THE INFLUENCE OF THE NASOLABIAL ANGLE ON PERCIEVED FACIAL AESTHETICS- A STUDY USING A 3D FACIAL IMAGE AND IMAGE MANIPULATION SOFTWARE.

By

SALWA EL-HABBASH

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College of Medical and Dental Sciences

University of Birmingham

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Abstract

Objectives: Orthodontists aims to achieve a Class I occlusion, without "harming" the facial profile. Movement of teeth and facial bones can result in changes of soft tissues including the nasolabial angle (NLA). Many studies assess the perception of the NLA using two-dimensional (2D) profile images, these may alter aesthetic judgement as three-dimensional (3D) images are closer to real-life.

Aims: To determine which NLA, from 70° to 110°, was rated as most attractive by laypeople and clinicians and if this was impacted by the type of image viewed i.e., 2D profile silhouettes, 3D textured and 3D grey non-textured images.

Methodology: Using a 3D facial image and image manipulation software, five 3D grey non-textured images were produced with NLA's of 70°, 80°, 90°, 100° and 110°. Using software from the gaming and film industry, the same male or female textured image was "wrapped" onto each of these images, producing ten further 3D images of the same individual with the five different NLA's. Five 2D profile silhouettes were generated from the 3D images resulting in 20 images which were embedded in a PowerPoint presentation. Seventy-two laypeople and fifty clinicians were recruited to rate the facial attractiveness of the images using a 7-point Likert scale.

Results: There was a statistically significant difference in the facial attractiveness scores across the NLA's being assessed ($p=0.001$) in both groups. Two-dimensional profile silhouettes underestimated the unattractiveness of 100° and 110° NLA's compared with 3D images in both groups ($p<0.05$).

Comparing 2D profile silhouettes and 3D grey non-textured images there was no statistical difference in attractiveness scores given by clinicians between NLA's of 70°, 80° and 90°. There was no statistical difference in attractiveness scores by laypeople for the 80° NLA, however the 3D grey non-textured images scored significantly lower than the 2D profile images with NLA's of 90°, 100° and 110° but significantly higher for the 70° NLA ($p<0.05$).

Overall, laypeople rated images more unattractive than clinicians, however clinicians were more likely to seek treatment. Both groups rated 3D grey non-textured images as less attractive than 2D facial profile silhouette images with NLA's of 100° and 110° ($p<0.05$). Both groups preferred rating 3D textured images overall.

Conclusion: The null hypothesis was rejected as there was a statistically significant difference ($p<0.05$) in facial attractiveness rating score between clinicians and laypeople assessing the NLA's on the images and in the rating of the NLA between 2D facial profile silhouette images and 3D grey non-textured images.

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CHAPTER 1

LITERATURE REVIEW

1.1 Introduction

Orthodontic treatment planning was initially based on the goal of long-term dental stability following treatment (Mills, 1968; Felton et al., 1987). This involved maintaining key dental pre-treatment parameters including the lower labial segment inclination, inter-molar, and inter-canine widths (Horowitz and Hixon, 1969). The dental objective of achieving a Class I incisor relationship would often be achieved without taking into consideration the overlying soft tissue effects resulting from treatment. This was particularly evident during overjet reduction in Class II mandibular retrusion cases. The more routine use of orthognathic surgery meant it was not only possible to move teeth, but also the underlying skeletal bone (Seo and Choi, 2021). Movement of both teeth and skeletal bone has the potential of causing a marked effect of the overlying facial soft tissue. More recently orthodontists are becoming more aware for the need to balance the desire to achieve an ideal Class I occlusion, without "harming" the facial profile but also working within the bounds of biological constraints (Seo and Choi, 2021). The nasolabial soft tissues play a key role in facial aesthetics and can have a large influence on a patient's appearance and profile emphasising the importance of soft tissue assessment prior to planning treatment (Schendel and Carlotti, 1991).

The nasolabial complex (NLC) anatomy is a compound with a many of muscles, nerves, and soft tissue structures. The position of these structures is influenced by tooth position during orthodontic treatment and bony movement with orthognathic surgery. This can have an impact on the position and appearance of the upper lip and nasolabial angle, as well as the nasal dorsum tip and alar base width (Schendel and Carlotti, 1991).

1.2 Anatomy of the nasolabial complex

The nasolabial complex (NLC) consists of the structures making up the nose and those of the upper lip. The nasolabial angle (NLA) is derived from two independent lines that arise from structures of the NLC (Freitas et al., 2014). The NLA provides a good representation of the anteroposterior position of the maxilla and can aid in differential diagnosis of dental or skeletal malocclusions (Elias, 1980). Nasal anatomy comprises skeletal, cartilaginous, muscular, and fascial components. The alar cartilages also known as the lower lateral cartilages, provide the shape and support for the tip and lobule of the nose. The alar cartilages consist of two parts; medial and lateral crus which fuse at the dome of the alar cartilage, which is also the highest point of the nose. The alar cartilages extent of separation governs the width of the nasal tip and the span of the domes (Schendel and Carlotti, 1991).

The major muscles of the NLC are closely linked and include the nasalis (transverse and alar components), dilator naris, depressor septi naris, levator labii superioris alaeque nasi, levator labii superioris, levator anguli oris, orbicularis oris and the zygomaticus major and minor (Schendel and Carlotti, 1991). The nasalis muscle originates in the midline of the dorsum of the nose and sweeps across the upper lateral cartilages and combines with fibres of the musculi levator labii muscle. These run downwards with some fibres inserting into the orbicularis oris muscle of the lip and others inserting along the piriform rim extending to the anterior nasal spine. This determines the shape of the lateral alar aspect and transverse width of the nose. Fibers of the zygomatic muscles retract laterally or superolaterally and play a key role in surgical cases and can result in widening of the alar base if not handled with care. The orbicularis oris muscle has oblique and transverse fibers. The oblique portion run obliquely upward and inserts close to the piriform rim and anterior nasal spine, whilst the transverse fibers run horizontally across the upper lip (Schendel and Carlotti, 1991; Schendel and DeLaire, 1985). Malformations in this region, as seen in cleft lip and palate patients, can result in alterations in the shape of the NLC, with one of the main aims of surgical intervention and orthodontic treatment to improve the nasolabial and facial aesthetics (Paiva and Andre, 2012).

The nasolabial angle, which is dependent on the inclination of the nasal columella and the upper lip, is formed by drawing a line tangent to the nasal columella and a line tangent to the upper lip, which both intersect at subnasale (Naini et al., 2015), Figure 1.1. The nasolabial angle however can be further subdivided into the upper and lower compartments using a true horizontal line through subnasale, with the patient in natural head position. This creates the upper compartment (UC) angle which is formed between the line tangent to columella and the true horizontal plane and the lower compartment angle or upper lip inclination (ULI), formed using the upper lip tangent line and the true horizontal plane (Naini et al., 2015), Figure 1.1. Although this method is mostly used to determine the NLA, four different alternative methods have been described to measure the NLA (Harris, 2016), Figure 1.2.

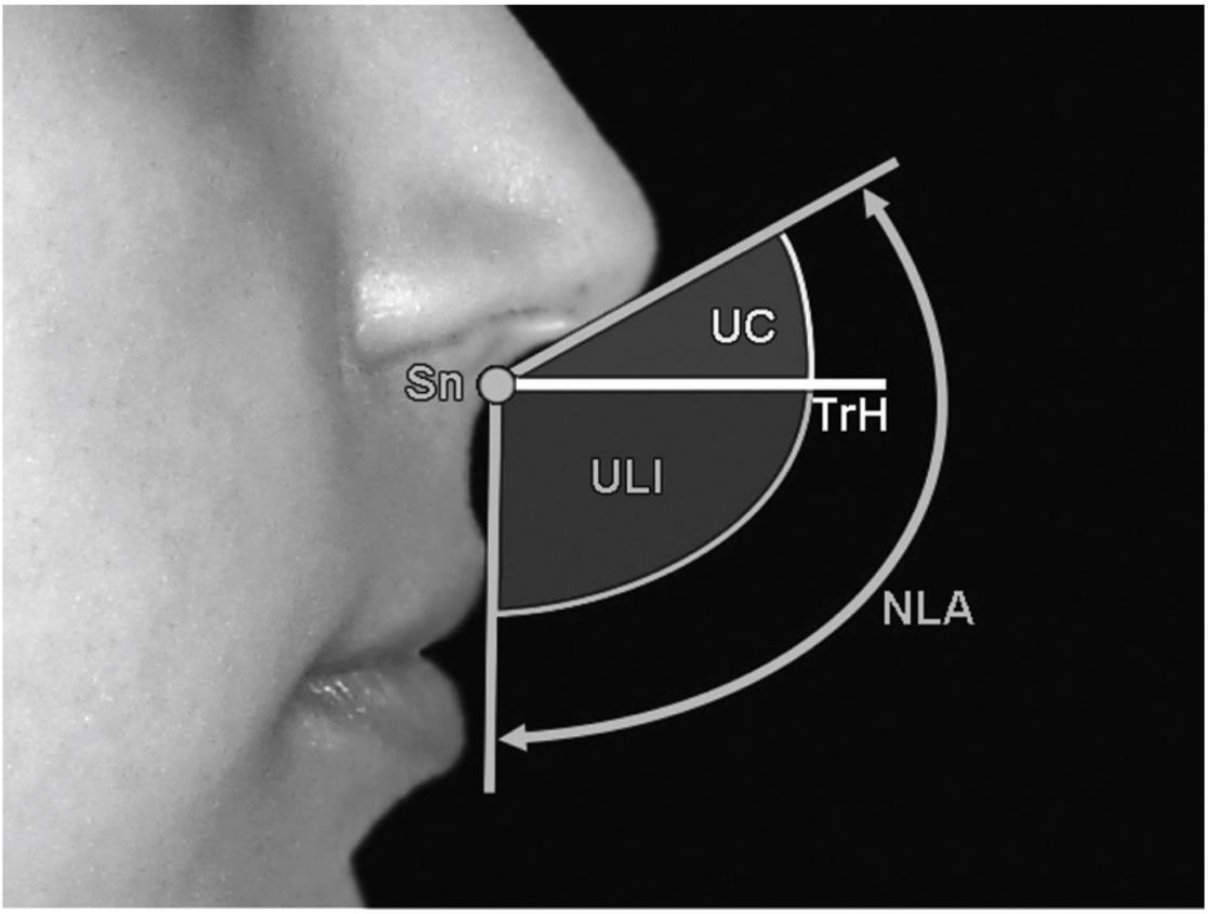
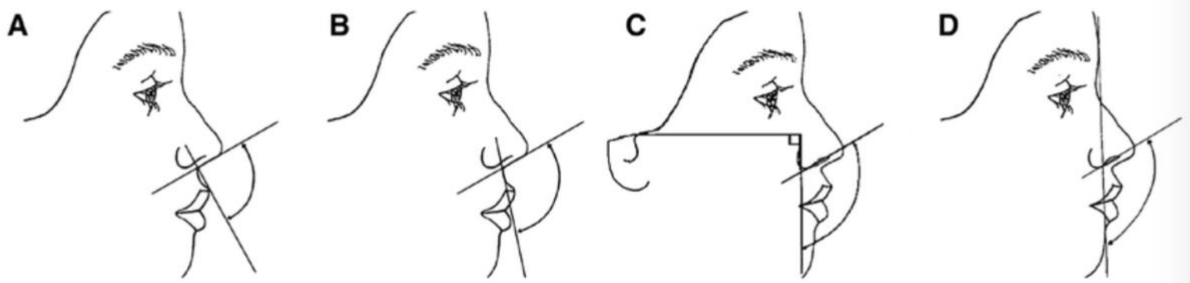


Figure 1. 1 Upper lip inclincation (ULI) and upper compartment (UC) of the nasolabial angle, which together form the nasolabial angle (NLA) TrH, true horizontl; Sn, subnasale (Naini et al., 2015).



Four common ways of measuring the nasolabial angle found in rhinoplasty literature 1 that were used in our survey: a, angle between columella and line intersecting subnasale and labrale superius 1 ; B, angle between columella and line tangent to cutaneous upper lip proper 2 ; C, angle between long axis of nostril and line perpendicular to Frankfort horizontal 3 ; and D, angle between long axis of nostril and line intersecting glabella and pogonion. 4 adapted with permission from leach J. aesthetics and the Hispanic rhinoplasty. Laryngoscope. 2002;112:1903–1916. adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Figure 1. 2 Four common ways of measuring the nasolabial angle (Harris, 2016).

1.3 Determinants of facial attractiveness

Facial attractiveness has been well documented to influence critical social outcomes, from social exchanges to hiring prospects, with physically attractive individuals being perceived to hold more positive personality attributes (Little et al., 2011; Langlois at al., 2000). It has been accepted that facial appearance can strongly affect self-esteem (Hershon and Giddon, 1980). Cultural differences can have an impact on the perception of facial attractiveness, however cross-cultural studies suggest universal commonalities in the features of attractive faces (Little et al., 2011). Features of facial attractiveness that have been universally established include facial symmetry, averageness or how strongly a face resembles the mainstream faces within a given population. In addition, secondary sexual characteristics of the face, such as the shape and cheek / jaw bones, sexual dimorphism, skin health and uniformity in colour have all been associated with facial attractiveness (Little et al., 2011; Heppt and Vent, 2015).

Static facial characteristics are well known to contribute to facial attractiveness i.e., positive facial expressions (Little et al., 2011; Heppt and Vent, 2015). The eyes and appearance of the teeth have also been shown to be key contributors for facial aesthetics, with people who smile more being considered more trustworthy (Krishnan et al., 2008). The psychological effects of seeing an attractive face should not be underestimated. It has been previously reported that viewing an attractive face can activate the medial orbito cortex, a region of the brain known to be involved in representing stimulus-reward value. In other words, seeing an attractive face can be considered a rewarding stimulus, and evoke the same response to pleasant music or monetary gain (O'Doherty et al., 2003).

As well as subjective assessment, objective measurements, based on facial profile photographic analysis, has shown an association between various facial profile anthropometric measurements and skeletal pattern classifications with perceived facial aesthetics (Reis et al., 2011). Class I skeletal patterns have been linked with the highest level of aesthetics compared with Class III skeletal patterns which were perceived as least attractive; suggesting the sagittal position of the mandible influences facial profile aesthetics (Dongieux and Sassouni, 1980). The convexity of facial profile angle, which is measured between soft tissue glabella, subnasale and pogonion, has been shown to be associated with facial profile attractiveness. Increased or decreased convexity of the face, often seen in Class II and Class III skeletal profiles respectively, tend to be deemed less attractive compared with a balanced Class I profile (Reis et al., 2011). Given that orthodontics is normally undertaken as an adolescent it is important to consider the age-related facial changes which are known to occur. Even though the majority of facial maturing and change occurs by the age of 18 years, with only minor changes developing throughout the rest of life. With age progression the nose and chin increase in prominence and the lips become thinner, leading to a more concave or retrusive profile, which is less aesthetically pleasing (Nanda et al., 1990).

