gender, racial group and malocclusion

Multiple linear regression (Table 3.9.1) analysis showed that there was a statistically significant association between maxillary arch length and hypodontia. Maxillary arch length was 2.17 mm shorter in mild hypodontia subjects when compared to the non-hypodontia control group (C.I. -3.33, -1.03, $p<0.001$). In subjects with moderate hypodontia it was reduced by 3.71 mm (C.I. -4.87, -2.57, $p<0.001$) and in the severe group was reduced by 5.54mm (C.I. -6.69, -4.39, $p<0.001$), respectively.

Female subjects had a smaller maxillary arch length compared to male subjects ($P<0.001$). Significant differences did not exist between racial groups ($p=0.296$). Class II division 1 malocclusion subjects had longer maxillary arch lengths than Class 1 subjects ($p<0.001$) and Class III malocclusions had a reduced maxillary arch length ($p=0.046$).

Fractional polynomial regression (Fig 3.9.1) showed a significant non-linear relationship between number of missing teeth and arch length ($P<0.0001$). Furthermore, the addition of interaction terms showed that there was no effect modification by gender ($p=0.84$), racial group ($p=0.503$) or malocclusion ($p=0.326$) on the relationship.

3.10 Statistical analysis of mandibular intercanine width

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	-1.09	-2.01 - -0.17	**0.02**
Mod Hypodontia	-1.36	-2.27 - -0.43	**0.004**
Severe Hypodontia	-1.97	-2.88 - -1.04	**<0.001**
Gender	-0.61	-1.27 - 0.04	0.064
Racial Group	-0.30	-0.95 - 0.34	0.356
Class II Div 1	-0.58	-1.48 - 0.32	0.206
Class II Div 2	-0.69	-1.62 - 0.23	0.142
Class III	0.08	-0.83 - 1.00	0.853

Table 3.10.1 Multiple linear regression of mandibular intercanine width adjusted for severity of hypodontia, gender, racial group and malocclusion

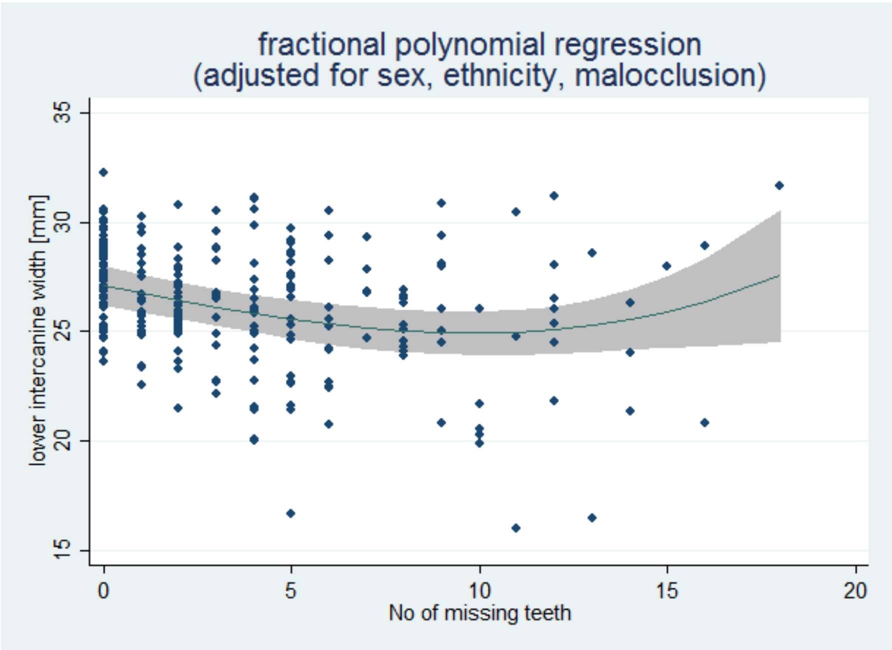

Fig 3.10.1 Fractional polynomial regression of mandibular intercanine width and number of missing teeth, adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.10.1) showed that there was a significant association between mandibular intercanine width and severity of hypodontia. Mandibular intercanine width was 1.09 mm narrower in mild hypodontia subjects compared to the non-hypodontia control group (C.I. -2.01, -0.17, $p=0.02$). Moderate hypodontia subjects were 1.36 mm narrower (C.I. -2.27, -0.43, $p=0.004$) and severe were 1.97mm smaller (C.I. -2.88, -1.04, $p<0.001$), respectively.

No significant gender ($p=0.064$) or racial ($p=0.356$) differences existed between subjects. There was no difference in mandibular intercanine width between the different malocclusion types when compared to Class I subjects (Class II Division 1 $p=0.206$, Class II Division 2 $p=0.142$, Class III $p=0.853$).

Fractional polynomial regression (Fig 3.10.1) showed a significant non-linear relationship between the number of missing teeth and mandibular intercanine width ($P=0.0003$). The addition of interaction terms showed that there was no effect modification by gender ($p=0.522$), racial group ($p=0.571$) or malocclusion ($p=0.354$) on the relationship.

3.11 Statistical analysis of mandibular intermolar width

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	-1.00	-1.95 - -0.07	**0.035**
Mod Hypodontia	-1.01	-1.95 - -0.07	**0.035**
Severe Hypodontia	-0.23	-1.17 - 0.71	0.629
Gender	-1.87	-2.53 - -1.21	**<0.001**
Racial Group	-0.67	-1.34 - -0.01	**0.045**
Class II Div 1	-1.22	-2.14 - -0.29	**0.01**
Class II Div 2	-1.03	-1.98 - -0.09	**0.033**
Class III	-0.17	-1.11 - 0.77	0.721

Table 3.11.1 Multiple linear regression of mandibular intermolar and severity of hypodontia adjusted for gender, racial group and malocclusion

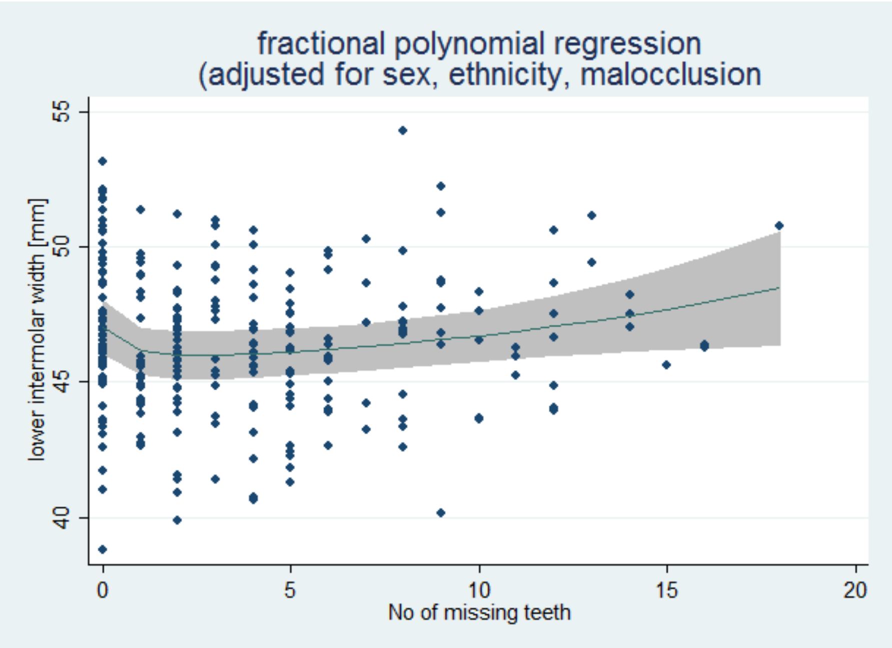

Fig 3.11.1 Fractional polynomial regression of mandibular intermolar width and number of missing teeth, adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.11.1) showed that there was an association between mandibular intermolar width and hypodontia. These differences were statistically significant for mild and moderate hypodontia. There were no statistically significant differences between subjects with severe hypodontia and the non-hypodontia control group. Mandibular intermolar width was 1.00 mm narrower in mild hypodontia subjects compared to the non-hypodontia control group (C.I. -1.95, -0.07, p=0.035). Moderate hypodontia subjects were 1.01 mm (C.I. -1.95, -0.07, p=0.035) narrower and severe were 0.23mm (C.I. -1.17, 0.71, p=0.29) narrower, respectively.

Female subjects had smaller dimensions compared to male subjects by 1.87mm (C.I. -2.53, -1.21, P<0.001). South Asian subjects had reduced measurements compared to White British subjects by 0.67mm (C.I. -1.34, -0.01, p=0.045). Subjects with Class II division 1 and Class II division 2 malocclusion had reduced mean mandibular intermolar widths compared to the Class I group (Class II Division 1 p=0.01, Class II Division 2 p=0.033).

Fractional polynomial regression (Fig 3.11.1) showed a significant non-linear association between number of missing teeth and mandibular intermolar width (P=0.0432). The addition of interaction terms showed that there was no effect modification by gender (p=0.89), racial group (p=0.349) or malocclusion (p=0.9315) on the relationship.

3.12 Statistical analysis of mandibular arch length

Group	Coefficient (mm)	95% C.I.	P Value
Mild Hypodontia	0.05	-0.86 - 0.97	0.912
Mod Hypodontia	-1.90	-2.82 - -1.01	**<0.001**
Severe Hypodontia	-2.31	-3.23 - -1.40	**<0.001**
Gender	-1.27	-1.92 - -0.62	**<0.001**
Racial Group	-0.35	-1.00 - 0.30	0.285
Class II Div 1	-0.01	-0.92 - 0.88	0.971
Class II Div 2	-0.18	-1.11 - 0.74	0.696
Class III	-0.22	-1.14 - 0.69	0.630

Table 3.12.1 Multiple linear regression of mandibular arch length adjusted for severity of hypodontia, gender, racial group and malocclusion

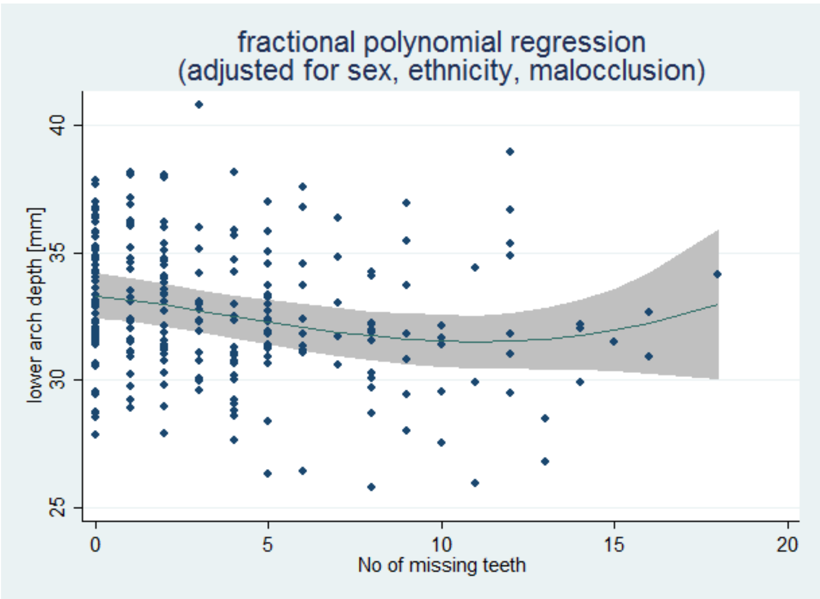

Fig 3.12.1 Fractional polynomial regression of mandibular arch length and number of missing teeth, adjusted for gender, racial group and malocclusion

Multiple linear regression analysis (Table 3.12.1) showed that there was a significant association between mandibular arch length and moderate and severe hypodontia. Mandibular arch length was 0.05mm longer in mild hypodontia subjects compared to the non-hypodontia control group (C.I. -0.86, 0.97, p=0.912). It was 1.90 mm shorter in subjects with moderate hypodontia (C.I. -2.82, -1.01, p<0.001) and 2.31mm shorter in the severe group (C.I. -3.23, -1.40, p<0.001).

Female subjects also had reduced measurements compared to male subjects (P<0.001). There were no differences between ethnic groups (p=0.285) or between malocclusions (Class II Division 1 p=0.971, Class II Division 2 p=0.696, Class III p=0.63).

Fractional polynomial regression (Fig 3.12.1) showed a significant linear relationship between number of missing teeth and mandibular arch length (P=0.0036). The addition of interaction terms showed that there was no effect modification by gender (p=0.985), racial group (p=0.884) or malocclusion (p=0.185) on the relationship.

Chapter 4

Discussion

4.1 Tooth size

Many studies have shown a reduction in tooth size of the remaining dentition in hypodontia subjects (Al-Shahrani *et al.,* 2014; Baum and Cohen, 1971; Brook, 1984; Brook *et al.*, 2009b; Garn and Lewis, 1970; Gungor and Turkkahraman, 2013; Kerekes-Máthé *et al.,* 2015; Khalaf, 2016; Lavelle, 1970; Mirabella *et al.,* 2012; Rune and Sarnäs, 1974; Yacoob *et al.,* 2011). A reduction in tooth size has also been shown in their fully dentate relatives (McKeown *et al.,* 2002; Schalk-Van der Weide and Bosman, 1996). The present study aimed to assess the tooth size of hypodontia subjects from a White British and South Asian population and to evaluate if there were significant differences between these racial groups. The mesio-distal tooth size of 186 hypodontia subjects was compared to 62 fully dentate control subjects. Thirty-one subjects per hypodontia category (mild, moderate, severe) were analysed for each racial group (White British and South Asian) and compared to 31 non-hypodontia control subjects per racial group. Each group had an equal gender distribution and all subjects were aged between 12 and 20 years.

Subjects with hypodontia had a reduction in the mesio-distal tooth size of the remaining dentition when compared to the control group. This reduction in tooth size increased with the severity of hypodontia. The mean reduction in tooth size with racial groups combined ranged from 2.78% - 10.58% in the mild hypodontia group, 4.17% - 15.16% in the moderate hypodontia group and 8.43% - 20.02% in the severe hypodontia group. (Table 3.3.2). The maxillary lateral incisor had the greatest mean reduction in tooth size. The maxillary first molar had the least reduction in the mild and moderate groups, while the mandibular first molar was least affected in the severe group.

The results of the present study are comparable to previous studies on tooth size and hypodontia, which consistently demonstrate a reduction in tooth dimensions. Mirabella *et al.* (2012) compared the mesio-distal tooth size of Italian subjects with mild hypodontia to a fully dentate control group. The mean reduction in tooth size of the remaining dentition ranged from 1.10% to 13.70%. The maxillary lateral incisor was most severely affected with the maxillary first molar was least affected. Yaqoob *et al.* (2011) in a similar study design compared the combined anterior mesio-distal tooth dimensions of British subjects with bilateral hypodontia of maxillary lateral incisors to a non-hypodontia control group. The combined anterior tooth dimensions were 5.07% smaller in the maxillary arch and 5.4% smaller in the mandibular arch in subjects with bilateral absence of maxillary lateral incisors. Brook *et al.* (2009b) compared the tooth size of 60 hypodontia subjects to 60 control subjects of European origin. The mean reduction in mesio-distal tooth size ranged from 4.9% to 13.9% in males and from 2.1% to 11.1% in females.

The severity of hypodontia has also been shown to affect the mesio-distal tooth size of the remaining dentition and the results of present study are in concurrence with this. Gungor and Turkkahramen (2013) compared the effects of mild and severe hypodontia on the tooth size of 154 Turkish hypodontia subjects. Subjects with mild hypodontia had a mean mesio-distal tooth size reduction ranging from 3.06% to 6.9%. In the severe group the mean reduction ranged from 2.16% to 17.54%. Khalaf (2016) investigated the tooth dimensions of 120 British hypodontia patients according to severity of hypodontia. This was the only study identified in the literature search that used the most common classification of hypodontia and is most comparable to the present study. The subgroups consisted of 40 mild, 40 moderate and 40 severe hypodontia subjects, with 20 males and 20 females in each subgroup. The mean reduction in mesio-distal tooth size ranged from 0.16% to 15.32% in the mild group, from 4.91% to 22.47% in the moderate group and from 10.65% to 32.35% in the severe group, respectively. The maxillary lateral incisor was most severely affected and the mandibular first permanent molar was least affected.

A significant overall effect of hypodontia on tooth size was demonstrated in the present study. This effect increased with the severity of hypodontia. Multiple linear regression analysis showed that the mean standardised tooth size was significantly smaller in each hypodontia group, with this difference increasing with the severity of hypodontia (Table 3.5.1). Standardising the mean tooth size allowed the overall effect of hypodontia on tooth size to be evaluated. The results of this study support the model (Fig 1.1.7) proposed by Brook (1984), which relates tooth size and number on an underlying scale of continuous variation. It outlines a threshold for the presence of anomalies in tooth size and number with polygenetic and environmental factors determining the position of an individual on this scale. Butler's Field theory for the mammalian dentition proposed that the earliest forming teeth within a morphogenetic field (incisor, canine and premolar/molar) are most stable with the latest forming teeth most susceptible to morphological change (Butler, 1939). The results of the present study are in agreement with previous studies that support this theory, as the maxillary lateral incisor was most susceptible to change in size and the first permanent molar was most stable (Brook *et al.,* 2009b; Gungor and Turkkahraman, 2013; Kerekes-Máthé *et al.,* 2015).

Gender dimorphism in human tooth size has been demonstrated, with males reported to have larger dental dimensions than female subjects (Baum and Cohen, 1971; Kieser *et al.,* 1985; Lavelle 1972). In the present study, the regression analysis showed that females had smaller teeth than males (Table 3.5.1). Garn *et al.* 1967 proposed that the mesio-distal gender difference was 4% of the overall size, with the greatest difference in the canines and the smallest difference in the incisors. This was supported by Arya *et al.* (1974), who observed that all permanent teeth, with the exception of the mandibular central incisor showed gender dimorphism. Kerekes-Máthé *et al.* (2015) found that males had larger tooth size dimensions than females for each tooth type in a mild hypodontia group. On the other hand, Khalaf (2016) found that although males had larger tooth size measurements than females, few of these differences reached statistical significance. Other researchers have also found few statistically significant differences between male and female tooth size (Grahnen, 1956; Rune and Sarnäs, 1974; Yaqoob *et al.,* 2009).

Research related to tooth size and malocclusion has traditionally concentrated on tooth size discrepancies, with Bolton's ratios most commonly used. There are a limited number of studies that focus on individual tooth size and malocclusion, all of which are on non-hypodontia subjects. Arya *et al.* (1974) found no differences in tooth size between Class I and Class II malocclusions when both genders were combined. Lavelle (1975) compared the dental dimensions of subjects with Class I, Class II and Class III malocclusions. The mesio-distal and bucco-lingual dimensions were larger for Class II and Class III subjects in the upper arch when compared to Class I subjects. Conversely, in the lower arch the measurements were greater for Class I subjects when compared to Class II and Class III. Peck *et al.* (1997) found reduced mesio-distal incisor dimensions in subjects with severe Class II division 2 malocclusions. The authors hypothesised that Class II division II subjects may have systematically reduced tooth size as an associated trait. The results of current study showed no significant differences in mean standardised tooth size between the malocclusion types, with the exception of Class II division 1 subjects. The regression analysis showed that Class II division 1 subjects had a mean standardised tooth size of 0.22 standard deviations (C.I. 0.02, 0.41, p=0.029) greater than Class I subjects (Table 3.5.1). Although this was shown to be statistically significant, this value is too small to be of clinical significance. Moreover, there was no significant effect modification by malocclusion on the relationship between hypodontia and tooth size (p=0.1004).

Studies on racial variation in tooth size in non-hypodontia subjects have primary focused on the differences between White, Black and Southeast Asian subjects. Lavelle (1972) compared the mesio-distal crown diameters of three ethnic groups, Black, White and Southeast Asian. Tooth size was greatest in Black subjects and smallest in Whites, with Southeast Asians intermediate. Yuen *et al.* (1997) found similar results when the dental dimensions of Southern Chinese, Caucasian and Australian Aboriginal subjects were compared. Differences in tooth size between South Asian subjects and other racial groups have been studied less extensively. Radnzic (1987) compared the mesio-distal tooth size of

60 White British males to 60 male immigrants of Pakistani origin in United Kingdom. There were no statistically significant differences between both groups. The present study supports this finding as no statistically significant racial differences in tooth size between White British and South Asian subjects were identified (Table 3.5.1). Moreover, the racial group had no effect on the relationship between hypodontia and tooth size (p=0.206). Radnzic (1987) proposed that the lack of difference in tooth size between the groups maybe due to both groups originating from the same Caucasian lineage. Differences in tooth size and shape are due to genetic, epigenetic and environmental factors (Brook, 2009). The population examined in the present study lived in the same geographical area and may have been exposed to the same environmental factors during dental development. However, it was not possible to determine whether the subjects were born in the United Kingdom or whether they had immigrated.

4.2 Arch dimensions

Although there has been a substantial amount of research on tooth size in subjects with hypodontia, the research on arch dimensions is less extensive. Wisth *et al*. (1974) did not show a significant difference in the arch dimensions of subjects with mild and moderate hypodontia when compared to a non-hypodontia control group. Woodworth *et al.* (1985) also found no differences in the arch dimensions of subjects with hypodontia of the maxillary lateral incisors. Other retrospective studies have shown a tendency towards reduced arch dimensions. LeBot and Salmon (1977) reported significantly reduced maxillary arch widths and arch lengths in subjects with lateral incisor hypodontia. More recently, Bu *et al.* (2008) found significantly reduced arch dimensions in subjects with oligodontia when compared to a non-hypodontia control group. Greater differences were seen in the maxillary arch than in the mandibular arch for all dimensions. Fekonja (2013) found similar results and reported a significant reduction in the intercanine and intermolar width of hypodontia subjects.

The results of the present study showed a reduction in arch dimensions for the majority of measurements, with a tendency towards greater reductions in the maxillary arch (Table 3.6.2). The mean maxillary and mandibular intercanine widths were reduced for each category of hypodontia. The mean reduction ranged from 0.9mm to 1.95mm (Table 3.6.2). Multiple linear regression showed that that these differences were statistically significant for all groups with the exception of the maxillary intercanine width in the moderate hypodontia group, which approached statistical significance (Table 3.7.1, Table 3.10.1). While the mandibular intercanine width reduced with the severity of hypodontia, the maxillary intercanine width had a greater reduction for mild and severe hypodontia than for the moderate group. This is most likely related to the variable position of the canine teeth in hypodontia patients, which may limit the validity of this measurement in such cases. For instance, a considerable number of mild hypodontia cases had absence of the maxillary lateral incisors with eruption of the canines into the lateral incisor position, leading to a reduction of the intercanine width. Conversely, in more severe cases of hypodontia the canines may erupt or drift distally into posterior hypodontia spaces leading to an increase in intercanine width. Other factors that may influence the measurements include the pattern of hypodontia, the angulation and inclination of the canines, the presence or absence of deciduous teeth and the presence of crowding or spacing within the arch.

In the present study, the mean maxillary and mandibular intermolar widths were reduced for each category of hypodontia. The mean reduction ranged from 0.20mm to 3.29mm (Table 3.6.2). Multiple linear regression showed that these differences were only statistically significant for severe hypodontia in the maxillary arch and for mild and moderate hypodontia subjects in the mandibular arch (Table 3.8.1, Table 3.11.1). Subjects with severe hypodontia had the greatest reduction in the maxillary intermolar width (3.29mm) but smallest reduction in the mandibular intermolar width (0.20mm). This is in agreement with Bu *et al*. (2008) who found a greater mean reduction in the maxillary intermolar width (3.40 mm) compared to mandibular intermolar width (1.8mm) in oligodontia subjects. In the present study, there was a greater reduction in arch length in the maxilla compared to the mandible which may have altered the transverse position of the molars. In severe cases of hypodontia where only a few teeth are remaining, the tongue may spread laterally into the edentulous areas (Hobkirk *et al.,* 2010). This may explain why there was a tendency for very severe hypodontia cases to have an average or increased mandibular intermolar width.

Changes in the maxillary and mandibular arch length were demonstrated in hypodontia subjects in the present study (Table 3.6.2). In the maxillary arch the mean reduction from the control group ranged from 2.15mm in mild hypodontia to 5.56mm in severe hypodontia and these were the most significant changes observed. Multiple linear regression showed that these differences were statistically significant (Table 3.9.1). In the mandibular arch, arch length was 0.09mm longer in the mild group, 1.88 mm shorter in the moderate group and 2.30mm shorter in the severe group, respectively (Table 3.6.2). These differences were statistically significant for moderate and severe hypodontia (Table 3.12.1). The results are in agreement with Bu *et al.* (2011) who found a mean reduction in arch length of 4.40mm in the maxilla and 2.80mm in the mandible in oligodontia subjects. The small and insignificant increase in the mandibular intercanine width in mild hypodontia cases may be due to the retention of the second deciduous molar in association with absence of the lower second premolar. A greater reduction in maxillary arch length may be attributed to a greater likelihood of spontaneous mesial movement of the maxillary first molars when teeth are absent compared to the mandible.

Overall, the present study showed a tendency for a reduction in arch dimensions in hypodontia subjects. While many of these differences were statistically significant, the majority of values were within 1-2 mm of the control group. Although such small values would suggest that they are unlikely to be of clinical significance, large individual variation in the position of the reference teeth was observed. This variation was often not related to the severity of hypodontia but rather to factors associated with hypodontia. These factors include the pattern of hypodontia, the presence and position of deciduous teeth, the angulation and inclination of the reference teeth and the presence of spacing or crowding in the arch. As previously suggested, these factors may limit the validity of dental references points in measuring the arch dimensions of hypodontia subjects and should be considered when interpreting the results.

Gender dimorphism in arch dimensions has been demonstrated in the majority of studies on non-hypodontia subjects, with males having larger dimensions than females (Al-Khateeb and Abu Alhaija, 2006; Bishara *et al*., 1997; Burris *et al.,* 2000; Chang *et al.,* 1986; da Silva Filho *et al.,* 2008; Kuntz *et al.,* 2008; Slaj *et al.,* 2010). The results of the present study are in concurrence with this, as multiple linear regression showed that males had significantly larger arch dimensions than females. This was observed for all measurements, with the exception of the mandibular intercanine width, where no difference was observed (Tables 3.7.1 – 3.12.1).

Differences in arch dimensions have also been reported for the different malocclusion types. In the present study, multiple linear regression showed narrower mandibular intermolar widths in Class II division 1 and Class II division 2 subjects (Table 3.11.1). Although the maxillary intermolar width was reduced in Class II division 1 subjects, this was not statistically significant (p=0.113). Class III subjects had a reduced maxillary intermolar width compared to the Class I subjects but there were no differences in the mandibular intermolar width (Table 3.8.1, Table 3.11.1). The results are in broad agreement with studies on non-hypodontia samples. Class II division 1 malocclusion has been associated with the equivalent or narrower arch widths than subjects with a Class 1 malocclusion (Bishara, 1996; Fröhlich, 1961; Sayin and Turkkahraman, 2004; Staley *et al*, 1985). There is controversy regarding the differences observed in Class II division 2 malocclusion, with researchers often with reporting contradictory results (Buschang *et al.,* 1994; Herren and Jordi-Guilloud, 1973; Moorees *et al.,* 1969; Uysal *et al.,* 2005b; Walkow and Peck, 2002). Class III subjects have been found to have narrower maxillary dimensions and wider mandibular dimensions although these differences have not always been statistically significant (Al-Khateeb and Abu Alhaija, 2006; Herren and Jordi-Guilloud, 1973; Kuntz *et al.,* 2008; Uysal *et al.,* 2005c).

Racial differences in arch dimensions have been investigated in non-hypodontia subjects. Mack (1981) found significantly larger arch dimensions in a Nigerian population compared to White British subjects. This is in agreement with Burris *et al.* (2000) and Lombardo *et al.* (2015) who found similar differences when comparing White and Black subjects. Nojimo *et al.* (2001) compared the arch dimensions of White Americans to Japanese subjects and observed that the Japanese group had larger arch dimensions. Similar to studies in tooth size, there is a lack of research comparing the arch dimensions of South Asian populations to other racial groups. Radnzic (1987) found no difference in the arch dimensions of British subjects and a Pakistani population. The interincisor width, intermolar width and arch length were assessed. No statistically significant differences in the arch dimensions were found between both racial groups. The results are similar to the findings of the present study, which did not show statistically significant differences in the arch dimensions between White British and South Asian subjects with hypodontia (Tables 3.7.1 – 3.12.1). The only exception was the mandibular intermolar width, which was smaller in South Asian subjects ($p=0.045$), however at 0.67mm this would not be of clinical significance (Table 3.11.1). Moreover, the racial group had no effect on the relationship between any of the arch dimensions measured and hypodontia.