1.4 Nasolabial angle and facial attractiveness

The nasolabial complex is the central aesthetic unit of the face. The nasolabial angle is reliant on the anteroposterior position or inclination of the upper anterior teeth, the anteroposterior position of the maxilla and the inclination of the nasal columella (Anicÿ-Miloševicÿ et al., 2008). Anecdotal evidence for normal or ideal nasolabial angles based on the perception of surgeons, have been widely accepted and have been described to be between 90° -120° (Powell and

Humphreys, 1984). Anthropometric studies of Caucasians adults have suggested that average values of nasolabial angle are 100° ± 12° in males and 104° ± 10° in females (Farkas, 1994).
It must however be noted that the perception of laypeople compared with clinicians has not historically always agreed; as laypeople are more forgiving when perceiving facial aesthetics (Kerr and O'Donnell, 1990; Cochrane et al., 1999). Studies assessing smile aesthetics in terms of missing teeth and spacing have shown orthodontists to be the most critical cohort when rating images, followed by orthodontic patients (Kokich et al., 2006; Machado et al., 2013; Rosa et al., 2013). However, some more recent studies have found agreement between clinicians and laypeople when considering facial aesthetics (Maple at al., 2005; Sari-Rieger and Rustemeyer, 2015).

Naini et al. (2015) assessed the aesthetic impact of the upper lip inclination, which is the lower component of the nasolabial angle, on facial aesthetics (Naini et al., 2015). The upper lip inclination / lower component of the nasolabial angle was utilised as it measured the nasolabial angle independent of the nose (Naini et al., 2015). The upper lip inclination is dependent on the position of the upper incisors, the position of the maxilla, the thickness and tonicity of the upper lip (thicker, flaccid lips will alter to a lesser extent), and the size of the space between the anterior dentoalveolus and the inner surface of the upper lip.

The relationship between the upper lip and nasal columella inclination is important in establishing a clinical diagnosis and key for planning treatment. The upper lip inclination is dependent on both the sagittal position of the anterior maxilla as well as the inclination of the maxillary incisors (Naini et al., 2015). Movement of the maxillary teeth alone will solely influence the lower compartment of the nasolabial angle, whereas maxillary advancement or impaction will likely affect both the lower component of the nasolabial angle and the upper component related to the nasal columella inclination. Therefore, often following orthodontic and orthognathic procedures that may affect the upper component of the nasolabial angle, cosmetic rhinoplasty procedures may be indicated (Naini et al., 2015). With orthognathic surgery both upper and lower compartments of the nasolabial angle will be affected to differing levels, whereas with orthodontic treatment alone, the upper lip inclination alone is more likely to change (Naini et al., 2015).

1.5 Effects of orthodontics and orthognathic surgery on the nasolabial complex

Changes in dental and skeletal maxillary position will occur following orthodontic and/or orthognathic treatment. These changes will be observed in the surrounding soft tissue of the nasolabial complex region. This can be attributed to orthodontic extraction, retraction or proclination of the upper incisors, use of headgear or temporary anchorage devises or orthognathic surgery. Some suggest that orthodontic treatment planning should be directed by the soft tissues to achieve the best results (Sarver, 2001).

1.5.1 Orthognathic surgery

During Le Fort I orthognathic surgery NLA changes are governed by the amount of decompensation of the maxillary incisors, the type of maxillary surgery undertaken, as well as the direction and scale of movement during maxillary surgery (Naini et al., 2015). Several techniques including the use of cinch sutures and VY closures also have a role in determining the nasolabial angle and are usually used to control the negative or less desirable changes that may occur during orthognathic surgery (Naini et al., 2015).

Without intervention, a Le Fort I osteotomy can produce several undesirable nasal and labial soft tissue changes. There tends to classically ensue a widening of the alar base of the nose with an accompanying flattening and thinning of the upper lip with a noticeable loss of the visible vermilion border (Mansour et al., 1983). Upward nasal tip rotation with amplification of the supratip break and reduction of the dorsal hump can also accompany maxillary advancements (Khamashta-Ldezma et al., 2017). One study showed that maxillary advancement with impaction resulted in the nasal tip being positioned more superiorly or upturning in 85% of cases, which may have the undesired effect of increased nostril show (Dantas et al., 2015). It has been speculated that this upturning of the nose is a result of ventral pressure of the maxillary bone on the lateral crurae (Khamashta-Ldezma et al., 2017). Some of these changes including changes in the nasal tip structure and dorsum may be avoided during maxillary surgery. However, this is dependent on the direction of skeletal movement, the management of soft tissues intra operatively and the thickness of the skin in the region. The changes that may occur are attributable to modifications in the local anatomy associated with the nasolabial complex during surgical repositioning (O'Ryan and Schendel, 1989; O'Ryan et al., 1989).

Widening of the alar base of the nose is not solely dependent on the amount of skeletal movement during maxillary osteotomy. More importantly is the amount of subperiosteal dissection and elevation achieved during surgery, which frequently involves the full face of the maxilla. The subperiosteal dissection disconnects the facial muscles from the nasolabial complex and the anterior nasal spine. The muscles then become unrestricted in their ability to retract laterally, as muscles routinely shorten when elevated. As a result of the surgical intervention lateral retraction of the muscles can occur which results in flaring, widening, and elevation of the base of the nose. As a sequalae to this, there is also thinning of the upper lip with lateral movement of the tissues and the loss of vermilion show because of a rolling in of the upper lip (Mansour et al., 1983). These changes result in increasing the upper and lower component of the nasolabial angle.

Following orthognathic surgery involving maxillary impaction or advancement there is a tendency for the nasal tip to elevate, which increases the upper component of the nasolabial angle. Humping of the nose can appear to reduce due to elevation of the nasal tip and base (Freihofer, 1977). However, changes after maxillary impaction or advancement can rotate the base of the nose superiorly making the nostrils more visible in frontal view, which is considered unaesthetic (Freihofer, 1977). Retraction of the anterior maxilla as a segmental procedure, also often results in widening of the alar base with a resultant susceptibility of the nasal tip to rotate downward and back and therefore increasing the nasolabial angle, which again can have an unaesthetic impact on the face in both frontal and profile views (Schendel and Carlotti, 1991).

Management of soft tissue components is imperative with any maxillary osteotomy by repositioning of the musculofascial constituents to their natural points of insertion. Several techniques including the use of cinch sutures and V-Y closures can play a role in determining the nasolabial angle and are usually used to control the negative or less desirable changes that may occur during orthognathic surgery (Schendel and DeLaire, 1985; Naini et al., 2015). One prospective review found that combing the V-Y and cinch sutures limited the changes in the nasal tip in the vertical dimension (Muradin et al., 2011). Studies have shown that the transverse width of the nose can be maintained close to its preoperative width, if desired, or allowed to expand slightly using the above techniques (Schendel and Carlotti, 1991; Muradin et al., 2011).

1.5.2 Orthodontic treatment

Orthodontic treatment with or without dental extractions can result in soft tissue profile changes (Stromboni, 1979; Finnoy et al., 1987). Burstone (1964) reported that lay people were likely to perceive facial balance in terms of the nasolabial angle (Burstone, 1964). There is however a lack of consensus in the literature as to whether orthodontic treatment with extractions results in poorer soft tissue aesthetics then if no extractions were undertaken. It is suggested that when accurate diagnosis and treatment planning takes place with the intention to resolve tooth size discrepancy there should not be a significant change in the post treatment facial profile (Freitas et al., 2019).

Premolar extractions have been reported to result in flattening of the facial profile, which may have a negative impact on facial aesthetics and is caused by retrusion of the upper and lower lips (Kocadereli, 2001). Conversely, other studies have reported that premolar extractions have no influence on the facial profile (Kirschneck et al., 2016). A study comparing soft tissue facial profiles of individuals undergoing orthodontic treatment with or without extractions found no significant differences in the nasolabial angle between the two groups (Freitas et al., 2019). The results of a systematic review based on a single clinical trial (26 participants) and 5 observational cohort studies (362 participants in total) also found no significant differences between the groups in terms of the aesthetic outcomes (Iared et al., 2017).

A high correlation between upper incisor retraction and nasolabial angle changes has been previously reported (Lo and Hunter, 1982). The study, based on a group of 9 to 16-year-olds with Class II division 1 malocclusions, found that the nasolabial angle increased by 1.63° on average for every one millimetre of upper incisor retraction as a result of orthodontic treatment. This was a linear correlation and was consistent in subjects who had minimal incisal retraction and those who had increased incisal retraction. The study also reported that approximately 90% of changes in the nasolabial angle where due to changes in the lower component or upper lip inclination, with the remaining 10% being related to the change in the inclination of the nasal columella. This increase in inclination of the nasal columella was thought to be attributable to the movement of the lip towards the retracted incisors creating a tension or pull on subnasale in a downward and forward direction which causes the inclination of the lower border of the nose to increase (Lo and Hunter, 1982).

Studies have documented an association between the thickness of the upper lip and upper incisor retraction. Changes in the thickness of the upper lip can affect the nasolabial angle. Some studies have found there to be no correlation between the amount of upper incisor retraction and the thickness of the upper lip (Lo and Hunter, 1982). Contrary to these, other studies have reported that upper lip thickness increases as a result of upper incisor retraction (Ricketts, 1968). This is believed to be related to the relaxation of the lip when its posture is changed. Thicker lips react less to movement of the incisors and therefor provide more support to the lip morphology compared with thinner lips (Guan et al., 2019).

1.6 Aesthetic perception of the nasolabial angle

Normative values of nasolabial angle are utilised in orthodontics and surgery to help devise appropriate treatment plans based on the guide of averageness in facial aesthetics. The nasolabial angle also helps to establish if deviations in the range are due to an anteroposterior discrepancy in maxillary position, inclination of the maxillary incisors, morphology, or thickness of the overlying soft tissues of the upper lip, or any combination of the aforementioned. This information is key in establishing the type of treatment required and making a decision whether orthodontics or orthognathic surgery may be required (Naini et al., 2015). The nasolabial angle norms within a group of people are specific for age, gender, and ethnicity (Naini et al., 2015).

Naini et al. (2015) demonstrated ideals of upper lip inclination, using 2D profile silhouettes based on currently accepted criteria for an idealised Caucasian male profile, in three group of observers including lay people, orthognathic patients and orthognathic and maxillofacial surgeons, Table 1.1. Further observation within this same study showed that silhouettes with a range between 67° and 94° was perceived as slightly unattractive, with any values outside of this range being deemed very unattractive (Naini et al., 2015).

In a study assessing facial perception of post orthognathic surgery Class II patients using three-dimensional pre- and post-surgery images, laypeople awarded statistically significantly higher mean attractiveness scores then orthodontists or surgeons (Storms et al., 2017). However, laypeople perceived the least improvement post-surgery when compared to the clinicians, as well as showing lower inter and intra-observer variability. This was suggested to be due to the inexperience of laypeople or to the lack of ability to critically evaluate a face objectively without considering variables such as skin tone, texture, eyes, and the shape of the nose (Storms et al., 2017).

A recent systematic review has reported that the aesthetic perception of the nasolabial angle for females has changed over time and that the perception is relative to the gender of the rater,

Table 1.1 Ideals of upper lip inclination, using 2D profile silhouettes based on currently accepted criteria for an idealised Caucasian male profile (Naini et al., 2015).

Upper lip inclination	Perception of attractiveness
79-85 ^{o}	Ideal
73-88 ^{o}	Acceptable
67-94 ^{o}	Unattractive

their ethnicity and age. It is also thought to be influenced by social media (Mohammadi et al., 2021). Although this systematic review did not identify an exact trend in the changes in aesthetic perception of the nasolabial angle in females, it indicated that currently sharper angles and fuller lips are perceived more attractive for females. This ideal of fuller lips with more acute nasolabial angles in the modern age and the era of social media has been further confirmed in studies looking at determining if modern day social media models fit the cephalometric norms for historical standards of beauty (Eggerstedt et al., 2020). The cross-sectional study found that the nasolabial angle varied with historical studies being up to 40° more acute than previous studies. The more acute nasolabial angle would be the result of fuller lips.

1.7 Nasolabial angle and gender

Bergman (1999) suggested that the nasolabial angle should always be 102° ± 8° regardless of what intervention is carried out and signified the importance of assessing the position of the upper lip prior to any treatment interventions (Bergman, 1999). In studies of Caucasian patients of Class I dental occlusions with good soft tissue facial profile, the nasolabial angle has been shown to be one of the most variable angular profile measurements between the genders with the mean value for males being 105.4° ± 9.5° and for females 109° ± 7.8° (Anicÿ-Miloševicÿ et al., 2008). However, it must be emphasised that a good occlusion does not always indicate good facial balance; in addition, age, gender, and ethnicity can affect the normative values (Bergman, 1999; Naini et al., 2015). The ranges of nasolabial angle documented in the literature as normative values are variable, however the majority for both genders tend to fall within 90° - 115°, with the larger figures being more representative of the female values (Guyuron, 1993; Orten and Hilger, 2002). A study investigating the ideal nasolabial angle in male and female subjects of a Caucasian background using 2D profile images found that there was a much closer range of nasolabial angles between males and females then had been previously reported. The ideal for males was 93.4° to 98.5° and for females was 95.5° to 100.1° (Armijo et al., 2012). This study was based on 10 male and 10 female modified images viewed by sixteen raters, including plastic surgery attending staff, residents, and office staff.

1.8 Nasolabial angle and ethnicity

A systematic review and meta-analysis, based on 38 studies, reporting 11 angular and 18 linear facial photogrammetric measurements revealed differences in the nasolabial angles between male and female subjects from different ethnic backgrounds including African, Asian and Caucasians (Weng et al., 2015). In the male categories, African males had the smallest mean nasolabial angle of 87.5° (95% confidence intervals 76.6° - 98.5°), followed by Asian males at 94.7° (95% confidence intervals 88.5° - 100.6°) and Caucasian males had the highest mean nasolabial angle of 100.1° (95% confidence intervals 94° - 105.8°). The female results were similar to the males, with African females having a mean nasolabial angle of 85.8° (95% confidence intervals 69.5° - 101.0°), Asian females of 94.2° (95% confidence intervals 88.8° - 99.8°) and Caucasian females having the highest mean value of 103.3° (95% confidence intervals 96.9° - 109.3°). Furthermore, more recent studies indicate that perception of the nasolabial angle is based on ethnic background, with more acute angles being considered more aesthetic or acceptable in African populations compared with Caucasian and Asian populations (Mohammadi et al., 2021).

1.9 Measuring aesthetic perception

1.9.1 Likert-type scale

Psychologists have historically agreed and accepted the Likert-type scale is a useful and popular method for measuring the perception of attractiveness (Langlois at al., 2000). These scales typically have three or more response categories to choose from (Sung and Wu, 2018). However, Likert-type scales have been associated with several disadvantages, including production of ordinal measurement values and response styles, such as participants tending towards choosing either neutral or middle category responses or opting for responses that lie at the extremities of the scale (Allen and Seaman, 2007; Albaum et al., 1997). These types of responses can result in bias and can result in the participants true thoughts not being communicated (Sung and Wu, 2018).

Likert-type scales are an ordinal level measure and do not have an interval level measure. Therefore, the response sets have a ranking order but the interval between the values must not be presumed to be equal (Jamieson, 2004). This can lead to errors in statistical analysis of the data. It has also been suggested that using too few categories for responding in the Likert-type scale will impede the participant's ability to accurately convey their feelings and therefore reduces reliability of the study (Viswanathan et al., 1996).

1.9.2 Visual Analogues Scale (VAS)

The visual analogues scale (VAS) was developed to overcome some of the deficiencies observed in the Likert-type scale. The VAS can be used as an aesthetic perception measurement tool and was found to be used more frequently than Likert-type scales in studies (Parrini et al., in 2016). It is thought to be the 'gold standard' of assessing perception of feelings, which are quite difficult to quantify as a figure due to their complexity (Cline et al., 1992; Lombardi, 1973).

The VAS captures more variability and uses a continuous line rather than several categories as seen in Likert-type scales (Sung and Wu, 2018). It has been suggested that giving participants' the opportunity to place their responses anywhere on a continuous line frees the VAS from the issues of determining the number of response categories, as well as producing continuous and interval level data (Reips and Frunke, 2008). The VAS can have a midpoint which has been found to be statistically insignificant in affecting differences between the rating; although average scores tend to be lower on a VAS without a midpoint (Couper, 2006). VAS marked only at both terminuses without a midpoint is considered more sensitive than those with a midpoint (Joyce et al., 1975). The 'central bias tendency' is an outcome that is observed when a VAS has a midpoint with a high proportion of participants rating on the midpoint (Couper, 2006; Millar et al., 1995). Subjects rating on the VAS take longer to complete the scale when a midpoint was not present, suggesting that when a midpoint is present it simplifies the understanding of the scale (Couper, 2006). For these reasons it has been proposed that training on the use of the VAS is provided to participants in depth prior to completing the scale in order to ensure valid results (Wewers and Lowe, 1990). Numeric scales on a VAS have been the subject of criticism as they are thought to influence ratings with larger numbers on the scale implying more positive results which can affect the reliability of the results (Couper, 2006; Schwarz et al, 1991; Scott and Huskisson, 1977).

However, it has been found that the most preferred, accepted, and beneficial methods of rating perception of attractiveness by psychologists in research is the Likert-type scale (Langlois et al., 2000). Recent studies in assessing facial profile attractiveness have used the 7-point Likert rating scale in order to rate the attractiveness of their 2D silhouette images with the extremities of their scales being indicated by 'extremely unattractive' to 'extremely attractive' (Naini et al., 2015; Naini et al., 2012).

1.10 Viewing of two-dimensional (2D) and three-dimensional (3D) images

Previous studies have utilised profile photographs and silhouette to evaluate perception of facial aesthetics (Todd et al., 2005; Naini et al., 2015; Naini et al., 2012). Given the technology of the day, two-dimensional (2D) profile images were routinely used to represent the face. With technological development it is now possible to capture the 3D shape of the face together with photorealistic texture which have been utilised for the assessment of facial attractiveness and perception studies (Todd et al., 2005; Storms et al., 2017).

Conventional photographs fail to capture the three-dimensional facial depth and shape and are susceptible to magnification and distortion (Sarver, 2001; Da Silveira et al., 2003). Three-dimensional soft tissue imaging enables the depiction of the facial surface in three dimensions, addressing the limitations of two-dimensional imaging (Souccar and Kau, 2012). It is also thought that possible bias linked with a single 2D image can be reduced by using 3D images, which allow representation of various angles of the image (Trebicky et al., 2018).

The most widely used 3D soft tissue capture systems are stereophotogrammetry and laser scanners (Rasteau et al., 2020; Awarun et al., 2019). These systems are non-invasive and do not irradiate the subjects. They operate by using multiple cameras to capture the image of an illuminated object (Hennessey et al., 2005; Hennessey et al., 2006). Increased numbers of treatment centres such as cleft centres have utilised 3D imaging methods for treatment planning and outcome evaluation using these 3D image capture systems (Awarun et al., 2019).

These imaging techniques yield accurate and reproducible images which are valuable tools for research and documentation (Stebel et al., 2016). However, many studies have been unclear regarding the benefit of evaluation of aesthetic outcome utilising 2D or 3D imaging techniques (Stebel et al., 2016). One study demonstrated that 2D and 3D images were comparable for evaluating some regions of the face such as the nose and midface, however there was poor correlation during assessment of the upper lip which is significant when assessing the nasolabial complex in a patient with cleft lip and palate (Al-Omari et al., 2003). Another study by Zhu et al. (2017) compared the reliability of using 2D versus 3D images and stereoscopic 3D projections for patient assessment and rating. They found that using stereoscopic 3D projections resulted in lower rating scores than either 2D or 3D images and that overall stereoscopic 3D projection was patients preferred method for rating (Zhu et al., 2017). This study also found that intra-rater reliability was dependent on both the viewing medium as well as which facial feature was being analysed.

The use of 3D images over 2D images has been associated with higher intra-rater reproducibility (Stebel et al., 2016). The study also noted that the rating panel found the 3D images to be more informative regarding the nasolabial appearance when compared with the 2D images. They also however showed a tendency that 2D images were easier to use for aesthetic evaluation compared with 3D images but concluded that overall 3D images are favoured to 2D images for rating nasolabial appearance (Stebel et al., 2016).

1.11 Raters in perception of aesthetic studies

Research of aesthetic perception of the nasolabial angle tends to use similar cohorts of subjects to rate their images. Professional groups such as orthodontists and maxillofacial surgeons tend to be selected and these are usually compared with a lay person group of varying ages (Naini et al., 2012; Naini et al., 2015; Todd et al., 2005; Zhu et al., 2017). The lay person group can sometimes be subdivided into the general public and those who are undergoing orthodontics and ready for orthognathic surgery (Naini et al., 2015)

The age categories of these individuals can vary, with the majority of studies recruiting individuals aged eighteen or above, without a history of severe psychological problems such as body dysmorphia and no history of facial deformity (Naini et al., 2015; Droubi et al., 2020). These groups of raters are commonly impacted by orthodontic, orthognathic or a combination treatment, through seeking orthognathic treatment in the second and third decade of life or through planning for treatment of patients as an orthodontic professional (Breacher et al., 2019). However, studies have shown that there is minimal difference in the perception of facial aesthetics between varying age groups, and therefore having a range of ages may not be necessary (Salehi et al., 2019).

When comparing male and female rater outcomes for assessing facial aesthetics, historically studies have found no association between gender and rating outcome (Tedesco et al., 1983b). This finding has been confirmed in more recent studies using both 2D and 3D images (Todd et al., 2005).

1.12 Summary

Movement of the teeth and facial bones during orthodontics and orthognathic surgery can result in changes of the overlying facial soft tissue. Modern orthodontics has placed emphasis on the need to balance the desire to achieve an ideal Class I occlusion, without "harming" the facial profile. The nasolabial soft tissues play a key role in facial aesthetics and can have a large influence on a patient's appearance and profile, emphasising the importance of soft tissue assessment prior to planning treatment. The nasolabial angle, which is dependent on the inclination of the nasal columella and the upper lip, is formed by drawing a line tangent to the nasal columella and a line tangent to the upper lip, which both intersect at subnasale.

Features of facial attractiveness that have been universally established include facial symmetry, averageness or how strongly a face resembles the mainstream faces within a given population. It has also been linked to a class I skeletal pattern and angle of convexity of the face which falls under a skeletal I profile appearance. This is influenced by the position of subnasale which plays a role in the nasolabial angle. Anecdotal evidence for normal or ideal nasolabial angles based on the perception of surgeons, have been widely accepted and have been described to be between 90°-120°. This however is affected by gender and ethnicity amongst other factors. The research is variable however, it has been suggested that the ideal nasolabial angle for males is 93.4° to 98.5° and the ideal for females is 95.5° to 100.1°. Furthermore, perception of the nasolabial angle is based on ethnic background, with more acute angles being considered more aesthetic or acceptable in African populations compared with Caucasian and Asian populations.

Changes in dental and skeletal maxillary position will occur following orthodontic and/or orthognathic treatment. These changes will be observed in the surrounding soft tissue of the nasolabial complex region. This can be attributed to orthodontic extraction, retraction or proclination of the upper incisors, use of headgear or temporary anchorage devices or orthognathic surgery. Studies have found that with orthodontic tooth movement the NLA can increase by 1.63° on average for every one millimetre of upper incisor retraction. Similarly, maxillary advancement with impaction may result in the nasal tip being positioned more superiorly or upturning, in up to 85% of cases, which may have the undesired effect of increased nostril show and increased nasolabial angle.

Psychologists have historically agreed and accepted the Likert-type scale is a useful and popular method for measuring the perception of attractiveness. However, using too few categories for responses on the Likert-type scale can impede a participant's ability to accurately convey their feelings and therefore reduces reliability of the study. Recent studies in assessing facial profile attractiveness have used the 7-point Likert rating scale in order to rate the attractiveness of their 2D silhouette images with the extremities of their scales being indicated by 'extremely unattractive' to 'extremely attractive'. Previous studies have utilised profile photographs and silhouette to evaluate perception of facial aesthetics. Conventional photographs fail to capture the three-dimensional facial depth and shape and are susceptible to magnification and distortion. Three-dimensional soft tissue imaging enables the depiction of the facial surface in three dimensions, addressing the limitations of two-dimensional imaging. It is also thought that possible bias linked with a single 2D image can be reduced by using 3D images, which allow representation of various angles of the image.

Professional groups such as orthodontists and maxillofacial surgeons tend to be selected and these are usually compared with a lay person group of varying ages. The lay person group can sometimes be subdivided into the general public and those who are undergoing orthodontics and ready for orthognathic surgery. However, studies have shown that there is minimal difference in the perception of facial aesthetics between varying age groups, and therefore having a range of ages may not be necessary.

With the evolution of beauty ideals and the greater influence of social media and cosmetic treatment on facial aesthetics, the orthodontic team must widen their knowledge of these norms to continue to assess and aim to achieve a balance of soft tissue and occlusal aesthetics. Studies of patient perception of the nasolabial angle have been historically carried out using 2-dimensional simulated silhouette images, however the literature does not document such studies being carried out using 3-dimensional images using male, female, and non-gender specific and non-textured images.

CHAPTER 2

AIMS AND NULL HYPOTHESIS

2.1 Primary aim

The primary aim of this study was to determine which nasolabial angle, from 70° to 110° was thought of as the most attractive by laypeople and clinicians and did the rating score depend on the type of image they viewed i.e., 2D facial profile silhouettes, 3D female textured, 3D male textured and 3D grey non-textured images.

2.1.1 Primary outcome measure

Difference in facial attractiveness rating score between clinicians and laypeople.

2.1.2 Null hypothesis

There was no statistically significant difference ($p < 0.05$) in facial attractiveness rating score between clinicians and laypeople when assessing 5 different nasolabial angles using 2D silhouettes, 3D female textured, 3D male textured and 3D grey non-textured images.

2.2 Secondary aims

The secondary aims of this study were to,

1. Assess whether 2D silhouettes, and 3D grey non-textured images were rated similarly.
2. Determine which nasolabial angles clinicians and laypeople would seek treatment.
3. Assess which type of image the clinician and laypeople group found most beneficial for rating.

2.2.1 Secondary null hypothesis

There was no statistically significant difference ($p < 0.05$) in facial attractiveness rating score between clinicals and laypeople rating 2D silhouettes and 3D grey non-textured images.

CHAPTER 3

MATERIALS & METHODS

3.1 Study Design

The study was executed as a cross-sectional study. Participants were recruited initially verbally by the principal investigators (SEH and BSK). This was followed up with a formal written invitation to participate in the study, providing study information sheets and written consent forms as hard or soft copies (Appendix I).

3.2 Ethical Approval

Ethical approval was sought and obtained from the University of Birmingham's Research and Ethics committee (ERN 20-1332).

3.3 Sample Size Calculation

A *priori* sample size calculation was carried out using G*power (Faul et al., 2007). For the calculation, the power was set at 0.9 (90%), the statistical significance level at p = 0.05, and an effect size of 0.2 (Cohen, 1988).

Following statistical advice it was suggested that the 7 point Likert scale should be considered as continuous data and the facial attractiveness score will probably not be normally distributed. In view of this an additional 15% should be added to the sample size calculation. Following this a minimum of 46 raters were required in each the clinician and laypeople group.

3.4 Rater recruitment

Fifty clinicians and seventy two laypeople were recruited as raters for the study. The clinician group were Orthodontists recruited from the West Midlands Orthodontic Society, the Northern Universities Consortium and past and present trainees from Birmingham Dental Hospital, working as Specialist Orthodontists. The laypeople group were recruited from the Birmingham School of Science, University of Birmingham. Seventy-two participants responded from the laypeople group and all were recruited and participated in the study to avoid selection bias.

3.4.1 Clinician group

The inclusion criteria included;

- Adults over the age of 18 years old, with capacity to consent.
- General Dental Council registered dentists.
- Registered specialist orthodontists.
- Trainee orthodontists – StR and post-CCST level.

The exclusion criteria were:

- Non English speakers.
- Non registered GDC dentists.
- Non registered Orthodontists.

3.4.2 Laypeople group

The inclusion criteria included;

- Adults over the age of 18 years old, with capacity to consent
- No previous history of facial surgery, treatment for facial deformities, or facial trauma

The exclusion criteria were:

- Non English speakers
- History of facial surgery, treatment for facial deformities, or facial trauma

3.5 Questionnaires

Each rater was provided with a rating sheet to complete (Appendix II).