Chapter 5

Conclusion

5.1 Conclusions

This study aimed to investigate if there were significant differences in the mesio-distal tooth size of hypodontia subjects compared to a fully dentate control group and evaluate if there were racial differences between White British and South Asian subjects. The following conclusions may be drawn from the findings of this study:

1. The mesio-distal tooth size was significantly smaller in subjects with hypodontia. The greater the severity of hypodontia was associated with a greater reduction in tooth size.
2. There were no differences in mesio-distal tooth size between White British and South Asian subjects.
3. There was no effect modification by racial group on the relationship between tooth size and hypodontia.
4. The arch dimensions (intercanine width, intermolar width and arch length) were generally reduced in subjects with hypodontia. While most values were statistically significant, the clinical differences were sometimes small. This may be attributed to the large individual variation in the position of the reference teeth. This variation in position was not always related to the severity of hypodontia but to other hypodontia related factors.
5. There were no differences in arch dimensions (intercanine width, intermolar width and arch length) between White British and South Asian subjects.
6. There was no effect modification by racial group on the relationship between hypodontia and arch dimensions.

5.2 Null hypotheses

1. There is no difference in tooth size between subjects with hypodontia and subjects without hypodontia.
    - Rejected
2. There are no differences in the arch dimensions between subjects with hypodontia and subjects without hypodontia.
    - Rejected
3. There is no difference in tooth size between White British and South Asian subjects with hypodontia.
    - Accepted
4. There are no differences in the arch dimensions between White British and South Asian subjects with hypodontia.
    - Accepted

5.3 Clinical implications

The present study shows that there are no differences in tooth size and arch dimensions of hypodontia subjects between the two main racial groups treated at Birmingham Dental Hospital. It also shows that hypodontia had the same effect on these measurements for both populations. While the present study does not offer any new information that would alter clinical practice, it emphasises the factors that add to the complexity of treating such cases. These factors should be considered carefully in the treatment planning process to ensure an efficient and optimal outcome for the patient.

5.4 Further Research

One of the main limitations of this study was the large variation in the position of the reference teeth when measuring arch dimensions. As previously highlighted this may have reduced the validity of these measurements. A more accurate method to assess arch dimensions may be to measure the intra-alveolar widths of the arches at set distances from the centre-line. This would outline the true dimensions of the maxillary and mandibular dental bases independent of tooth position. Differences in dental arch form of hypodontia subjects compared to a non-hypodontia control group could also be compared.

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RAW DATA

White British Subjects – Arch Dimensions

Subject No	Group	Gender	Malocclusion	No Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
1	0	0	0	0	33.3	52.41	37.95	29.12	53.13	35.9
2	0	0	0	0	35.52	54.36	42.21	27.36	48.72	39.7
3	0	0	0	0	32.26	46.28	41.54	28.75	49.1	38.78
4	0	0	0	0	34.68	49.52	37.8	26.98	47.52	34.64
5	0	0	1	0	34.65	50.45	36.06	27.96	42.49	33.56
6	0	0	1	0	34.35	49.28	37.42	27.26	42.98	33.39
7	0	0	1	0	33.54	49.73	43.66	29.89	49.84	34.62
8	0	0	1	0	29.58	47.35	43.34	24.68	39.88	37.8
9	0	0	2	0	35.14	50.9	39.56	29.32	50.96	34.74
10	0	0	2	0	33.38	51.11	40.12	23.43	42.03	34.72
11	0	0	2	0	30.79	47.36	37.22	26.62	45.98	33.53
12	0	0	3	0	35.34	45.78	35.38	27.82	38.72	33.19
13	0	0	3	0	34.48	49.83	36.06	25.8	45.78	35.15
14	0	0	3	0	31.14	53.8	32.79	25.39	50.05	30.57
15	0	0	3	0	34.76	49.83	41.26	26.98	47.27	33.26
16	0	1	0	0	35.84	51.73	42.69	27.36	43.65	33.1
17	0	1	0	0	32.44	47.6	36.76	27.7	47.61	34.32
18	0	1	0	0	32.97	49.46	38.06	27.73	43.99	37.19
19	0	1	0	0	28.82	44.27	41.24	24.51	44.82	32.41
20	0	1	3	0	34.05	47.83	35.44	23.83	40.47	33.07
21	0	1	1	0	36.85	53.35	38.36	29.43	47.69	31.69
22	0	1	1	0	33.64	48.48	42.6	27.27	43.5	35.52
23	0	1	1	0	31.75	48.48	40.36	25.31	42.14	33.68

Subject No	Group	Gender	Malocclusion	No Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
24	0	1	1	0	30.68	44.56	38.98	27.5	46.76	32.72
25	0	1	2	0	32.89	48.24	39.64	27.88	45.15	32.53
26	0	1	2	0	31.15	47.42	38.29	24.92	38.75	29.27
27	0	1	2	0	29.45	45.87	38.54	26.15	45.75	31.22
28	0	1	2	0	33.98	50.55	41.16	27.68	48.4	37.55
29	0	1	3	0	37.13	50.76	35.66	27.02	42.96	35.23
30	0	1	3	0	30.87	45.07	33.39	23.16	43.68	29.05
31	0	1	3	0	29.56	54.59	34.91	27.24	45.28	31.09
32	1	0	0	1	34.14	56.03	40.55	29.77	49.43	38.07
33	1	0	0	1	31.15	46.38	36.28	24.82	45.97	35.53
34	1	0	0	1	31.12	53.7	36.48	23.38	48.12	34.41
35	1	0	1	1	36.59	49.36	40.36	29.73	46.22	38.07
36	1	0	2	1	34.17	51.27	39.98	28.85	47.85	38.12
37	1	0	2	1	37.59	50.35	36.44	27.84	44.52	38.01
38	1	0	2	1	36.35	49.09	32.94	25.84	44.55	32.95
39	1	0	3	1	33.27	49.15	40.69	25.17	42.56	38.71
40	1	1	0	1	27.22	47.38	33.8	22.77	42.5	31.88
41	1	1	0	1	31.96	47.02	36.98	24.28	43.25	35.5
42	1	1	1	1	36.2	49	40.16	25.56	40.78	33.01
43	1	1	1	1	30.2	45.44	37.64	23.79	41.23	33.8
44	1	1	1	1	23.96	41.4	34.51	21.39	39.91	30.94
45	1	1	3	1	30.73	49.26	38.99	27.24	42.87	37.66
46	1	1	3	1	33.8	53.35	37.51	27	49.37	35.13
47	1	0	0	2	34.39	49.68	39.93	27.21	44.37	37.12
48	1	0	1	2	36.41	54.67	39.53	26.03	47.21	38.01
49	1	0	0	2	32.95	51.32	40.91	27.28	45.14	39.92

Subject No	Group	Gender	Malocclusion	No Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
50	1	0	1	2	25.21	44.73	37.52	25.14	42.74	32.75
51	1	0	2	2	33.38	51.41	37.58	25.64	45.06	35.94
52	1	0	3	2	34.28	49.41	38.83	27.18	44.14	37.98
53	1	0	3	2	27.04	54.88	35.55	25.61	51.11	31.6
54	1	0	3	2	32.93	44.84	30.52	27.4	44.69	36.58
55	1	1	0	2	27.7	43.96	32.6	20.85	39.69	28.61
56	1	1	0	2	33.46	50.76	33.45	25.32	43.89	31.99
57	1	1	1	2	34.58	46.07	41.59	25.9	42.13	38.78
58	1	1	2	2	33.26	49.76	38.48	25.84	44.76	35.26
59	1	1	3	2	29.66	52.13	33.93	22.34	44.3	34.14
60	1	1	2	2	27.65	42.77	32.75	24.6	38.42	31.74
61	1	1	2	2	33.45	50.34	38.5	25.85	44.43	35.09
62	1	1	1	2	30.89	49.52	37.48	25.2	45.42	34.36
63	2	0	0	3	34.23	56.98	37.24	28.77	47.79	33.35
64	2	0	1	3	34.95	50.21	38.48	22.2	43.72	31.07
65	2	0	3	3	31.45	47.68	36.1	25.76	41.34	31.57
66	2	1	0	3	33.21	50.79	36.38	22.09	41.57	32.75
67	2	1	0	3	22.44	48.87	35.5	21.53	43.95	30.78
68	2	1	2	3	36.39	44.58	32.37	25.2	44.36	29.15
69	2	0	0	4	31.17	44.23	35.79	24.88	42.18	31.68
70	2	0	1	4	26.47	45.43	34.54	19.46	44.48	31.73
71	2	0	1	4	33	52.52	36.48	30.03	47.42	35.7
72	2	0	3	4	31.77	38.04	33.25	26.1	40.67	30.04
73	2	0	3	4	31.67	51.2	33.54	26.01	44.06	28.44
74	2	1	1	4	29.96	50.72	36.06	18.93	47.54	28.32
75	2	1	1	4	30.08	49.94	35.74	20.24	46.98	29.88

Subject No	Group	Gender	Malocclusion	No Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
76	2	1	3	4	35.02	48	32.33	27.65	44.46	30.5
77	2	1	3	4	30.96	47.86	34.39	24.79	43.89	31.86
78	2	0	0	5	35.34	46.32	36.54	29.67	42.43	31.67
79	2	0	0	5	31.72	49	34.59	22.93	41.83	32.81
80	2	0	3	5	28.97	46.38	31.03	24.28	44.16	32.37
81	2	0	2	5	31	46.73	32.9	20.95	41.22	29.26
82	2	0	2	5	35.73	51.29	36.81	26.44	47.99	33.85
83	2	0	2	5	35.51	51.26	33.6	23.93	47.39	32.09
84	2	0	2	5	32.56	49.15	35.26	25.87	45.1	34.57
85	2	0	3	5	25.91	48.84	33.57	16.84	47.45	32.1
86	2	1	0	5	29.7	43.19	31.2	26.32	42.47	32.72
87	2	1	0	5	33.96	52.53	39.73	27.02	45.11	35.54
88	2	1	3	5	30.02	44.76	32.13	26.45	43.19	33.07
89	2	1	1	5	34.76	49.23	37.23	27.03	42.32	34.76
90	2	1	2	5	29.58	46.18	32.85	27.74	42.46	32.88
91	2	1	2	5	31.06	47.65	33.46	24.28	43.9	31.98
92	2	1	2	5	28.84	45.28	31.89	27.34	41.98	31.89
93	2	1	3	5	35.21	47.94	33.1	26.45	44.29	34.08
94	3	0	0	6	32.02	47.07	33.72	22.66	49.82	33.39
95	3	0	3	6	34.15	50.84	31.17	23.66	45.21	34.56
96	3	0	2	6	32.95	49.15	37.77	29.96	48.55	37.76
97	3	0	3	6	30.66	42.93	33.92	24.29	42.56	34.54
98	3	1	1	6	24.35	43.76	33.56	19.56	41.32	31.56
99	3	0	0	7	34.93	52.89	37.03	29.3	48.63	35.84
100	3	0	1	7	32.21	44.77	32.39	26.23	42.11	31.58
101	3	0	2	7	29.45	47.45	33.16	26.15	46.14	32.56

Subject No	Group	Gender	Malocclusion	No Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
102	3	0	3	7	35.09	48.81	37.28	24.86	50.18	33.85
103	3	0	1	8	31.46	46.32	35.19	24.56	45.73	32.98
104	3	0	2	8	35.43	51.56	37.54	26.23	48.78	35.1
105	3	1	3	8	27.12	38.21	25.85	24.83	52.31	33.61
106	3	1	3	8	30.12	44.36	31.56	23.45	44.78	31.06
107	3	0	2	9	28.98	49.83	37.51	27.29	47.59	34.57
108	3	1	3	9	31.14	42.98	33.48	24.64	47.65	28.84
109	3	1	0	9	33.13	49.12	34.98	28.72	46.84	30.56
110	3	1	3	9	31.9	42.49	32.05	29.51	43.86	36.49
111	3	1	3	9	32.89	49.25	36.58	27.66	49.29	34.98
112	3	1	0	10	.	41.32	27.1	20.51	40.64	27.26
113	3	0	0	11	32.67	50.76	33.57	30.41	45.23	26.94
114	3	0	3	12	.	43.69	40.31	25.52	43.89	36.14
115	3	1	3	12	32.26	47.3	33.2	23.86	46.74	38.66
116	3	1	2	12	28.94	47.69	33.55	25.23	43.71	31.38
117	3	1	2	12	33.41	46.02	36.18	27.54	42.07	30.02
118	3	0	0	13	32.06	42.8	31.44	28.58	49.39	29.52
119	3	1	1	13	27.75	43.14	30.06	15.31	48.09	26.52
120	3	0	2	14	.	46.85	34.34	23.33	47.17	32.86
121	3	1	2	14	31.47	48.38	32.83	20.73	45.61	29.64
122	3	1	1	15	36.36	46.67	32.57	26.79	42.59	31.2
123	3	1	0	16	31.12	40.54	27.36	20.21	44.38	30.65
124	3	1	2	16	26.62	44.34	37.16	27.62	43.41	32.25

British Subjects – Tooth Dimensions

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
1	11.02	11.8	7.32	7.36	7.99	6.83	9.26	9.31	6.9	7.92	7.4	7.05	11.61	10.98	10.84	11.75	7.48	7.56	7.6	6.31	6.19	6.12	6.35	7.49	7.48	7.37	11.85	10.76
2	10.95	11.08	7.09	7.5	8.24	7.44	9.36	9.43	7.36	8.24	7.64	7.15	11.12	11.02	10.98	11.05	7.93	7.9	7.27	6.31	5.54	5.66	6.48	7.19	8.02	8.27	11.14	11.06
3	10.96	11.29	7.54	7.4	8.74	8.21	9.3	9.28	8.24	8.79	8.07	8.03	11.47	10.95	11.11	12.33	8.32	7.36	7.67	6.76	6.02	6	6.51	7.92	7.46	8.49	12.25	11.25
4	10.35	10.45	6.5	6.85	8.12	7.21	8.92	8.89	7.23	8.48	6.83	7.03	10.56	10.42	10.75	10.82	6.89	6.85	7.18	5.95	5.65	5.61	5.97	7.19	6.84	6.72	10.75	10.64
5	10.74	11.54	7.19	7.18	7.08	6.2	8.44	8.31	6.15	7.12	7.12	7.19	11.15	10.81	10.32	11.48	7.3	7.11	6.73	6.09	5.38	5.45	6.17	6.87	6.97	7.17	11.38	10.43
6	10.93	10.23	6.93	7.19	7.46	7.17	9.26	9.31	6.74	7.52	7.24	6.84	10.18	10.45	11.09	10.96	7.5	6.92	6.62	6.01	5.71	5.82	5.98	6.59	6.86	7.24	10.84	10.98
7	10.72	10.92	7.49	7.85	9.14	6.64	9.3	9.27	7.2	8.97	7.93	7.61	11.01	10.95	11.31	11.65	7.96	8.01	8.06	6.68	5.71	5.79	6.42	8.16	7.93	8.02	11.81	11.46
8	10.41	10.81	7.6	7.58	8.31	7.22	8.44	8.71	7.36	8.36	7.73	7.75	11.01	10.5	10.95	11.35	7.89	7.53	7.12	6.07	5.38	5.25	6.14	7.14	7.47	7.88	11.14	10.98
9	10.46	11.22	7.11	7.24	7.98	6.68	8.61	8.6	6.65	7.85	7.38	7.14	11.13	10.31	11.18	11.6	7.67	7.28	6.73	5.9	5.53	5.44	5.88	6.68	7.29	7.69	11.67	11.04
10	10.36	10.87	7.51	7.88	8.32	6.57	8.57	8.32	6.55	8.26	7.81	7.39	10.81	10.14	10.22	11.24	7.47	7.6	7.16	5.85	5.42	5.45	5.95	7.14	7.55	7.8	11.37	10.13
11	10.51	10.64	6.93	7.02	8.06	6.22	8.72	8.85	5.99	7.82	7.16	6.85	10.59	10.23	11.07	11.33	7.81	7.39	6.92	6.05	5.65	5.7	6.07	6.94	7.26	7.32	11.29	10.98
12	10.81	11.51	7.02	7.12	7.93	7.12	8.5	8.6	6.64	7.86	7.15	7.04	11.46	10.95	10.1	10.33	7.29	7.4	6.84	5.81	5.82	5.9	5.54	6.75	7.39	7.53	10.57	10.25
13	10.26	10.47	7.38	7.3	8.24	6.62	8.23	8.14	6.55	8.13	7.41	7.24	10.48	12.05	11.18	11.39	7.64	7.41	7.14	5.53	5.25	5.3	5.65	7.27	7.38	7.76	11.25	11.31
14	10.12	11.09	7.52	7.18	7.95	7.22	8.88	8.86	6.95	7.82	7.39	7.15	11.1	10.19	10.63	11.58	7.34	7.11	7.16	5.87	5.7	5.65	5.93	7.19	7.05	7.43	11.57	10.56
15	10	10.6	7.03	7.05	8.44	6.88	8.7	8.92	7.13	8.21	7.16	7.14	10.69	10.5	10.6	11.58	7.13	7.25	7.05	5.75	5.74	5.89	5.79	7.12	7.14	7.19	11.42	10.62
16	10.59	10.8	6.71	6.82	7.69	7	8.83	8.45	6.36	7.69	6.68	6.69	10.79	10.62	10.45	10.92	6.72	6.75	6.86	6.09	5.47	5.25	5.79	6.77	6.68	6.78	10.85	10.47
17	9.67	10.43	6.88	7.19	7.9	6.3	8.66	8.58	6.29	7.86	6.97	6.86	10.26	9.53	9.64	11.22	6.82	7.37	6.92	5.68	5.29	5.31	5.78	7.03	7.21	6.96	11.06	10.13
18	11.86	11.44	7.74	7.59	8.25	6.71	9.24	9.33	6.93	8.28	7.77	7.91	11.46	11.48	10.98	11.88	8.05	8.2	7.59	6.85	6.14	6.19	6.98	7.82	8.14	7.98	12.03	11.13
19	10.46	11.18	7.02	7.06	7.64	6.7	8.84	8.87	6.61	7.55	6.98	7.05	11.03	10.64	10.21	11.21	7.8	6.97	6.98	6.28	5.37	5.6	6.45	6.95	7.05	7.51	11.32	10.42
20	10.3	10.39	6.84	6.7	7.33	7.09	8.52	8.41	7.52	7.36	7.08	6.92	10.24	10.29	10.65	10.92	6.95	6.84	7.03	5.75	5.52	5.49	5.74	7.06	6.98	7.06	11.03	10.85
21	10.06	10.87	7.36	7.04	7.84	7.14	8.97	9.1	7.04	7.85	7.12	7.16	10.9	10.23	10.4	11.38	7.54	6.55	6.47	5.59	5.37	5.39	5.61	6.49	6.86	7.32	11.25	10.87
22	10.96	11.21	7.13	7.02	8.77	6.82	8.88	8.89	6.88	8.68	7.5	7.02	11.06	11.02	11.06	11.44	7.68	7.66	7.35	6.28	6	6.02	6.35	7.31	7.53	7.58	11.11	11.03
23	10.02	10.57	6.85	6.8	7.42	6.46	8.41	8.48	6.34	7.6	7.02	6.73	10.42	10.03	9.78	10.52	6.83	6.94	7.13	5.8	5.46	5.33	5.84	6.83	6.96	6.98	10.95	9.88
24	10.02	10.45	7.03	7.01	7.72	6.42	8.98	8.95	6.52	7.75	7.03	6.98	10.35	10.21	10.78	10.98	7.03	7.01	6.98	6.03	5.56	5.65	5.98	6.84	7.05	7.06	10.94	10.41

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
25	10.24	10.38	7.1	7.01	8	6.77	9.37	9.4	6.94	8.13	7.18	7.17	10.27	10.23	10.06	10.88	7.56	7.42	7.31	6.45	5.9	5.84	6.29	7.14	7.39	7.65	10.92	10.34
26	10.3	10.74	6.75	6.94	7.96	6.6	9.13	8.93	6.68	7.79	7.38	7	11.07	10.45	10.53	12.05	7.31	7.24	6.76	5.65	5.22	5.26	5.62	6.8	7.16	7.25	12.12	10.98
27	10.12	10.28	6.45	6.52	7.62	6.12	8.21	8.26	6.21	7.87	6.85	6.76	10.36	10.21	10.14	10.56	7.08	7.11	6.85	5.4	5.4	5.39	5.33	6.95	7.01	7.06	10.51	10.27
28	10.76	11.12	7.48	7.42	8.14	7.41	9.59	9.58	7.3	8.12	7.59	7.33	11.21	10.84	11.46	11.88	7.5	7.68	7.27	6.18	5.77	5.66	6.09	7.33	7.85	7.75	11.88	11.54
29	10.75	11.12	7.29	7.43	8.04	6.69	8.46	8.56	6.57	8.03	7.3	7.13	11.17	10.8	10.89	11.7	7.52	7.39	6.94	5.97	5.46	5.56	6.02	6.96	7.23	7.52	11.66	10.75
30	9.86	10.33	6.86	7.19	7.77	6.8	8.24	8.49	6.88	7.77	6.79	6.43	10.31	10.02	10.55	10.99	7.26	6.96	6.89	6.19	5.53	5.47	6.25	6.83	6.99	7.17	11.17	10.73
31	9.95	10.78	7.31	7.82	7.96	7.11	9.25	9.15	7.14	8.58	7.84	7.23	10.62	9.92	10.13	10.81	7.84	7.8	7.28	6.71	5.96	5.97	6.55	7.67	7.85	7.93	10.95	9.98
32	11.02	12.01	6.35	7.58	7.39	5.1	8.46	8.74	.	7.57	7.19	7.17	12.15	11.05	11.23	11.97	7.57	7.62	7.07	5.63	5.58	5.58	5.72	7.16	7.7	7.58	11.68	11.08
33	9.16	9.96	6.03	5.94	6.22	5.24	7.41	6.9	5.57	6.36	6.26	6.38	8.94	9.2	10.08	10.12	.	6.28	6.28	5.21	5.15	5.14	5.32	6.29	6.24	6.52	10.02	9.98
34	10.06	10.71	6.54	7.39	7.61	5.68	8.72	8.75	6.28	7.6	7.3	6.52	10.78	10.03	11.06	12.13	.	7.36	6.73	5.76	5.56	5.4	5.69	7.3	7.34	7.11	11.53	10.87
35	9.84	11.69	7.4	7.73	8.31	6.78	8.9	9.01	7	8.32	7.92	7.11	11.76	10.21	10.95	11.42	7.88	7.38	7.46	5.56	5.42	.	5.63	7.58	7.4	7.59	11.86	10.98
36	10.98	11.94	6.45	7.95	7.35	5.15	8.47	8.52	.	7.42	7.25	7.18	12.15	11.03	10.95	11.92	7.43	7.58	7.12	5.58	5.52	5.24	5.56	7.18	7.71	7.54	11.69	11.03
37	10.22	11.02	7.18	7.08	8.63	6.81	9	8.83	7.1	8.63	7.11	7.34	11.17	10.02	11.05	11.69	.	7.45	7.34	5.97	5.65	5.46	6.25	7.12	7.73	7.23	11.88	11.08
38	8.38	10.21	.	7.12	7.57	6.74	8.6	9.03	6.63	7.74	7.08	7.06	10.05	9.17	9.74	10.13	7.65	7.38	6.68	6.16	5.89	5.76	6.25	6.65	6.8	7.51	10.83	9.57
39	9.86	10.95	7.11	7.05	8.04	6.96	8.85	8.6	6.98	7.96	7	.	10.94	9.76	10.62	11.12	7.45	7.25	6.92	5.75	5.7	5.75	5.88	6.47	7.29	7.39	11.45	11.07
40	9.21	9.48	6.12	6.52	6.72	4.58	8.59	8.63	.	6.74	6.15	6.25	9.88	9.68	9.45	10.15	6.38	6.75	6.47	5.4	5.41	5.38	5.48	6.36	6.59	6.42	10.21	10.05
41	10.28	9.6	6.28	6.11	7.85	5.96	8.75	9.26	.	7.79	6.87	6.19	9.07	9.8	9.61	10.25	6.51	6.93	6.46	5.52	5.3	5.38	5.57	6.63	6.61	6.39	10.97	10.11
42	9.98	10.06	6.6	6.9	7.97	6.43	8.84	9.05	6.83	8.24	6.63	6.58	10.15	9.84	10.45	11.05	6.95	6.64	6.51	5.75	.	5.59	6.02	6.92	6.7	7.07	11.25	10.64
43	10.15	10.35	6.39	6.27	7.43	5.91	8.35	8.45	5.87	7.43	6.61	6.26	10.44	.	8.93	9.26	6.84	6.58	6.31	5.68	5.15	5.18	5.53	6.07	6.57	6.58	9.54	9.53
44	9.31	9.53	6.02	6.48	6.68	.	8.61	8.59	3.57	6.75	6.12	6.36	9.87	9.67	9.7	10.09	6.35	6.6	6.25	5.39	5.51	5.36	5.46	6.35	6.58	6.54	10.19	10.02
45	9.92	10.14	7.07	7.19	7.81	5.48	9	9.04	.	7.78	7.25	7.05	10.51	10.05	9.81	10.59	7.46	6.64	7.01	6.04	6.01	6.17	6.26	7.04	6.57	7.75	10.62	9.95
46	9.37	9.96	6.47	6.71	7.05	6.31	8.28	8.19	6.52	6.98	6.57	6.53	10.08	9.91	9.83	10.23	.	6.68	6.55	5.45	5.17	5.17	5.52	6.44	6.73	6.75	10.03	9.44
47	10.19	10.87	7.19	7.78	7.72	.	9.15	9.31	.	7.95	7.16	6.91	11	10.23	11.07	11.57	7.72	7.44	7.2	6.83	5.91	5.93	6.78	7.5	7.59	7.89	11.22	10.98
48	10.98	11.16	7.25	7.36	7.99	.	8.7	8.53	.	7.64	7.46	7.4	11.14	10.94	10.54	10.8	7.8	7.31	6.98	5.45	5.77	5.72	5.29	6.8	7.29	7.36	10.58	10.76
49	10.14	10.38	6.82	7.2	7.85	6.46	9.04	9	5.29	7.9	7.29	6.69	10.18	10.15	10.42	10.54	.	6.88	7.09	6.23	5.63	5.62	5.96	6.9	7.02	.	10.69	10.52
50	10.43	12.25	6.94	7.01	7.25	.	8.16	8.04	.	7.31	7.34	6.72	11.18	10.85	11.01	11.46	7.27	7.71	6.57	6.16	5.51	5.49	6.23	6.61	7.25	7.49	11.36	10.97