3.5.1 Rating sheet

Image rating was undertaken using a 7-point scale Likert scale with the following headings: 1, extremely unattractive; 2, very unattractive; 3, slightly unattractive; 4, neither attractive nor unattractive; 5, slightly attractive; 6, very attractive; or 7, extremely attractive. The Likert scale was completed on paper for those who participated in the study on site (face to face) at the University of Birmingham. For those completing the ratings virtually, via Microsoft Teams, the Likert scale was completed using a Microsoft Word document or a PDF document.

For each image, raters were also asked two additional follow up questions,

1. *'Would you consider seeking treatment if this image represented your own appearance?' (Yes or No).*
2. *'Which image did you find easiest to rate? (2D silhouette, 3D grey (non textured) image or 3D textured image).*

3.6 Three-dimensional image generation

3.6.1 Di4DSNAP imaging system

The 3D imaging system (Di4DSNAP, Dimensional Imaging Ltd, Hillington, Glasgow) used to construct the 3D facial stimuli was made up of six cameras (Canon) arranged in three banks of two cameras, connected to a personal computer. The left and right camera banks captured the left and right aspects of the face respectively, whilst the centre camera captured the mid-region of the face. This allowed full facial coverage from ear to ear. In addition to the camera system, there were two light sources (Esprit Digital DX1000, Bowens, Essex, UK) which illuminated the subject during capture. The capture time was approximately 1ms.

3.6.2 System calibration

Prior to image capture the system required calibration according to the manufactures instructions. The purpose of the calibration was to determine the intrinsic and extrinsic camera properties. The calibration process involved capturing a calibration target, provided by the manufacturers of the system, at six different orientations. The calibration target was made up of a series of dots with a known distance between their centres, in this case 2 centimetres. The system used the calibration data and the principle of triangulation to determine the depth. This calibration data was required to reconstruct the 3D image from the six 2D images captured by the camera system.

3.6.3 Subject capture

An adult male and female from the staff at the Birmingham Dental Hospital and School volunteered and consented to their facial texture being used in this study. The male volunteer had no facial hair (moustache and beard), as this would obscure the nasolabial region. Both were of Caucasian background.

The male subject was positioned a set distance, determined by the manufacturer, in front of the Di4DSNAP system, immediately behind the subject was a blue screen. Prior to image capture any loose hair, over the volunteers forehead, was tied back and any makeup, jewellery and spectacles removed. The male volunteer was positioned in front of the camera system in rest position and several images taken. This process was repeated for the female subject.

The images were then saved as Wavefront (.OBJ files) which was made up of the following files:

1. An OBJ file which contained, the position of each vertex, the UV position of each texture coordinate vertex, vertex normals and the faces that made each polygon. These were defined as a list of vertices, and texture vertices, these together made up the "wire frame mesh". The UV position was used during the 3D modelling process for projecting the 2D image onto the 3D model's surface for texture mapping.
2. A separate texture file (.JPEG or .BMP) file as a 2D photograph.
3. A material library (.MTL) file which described surface shading (material) properties of objects.

The three files together were required for the re-generation of a 3D image with the appropriate photorealistic texture.

3.7 Creation of visual stimuli

The following stages were necessary to produce a 3D face with differing nasolabial angles and with either a male or female texture.

1. Generation of a symmetrical 3D face (generic mesh) with anatomical correct features (grey image) without any photorealistic texture.
2. Creation of a conformed generic mesh with addition of texture.
3. Modification of nasolabial angle of the image.
4. Addition of texture to modified 3D facial image – male or female.

3.7.1 Generation of a symmetrical 3D face with anatomical correct features (grey image) without any photorealistic texture.

A computer generated three-dimensional (3D) symmetrical face was used. The 3D image was provided as a “generic mesh” by Dimensional Imaging Ltd. The generic mesh was constructed from 3,800 vertices and was textureless, Figure 3.1.

3.7.2 Creation of a conformed generic mesh with addition of texture.

The process involved replacing the original Di4DSNAP image wire frame mesh with the generic mesh. This was achieved by the process of “conformation”. Conformation changed the shape of the generic mesh so it was the same shape at the original mesh.

The male original .OBJ file and generic mesh .OBJ were imported into Di3DView. The generic mesh was conformed to the original mesh by identifying 22 corresponding anatomical landmarks on both the original mesh and generic mesh, Figure 3.2. Then using the “Shape Transfer” function in Di3DView the generic mesh was elastically deformed to the same shape as the original mesh constrained at the key 22 anatomical landmarks, Figures 3.3 and 3.4. The male conformed generic mesh was then saved as an .OBJ file. This file contained the data to reconstruct the wire frame but had no texture.

The original photorealistic texture needed to be transferred to the conformed generic mesh. This was achieved using the “Material Transfer” function in Di3DView which mapped the original UV’s to the conformed generic mesh. This process involved selecting the polygon faces

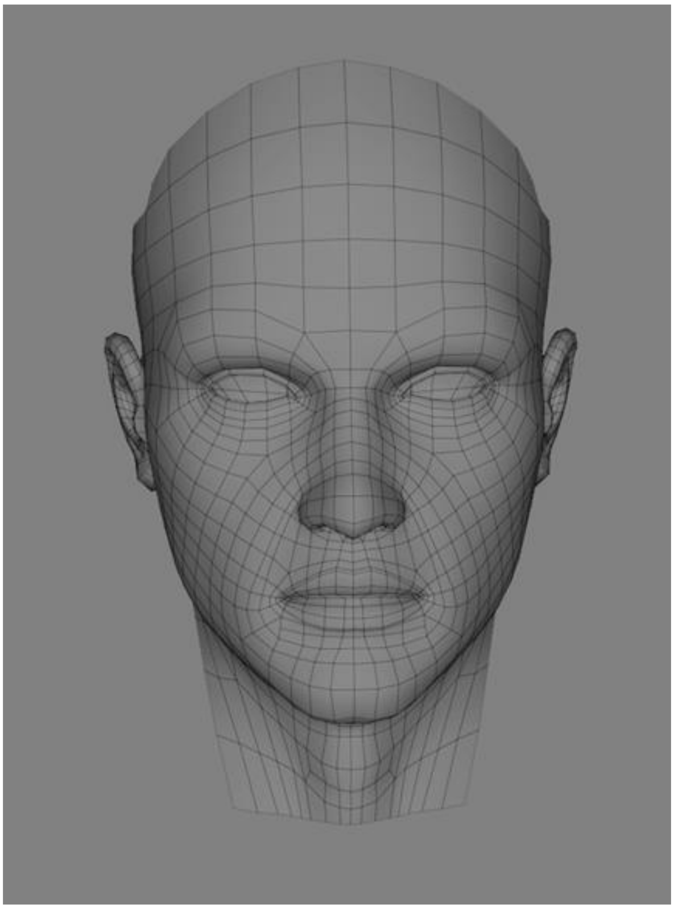


Figure 3. 1 Three-dimensional (3D) “generic mesh” provided by Dimensional Imaging Ltd. The generic mesh was constructed from 3,800 vertices and was textureless.

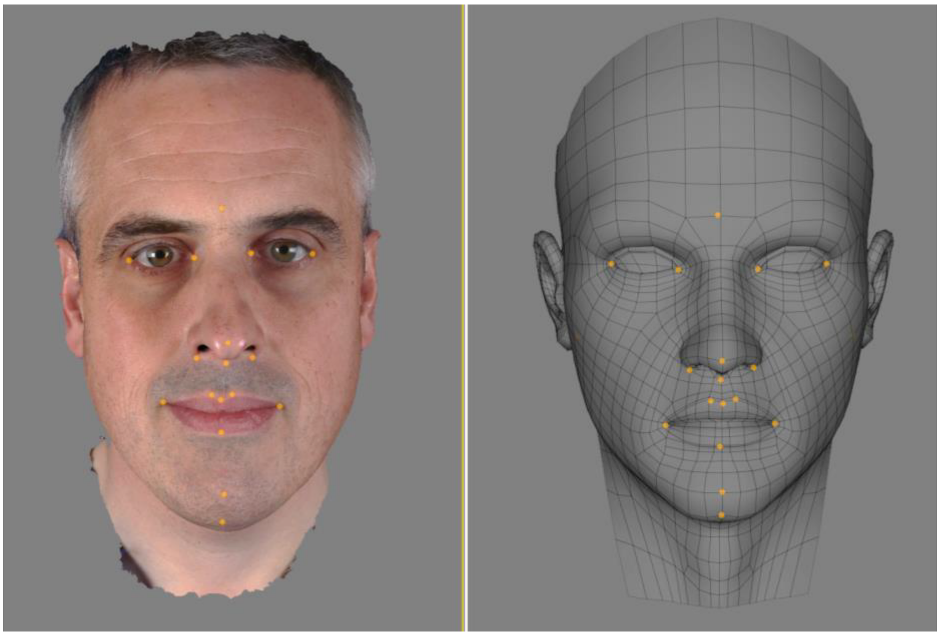


Figure 3. 2 Corresponding anatomical landmarks on both the original mesh and generic mesh, for conformation.

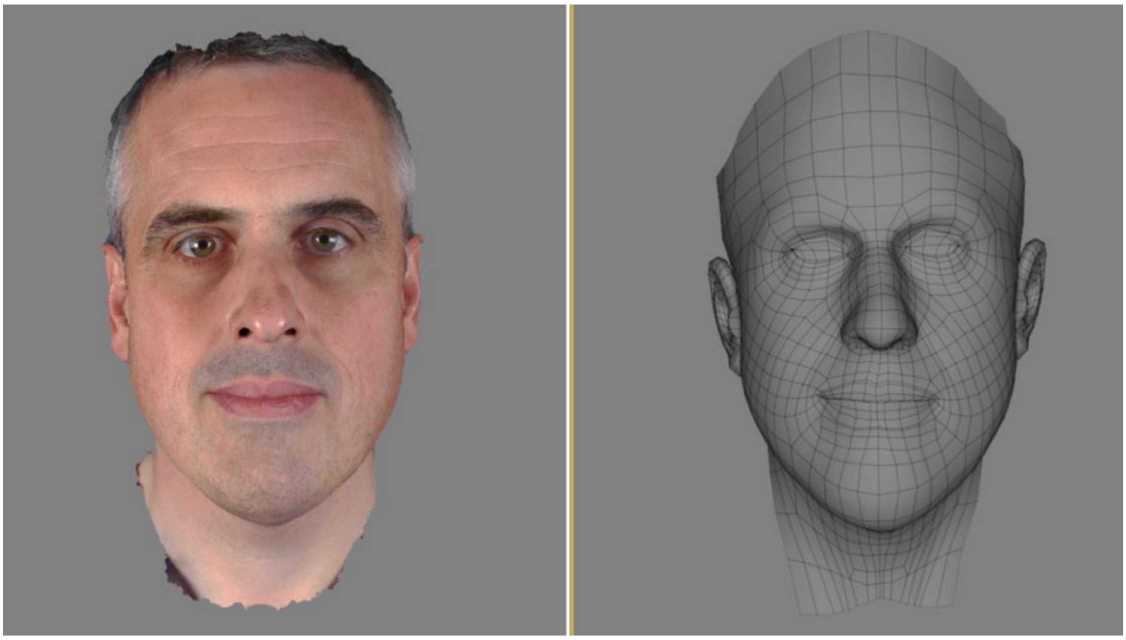


Figure 3. 3 Conformed generic mesh – same shape as original facial mesh – frontal view

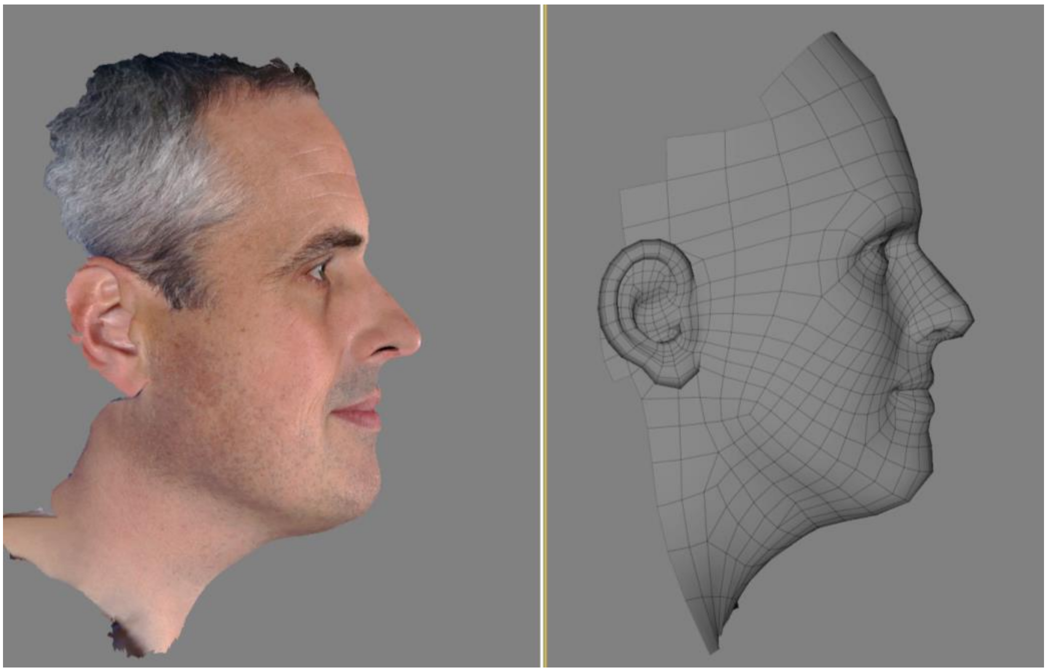


Figure 3. 4 Conformed generic mesh – same shape as original facial mesh – profile view

on the conformed generic mesh and assigning the male texture to the polygon face, Figures 3.5 and 3.6. This was saved as a new .OBJ file, with new .MTL file and the original male texture file (.JPEG), Figure 3.7. This entire process was repeated for the female subject, again producing a new .OBJ file, with new .MTL file and the original female texture file (.JPEG). It is worth noting that both the male and female images originated from same generic mesh and so had the same number of vertices (but different co-ordinates), as well as the same UV position for each texture coordinate vertex, vertex normals and the faces that made each polygon.