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
51	10.23	10.74	6.86	7.79	8.22	6.03	9.01	9.13	5.1	8.12	7.01	6.67	10.13	10.25	10.05	9.7	.	7.57	6.91	5.72	5.47	5.81	5.95	6.76	7.51	.	9.58	10.02
52	10.08	10.92	7.18	7.48	7.74	.	9.1	9.25	.	7.8	7.18	6.95	10.98	10.18	10.98	11.32	7.65	7.42	7.13	6.88	5.91	5.89	6.85	7.41	7.58	7.91	11.15	10.92
53	10.37	10.95	6.94	7.06	8.08	.	8.44	8.16	.	7.95	7	6.51	10.45	10.25	10.71	11.53	7.92	7.96	6.61	5.98	5.29	5.27	5.87	6.8	7.53	7.62	11.55	10.97
54	9.56	10.53	7.26	7.15	6.67	.	8.79	8.79	.	6.78	7.12	7.3	10.55	9.55	10.56	11.31	7.11	7.02	6.11	5.68	5.48	5.35	5.59	6.02	6.78	5.82	11.16	10.57
55	9.83	10.29	7.24	6.56	7.89	.	8.04	7.97	.	7.62	6.55	7.14	9.91	9.2	10.15	10.2	7.06	6.4	6.01	5.34	4.98	5.11	5.58	6.26	6.72	6.98	10.97	10.2
56	8.91	9.41	.	6.81	7.86	6.8	8.79	8.83	6.79	7.8	6.75	6.8	9.2	8.81	9.26	9.66	.	6.39	6.86	6.37	5.84	5.61	6.43	6.84	6.87	7.11	9.53	9.85
57	9.95	10.13	6.84	6.64	7.65	6.92	9.25	9.5	7.48	7.74	6.63	6.8	9.68	9.3	10.02	10.07	.	6.95	6.87	6.23	5.72	5.45	6.12	6.63	7.02	.	10.42	10.08
58	9.98	9.59	6.89	7.15	7.68	6.54	8.51	8.24	6.25	7.81	7.06	6.53	9.78	8.84	10.15	10.25	.	7.43	6.85	5.71	5.06	5.08	5.82	6.91	7.28	.	10.28	10.15
59	10.38	10.45	6.53	6.83	7.17	5.99	7.9	7.95	5.94	7.71	6.64	6.39	10.18	9.72	10.07	10.8	.	6.48	6.63	5.42	5.36	5.06	5.72	6.36	6.88	.	10.94	10.62
60	8.15	9.68	6.63	6.9	6.98	.	7.61	7.46	.	6.93	7.18	6.16	9.84	9.46	10.2	10.5	6.61	6.68	6.61	5.69	4.92	4.52	5.27	6.46	6.92	6.61	10.42	9.95
61	9.16	9.34	6.68	7.09	7.65	6.58	8.49	8.23	6.35	7.75	7.07	6.51	9.8	8.89	10.17	10.32	.	7.42	6.82	5.73	5.08	5.18	5.95	6.9	7.2	.	10.22	10.12
62	9.3	9.48	6.57	6.44	6.44	.	7.93	7.84	.	6.67	6.77	6.37	9.91	9.54	10.26	10.36	7.1	7.06	6.19	5.21	5.24	5.18	5.1	5.95	6.67	6.72	10.34	10.45
63	11.42	11.62	6.99	7.28	8.03	.	8.28	8.29	.	7.98	7.12	6.93	11.35	11.26	11.48	11.02	6.8	6.88	6.99	5.9	5.59	5.49	5.67	6.82	6.97	.	11.49	11.36
64	9.53	10.47	6.48	6.77	7.71	.	9.41	9.38	.	7.59	7.15	6.55	10.07	9.58	10.23	10.35	6.99	7.23	6.69	5.7	5.4	.	5.44	6.91	7	6.92	10.58	10.28
65	10.05	10.45	7.14	7.13	7.03	5.38	8.18	8.19	.	7.15	7.16	7.19	10.69	10.18	10.45	11.14	.	7.15	5.87	5.66	5.61	5.5	6.32	5.64	7.12	.	11.2	10.56
66	9.64	10.15	6.98	6.95	7.02	.	8.05	7.95	.	7.15	6.85	6.8	10.2	10.14	10.05	10.54	.	6.93	6.45	5.54	5.13	5.19	5.62	6.87	6.84	6.88	10.63	10.47
67	9.72	10	6.43	6.44	7	.	8.08	8.12	.	7.3	6.4	6.57	10.29	9.02	9.63	10.94	6.52	6.85	5.85	5.4	5.3	5.18	5.4	5.66	6.34	.	10.99	10.22
68	8.53	8.74	.	5.96	7.08	4.43	7.1	6.98	4.88	6.94	6.27	.	9.57	8.72	8.97	9.59	6.09	6.11	6.54	5.09	.	5.06	4.97	6.59	6.17	6.09	9.54	9.41
69	9.46	10.92	7.33	7.47	8.22	.	9.02	9.05	.	8.03	7.47	6.68	10.73	9.69	10.48	11.22	.	7.42	6.78	5.67	5.93	5.76	5.61	6.66	7.33	.	11.42	10.33
70	9.86	10.16	.	6.41	7.18	5.39	7.59	7.52	5.22	7.28	6.2	.	10.32	9.75	9.82	10.44	.	6.64	6.14	5.27	4.79	4.82	5.34	6.02	6.31	.	10.51	9.98
71	10.95	11.76	.	7.15	7.78	6.43	9.12	8.9	6.56	7.86	7.36	.	11.68	10.84	10.26	10.43	.	7.27	7.2	6.31	5.96	5.7	6.37	7.27	7.55	.	10.26	10.2
72	9.54	9.56	.	7.17	7.84	7.06	7.96	8.06	7.04	7.75	7.07	.	9.97	9.34	10.95	9.89	.	7.15	6.82	5.37	4.81	4.79	5.41	6.5	7.22	.	9.82	10.48
73	6.49	10.19	6.71	6.65	7.68	.	7.53	7.69	.	7.6	6.9	6.26	10.34	10.22	10.08	10.36	7.01	6.45	6.41	4.82	.	.	5.02	6.64	6.85	6.77	10.16	9.92
74	10.2	10.61	6.89	7.06	7.46	.	7.96	7.98	.	7.81	7.04	6.95	10.45	10.34	10.5	10.43	7.02	7.18	6.73	5.46	.	.	5.46	6.23	7.23	7.29	10.62	10.11
75	10.03	10.58	6.68	7.03	7.23	.	7.98	7.96	.	7.73	7.01	6.98	10.45	10.12	10.34	10.48	7.02	7.05	6.93	5.34	.	.	5.29	6.42	7.02	7.16	10.57	10.39
76	9.14	9.4	6.56	6.71	6.5	.	7.64	7.35	.	6.45	6.79	6.66	9.82	9.27	10.5	10.3	6.7	6.88	5.82	5.14	.	.	4.62	5.84	7.08	6.95	10.45	10.3

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
77	9.3	9.8	6.18	6.38	6.95	.	7.08	7.26	.	7.16	6	.	9.55	8.74	9.83	10.23	6.95	6.21	6.04	5.27	4.59	4.61	5.5	6.16	.	6.55	10.07	9.33
78	10.42	11.23	.	.	7.96	7.08	8.54	8.38	7.03	8.09	.	.	11.44	10.39	10.95	11.87	7.5	7.38	7.32	6.05	5.78	5.71	6.01	7.25	7.39	.	11.58	11.02
79	9.63	10.18	6.7	6.75	7.62	.	7.41	7.4	.	7.61	6.43	6.35	10.17	9.87	10.45	11.01	7.19	7.19	6.77	5.8	.	.	.	4.61	7.1	6.69	11.22	9.79
80	8.54	10.2	.	6.23	7.45	6.41	8.48	9.03	6.63	7.69	6.56	6.51	10.02	9.4	9.84	11.08	7.53	6.83	6.58	.	.	.	.	6.76	6.8	7.68	11.06	9.96
81	9.69	9.98	5.83	6.09	7.33	.	7.75	7.65	.	7.37	6.39	.	10.35	10.11	10.66	9.61	.	6.66	6.31	5.04	4.6	4.72	4.88	6.35	6.56	.	9.95	10.34
82	9.06	10.12	6.72	6.36	6.94	5.56	8.25	8.4	5.38	6.78	6.15	6.27	9.38	9.68	.	9.32	6.61	6.23	6.11	.	.	.	5.33	6.09	6.28	6.56	9.79	.
83	9.64	10.26	.	6.1	7.27	5.89	7.51	7.33	5.91	7.52	.	.	10.45	9.45	10.05	10.62	.	6.82	6.38	5.31	5.1	4.94	5.28	6.28	6.68	.	10.39	10.02
84	10.23	11.59	.	6.93	7.62	6.17	8.4	8.49	6.15	7.6	7.03	.	11.08	10.32	10.54	11.75	.	.	6.76	5.05	5.06	5.06	5.05	6.72	7.02	.	11.08	10.61
85	10.14	10.72	6.68	6.66	7.32	.	8.73	8.62	.	7.17	6.51	6.4	10.58	10.24	10.45	10.65	.	6.66	6.37	5.32	5.15	.	.	6.68	6.77	7.03	10.59	10.51
86	9.66	10.06	.	.	7.57	5.13	8.47	8.39	5.02	7.37	.	.	10.24	9.42	10.54	10.88	.	6.75	6.61	5.5	5.27	5.32	5.68	6.62	6.53	7.33	10.8	10.71
87	9.91	10.12	.	.	7.34	6.27	7.87	7.97	6.17	7.54	.	.	10.46	9.91	10.6	10.74	.	7.3	6.34	5.2	5.19	5.15	5.22	6.58	6.7	6.91	10.47	10.01
88	9.59	9.98	.	.	7.23	5.29	8.43	8.46	5.21	7.42	.	.	10.18	9.32	10.21	10.89	6.94	6.73	6.59	5.49	5.21	5.28	5.51	6.62	6.45	.	10.75	10.51
89	9.92	10.08	.	6.94	7.26	6.25	7.9	7.96	6.25	7.19	6.71	.	10.28	9.98	10.24	10.45	.	7.19	6.28	5.16	5.17	5.13	5.21	6.33	6.72	.	10.34	.
90	8.15	9.71	6.19	6.94	7.09	.	8.08	7.97	.	7.1	6.68	5.89	9.74	8.45	9.87	9.89	6.6	7.46	6.44	5.47	.	.	5.54	6.45	6.44	6.47	10.37	.
91	8.7	9.86	.	5.76	6.43	4.24	7.79	7.9	3.81	6.54	.	.	9.88	8.87	10.01	10.6	.	6.32	5.83	5.06	4.78	4.63	5.22	5.53	5.78	.	10.48	10.05
92	8.59	9.98	6.26	6.94	7.1	.	8.03	7.93	.	7.13	6.63	6.69	9.96	8.73	.	9.99	6.85	6.94	6.45	5.32	.	.	5.39	6.49	6.78	6.58	10.45	9.94
93	10.95	10.98	.	6.56	7.53	6.58	8.62	8.47	6.31	7.67	.	.	10.95	10.95	10.42	10.85	7.23	6.56	6.65	5.85	5.43	5.37	5.92	6.66	.	.	10.75	10.71
94	9.48	10.47	.	6.25	7	4.61	7.44	7.49	4.71	7.02	6.56	5.95	10.55	9.47	.	10.61	.	6.29	6.49	4.78	.	.	4.87	6.33	6.47	.	10.25	10.08
95	11.15	11	.	6.89	8.28	6.64	8.48	8.84	6.82	8.26	6.95	.	11.28	10.84	10.78	10.89	.	.	7.52	6.29	5.44	5.5	6.19	7.35	.	.	10.95	10.86
96	10.24	10.75	.	.	7.84	6.76	8.61	8.62	6.36	7.92	.	.	10.99	10.14	10.45	10.89	.	7.12	7.02	6.05	5.22	5.37	5.94	7.12	7.21	.	10.53	10.15
97	.	10.03	.	5.79	6.88	5.53	6.67	6.67	5.56	6.6	6.05	5.62	9.9	8.93	.	9.66	.	5.92	5.95	5.19	4.95	4.47	4.92	5.82	6.1	.	9.85	.
98	9.28	9.55	.	5.95	6.79	.	7.81	7.85	.	6.55	6.2	.	9.47	9.74	9.57	10.09	.	6.66	6.02	5.34	4.69	4.91	4.83	5.99	6.41	.	10.36	10.08
99	9.52	10.93	.	7.34	8.59	6.69	8.54	8.57	6.49	8.49	.	.	10.53	9.7	11.2	11.27	.	.	7.1	5.89	5.78	5.26	5.71	7.24	.	.	11.01	10.47
100	10.3	10.53	.	.	8.36	5.19	8.4	8.24	.	8.55	.	.	10.34	10.25	10.14	10.32	.	6.98	7.03	5.98	5.13	5.14	5.75	6.89	6.74	.	10.25	10.19
101	8.77	10.52	.	.	6.9	5.51	7.68	7.67	5.49	6.8	.	.	10.34	9	9.77	10.48	.	7.04	6.35	5.53	5.5	.	5.3	6.44	7.05	.	10.36	10.2
102	.	9.82	5.59	6.03	7.09	5.59	7.5	7.5	6.39	7	6.11	5.35	9.53	.	.	10.49	5.75	6.55	6.27	.	.	.	5.3	6.34	6.47	6.4	10.66	.

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
103	.	10.67	.	6.59	7.69	5.38	7.33	6.69	5.85	7.62	.	.	10.64	9.51	.	10.67	.	7.02	6.88	5.73	5.3	4.53	5.04	7.08	6.95	.	11.18	.
104	.	10.45	.	.	7.59	6.63	7.58	7.79	6.43	7.74	.	.	10.04	.	9.87	11.12	.	6.76	6.45	5.34	5.21	5.31	5.42	6.83	6.93	.	10.85	9.89
105	.	10.92	.	6.55	7.5	.	8.49	8.54	.	7.47	6.72	.	10.78	.	10.58	11.98	7.27	7.37	6.86	5.79	5.43	5.43	5.88	6.92	7.25	.	10.57	.
106	8.43	8.68	5.88	5.73	5.79	.	7.21	6.94	.	5.61	5.93	5.48	8.72	8.14	8.13	9.26	.	.	5.8	.	.	4.68	.	5.94	5.55	.	9.05	8.2
107	.	9.05	5.64	5.73	5.66	.	8.48	8.35	.	5.86	5.91	.	9.53	.	.	10.07	6.01	6.11	5.42	.	5.12	.	5.32	5.07	6.15	6.44	10.21	.
108	.	8.82	.	5.14	6.59	.	6.68	6.7	.	6.7	5.33	.	8.12	.	.	8.9	5.53	5.65	5.35	4.86	4.6	4.3	4.83	5.41	.	5.5	8.7	.
109	8.5	9.71	.	.	7.5	6.1	7.51	7.32	6.09	7.51	.	.	9.88	8.51	9.76	10.68	.	.	6.1	5.7	.	.	4.75	5.98	6.53	.	10.38	9.84
110	10.44	10.47	.	.	7.15	.	7.82	7.91	.	6.68	6.02	.	10.29	10.11	10.53	9.93	.	.	6.36	4.68	4.74	4.77	4.67	6.46	.	.	9.73	10.02
111	.	9.07	.	6.2	6.69	.	7.45	7.37	.	6.85	6.43	.	9.03	.	.	10.13	6.41	6.67	5.95	5.15	.	5.47	5.45	6.03	6.36	6.68	10.24	.
112	10.05	9.8	.	6.56	.	.	8.42	8.37	5.21	7.08	.	.	9.72	9.57	.	10.1	.	7	5.96	5.47	4.86	4.9	5.23	6.12	.	.	9.25	.
113	.	9.08	.	6.61	7.18	5.71	8.8	8.22	6.15	7.16	6.63	.	9.56	.	.	10.4	6.56	6.15	6.48	.	.	.	.	6.51	6.24	.	10.01	.
114	.	10.25	6.24	6.19	.	.	8.32	8.41	.	.	6.3	6.41	10.29	.	.	10.61	.	6.51	7.01	5.36	.	.	5.4	6.81	.	6.45	10.61	.
115	.	7.74	5.33	6.45	7.1	.	8.1	8.21	.	7.25	5.85	5.87	7.71	.	.	9.23	.	6.41	6.05	.	.	.	.	5.98	5.87	.	8.91	.
116	.	8.54	.	6.24	6.7	.	7.66	7.34	.	6.91	6.29	.	8.58	.	.	10.34	.	.	6.2	5.35	4.82	4.79	5.34	6.38	.	.	10.22	.
117	.	9.22	.	6	7.25	.	7.44	7.15	.	7.33	5.94	.	9.61	.	.	10.24	.	.	6.33	5.49	5.18	5.12	5.7	5.97	.	.	10.02	.
118	.	8.4	.	.	6.03	4.57	6.95	6.87	4.76	6.25	.	.	8.66	.	.	9.87	.	.	6.27	4.38	.	4.3	4.74	6.08	.	.	9.42	.
119	.	9.39	.	5.73	6.48	.	6.37	6.67	.	6.37	4.95	.	8.9	.	9.4	9.46	.	.	4.89	.	.	.	4.78	5.77	.	.	9	9.1
120	.	10.22	.	6.31	.	.	7.36	7.46	.	7.16	6.18	.	10.34	10.06	.	10.55	.	6.87	6.48	.	.	.	.	6.58	6.89	.	10.69	.
121	.	9.72	.	.	6.9	.	8.34	8.26	.	6.92	.	.	9.7	.	.	10.05	.	.	6.75	5.36	5.05	4.88	5.15	6.49	.	.	10.08	.
122	.	8.92	.	.	6.22	.	6.96	6.93	.	6.24	.	.	9.74	.	11.13	10.54	.	.	6.42	4.84	.	.	4.73	6.3	.	.	10.72	.
123	.	9.09	.	.	6.42	.	7.29	7.11	.	6.68	.	.	9.18	.	.	10.09	.	6.19	5.65	.	.	.	.	6.1	6.22	.	10.21	.
124	.	8.94	.	.	7.42	.	7.74	7.71	.	7.35	.	.	9.25	8.92	.	9.85	.	.	6.22	4.7	.	.	.	5.76	.	.	9.87	.