3.7.3 Modification of nasolabial angle

The generic mesh (.OBJ) was imported into 3dMD. Patient and a facial mid-plane was extracted using the "Extract Facial Mid-Plane" tool in the software. The mid-plane was created following the manual selection of three points; Glabella, Nasal tip and Subnasale. Following this the "Free-form" tool was selected which opened a separate window with a 2D profile of the 3D image created from the mid-facial plane. The shape of the 2D profile could be changed by dragging the outline to a new position on the 2D image. Any changes made to the surface of the 2D image were propagated into 3D affecting the whole surface. The nasolabial angle was adjusted until it was at 70^{o} and the image saved in .OBJ format. This was repeated for nasolabial angles of 80^{o}, 90^{o}, 100^{o} and 110^{o}, Figures 3.8 and 3.9.

3.7.4 Addition of texture to modified 3D facial image – male and female.

As highlighted previously the conformed generic meshes for both the male and female subject were constructed from the same generic mesh. Therefore, at this stage the .MTL file could be edited so either the male or female photorealistic soft tissue textured image (.JPEG) file could

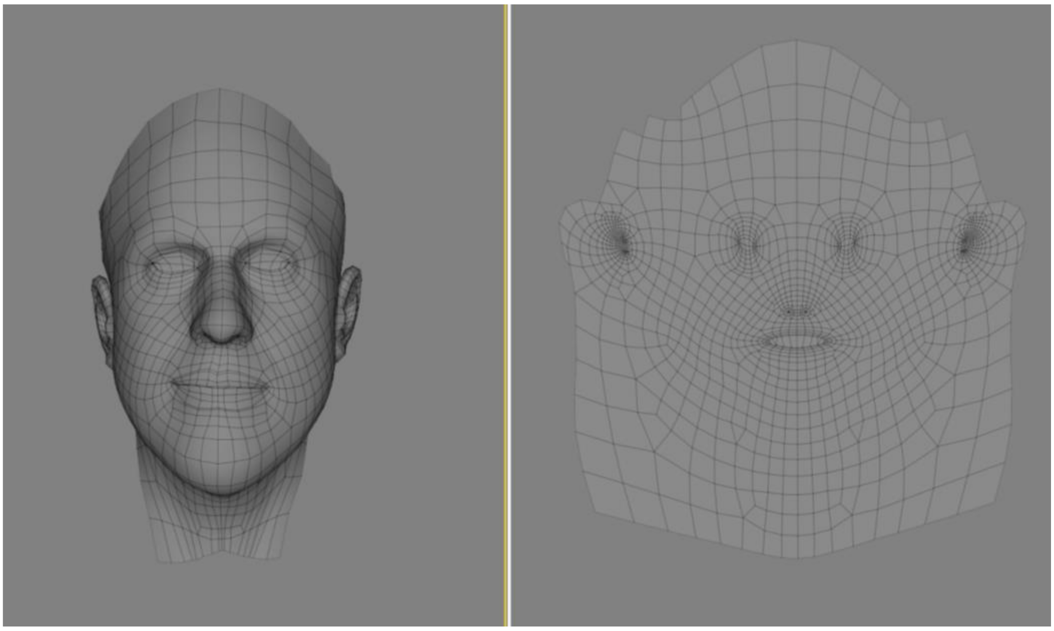


Figure 3. 5 Aligning texture to conformed generic mesh – faces & UV's identified

Figure 3. 6 Aligning texture to conformed generic mesh – texture transfer

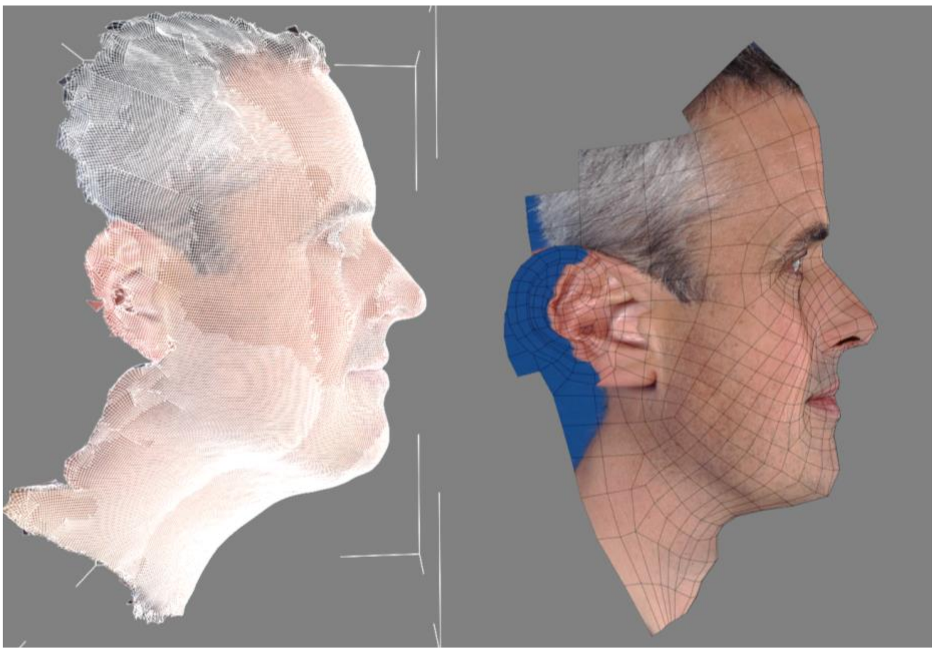


Figure 3. 7 Final 3D image – male, textured 3D conformed mesh

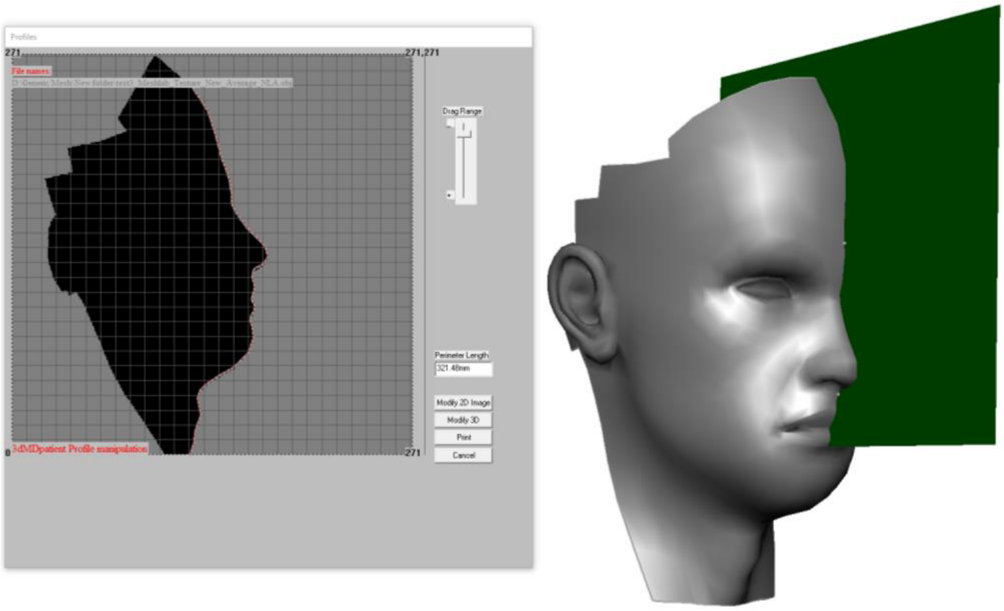


Figure 3. 8 Creation of modifiable 2D profile using 3dMD

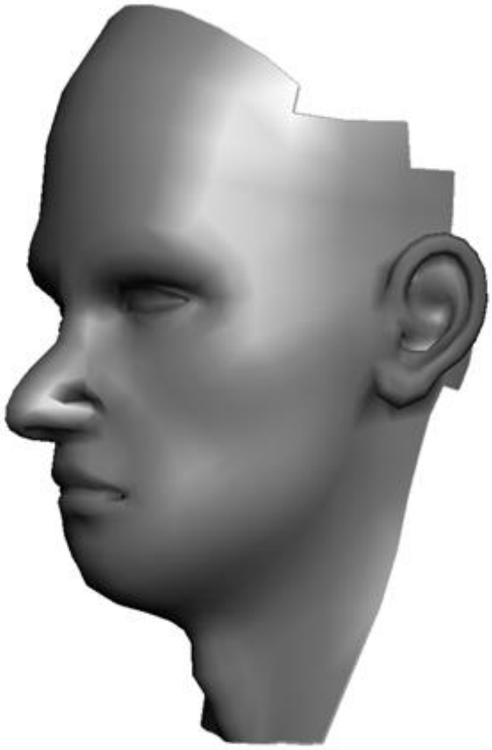


Figure 3. 9 Example 3D image – 2D profile images was adjusted to increase nose

be loaded. In other words, the female texture map could be loaded over the male facial surface shape and vice versa.

3.7.4.1 Two-dimensional (2D) facial profile silhouette with different nasolabial angles

The modified generic mesh with a nasolabial of 70^{o} was opened in Di3DView, the MTL file was edited to read no texture. The image was re-orientated so that the Frankfort plane was parallel to the horizontal plane with the subject facing to the right and the screen captured. This was then copied into Adobe Photoshop and the image converted into a facial profile silhouette by finding the soft tissue / background boundary and filling the profile soft tissue outline in black and the surrounding background in white. This was repeated for the images with a nasolabial angle of 80^{o}, 90^{o}, 100^{o} and 110^{o} and the 5 images saved in Powerpoint, Figure 3.10.

3.7.4.2 Male and female 3D textured images with different nasolabial angles

The modified generic mesh with a nasolabial of 70^{o} was copied into a new folder containing its .MTL file and the male and female texture file (.JPEG). The .MTL file was edited to read the male texture, and the image opened in Di3DView. This produced a 3D facial image of a male with a 70^{o} nasolabial angle. The images were re-orientated so that the Frankfort plane was parallel to the horizontal plane with the subject facing to the right. The image was rotated from the right profile position to the left by 45^{o} and back again to right profile. This was repeated 3 times over a 30 second period, whilst being recorded with an on-screen recorder, and saved as a .MP4 file. This was repeated for the female image, after having edited the .MTL file to read the female .JPEG file. This entire process was repeated for the images with a nasolabial angle of 80^{o}, 90^{o}, 100^{o} and 110^{o}. In total this produced 10 video clips (.MP4), 5 female and 5 male textured images, Figures 3.11 and 3.12.

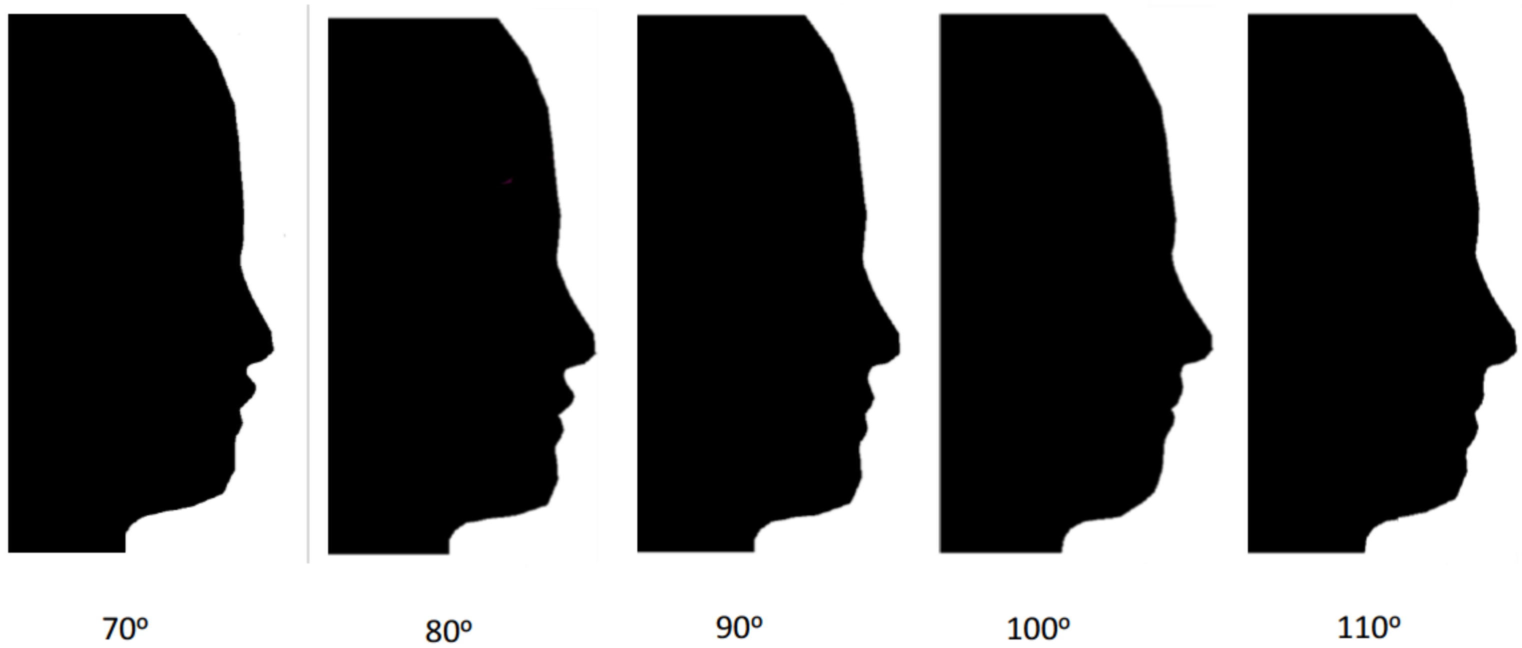


Figure 3. 10 Two-dimensional (2D) facial profile silhouette with different nasolabial angles

70º 80º 90º 100º 110º

Figure 3. 11 Female 3D textured images with different nasolabial angles

70°　　80°　　90°　　100°　　110°

Figure 3. 12 Male 3D textured images with different nasolabial angles

3.7.4.3 3D grey images with different nasolabial angles

The modified generic mesh with a nasolabial of 70° was opened in Di3DView, the MTL file was edited to read no texture. This produced a grey 3D facial image with a 70° nasolabial angle. As before, the image was re-orientated so that the Frankfort plane was parallel to the horizontal plane with the subject facing to the right. The image was rotated from the right profile position to the left by 45° and back again to right profile. This was repeated 3 times over a 30 second period, whilst being recorded with an on-screen recorder, and saved as a .MP4 file. This was repeated for the images with a nasolabial angle of 80°, 90°, 100° and 110°; in total producing 5 video clips (.MP4), Figure 3.13.

3.8 Preparation of images for rating

For ease of viewing, the video sequences (.MP4) were embedded into a PowerPoint presentation, together with the 2D facial profile silhouette images. The images were grouped together into their main categories i.e. 2D facial profile silhouette, 3D textured (female), 3D textured (male) and 3D non textured grey. Within each group the different nasolabial angle images appeared in a random order. In addition, two duplicate images from each group were chosen at random and included in each respective group. In total 28 images where embedded into the Powerpoint presentation.

3.8.1 Image rating

Prior to image rating, written and verbal instruction were provided on completing the 7-point rating scale. Raters were directed towards assessing the nasolabial region and were given the opportunity to ask questions prior to beginning the image rating session.

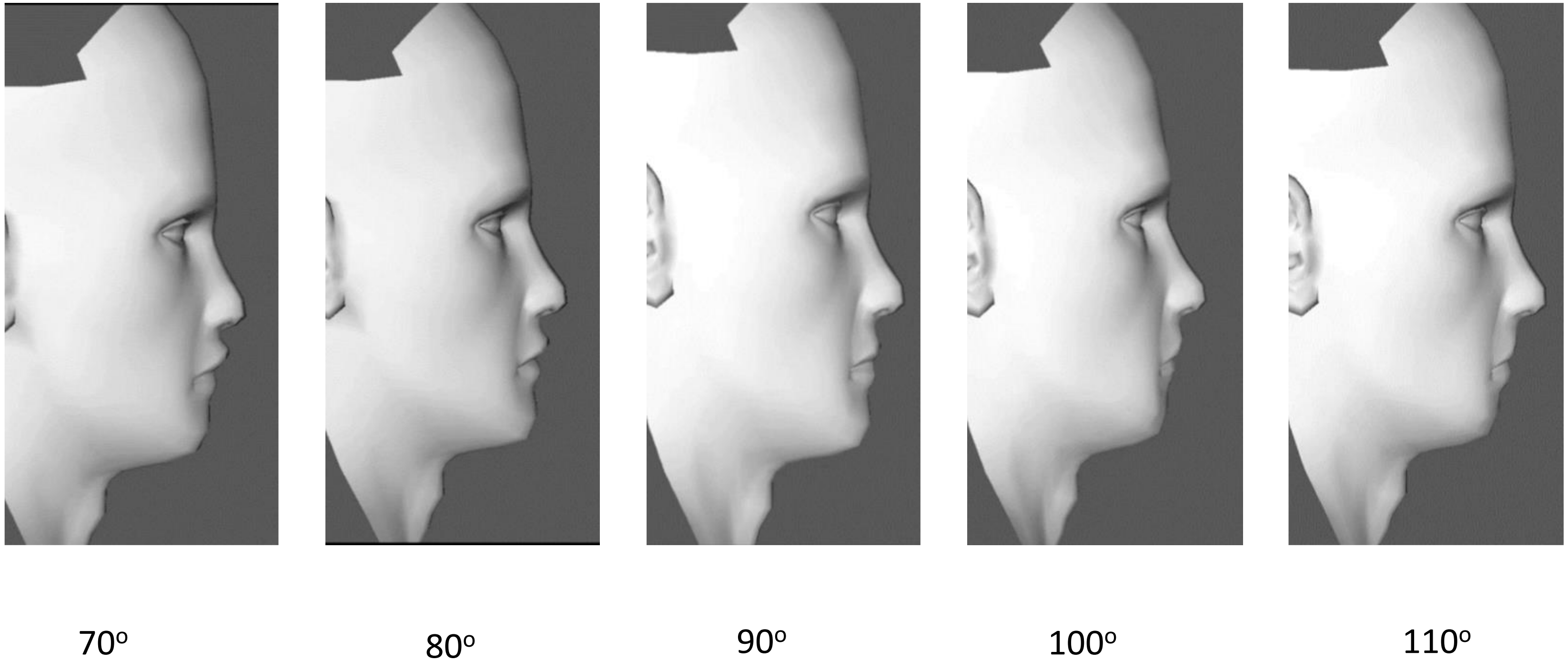


Figure 3. 13 3D grey images with different nasolabial angles

3.8.1.1 Laypeople group

The images, embedded in the PowerPoint presentation, were viewed on a projector screen in a seminar room within the University of Birmingham. Due to social distancing and COVID restrictions three back to back consecutive presentations were necessary to allow the 72 individuals to view the presentation. A timer was set to ensure the participants viewed each image for 30 seconds during the rating presentation. The laypeople group were asked to complete a paper based scoring sheet which was transferred to an EXCEL file for further analysis.

3.8.1.2 Clinician group

Collecting data for the orthodontist group was more complex due to COVID-19 restrictions, resulting in face to face meetings being cancelled, delays in meetings and availability of participants due to redeployment. Multiple Microsoft Team meetings were held and the presentations were carried out virtually. Again, a timer was set to ensure the participants viewed each image for 30 seconds during the rating presentation. The clinician group were asked to either complete a paper based scoring sheet or WORD document, which was returned to the principal investigator SEH. Two separate EXCEL sheets were created, one for the clinician group and the other for the laypeople group. The Excel sheets were completed with coded information to allow the anonymous data to be analysed.

3.9 Statistical analysis

Following statistical advice, rater scores derived from the 7-point Likert scale were treated as continuous data which would not be normally distributed. In view of this median and interquartile ranges data was predominately presented, together with the mean and standard deviation.

To determine the intrarater reliability analyses the intraclass correlation coefficient (ICC) was used.

To determine if there was a statistically significant difference (p = 0.05) in facial attractiveness rating score between clinicians and laypeople when assessing 5 different nasolabial angles using 2D facial profile silhouettes, 3D female textured, 3D male textured and 3D grey non-textured images a Freidman test was performed, followed by a post hoc analysis using a Wilcoxon signed-rank test with a Bonferroni correction were appropriate.

A Mann-Whitney U test was used to determine if there was a statistically significant difference (p = 0.05) in facial attractiveness rating score between clinicians and laypeople when assessing 5 different nasolabial angles using 2D facial profile silhouettes, 3D female textured, 3D male textured and 3D grey non-textured images.

To determine if there was a statistically significant difference (p = 0.05) in facial attractiveness rating score between clinicians and laypeople when assessing 5 different nasolabial angles using 2D facial profile silhouettes and 3D grey non-textured images a Wilcoxon signed rank test was performed.

CHAPTER 4

RESULTS

4.1 Intrarater reliability

Table 4.1 shows the intraclass correlation coefficients for the intra-rater reliability of clinicians and laypeople when they scored the 4 different types of duplicate image. Values less than 0.5 are indicative of poor reliability, between 0.5 and 0.75 indicate moderate reliability, between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability (Koo and Li, 2016). For both the clinicians and laypeople the ICC was between 0.80 and 0.86 for clinicians and 0.75 to 0.89, indicating a good level of reliability.

4.2 Effect of nasolabial angle on facial attractiveness rating based on the different image types

4.2.1 Two-dimension (2D) facial profile silhouettes

For the laypeople group, based on a Freidman test, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (p = 0.001). A post hoc analysis using a Wilcoxon signed-rank test was conducted with a Bonferroni correction. The median (IQR) facial attractiveness scores for nasolabial angles of 70°, 80°, 90°, 100° and 110° were 3 (3 to 4), 4 (4 to 5), 4 (4 to 5), 4 (3 to 5) and 3 (2 to 4) respectively, Table 4.2. There were no significant differences between nasolabial angles of 80°, 90° and 100° (p = 0.968), or between 70° and 110° (p = 0.956). However, the facial attractiveness scores were statistically significantly lower (p = 0.001) for 70°, 110° than for 80°, 90°, 100°.

For the clinician group, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (p = 0.001). The median (IQR) facial attractiveness scores for a nasolabial angle of 70°, 80°, 90°, 100° and 110° were 3 (2 to 3),

Table 4. 1 The intraclass correlation coefficients for the intra-rater reliability of clinicians and laypeople when they scored the 4 different types of duplicate image

Viewing image	Intraclass Correlation Coefficients (ICC)	
	Clinician	Laypeople
2D facial profile silhouette	0.86	0.86
3D female textured	0.75	0.80
3D male textured	0.85	0.80
3D non-textured grey	0.89	0.82

Table 4. 2 Descriptive statistics for the laypeople group facial attractiveness rating assessing five different nasolabial angles using 2D facial profile silhouettes

Nasolabial angle	Median rating	IQR	Mean rating	SD
70 °	3	3 to 4	3.4	0.9
80 °	4	4 to 5	4.5	0.9
90 °	4	4 to 5	4.2	0.9
100 °	4	3 to 5	3.9	0.9
110 °	3	2 to 4	2.9	1.0

5 (4 to 6), 5 (4 to 6), 4 (3.75 to 5) and 3 (2.75 to 3) respectively, Table 4.3. Again, there were no significant differences for nasolabial angles between 80°, 90° and 100° (*p* = 0.998), or between 70° and 110° (*p* =0.945). The facial attractiveness scores were statistically significantly lower (p = 0.001) for nasolabial angles of 70°, 110° than for 80°, 90°, 100°.

Clinicians and laypeople rated 2D facial profile silhouette images with 70° and 110° nasolabial angles as the least attractive. Both groups gave the 80° nasolabial angle the highest facial attractiveness score. However, there was no statistically significant differences between nasolabial angles of 80°, 90° and 100°. A Mann-Whitney U test showed clinicians rated the images with a 70° nasolabial angle as significantly more unattractive than laypeople (p=0.005). For a 90° nasolabial angle, clinicians rated the images as significantly more attractive than laypeople (p=0.005), Table 4.4.

4.2.2 Three-dimensional (3D) female textured images

For the laypeople group, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (*p* = 0.001). The median (IQR) facial attractiveness scores for nasolabial angles of 70°, 80°, 90°, 100° and 110° were 4 (3 to 5), 5 (4 to 5), 4 (3 to 5), 2 (2 to 3) and 2 (2 to 3) respectively, Table 4.5. There were no significant differences between 100° and 110° (*p* = 0.307), 70° and 90° (*p* = 0.998) and 80°and 90° (p=0.651). 3D female textured images with nasolabial angles of 100° and 110° had statistically significantly (p = 0.001) lower facial attractiveness scores than nasolabial angles of 70°, 80° and 90°.

Table 4. 3 Descriptive statistics for the clinician group facial attractiveness rating assessing five different nasolabial angles using 2D facial profile silhouettes

Nasolabial angle	Median rating	IQR	Mean rating	SD
70°	3	2 to 3	3.1	1.1
80°	5	4 to 6	4.8	1.2
90°	5	4 to 6	4.7	1.1
100°	4	3.75 to 5	4.2	0.8
110°	3	2.75 to 3	2.9	0.8

Table 4. 4 Difference in attractiveness rating assessing five different nasolabial angles using 2D facial profile silhouettes between the clinician and laypeople group following a Mann-Whitney U test

Nasolabial angle	p-value
70 º	0.005*
80 º	0.054
90 º	0.005*
100 º	0.255
110 º	0.720

Mann-Whitney U test *(p<0.05)

Table 4. 5 Descriptive statistics for the laypeople group facial attractiveness rating assessing five different nasolabial angles using 3D female textured images

Nasolabial angle	Median rating	IQR	Mean rating	SD
70°	4	3 to 5	3.7	1.3
80°	5	4 to 5	4.4	1.0
90°	4	3 to 5	3.9	1.1
100°	2	2 to 3	2.8	1.2
110°	2	2 to 3	2.4	0.9

For the clinician group, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (*p* = 0.001). The median (IQR) facial attractiveness scores for a nasolabial angle of 70°, 80°, 90°, 100° and 110° were 3 (3 to 4), 5 (4 to 6), 5 (4 to 6), 3 (2 to 3) and 2 (2 to 3) respectively, Table 4.6. Again, there were no significant differences for nasolabial angles between 80° and 90° (*p* = 0.998) or between 70°, 100° and 110° (*p* = 0.999). There was however a statistically significant difference (p = 0.001) between the two groups of angles.

Clinicians and laypeople rated 3D female textured images with 70°, 100° and 110° nasolabial angles as the least attractive. Both groups gave the 80° nasolabial angle the highest facial attractiveness scores. There was no there were no statistically significant differences in the facial attractiveness score between nasolabial angles of 80° and 90°. A Mann-Whitney U test showed clinicians rated the images with an 80° and 90° nasolabial angle as both significantly more attractive than laypeople (p=0.036 and p=0.001 respectively), Table 4.7.

4.2.3 Three-dimensional (3D) male textured images

For the laypeople group, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (*p* = 0.001). The median (IQR) facial attractiveness scores for a nasolabial angle of 70°, 80°, 90°, 100° and 110° were 3 (3 to 4), 4 (3 to 5), 5 (4 to 5), 3 (2 to 3) and 3 (2 to 3) respectively. Table 4.8. There were no statistically significant differences in rating score for nasolabial angles between 70°, 100° and 110° (*p* = 0.973). The laypeople group scored the 90° nasolabial angle as the most attractive, this was statistically significantly greater (p=0.001) then the remaining nasolabial angles.

Table 4. 6 Descriptive statistics for the clinician group facial attractiveness rating assessing five different nasolabial angles using 3D female textured images

Nasolabial angle	Median rating	IQR	Mean rating	SD
70°	3	3 to 4	3.5	1.2
80°	5	4 to 6	4.9	1.1
90°	5	4 to 6	4.7	1.1
100°	3	2 to 3	2.8	0.9
110°	2	2 to 3	2.4	0.7

Table 4. 7 Difference in attractiveness rating assessing five different nasolabial angles using 3D female textured images between the clinician and laypeople group following a Mann-Whitney U test

Nasolabial angle	p-value
70 ^{o}	0.171
80 ^{o}	0.036*
90 ^{o}	0.001*
100 ^{o}	0.713
110 ^{o}	0.944

Mann-Whitney U test *($p<0.05$)

Table 4. 8 Descriptive statistics for the laypeople group facial attractiveness rating assessing five different nasolabial angles using 3D male textured images

Nasolabial angle	Median rating	IQR	Mean rating	SD
70 ^{o}	3	3 to 4	3.1	1.0
80 ^{o}	4	3 to 5	3.9	1.3
90 ^{o}	5	4 to 5	4.6	0.9
100 ^{o}	3	2 to 3	2.9	1.0
110 ^{o}	3	2 to 3	2.8	0.9

For the clinician group, there was a statistically significant difference in the facial attractiveness scores depending on the nasolabial angle being assessed (*p* = 0.001). The median (IQR) facial attractiveness scores for a nasolabial angle of 70°, 80°, 90°, 100° and 110° were 3 (2 to 3), 4 (3 to 4), 6 (5 to 6), 3 (3 to 4) and 3.5 (3 to 4) respectively, Table 4.9. There were no significant differences for nasolabial angles between 80°, 100° and 110° (*p* = 1.0). The facial attractiveness score for the 70° nasolabial angle was the lowest and was statistically significant less (p=0.001) then the remaining nasolabial angles. Again, the clinician group scored the 90° nasolabial angle as the most attractive, which was statistically significantly greater (p=0.001) then the remaining nasolabial angles.