RAW DATA

South Asian Subjects – Arch Dimensions

Subject No	Group	Gender	Malocclusion	Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
125	0	0	0	0	35.01	58.11	43.46	29.33	51.09	38
126	0	0	0	0	30.48	52.42	38.37	26.49	51.47	31.19
127	0	0	0	0	33.85	48.93	41.88	26.19	41.97	38.39
128	0	0	0	0	30.88	42.4	38.77	28.51	46.91	33.53
129	0	0	1	0	29.57	48.24	38.39	24.8	44.96	33.86
130	0	0	1	0	32.3	51.61	39.98	24.15	44.77	37.81
131	0	0	1	0	30.37	44.69	37.47	24.12	43.92	29.48
132	0	0	1	0	31.39	51.16	40.31	25.22	45.82	35.65
133	0	0	2	0	33.98	53.29	43.13	24.3	48.83	37.86
134	0	0	2	0	32.47	52.27	37.66	27.14	44.04	33.23
135	0	0	2	0	37.29	52.81	36.9	27.29	46.91	36.58
136	0	0	2	0	27.07	41.58	37.29	25.14	44.59	30.23
137	0	0	3	0	35.69	50.04	37.79	29.24	48.66	35.3
138	0	0	3	0	33.97	49.47	41.9	26.51	45.03	38.13
139	0	0	3	0	33.31	47.63	41.75	29.97	43.39	37.92
140	0	0	3	0	33.52	52.14	39.56	26.11	44.95	34.45
141	0	1	0	0	32.55	51.01	42.06	23.11	43.73	36.16
142	0	1	0	0	33.27	49.6	33.68	26.55	42.37	33.48
143	0	1	0	0	30.76	50.44	41.29	26.13	47.02	34.65
144	0	1	0	0	31.58	47.99	37.27	28.81	46.52	32.25
145	0	1	1	0	31.24	45.88	39.99	26.04	43.25	35.55
146	0	1	1	0	32.08	44.92	38.5	26.8	43.07	33.21
147	0	1	1	0	33.53	45.86	41.06	24.14	41.41	34.53
148	0	1	1	0	31.36	47.41	40.59	28.18	42.69	32.42

Subject No	Group	Gender	Malocclusion	Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
149	0	1	2	0	34.74	52.93	42.47	24.62	42.58	34.93
150	0	1	2	0	38.06	50.97	39.53	23.16	42.51	35.1
151	0	1	2	0	32.9	50.22	42.34	23.11	42.46	35.45
152	0	1	2	0	28.91	47.33	35.24	25.21	39.78	29.62
153	0	1	3	0	33.46	49.82	40.75	27.19	42.42	35.8
154	0	1	3	0	31.91	47.19	38.9	24.39	49.16	32.15
155	0	1	3	0	37.21	52.71	40.5	31.49	46.07	37.98
156	1	0	0	1	33.06	56.9	34.25	27.81	48.34	30.52
157	1	0	0	1	29.27	41.08	37.26	25.57	42.12	32.55
158	1	0	0	1	35.12	50.14	39.84	25.12	43.52	36.85
159	1	0	1	1	34.77	50.21	39.86	24.18	43.89	35.97
160	1	0	3	1	29.03	49.99	29.25	27.81	44.1	33.11
161	1	1	0	1	28.51	50.6	38.22	25.39	42.29	33.62
162	1	1	1	1	35.31	51.23	36.92	24.4	41.26	32.38
163	1	1	1	1	31.53	48.2	40.9	24.35	44.66	38.53
164	1	1	2	1	32.8	45.99	32.45	23.6	41.68	31.72
165	1	1	2	1	33.1	44.74	29.67	23.59	46.12	29.96
166	1	1	2	1	32.19	45.12	30.76	24.12	45.98	29.42
167	1	0	0	2	33.86	53.94	34.67	24.67	44.95	33.2
168	1	0	1	2	32.29	51.41	43.28	27.47	43	30.61
169	1	0	1	2	31.87	51.79	40.26	24.02	46.49	34.73
170	1	0	1	2	32.65	49.97	43.18	24.3	43.6	34.35
171	1	0	2	2	33.45	48.85	42.85	24.17	44.15	35.14
172	1	0	2	2	32.15	47.58	42.15	25.19	45.98	34.87
173	1	0	2	2	32.81	48.09	33.87	29.82	41.45	34.88
174	1	0	1	2	39.26	41.61	54.66	24.76	46.7	35.41

Subject No	Group	Gender	Malocclusion	Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
175	1	0	3	2	28.81	47.63	33.45	23.14	46.63	31.72
176	1	0	3	2	29.15	46.59	39.2	25.14	47.59	34.15
177	1	0	3	2	31.84	51.74	41.26	24.85	45.85	36.77
178	1	1	0	2	27.97	47.61	32.33	27.03	43.5	33.72
179	1	1	0	2	28.72	46.33	36.09	23.17	44.38	33.45
180	1	1	0	2	30.15	45.9	33.12	24.64	43.52	32.48
181	1	1	1	2	29.24	41.74	35.66	26.12	43.06	33.42
182	1	1	1	2	31.57	49.33	38.19	27.38	45.6	34.32
183	1	1	3	2	29.69	45.58	31.24	24.77	38.3	31.56
184	1	1	3	2	24.44	49.26	30.02	25.98	44.43	31.4
185	1	1	3	2	30.02	45.21	31.05	25.03	37.28	32.02
186	1	1	3	2	24.44	49.25	30.15	25.5	44.31	31.17
187	2	0	0	3	33.11	49.6	36.91	26.25	44.64	30.58
188	2	0	1	3	36.25	55.2	41.21	23.52	49.19	33.6
189	0	0	1	3	32.24	53.8	42.75	24.75	48.95	32.56
190	2	0	2	3	32.52	46.97	35.22	25.8	43.7	34.67
191	2	0	3	3	32.78	48.45	34.37	29.43	49.33	32.7
192	2	1	0	3	34.92	51.54	34.73	27.27	46.21	31.71
193	2	1	0	3	26.46	49.32	34.64	27.9	45.1	34.5
194	2	1	0	3	31.29	49.73	33.2	23.92	46.78	32.13
195	2	1	0	3	23.48	45.78	39.14	27.96	41.1	35.17
196	2	1	3	3	30.6	49.58	33.13	25.91	46.62	32.25
197	2	1	3	3	28.91	43.83	28.64	29.7	45.4	39.97
198	2	0	0	4	33.34	46.31	35.08	23.39	45.76	29.72
199	2	0	1	4	34.63	45.43	35.03	25.68	45.13	31.31
200	2	0	2	4	38.79	51.84	41.23	25.1	45.47	38.64

Subject No	Group	Gender	Malocclusion	Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
201	2	0	3	4	31.23	45.46	33.08	24.07	42.42	30.43
202	2	0	0	4	33.58	49.63	37.29	24.89	45.38	32.93
203	2	1	0	4	29.84	49.35	33.65	25.94	45.56	30.45
204	2	1	1	4	29.72	46.13	38.67	29.58	41.91	35.04
205	2	1	1	4	34.24	44.99	36.01	29.63	40.35	30.64
206	2	1	1	4	33.67	46.06	39.46	25.91	41.69	33.61
207	2	1	2	4	31.82	47.15	37.06	19.92	37.08	35.11
208	2	1	2	4	31.54	46.79	31.92	21.17	43.37	27.99
209	2	1	3	4	33.14	46.67	32.84	29.05	46.54	32.16
210	2	0	0	5	36.57	48.75	36.75	28.18	42.04	31.56
211	2	0	0	5	31.76	50.05	37.08	22.4	43.9	37.63
212	2	0	1	5	35.8	51.49	36.08	26.28	45.78	33
213	2	0	2	5	30.26	51.24	38.49	21.65	42.4	26.81
214	2	0	2	5	31.29	41.67	35.62	20.42	39.61	33.22
215	2	0	3	5	33.89	48.37	37.7	25.13	44.71	32.79
216	2	1	1	5	29.85	48.25	36.13	27.71	44.21	31.26
217	2	1	2	5	33.16	48.95	35.86	25.9	43.25	32.45
218	3	0	3	6	37.36	47.34	30.54	29.22	48.45	31.78
219	3	0	3	6	30.67	37.31	30.15	22.29	43.29	31.57
220	3	0	3	6	33.25	44.21	33.19	25.42	44.32	31.59
221	3	1	0	6	32.34	42.15	30.45	25.16	43.29	25.79
222	3	1	0	6	27.12	45.39	34.04	21.56	41.34	30.45
223	3	1	0	6	31.51	43.83	31.86	24.27	43.24	31.75
224	3	1	2	6	30.04	49.23	40.36	24.08	42.26	36.93
225	3	1	2	6	29.05	47.59	35.11	26.61	43.02	31.6
226	3	1	1	7	31.89	46.07	39.4	26.35	40.54	34.72

Subject No	Group	Gender	Malocclusion	Missing	Up ICW	Up IMW	Up AL	Lr ICW	Lr IMW	Lr AL
227	3	0	0	8	30.47	45.72	34.91	23.81	42.98	30.91
228	3	0	3	8	29.8	42.77	27.42	23.45	45.4	29.35
229	3	0	1	8	35.4	49.64	38.69	25.68	45.17	30.68
230	3	0	3	8	29.94	45.67	32.56	25.76	45.98	32.84
231	3	1	1	8	33.5	42.32	29.99	25.16	40.88	25.12
232	3	1	2	8	30.09	46.33	31.75	24.72	39.74	31.43
233	3	1	3	8	29.36	39.87	28.78	23.75	40	28.84
234	3	1	3	8	.	44.56	32.02	23.12	44.65	31.05
235	3	0	0	9	27.76	42.79	32.61	24.71	39.54	33.45
236	3	0	2	9	36.38	49.42	29.84	19.84	44.69	29.94
237	3	1	3	9	32.89	48.78	31.91	25.23	49.64	28.6
238	3	0	3	10	32.19	45.38	32.17	25.9	46.89	32.56
239	3	1	1	10	33.68	46.98	30.85	19.06	42.85	30.75
240	3	1	2	10	32.62	49.5	29.66	18.71	44.74	28.74
241	3	1	3	10	26.47	38.07	27.88	19.07	41	30.82
242	3	0	1	11	31.29	43.62	33.9	23.92	44.16	30.53
243	3	0	1	11	35.01	49.17	41.19	15.05	44.56	34.88
244	3	0	0	12	34.08	47.86	38.41	30.84	49.95	35.5
245	3	0	0	12	35.65	52.68	40.37	21.52	46.9	37.31
246	3	1	2	12	29.99	44.77	31.73	24.45	41.29	30.23
247	3	1	0	14	33.55	47.94	39.73	25.38	44.52	31.52
248	3	0	2	18	34.27	49.82	31.77	30.69	49.07	34.63