Clinicians and laypeople rated 3D male textured images with 70°, 100° and 110° nasolabial angles as the least attractive. Both groups gave the 90° nasolabial angle the highest facial attractiveness scores. A Mann-Whitney U test showed clinicians rated the images with 70°, 90°, 100° and 110° nasolabial angles as significantly more attractive than laypeople, Table 4.10.

4.3 Comparison using 2D facial profile silhouettes and 3D non-textured grey images on facial attractiveness rating.

4.3.1 Clinician group

The facial attractiveness scores, given by clinicians, for two-dimensional (2D) facial profile silhouettes and 3D non-textured grey images for each of the five different nasolabial angles (70°, 80°, 90°, 100° and 110°) were compared using the Wilcoxon signed rank test. The median (mean ± SD) facial attractiveness scores for the 2D facial profile silhouettes with nasolabial angles of 70°, 80°, 90°, 100° and 110° were 3.0 (3.1 ± 1.1), 5.0 (4.8 ± 1.2), 5.0 (4.7 ± 1.1), 4.0 (4.1 ± 0.8), 3.0 (2.9 ± 0.8) respectively. The median (mean) scores for facial attractiveness for

Table 4. 9 Descriptive statistics for the clinician group facial attractiveness rating assessing five different nasolabial angles using 3D male textured images

Nasolabial angle	Median rating	IQR	Mean rating	SD
70°	3	2 to 3	2.7	0.8
80°	4	3 to 4	3.7	0.9
90°	6	5 to 6	5.6	0.9
100°	3	3 to 4	3.6	0.8
110°	3.5	3 to 4	3.6	0.9

Table 4. 10 Difference in attractiveness rating assessing five different nasolabial angles using 3D male textured images between the clinician and laypeople group following a Mann-Whitney U test

Nasolabial angle	p-value
70 ^{o}	0.022*
80 ^{o}	0.217
90 ^{o}	0.001*
100 ^{o}	0.001*
110 ^{o}	0.001*

Mann-Whitney U test *($p<0.05$)

the 3D non-textured grey images with nasolabial angles of 70°, 80°, 90°, 100° and 110° grey images were 3.0 (3.4 ± 1.0), 5.0 (5.2 ± 1.0), 4.5 (4.4 ± 1.0), 3.0 (2.8 ± 0.7), 3.0 (2.6 ± 0.7) respectively. There was no statistical difference in the facial attractiveness rating scores given by clinician raters when viewing 70° (p = 0.113), 80° (p = 0.086) and 90° (p = 0.096) nasolabial angles using 2D facial profile silhouettes and 3D non-textured grey images. However, the 3D non-textured grey images scored significantly lower facial attractiveness scores than the 2D profile silhouettes with nasolabial angles of 100° (p = 0.001) and 110° (p = 0.020), Table 4.11.

4.3.2 Laypeople group

The median (mean ± SD) scores for facial attractiveness awarded by laypeople, when viewing the 2D facial profile silhouettes with a nasolabial angle of 70°, 80°, 90°, 100° and 110° were 3.0 (3.4 ± 0.9), 4.0 (4.5 ± 0.9), 4.0 (4.2 ± 1.0), 4.0 (3.9 ± 1.0), 3.0 (2.9 ± 0.9) respectively. For 3D non-textured grey images and nasolabial angle of 70°, 80°, 90°, 100° and 110°, the median (mean ± SD) facial attractiveness scores were 4.0 (3.8 ± 0.9), 5.0 (4.9 ±1.0), 3.0 (3.4 ± 1.1), 3.0 (2.5 ± 1.0), 3.0 (2.7 ± 1.0) respectively.

There was no statistical difference in the facial attractiveness rating scores given by laypeople when viewing 80° (p = 0.08), nasolabial angles using the 2D facial profile silhouettes and 3D non-textured grey images. However, the 3D non-textured grey images scored significantly lower facial attractiveness scores than the 2D facial profile silhouettes with nasolabial angles of 90° (p = 0.001), 100° (p = 0.001) and 110° (p = 0.022). For a nasolabial angle of 70° the 3D non-textured grey images scored significantly higher facial attractiveness scores than the 2D facial profile silhouettes (p = 0.021), Table 4.11.

Table 4. 11 Descriptive statistics showing the effect of using 2D facial profile silhouettes or 3D non-textured grey images on facial attractiveness rating.

	Clinicians			Laypeople		
Nasolabial angle	Median rating	Mean rating	SD	Median rating	Mean rating	SD
2D profile silhouettes						
70 º	3.0	3.1	1.1	3.0	3.4	0.9
80 º	5.0	4.8	1.2	4.0	4.5	0.9
90 º	5.0	4.7	1.1	4.0	4.2	1.0
100 º	4.0	4.1	0.8	4.0	3.9	1.0
110 º	3.0	2.9	0.8	3.0	2.9	0.9
3D grey non-textured images						
70 º	3.0	3.4	1.0	4.0	3.8	1.0
80 º	5.0	5.2	1.0	5.0	4.9	1.0
90 º	4.5	4.4	1.0	3.0	3.4	1.1
100 º	3.0	2.8	0.7	3.0	2.5	1.0
110 º	3.0	2.6	0.7	3.0	2.7	1.0

4.4 Nasolabial angle and seeking treatment

4.4.1 Clinician group

The percentage of clinicians who said they would be seeking treatment for each nasolabial angle is shown in Table 4.12 and Figure 4.1.

4.4.1.1 Two-dimension (2D) facial profile silhouettes

Based on 2D facial profile silhouettes, 41.7% and 33.3 % of clinicians would seek treatment for nasolabial angles of 110° and 70° respectively. Only 8.3% of clinicians would seek treatment for an 90° nasolabial angle, but this similar for 80° and 100° nasolabial angles.

4.4.2.2 Three-dimensional (3D) female textured images

The highest percentage of clinicians seeking treatment were for nasolabial angles of 110° and 100° angles, 40.3% and 47.2% respectively. Based on the 3D female textured image only 4.2% of clinicians would seek treatment for an 80° nasolabial angle.

4.4.3.3 Three-dimensional (3D) male textured images

Based on 3D male textured images, the highest percentage of clinicians seeking treatment were for nasolabial angle of 70°, 41.4%. Based on the 3D male textured image only 2.8% of clinicians would seek treatment for an 90° nasolabial angle.

4.4.3.4 3D non-textured grey image

The highest percentage of clinicians seeking treatment were for nasolabial angles of 110° and 100° angles, 36.1% and 44.4% respectively. Based on the 3D non-textured grey textured image only 6.9% of clinicians would seek treatment for an 80° nasolabial angle.

Table 4. 12 Percentage of laypeople that would seek treatment for each nasolabial angle and the viewing media on which the decision was based.

Viewing image	Nasolabial angle				
	70°	80°	90°	100°	110°
2D facial profile silhouette	22.2%	1.4%	8.3%	12.5%	25.0%
3D female textured	18.1%	5.6%	12.5%	36.1%	48.6%
3D male textured	22.2%	11.1%	1.4%	23.6%	26.4%
3D non-textured grey	15.3%	4.2%	16.7%	48.6%	36.1%

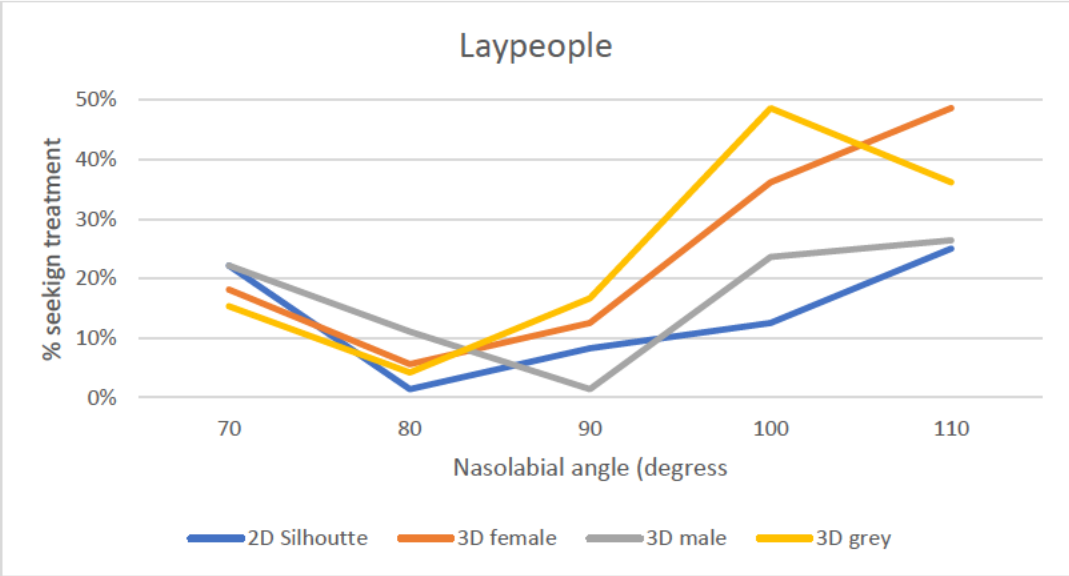


Figure 4. 1 Percentage of laypeople group who would seek treatment for each of the 5 different nasolabial angles.

4.4.2 Laypeople group

The percentage of laypeople who said they would be seeking treatment for each nasolabial angle is shown in Table 4.11 and Figure 4.2.

4.4.2.1 Two-dimension (2D) facial profile silhouettes

Based on 2D facial profile silhouettes, 25.0% and 22.2% of laypeople would seek treatment for nasolabial angles of 110° and 70° respectively. Only 1.4% of laypeople would seek treatment for an 80° nasolabial angle.

4.4.2.2 Three-dimensional (3D) female textured images

The highest percentage of laypeople seeking treatment were for nasolabial angles of 110° and 100° angles, 48.6% and 36.1% respectively. Based on the 3D female textured image only 5.6% of laypeople would seek treatment for an 80° nasolabial angle.

4.4.2.3 Three-dimensional (3D) male textured images

Based on 3D male textured images, the highest percentage of laypeople seeking treatment were for nasolabial angles of 70°, 110° and 100° angles, 22.2%, 23.6% and 26.4% respectively. Based on the 3D male textured image only 1.4% of laypeople would seek treatment for a 90° nasolabial angle.

4.4.2.4 Three-dimensional (3D) grey non-textured images

The highest percentage of laypeople seeking treatment were for nasolabial angles of 110° and 100° angles, 48.6% and 36.1% respectively. Based on the 3D non-textured grey textured image only 4.2% of laypeople would seek treatment for an 80° nasolabial angle.

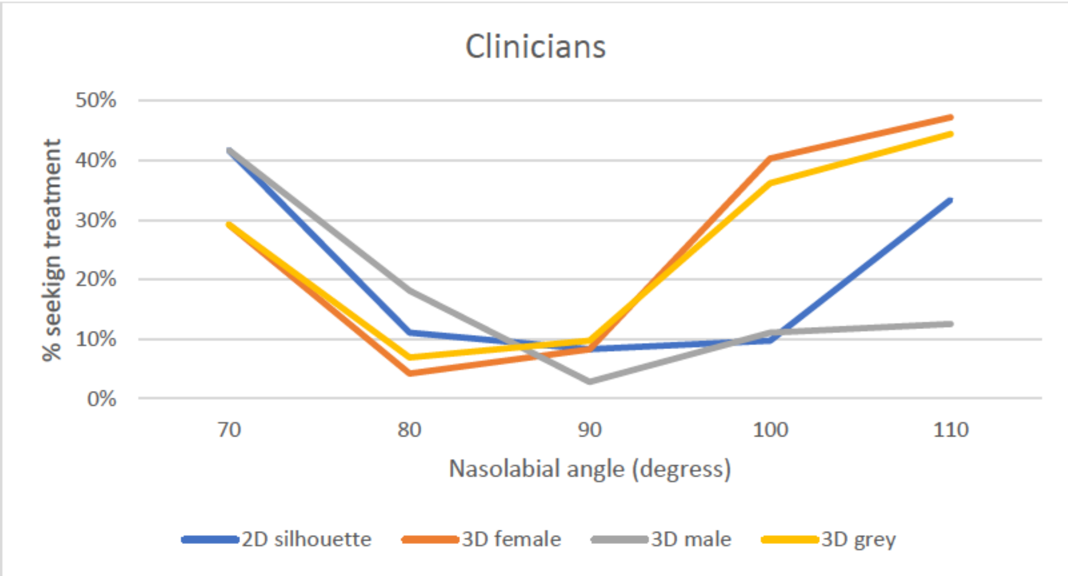


Figure 4. 2 Percentage of laypeople group who would seek treatment for each of the 5 different nasolabial angles.

4.5 Raters preference for image rating

Table 4.13 shows the preference of clinicians and laypeople for viewing 2D facial profile silhouettes, combined 3D female and 3D male textures images, and 3D grey non-textured images. Both groups reported that 2D facial profile silhouettes were the least beneficial and 3D images either grey non-textured or textured as equally beneficial.

Table 4. 13 Preference of clinicians and laypeople viewing 2D facial profile silhouettes, combined 3D female and 3D male textures images, and 3D grey non-textured images.

Viewing image	Rater group	
	Clinician	Laypeople
2D facial profile silhouette	8%	10%
3D textured (male & female)	48%	46%
3D non-textured grey	44%	44%

CHAPTER 5

DISCUSSION

5.1 The significance of the nasolabial angle in orthodontic treatment

The nasolabial complex occupies the central portion of the face and its position and dimensions are at risk of being impacted on by both orthodontic treatment and orthognathic surgery. Therefore, it is important to perform a clinical assessment, and to treatment plan considering the possibility of changing the nasolabial angle and subsequent facial aesthetics (Stromboni, 1979; O'Ryan et al., 1989). Some authors have advocated orthodontic and orthognathic treatment planning should be centred around the soft tissues of the nasolabial complex in order to achieve the most aesthetic results, as good occlusion alone does not always indicate good facial balance (Sarver, 2001; Bergman, 1999; Naini et al., 2015). Soft tissue analysis should be tailored to each individual, with variations in dimensions of the nasolabial angle depending on gender, ethnicity and raters perception (Anicÿ-Miloševicÿ et al., 2008). For some patients there will be a beneficial change in the nasolabial angle whilst in others it could be detrimental.