Tooth Dimensions – South Asian Subjects

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
125	11.94	12.04	7.98	8.17	9.07	7.03	9.17	9.06	6.89	9.27	8.28	8.02	11.92	11.91	12.37	12.34	8.49	8.46	8.13	6.81	5.36	5.43	6.71	8.21	8.52	8.48	12.47	12.36
126	10.31	10.5	6.64	6.68	7.83	5.85	8.9	9.76	6.35	7.86	7.13	6.83	10.43	10.35	10.97	12.07	7.27	7.36	7.05	6.18	5.9	6.06	6.26	6.98	7.55	7.45	12.16	10.96
127	10.74	10.21	7.01	7.43	7.79	7.37	9.23	9.2	7.18	7.86	8.15	7.33	10.61	10.73	10.79	11.81	7.51	8.09	6.99	5.45	5.26	5.28	5.62	7.01	8.08	7.91	11.85	10.89
128	10.58	10.81	6.64	7.17	8.07	7.3	8.68	8.55	7.64	8.02	7.03	7.12	11.28	11.15	11.38	12.39	7.77	6.75	7.13	6.06	5.73	5.7	6.2	7.23	7.28	7.63	12.15	11.6
129	9.45	9.6	7.62	7.44	8.34	6.48	9.02	8.95	6.95	8.03	7.43	7.27	9.56	9.41	9.97	10.97	7.23	7.49	7.04	5.72	5.54	5.57	5.71	6.93	7.3	7.28	10.92	9.76
130	9.68	10.94	7.22	7.61	7.94	7.54	9.71	9.72	7.17	7.84	7.5	7.01	10.98	9.83	10.14	11.41	7.92	7.93	7.15	6.64	5.88	6.08	6.52	7.31	7.68	7.87	11.33	10.29
131	10.29	10.45	6.9	7.24	7.85	6.29	8.25	8.24	6.57	7.69	7.59	6.83	10.5	10.21	10.5	10.61	7.24	6.98	7.01	5.62	5.07	5.06	5.6	7.02	6.93	7.09	10.43	10.37
132	10.98	11.24	7.62	7.39	8.58	7.28	9.31	9.28	6.58	8.56	8.01	7.7	10.98	10.95	10.93	11.52	7.95	7.69	7.43	6.23	5.75	6.01	6.43	7.24	7.99	8.24	11.75	11.06
133	10.98	11.02	6.95	7.89	9.16	7.62	9.19	9.05	7.33	8.81	7.98	7.54	11.26	11.06	11.42	11.91	7.76	7.83	7.63	6.35	6	6.03	6.24	7.74	7.96	7.98	12.08	11.93
134	10.36	10.37	7.13	7.18	8.09	7.23	8.62	8.43	7.33	8.1	7.32	7.23	10.93	10.38	10.01	11.21	7.58	7.53	7.12	5.92	5.3	5.27	5.84	7.04	7.35	7.73	11.4	10.14
135	11.21	10.76	7.04	7.18	8.23	7.3	9.13	8.95	7.1	7.95	7.26	6.91	10.84	11.28	10.55	10.47	7.47	7.26	7.28	5.91	5.31	5.33	5.93	7.3	7.46	7.59	10.36	10.45
136	9.86	9.93	6.78	6.59	7.69	6.16	9.26	9.36	6.14	7.63	6.79	6.55	10.19	9.98	10.77	11.65	7.08	7.16	7.1	6.35	6.16	6.09	6.27	7.02	7.35	7.36	11.58	10.64
137	10.61	11.17	7.36	7.45	8.5	7.99	8.92	8.96	7.66	8.26	7.38	7.08	11.31	10.61	11.28	12.11	8.09	8.02	7.86	6.1	5.31	5.62	5.85	7.87	7.62	7.86	12.13	11.42
138	10.71	11.38	7.81	8.29	9.11	7.64	9.48	9.8	7.65	9.03	8.03	7.79	11.48	11.02	11.69	11.8	8.23	8.56	8.41	6.75	6.47	6.39	7.03	8.27	8.47	8.3	12.1	11.48
139	10.39	11.55	6.69	7.92	7.83	7.82	9.7	9.73	7.75	8.07	7.37	7.75	11.74	11.13	10.6	12.51	7.11	7.79	7.9	6.66	6.16	6.07	6.56	7.7	7.85	7.78	12.57	10.16
140	10.12	11.11	6.94	6.97	8	7.27	9.4	9.36	7.25	8.05	7.08	7.5	10.32	10.22	11.42	11.76	7.5	7.58	7.67	6.41	5.66	5.85	6.62	7.72	7.59	7.63	11.78	11.59
141	9.49	10.44	6.89	7.23	8.2	7.35	8.42	8.56	7.42	8.53	7.43	7.31	10.47	9.46	10.52	10.7	7.33	7.66	7.49	5.79	5.4	5.49	5.94	7.37	7.56	7.68	11.28	10.78
142	9.7	10.15	6.22	6.51	7.56	6.41	8.28	8.19	6.36	7.41	6.74	6.49	10.05	9.68	10.42	10.81	6.88	7.12	6.45	5.72	5.16	5.21	5.85	6.51	7.07	7.13	10.75	10.14
143	10.16	10.75	7.27	7.71	8.02	6.72	9.22	9.19	6.65	7.98	7.54	7.43	10.85	10.45	10.01	10.87	7.62	7.49	7.01	5.55	5.5	5.56	5.53	6.94	7.42	7.68	10.65	10.45
144	9.76	10.41	7.05	7.06	7.85	6.65	8.14	8.13	7.07	7.74	7.12	7.09	10.35	9.98	10.05	10.57	7.34	7.33	6.98	5.93	5.09	5.12	5.99	6.95	7.28	7.15	10.65	10.12
145	10.12	10.6	7.42	7.24	7.86	7.17	9.47	9.72	7.56	7.72	7.51	7.05	10.89	10.14	10.41	11.76	7.47	7.67	7.6	6.66	6.12	6.14	6.99	7.21	7.71	7.45	12.24	10.42
146	9.54	10.54	6.6	6.92	7.92	7.32	8.34	8.44	7.13	7.79	6.98	7.07	10.75	9.69	10.7	11.73	7.41	7.22	6.89	5.76	5.64	5.65	5.75	6.82	7.22	7.56	11.95	10.56
147	10.56	10.94	6.98	6.95	7.45	6.32	9.1	9.15	6.25	7.68	6.92	6.75	10.83	10.47	10.21	10.77	7	7.37	6.67	6.06	5.72	5.54	6.09	6.71	7.21	7.01	10.86	10.31
148	9.91	10.41	7.02	7.23	8.05	7.17	9.03	9.01	7.16	8.13	7.12	7.09	10.49	9.71	10.51	10.95	7.26	7.03	7.23	5.79	5.56	5.57	5.83	7.29	7.06	7.35	10.98	10.49

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
149	10.15	10.42	7.62	7.54	8.09	7.24	8.52	8.6	7.58	8.03	7.88	7.35	10.63	10.25	10.68	11.85	8.08	7.64	6.79	6.29	5.35	5.32	6.2	6.77	7.6	8.06	11.81	10.96
150	10.24	10.44	6.98	7.74	8.19	7.53	9.77	9.5	7.54	8.09	7.95	6.55	10.45	9.72	11.1	11.15	7.92	7.57	6.99	6.72	5.81	5.83	6.94	7.36	7.57	7.81	11.05	10.94
151	10.12	10.47	7.27	7.24	7.52	6.86	8.43	8.5	6.98	7.88	7.39	7.32	10.77	10.33	11.67	11.81	7.19	7.75	7.08	5.93	5.47	5.52	5.95	7.05	7.55	7.74	11.73	11.01
152	10.95	10.76	7.63	7.4	8.48	8.28	9.64	9.73	8.42	8.35	7.75	7.84	10.78	10.63	10.87	11.34	7.85	7.84	7.82	6.8	6.09	6.08	6.7	7.71	7.84	7.72	11.18	10.74
153	10.05	10.61	7.11	7.35	7.4	6.95	8.25	8.32	7.25	7.29	7.24	7.05	10.72	9.96	10.7	11.56	7.21	7.41	7.03	6.67	5.78	5.82	6.57	6.98	7.14	7.26	11.47	10.98
154	10.46	10.56	6.9	7.43	8.3	7.06	8.53	9.03	6.71	8.2	7.52	7.32	10.57	10.49	10.1	11.69	7.49	7.37	6.98	5.28	5.89	5.43	6.21	6.75	7.38	7.54	12.03	11.15
155	10.85	10.97	7.61	7.55	8.18	6.97	8.81	8.92	6.99	8.12	7.55	7.63	10.96	10.75	11.36	11.93	7.71	7.8	7.1	5.83	5.48	5.56	6.14	6.98	7.79	7.79	11.98	11.54
156	9.38	10.91	7.51	7.12	7.93	.	9.06	8.99	5.96	8.19	7.39	7.05	10.56	9.3	10.59	11.53	7.81	7.91	7.5	6.21	5.97	5.9	6.32	7.34	7.52	8.17	11.24	10.98
157	10.25	10.57	7.25	7.31	8.2	7.85	8.79	8.7	7.89	7.97	7	7.05	10.75	9.37	10.67	10.93	.	7.67	6.79	6.07	5.81	6.04	6.25	6.94	7.18	7.47	10.84	10.36
158	10.15	10.5	6.58	6.73	8.43	7.76	8.81	8.62	7.42	8.61	7.02	6.74	10.35	9.98	9.69	11.14	7.84	7.66	7.14	5.64	5.51	.	5.56	7.15	7.1	7.23	11.23	10.54
159	10.32	10.53	6.56	6.74	8.46	7.9	8.83	8.65	7.69	8.63	6.9	5.58	10.31	9.96	9.69	11.14	7.84	7.66	7.14	5.64	5.51	.	5.56	7.15	7.1	7.23	11.23	10.54
160	10.7	11.17	6.81	7.26	8.53	.	8.77	8.85	5.76	8.34	7.32	6.45	10.79	10.6	10.69	12.02	7.63	7.49	7.75	6.38	5.7	5.55	6.05	7.72	7.56	7.67	11.89	10.93
161	9.93	10.47	7	7.15	7.02	.	8.97	8.82	5.01	7.14	7.05	6.97	10.27	9.67	10.95	11.43	7.95	7.6	6.73	5.97	5.62	5.85	5.95	6.72	7.74	7.89	11.03	10.86
162	10.24	10.51	6.89	6.54	7.36	6.24	8.79	8.89	6.62	7.36	6.59	.	10.62	10.15	10.81	10.16	7.16	6.77	6.22	5.75	5.35	5.24	5.8	6.25	6.95	6.98	10.57	10.19
163	10.85	11.12	6.63	6.83	7.21	5.95	8.38	8.25	6.5	7.4	7.04	6.93	10.96	10.83	9.77	10.36	.	7.03	6.39	5.92	5.51	5.41	5.93	6.4	7.09	7.02	10.45	10.1
164	10.34	10.94	6.89	7.6	7.36	6.02	8.51	8.61	5.7	7.54	7.28	7.12	10.67	10.38	9.84	10.72	.	7.22	6.82	6.12	5.25	6.31	6.17	6.85	7.01	7.39	10.49	10.67
165	9.19	10.22	6.47	7.03	6.75	5.48	8.65	8.68	4.64	6.85	6.59	6.57	10.34	9.1	9.81	10.25	.	6.73	6.24	4.69	4.91	5.29	5.17	6.29	6.86	6.8	10.09	9.54
166	10.04	10.31	6.98	7.05	6.78	5.45	8.68	8.67	5.12	6.74	6.98	6.92	10.35	10.02	10.02	10.28	6.78	6.71	6.21	4.78	4.91	4.98	5.03	6.29	6.86	.	10.15	9.81
167	8.99	10.09	6.74	7.06	7.6	5.59	7.2	7.17	5.55	7.7	6.96	6.41	10.08	9.04	11.2	10.69	7.98	7.01	6.55	5.59	.	.	5.53	6.46	7.28	8.2	10.34	11.2
168	9.86	11.04	6.8	7.58	7.32	6.78	8.75	8.96	6.99	7.78	7.68	7.27	11.12	10.45	10.45	10.18	.	6.95	6.86	5.9	5.58	5.57	5.88	6.94	6.85	.	10.45	10.32
169	10.45	11.08	7.01	6.95	7.9	7.06	8.93	8.85	7.16	7.95	7.02	7.15	10.9	10.55	10.46	10.64	7.02	6.98	6.6	6.3	.	.	6.44	6.45	6.94	7.06	10.13	10.32
170	9.84	10.88	7.59	7.6	7.72	6.93	8.38	8.45	7.1	7.79	6.93	6.74	10.57	9.75	10.75	11	7.4	7.3	7.12	6.09	.	.	6.16	7.18	7.29	7.48	11.36	10.95
171	9.94	10.75	7.52	7.58	7.68	6.95	8.85	8.51	7.01	7.74	7.04	7.41	10.85	9.82	10.68	11.03	.	7.24	7.14	6.09	5.57	5.59	6.28	7.14	7.26	.	11.08	10.87
172	9.8	10.17	.	6.88	8.25	6.71	8.56	8.6	6.53	8.09	7.13	6.27	9.97	9.8	10.42	.	6.95	7.05	7	5.66	5.49	5.49	5.69	7.25	7.38	6.85	10.35	9.58
173	9.4	10.72	6.25	6.5	7.12	6.46	8.1	7.73	6.96	7.23	6.59	6.05	10.17	8.71	9.16	10.51	6.52	6.35	6.31	5.69	.	.	4.59	6.4	6.35	6.44	10.42	9.16
174	10.35	10.85	6.35	6.3	7.05	.	9	8.95	5.8	7.16	6.2	6.48	10.82	10.16	10.27	10.97	6.85	.	6.15	5.97	5.5	5.47	5.82	6.37	6.71	6.82	11.1	10.33

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
175	8.41	9.64	6.54	6.76	6.21	5.76	7.43	7.49	5.91	6.24	6.76	6.41	9.75	8.97	8.95	10.22	6.66	6.53	6.17	5.05	.	.	5.13	5.92	6.43	6.81	10.12	9.11
176	10.18	12.09	8.27	8.29	8.57	.	9.98	9.97	.	8.74	8.31	8.18	12.06	10.33	11	11.69	8.83	8.07	7.61	6.75	6.38	6.41	6.73	7.59	8.19	8.55	11.75	11.12
177	10.48	11.12	7.08	6.98	7.89	7.04	8.85	8.91	7.14	7.98	7.01	7.14	10.92	10.58	10.38	10.7	7.01	6.99	6.98	6.41	.	.	6.44	6.41	6.93	7.08	10.75	10.28
178	9.29	9.96	6.89	7.17	7.36	.	8.24	8.1	.	7.44	6.93	6.85	9.78	9.16	9.67	9.98	6.89	6.33	6.85	5.4	5.2	5.16	5.2	6.44	6.75	6.97	10.39	10.21
179	9.68	9.72	.	6.49	7.03	5.61	7.33	7.37	6.19	7.25	6.46	.	9.53	9.23	9.95	10.28	6.57	6.04	5.65	5.01	4.57	4.61	5.13	5.73	5.95	6.77	10.57	9.98
180	8.97	9.98	6.7	6.7	7.13	6.22	8.16	8.21	6.38	7.2	6.66	6.59	9.83	9.26	9.52	10.84	.	6.97	6.1	5.46	5.38	5.29	5.44	6.24	6.59	.	10.8	9.8
181	9.3	10.85	.	7.08	7.49	6.86	8.83	8.65	6.81	7.49	6.59	.	10.04	9.85	9.87	10.02	6.93	6.34	6.61	5.67	5.36	5.57	5.44	6.38	7.09	6.95	9.96	9.67
182	10.36	11.61	6.68	7.37	8.01	7.85	9.41	9.31	7.91	8.29	7.67	7.24	11.63	10.75	10.03	10.59	.	7.01	6.75	5.5	5.24	5.31	5.48	6.81	6.98	.	10.42	10.05
183	9.91	10.88	.	6.97	7.14	6.42	8.36	8.48	6.44	7.15	6.45	.	9.88	9.71	10.45	11.23	7.01	6.59	6.47	5.72	5.23	5.3	5.86	6.56	6.74	7.02	11.37	10.6
184	10.58	10.09	6.9	6.93	7.37	.	8.8	8.48	.	7.41	6.64	6.48	10.05	9.84	9.82	10.64	7.09	6.91	6.61	5.25	4.95	4.92	5.24	6.71	6.27	6.91	10.27	9.95
185	10.56	10.92	.	6.99	7.08	6.39	8.41	8.45	6.75	7.09	6.59	.	10.55	10.25	10.39	11.19	7.06	6.67	6.51	5.74	5.18	5.21	5.81	6.61	6.81	7.05	11.21	10.41
186	10.62	10.76	7.1	6.95	7.45	.	8.61	8.66	.	7.43	6.68	6.54	10.1	10.02	10.01	10.59	7.05	6.89	6.47	5.16	4.93	4.85	5.21	6.84	6.34	6.74	10.31	10.05
187	10.07	10.74	6.67	7.27	7.39	5.33	9.13	9.04	5.08	8.45	7.5	6.71	10.9	10.36	10.91	11.51	.	7.42	7.64	5.54	5.67	.	6.03	7.49	7.42	.	11.67	10.54
188	11	11.46	7.45	8	9.03	7.63	10.1	10.07	8.06	9.52	7.64	.	10.69	10.41	10.59	10.98	.	7.45	7.03	5.55	5.13	0.26	5.47	7.08	7.21	.	10.49	10.41
189	10.13	10.97	.	6.95	7.49	6.32	9.05	9.1	6.26	7.69	7.01	.	10.5	10.03	10.09	10.8	8.32	8.28	7.62	6.12	.	5.54	6.01	7.44	8.16	7.75	10.8	10.05
190	10.07	10.57	6.82	7.06	7.92	6.95	8.87	8.98	7.17	7.82	6.95	.	10.76	10.22	10.18	10.44	.	7.17	6.87	6.16	5.6	5.56	6.15	6.79	7.12	.	10.79	10.39
191	9.33	10.3	6.33	6.73	8.47	6.89	8.12	7.98	6.76	8.65	6.9	.	10.66	9.46	10.85	11	.	7.78	7.57	6.3	6.04	6.07	6.44	7.48	7.43	.	11.38	9.95
192	10.9	10.75	6.01	6.35	7.2	.	7.98	7.73	6.34	7.34	6.01	.	10.28	9.98	10.45	11.02	.	6.38	6.4	5.62	5.03	5.18	5.61	6.17	6.63	7.03	10.5	
193	9.18	9.32	6.07	6.52	6.68	.	7.48	7.51	.	6.45	6.57	6.12	9.7	9.26	9.01	10.59	7.09	6.95	6.2	5.16	4.8	5.1	5.05	6.57	6.43	.	10.07	9.07
194	9.84	9.95	6.54	6.51	7.02	.	7.5	7.76	4.85	7.14	6.31	6.58	9.93	9.76	9.12	9.63	.	6.43	6.51	5.44	4.8	4.92	5.43	6.37	6.53	.	9.81	9.46
195	9.97	10.65	6.55	6.54	7.48	.	9.67	9.56	.	7.5	6.66	6.22	10.74	9.63	10.39	10.95	.	7.08	7.03	6.14	6.04	6.08	6.21	6.84	6.6	6.96	11.17	10.48
196	10.03	10.24	6.87	6.98	7.43	.	8.82	8.72	.	7.51	7.02	.	10.27	10.06	10.45	10.87	7.21	6.76	6.52	5.93	5.03	4.99	6.03	6.47	6.68	6.99	10.53	10.07
197	10.37	10.76	.	7.82	7.76	6.19	8.89	8.86	6.49	7.54	8.06	7.74	10.72	10.65	10.54	10.99	.	7.77	6.73	5.94	5.21	5.39	5.6	6.56	8.01	.	11.45	10.67
198	9.27	9.63	5.48	5.98	6.36	5.35	8.23	8.19	5.43	6.85	5.72	5.58	9.07	9.38	9.3	10.24	.	5.81	5.99	5.28	.	.	5.24	5.87	5.93	.	10.05	9.57
199	10.98	11.15	.	6.52	7.17	.	8.63	8.61	.	7.27	6.79	.	10.72	9.95	11.51	12.19	7.4	7.57	6.49	5.24	4.73	4.49	5.26	6.5	6.98	7.47	12.32	11.61
200	10.2	10.36	7.21	6.56	8.2	.	8.79	8.84	4.5	8.88	6.49	6.99	10.69	10.32	10.69	11.06	.	7.14	6.61	5.57	.	.	5.19	6.78	7.4	7.03	11.21	10.75

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
201	10.94	11.04	.	6.96	7.47	6.43	8	8.23	6.85	7.33	7.02	.	10.52	9.88	10.01	10.51	.	7.06	6.17	5.37	4.83	4.78	5.46	6.69	7.01	.	10.48	10.06
202	10.03	10.65	.	6.93	7.42	6.61	8.34	8.25	6.24	7.43	6.93	.	10.45	9.91	10.52	10.45	7.14	7.04	6.79	5.62	.	.	5.57	6.83	7.13	7.21	10.51	9.98
203	9.3	9.73	5.65	5.23	6.97	.	7.77	7.85	.	6.81	5.31	5.29	9.64	9.24	9.95	10.13	6.12	5.8	6.35	4.45	.	.	4.15	6.2	5.85	6.05	10.21	10.01
204	9.38	10.39	.	7.53	7.42	5.21	8.17	8.04	4.74	7.43	7.33	.	10.7	9.35	10.58	11.76	.	7.01	6.51	6.12	5.61	5.8	6.16	6.28	7.12	.	11.21	10.64
205	10.05	10.55	.	6.95	7.95	6.94	8.7	8.64	6.98	7.92	7.05	.	10.31	10.2	10.54	10.94	.	7.36	6.9	6.12	5.62	5.65	6.18	6.92	7.56	.	11.02	10.98
206	9.62	10.4	.	6.41	7.66	6.09	8.43	8.45	6.12	7.53	6.31	.	10.26	10.8	10.99	11.09	.	6.65	6.28	5.8	5.31	5.27	5.82	6.38	6.44	.	10.98	10.66
207	10.29	10.75	6.95	7.19	7.83	.	8.59	8.63	.	7.76	7.23	7.24	10.65	10.35	10.7	10.45	7.15	6.8	6.48	5.98	.	.	5.75	6.47	7.18	7.02	10.58	10.32
208	7.79	9.23	5.85	5.66	7.22	.	7.02	6.87	.	7	6.19	5.8	9.71	7.99	9.08	8.8	6.28	6.16	5.85	4.95	.	.	4.82	5.89	6.05	6.63	9.54	9.49
209	.	8.61	5.66	6.59	7.23	4.11	6.73	6.97	.	7.34	6.53	.	8.86	5.6	.	10.18	5.67	7.03	6.81	5.12	5.14	5.12	5.13	6.53	6.98	6.47	9.76	9.72
210	10.08	10.78	.	.	7.71	5.62	8.11	8.16	5.93	7.42	.	.	10.84	10.32	10.39	10.4	.	7.13	6.41	5.27	5.56	5.03	5.57	6.51	7.23	7.56	10.75	10.66
211	8.9	9.75	.	.	6.99	5.47	8.32	8.25	5.26	6.72	.	.	9.68	8.81	10.8	10.88	7.03	6.52	6.69	5.58	4.84	4.36	5.48	6.22	6.62	.	10.9	10.9
212	9.61	10.36	.	6.36	7.36	6.26	8.52	8.15	5.57	7.49	.	.	10.48	9.66	9.85	10.45	.	6.94	6.51	5.65	5	5.16	5.32	6.62	.	6.95	10.55	9.85
213	9.96	10.8	7.23	6.95	7.31	6.75	8.76	9.12	6.88	7.38	6.68	7.12	10.65	10.21	10.85	11.26	7.02	7.94	6.85	.	.	.	.	6.76	.	7.54	11.21	10.17
214	9.57	11.02	.	6.94	7.73	.	8.28	7.92	.	8.05	6.73	6.35	10.5	9.6	10.33	11.45	6.9	6.96	6.92	5.06	.	.	5.43	6.65	7.17	7.18	11.32	10.28
215	10.45	10.59	6.96	7.23	7.93	6.98	8.74	8.89	6.89	7.95	7.46	.	10.75	10.54	10.7	10.96	.	.	6.79	6.23	5.68	.	6.28	6.35	.	6.42	10.92	10.83
216	9.74	10.23	6.59	6.53	7.34	6.22	8.68	8.21	6.25	7.39	6.66	.	10.18	9.98	.	10.98	.	6.66	6.31	5.74	5.12	5.11	5.68	6.31	6.92	.	10.72	.
217	9.82	9.89	6.21	6.91	6.96	5.56	6.71	6.81	5.32	6.97	6.5	5.95	9.92	9.85	.	10.16	6.33	6.59	5.99	4.82	.	.	5.02	5.99	6.7	.	9.89	.
218	10.11	10.65	.	.	8.01	6.62	8.44	8.45	6.19	8.03	.	.	10.65	10.45	10.68	12.31	.	7.01	6.96	5.93	5.96	5.79	5.95	6.67	7.66	.	12.17	11.25
219	9.62	10.98	.	5.87	7.18	4.85	7.46	7.26	4.92	7.4	6.36	.	10.13	9.22	10.07	10.77	7.18	6.81	7.18	3.98	.	.	.	7.14	7.15	.	10.26	10.05
220	9.81	9.86	6.65	6.43	6.98	5.38	7.83	7.93	.	6.4	6.41	.	9.99	9.72	9.84	10.15	.	6.74	6.38	5.31	.	.	5.29	6.29	6.67	.	10.28	10.03
221	9.66	9.78	.	6.3	6.84	6.61	7.73	8.14	6.44	6.75	6.11	.	9.31	9.24	10.03	10.77	.	.	5.9	5.58	5.42	5.4	5.41	5.83	.	.	10.59	10.01
222	.	7.61	6.07	6.28	7.1	.	7.39	7.47	.	7.15	6.27	5.88	8.32	.	9.05	9.66	.	6.56	6.09	5.09	5.07	5.67	5.3	6.11	5.76	.	10.23	9.45
223	8.88	9.52	.	6.14	6.54	.	6.59	6.58	.	6.48	6.38	.	9.48	8.91	8.91	10.02	.	6.36	6.45	5.12	5.01	5.06	5.14	6.53	6.41	.	10.13	9.03
224	10.45	10.56	.	.	7.55	5.73	8.64	8.58	5.5	7.1	.	.	10.62	10.57	10.43	10.54	.	6.43	6.34	5.87	5.69	5.6	5.56	6.85	6.45	.	10.5	10.42
225	.	9.78	.	6.65	7.02	.	8.35	8.18	.	7.14	6.54	.	9.77	.	9.45	10.32	6.82	6.84	6.6	5.54	5.24	5.15	5.15	6.38	6.81	6.93	10.48	9.69
226	.	10.22	6.98	6.66	7.14	.	7.51	7.49	.	7.36	6.95	6.75	9.78	.	.	10.42	7.6	6.73	6.65	5.01	5.03	.	5.07	6.96	6.86	7.63	10.39	.

Subject No	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7
227	8.82	9.91	.	6.25	6.86	.	7.81	7.85	5.45	6.89	.	.	9.98	8.83	.	10.03	6.98	6.71	6.29	5.48	5.05	5.02	5.37	6.26	.	.	10.01	.
228	9.96	10.12	.	6.05	6.76	.	7.21	7.3	.	6.8	.	6.03	10.19	9.44	10.12	10.41	.	.	6.53	5.38	5.06	4.9	5.44	6.58	.	.	10.76	10.21
229	9.86	10.67	.	.	7.23	6.16	8.48	8.53	6.21	7.14	.	.	10.47	9.88	10.65	11.29	.	.	6.18	5.99	4.99	5.13	5.55	6.18	.	.	11.23	10.56
230	9.54	9.68	.	.	6.98	4.86	7.32	7.38	4.65	6.84	.	.	9.74	9.45	9.98	10.04	.	.	6.26	5.03	4.96	4.98	5.11	6.34	.	.	10.01	9.93
231	9.79	9.97	.	.	6.55	6.6	8.03	8.03	6.3	6.64	.	.	9.42	8.8	10.44	10.71	.	.	5.96	5.31	5.46	5.1	5.64	5.37	.	.	10.78	10.87
232	9.68	9.71	.	.	7.09	5.63	7.8	7.62	5.73	6.96	.	.	9.75	9.73	9.98	10.07	.	.	6.04	5.4	5.03	4.87	5.26	6.02	.	.	9.94	9.5
233	.	8.41	.	5.94	6.68	5.59	7.27	7.1	5.29	6.37	6.13	5.33	7.49	.	.	8.85	.	6.15	5.83	4.99	.	.	4.91	5.77	6.18	5.98	8.95	.
234	8.46	8.98	5.91	5.78	6.01	.	7.16	7.14	.	.	5.98	5.64	8.97	8.53	8.93	9.28	.	6.03	5.96	.	4.72	.	.	5.95	.	5.91	9.18	8.86
235	.	9.94	.	6.25	7.18	.	8.03	8.01	5.03	7.21	6.37	.	9.85	.	.	10.54	.	6.47	6.42	5.32	5.16	5.18	5.36	6.24	6.32	.	10.32	.
236	8.98	9.46	6.7	6.81	7.32	.	7.25	7.32	.	7.4	6.42	.	9.45	8.95	.	10.2	5.89	6.23	6.08	.	.	.	.	5.77	6.36	5.94	10.15	.
237	9.9	10.42	.	.	6.28	.	8.23	8.12	.	6.57	.	.	10.41	9.68	9.98	10.14	.	6.69	5.89	5.89	4.65	4.79	5.58	5.6	.	.	10.03	9.96
238	8.98	9.63	.	.	6.62	.	7.75	7.73	.	6.59	6.41	.	9.68	9.01	9.96	10.08	.	.	6.16	5.09	.	.	5.16	6.24	6.56	.	10.03	9.85
239	9.79	10.67	.	.	7.98	.	8.22	8.26	.	7.82	.	.	10.5	9.51	10.7	10.9	.	6.46	6.45	6.08	.	.	6.12	7.01	6.43	.	10.5	10.23
240	9.45	9.82	.	.	6.65	3.81	7.6	7.77	3.83	6.78	.	.	9.73	9.34	.	9.45	.	6.42	5.81	.	5.18	5.3	.	5.79	6.36	.	9.45	.
241	.	9.09	.	.	6.72	5.91	7.64	7.57	4.57	6.72	.	.	9.56	.	10.64	9.99	6.99	6.83	6.34	5.59	4.73	.	.	6.29	.	6.93	10.12	.
242	.	10.14	.	6.16	7.23	.	7.41	7.39	.	7.18	6.28	.	10.09	.	.	10.63	.	6.58	6.48	.	5.23	5.26	5.31	6.37	6.62	.	10.72	.
243	.	10.02	.	6.82	6.98	.	7.36	7.38	.	6.82	6.91	6.55	10.19	.	.	10.97	6.89	6.55	6.07	.	.	.	.	5.79	6.56	6.83	10.93	.
244	8.72	8.91	.	.	5.84	.	7.81	7.89	.	5.82	6.63	.	8.87	.	9.93	10.17	.	6.55	5.73	.	.	.	.	6.26	6.64	.	9.81	9.73
245	.	9.26	6.53	.	7.77	.	8.57	8.4	.	7.67	.	6.4	9.72	.	9.6	11.27	.	6.64	6.94	4.86	.	.	.	7.05	.	.	11.09	9.74
246	.	8.6	.	5.87	6.52	3.73	6.98	6.95	5.21	6.4	5.94	.	8.9	.	.	9.26	.	.	6.1	.	.	4.83	.	6.1	6.29	.	9.19	.
247	.	9.66	.	.	7.68	.	6.97	7	.	7.39	.	.	9.53	.	.	8.8	.	.	6.86	5.49	4.64	4.52	5.51	7.03	.	.	8.48	.
248	.	9.45	.	.	7.02	.	7.56	7.18	.	6.82	.	.	9.16	.	.	9.56	.	.	5.74	.	.	.	.	5.72	.	.	10.82	.