Historically normative population values for nasolabial angle have been derived as part of larger normative cephalometeric studies, measurements from profile photographs and from profile silhouette studies. Generally, the measurements from cephalometeric studies and measurements from profile photographs have been based on inclusion criteria determined by clinicians i.e. well-balanced facial appearance, class I incisors etc. Whilst profile silhouette studies have been used to assess perceived facial attractiveness; these involve modifying the 2D profile silhouette and assessing the effect on the perceived facial attractiveness. These later types of studies have not solely relied on clinician preferences but have involved laypeople and patients. Involving patients and laypeople in the decision-making process is essential, especially given there is potential to change their facial appearance. As clinicians are trained to interpret profile images, laypeople and patients in general will have had little exposure to these types of images and may find it difficult to relate to the image. This questions the use of 2D profile silhouette images in perceived facial attractiveness studies as they lack texture, anatomical detail, depth and are non-gender specific. Three dimensional images are more clinically representative compared to two dimensional images, as they have texture, anatomical detail and depth (Sarver, 2001; Da Silveira et al., 2003; Souccar and Kau, 2012; Trebicky et al., 2018). Three-dimensional imaging has the ability to address the shortcomings of 2D profile silhouettes and provide additional information and have a greater impact on a raters perception of facial attractiveness.

5.2 Perception of nasolabial aesthetics based on 2D profile silhouette and 3D textured images

The novelty of the present project was the ability to substitute male or female textures onto standardised 3D facial images with five different nasolabial angles, enabling direct comparison of the effect of gender on perceived facial attractiveness, whilst minimising confounding factors. In addition, the perceived facial attractiveness rating of the 3D images were compared to stationary conventional 2D profile silhouette images. This same technique could further be used to compare varying textures in terms of ethnicity and skin colour in future studies, however this was outside of the remit of this investigation.

The results of the present study showed there were differences in perceived facial attractiveness rating between laypeople and clinicians when assessing nasolabial angle aesthetics using 2D profile silhouette and 3D textured images. This is a key finding as many previous studies have used 2D silhouette profiles, compared with 3D imaging, which may not be representative of the real-life clinical situation (Naini et al., 2012; Naini et al., 2015).

The rating of facial attractiveness differed between clinicians and laypeople based on the different nasolabial angles, as well as the type of image being viewed. Based on 2D silhouette images both the clinician group and layperson group rated nasolabial angles of 80°, 90° and 100° as attractive, and an 80° nasolabial angle the most attractive, which was consistent with previous studies (Naini et al., 2015). However, 2D silhouettes with nasolabial angles of 70° and 110° were rated significantly lower (least attractive). This would suggest, based on 2D silhouette images, nasolabial angles of between 80° and 100° would be acceptable to both clinicians and laypeople, and that larger nasolabial angles (110°) would universally be found to be unattractive. In addition, clinicians found more acute nasolabial angles less attractive than laypeople who were more accepting. These findings are not in direct agreement with the range of nasolabial angles in a recent systematic literature review that reported that a nasolabial angle range of 86° to 107° was preferred for men, and 84° to 123° for women (Mohammadi et al., 2021). The review included 21 studies which were based on different raters (orthodontists, laypeople, and patients), different viewing media (colour photographs, black and white photographs, cephalograms, tracings, silhouettes and sketches) as well as different ethnic group subjects (African American, White, Japanese, Iranian and Persian). This heterogeneity may explain the wide range of nasolabial angles reported.

Overall laypeople and clinicians both rated facial attractiveness using 3D textured image, male and female, differently to 2D profile silhouette images. This would suggest that gender and / or facial shape may have an impact on the perception of facial attractiveness. This is important, as previous studies to date, have assessed the effect of nasolabial angle on facial attractiveness based on non-textured and non-gendered 2D profile silhouettes, which are not representative of the three dimensional human face, and are therefore not clinically valid. The human visual system and the brain are hard wired to look firstly for general patterns in an image and then, if time permits, to acquire more detailed information about the image. This is more efficient as it allows a rapid assessment of the visual situation and time to respond appropriately. Unfortunately, this may lead to erroneous outcomes, but this is the method by which individuals recognise caricatures and silhouettes of images. The human eye is more sensitive to colour than to black and white images, this coupled with information gained from depth, provided by the 3D images, may account for the differences in facial attractiveness scores between 2D profile silhouettes and 3D male and female textured images (Sabih et al., 2011).

Using 3D female textured images, the perceptions of facial attractiveness and different nasolabial angles were different to those based on 2D profile silhouettes. Both the clinicians and laypeople rated the 3D female textured image with a 100° nasolabial angle lower (less attractive) than on the 2D silhouette image. This suggests that the viewing media influences perception of facial attractiveness, as the 100° nasolabial angle on a 2D silhouette was acceptable, but on a 3D female textured image the same nasolabial angle was no longer found attractive. So, the addition of 3D facial shape and texture resulted in a reduction in facial attractiveness score. In comparison to previous normative nasolabial values of 105° ± 10° for women (Brownlee, 1995), the results of the present study showed that more acute nasolabial angles of around 80° - 90° were preferred for females. This study has found that both laypeople, and more so clinicians, rate nasolabial angles of between 80°- 90° for female subjects as the most attractive. This study also found that both laypeople and clinicians rate a nasolabial angle of 90° for male subjects as the most attractive. In comparison to previous normative nasolabial values of 100° ± 12° for men (Brownlee, 1995), the results of the present study showed again that a more acute nasolabial angle of around 90° was preferred for males.

Secular facial profile changes have recently been reported in the literature and is significantly more noticeable in women's profiles (Mohammadi et al., 2021; Quinzi et al., 2021). Although the systematic review did not identify an exact trend in the changes in aesthetic perception of the nasolabial angle in females, it indicated that currently sharper angles and fuller lips are perceived more attractive for females (Mohammadi et al., 2021).

This would imply the present historical normative database that drive clinical treatments, may no longer be valid in the 21st century. The ideal of fuller lips with a more acute nasolabial angle, in the modern age and in the era of social media, has recently been reported (Eggerstedt et al., 2020). The cross-sectional study found that the nasolabial angle differed from historical studies, with up to 40^{o} more acute than previous studies. With a rise in lip fillers, which are becoming ever more popular, the impact on the nasolabial angle must be assessed and communicated with patients particularly if orthodontic or orthognathic treatment is desired (Droubi et al., 2020).

The use of hyaluronic acid fillers to alter the nasolabial angle has also been reported as a treatment modality in patients undergoing non-surgical rhinoplasty to treat depression of the mid facial region because of downward rotation of the nasal tip (Xiong et al., 2019; Quinzi et al., 2021). The hyaluronic filler was used in the region of the columella and the nasal spine to modify the nasal tip resulting in an acute nasolabial angle (Youn, 2016). Using this method, the nasolabial angle value increased by up to 13.9^{o} following treatment (Quinzi et al., 2021). This non-surgical rhinoplasty results in a more obtuse nasolabial angle compared with lip fillers which result in a more acute nasolabial angle. Therefore, the appropriate technique should be used to address a particular problem and patients should be informed of the risks, benefits, and effects these changes can have on the facial profile. With the increase in patients seeking such treatments, this is a necessity to communicate to patients prior to treatment as part of the informed consent process.

Psychology based research has shown that facial form, shape, skin texture and viewing angle can all have an impact in an individual's perception of personality and health of subjects (Jones et al., 2012). Multiple parameters have been shown to affect the perception of attractiveness, such as the luminance of skin tone, colour of the lips as well as the fullness of the lip; fuller lips being universally seen as more attractive than thinner lips (Russell, 2009; Stephen and McKeegan, 2010; Bisson and Grobbelaar, 2004). Lip form and position can have an impact on the nasolabial angle and therefore may influence the perception of attractiveness of the nasolabial region (Eggerstedt et al., 2020).

Naini et al (2015) compared the upper and lower components of the nasolabial angle. They assessed the aesthetic impact of the upper lip inclination, which is the lower component of the nasolabial angle, on facial aesthetics (Naini et al., 2015). The upper lip inclination is dependent on the position of the upper incisors, the thickness and tonicity of the upper lip (thicker, flaccid lips will alter to a lesser extent), and the size of the space between the anterior dentoalveolus and the inner surface of the upper lip. The upper lip inclination alters the nasolabial angle independent of the nose (Naini et al., 2015).

The relationship between the upper lip and nasal columella inclination is important in establishing a clinical diagnosis and key for planning treatment. The upper lip inclination is dependent on both the sagittal position of the anterior maxilla as well as the inclination of the maxillary incisors (Naini et al., 2015). Movement of the maxillary teeth alone will solely influence the lower compartment of the nasolabial angle, whereas maxillary advancement or impaction will likely affect both the lower component of the nasolabial angle and the upper component related to the nasal columella inclination. Therefore, often following orthodontic and orthognathic procedures that may affect the upper component of the nasolabial angle, cosmetic rhinoplasty procedures may be undertaken (Naini et al., 2015).

The use of 3D facial imaging allows capture of the 3D shape of a face together with its photorealistic texture (Todd et al., 2005; Storms et al., 2017). Conventional 2D photographic images, even though they capture texture, fail to adequality capture the true 3D facial depth and shape (Sarver, 2001; Da Silveira et al., 2003). The depiction of facial shape in three dimensions, which the 3D images in this study provided, goes partway in addressing the limitations of conventional 2D images (Souccar and Kau, 2012). The more clinically realistic the image, the more insight it provides to the perception of attractiveness for clinicians and patients (Jones et al., 2012). As well as capturing 3D facial form and texture, appropriate viewing of the images is necessary to unlock its full potential. Ideally 3D images should be viewed using stereoscopic 3D projection as this most closely represents the human visual system (Zhu et al., 2017). The use of stereoscopic 3D projections has been shown to be more reliable than 2D profile and 3D images for rating facial attractiveness. Stereoscopic 3D projections were found to result in lower facial attractiveness scores than either 2D profile or 3D textured images. Overall stereoscopic 3D projection was the preferred method for rating (Zhu et al., 2017). Unfortunately, stereoscopic 3D projection is not routinely used in a clinical setting as it requires specialised viewing equipment. In the present study, the laypeople group viewed the images on a large screen with standardised room lighting. Everyone in this group sat and individually rated the images simultaneously. With the clinician group however, everyone viewed the images on their personal computer. This would affect the standardisation of viewing the images in this group and should subsequently have only a minor impact on the outcome of the results compared with the layperson group (Jones at al., 2012). The length of time all raters had to view the images was standardised to thirty seconds as it has been previously found that the time viewing and image and making a decision can influenced the outcome of perception (Sabih et al., 2011).

5.3 Repeatability, reliability and reproducibility

Intra-rater reliability is a measure of the level of agreement and consistency between different raters or subjects observing the same entity (Hallgren, 2012). High inter-rater reliability is important as it reduces the risk of bias by minimizing subjectivity and therefore increases the validity of the assessment (Borsboom et al., 2004). Reproducibility on the other hand is obtaining consistent results using the same input (Peng and Hicks, 2021).

Several options exist to determine intra-rater reliability; these include the use of duplicate images within the same rating session or re-rating the images on a second occasion. In the present study repeat duplicate images in the same session were used to assess intra-rater reliability of the raters. This was achieved by duplicating two random images in each group - a total of eight images where duplicated, two in the 2D silhouette group, two from the 3D non textured group and two in each of the female and male textured 3D images. This could have resulted in memory bias as the raters may call the previous score, given the short time interval between rating images. However due to Covid-19, social distancing and re-deployment it was felt that the additional burden of re-arranging a second rating session was not appropriate. As with the present study, previous studies have used the same methodology and found a good level of intra-rater reliability (Naini et al., 2015). Interestingly, previous studies have reported that 3D images are associated with higher intra-rater reproducibility compared with 2D images and again are the preferred method of rating aesthetics over 2D images (Stebel et al., 2016).

5.4 Limitation of the Likert scale

The Likert-type scale has been described as the most preferred, accepted, and beneficial method of rating perception of attractiveness by psychologists in research (Langlois et al., 2000). Recent studies in assessing facial profile attractiveness have used the 7-point Likert rating scale to rate the attractiveness of 2D silhouette images, with the extremities of the scale being indicated by 'extremely unattractive' to 'extremely attractive' (Naini et al., 2015; Naini et al., 2012).

It has been suggested that using too few categories for responding in the Likert-type scale will impede the participant's ability to accurately convey their feelings and therefore reduces reliability of the study (Viswanathan et al., 1996). The Likert scale used in the present study had seven points which widened the response options, reducing the risk of raters feeling unable to convey their feelings (Viswanathan et al., 1996). The following categories were used in this scale to enable full expression of rater thoughts and perception; 'extremely unattractive, very unattractive, slightly unattractive, neither attractive nor unattractive, slightly attractive, very attractive, extremely attractive', which were in line with previous studies (Naini et al., 2012; Naini et al., 2015).

A possible limitation of the Likert-type scale includes the production of ordinal measurement values and response styles, such as participants tending towards choosing either neutral or middle category responses or opting for responses that lie at the extremities of the scale (Allen and Seaman, 2007; Albaum, 1997). These types of responses can result in bias and can result in the participants true thoughts not being communicated (Sung and Wu, 2018). However, with the high number of categories to choose from on the 7-point Likert-type scale used in the present study this bias was reduced (Viswanathan et al., 1996). In addition, Likert scales are generally considered ordinal as they consist of a series of systematised categories. However, for the purpose of statistical analysis the outcome values of Likert scales with five or more points, can be considered as continuous data without undermining the integrity of the data (Norman, 2010; Sullivan and Artino, 2013; Zumbo and Zimmerman, 1993).

5.5 Sample size calculation

The sample size for the present study determined that a minimum of 46 raters were required for each rater group. The total number of participants rating in each group was 50 for the clinician group and 72 in the laypeople group. Previous studies have used a similar number of raters analysing the aesthetics of changing the nasolabial angle of 2D silhouette images (Naini et al., 2015). In this study the orthodontist group of raters consisted of 35 individuals, whilst the laypeople group consisted of 75 individuals. The study did however have a third group of raters (n=75), who were categorized as pre-treatment orthognathic patients. Similarly, a study comparing the perception of facial aesthetics of Class I, Class II and Class III skeletal patterns between 2D and 3D black and white images utilised three rater groups to assess facial attractiveness (Todd et al., 2005). The three rater groups included 47 orthodontists, 25 maxillofacial surgeons and 78 members of the public (laypeople).

5.6 Raters

The primary aim of the present study was to determine if there were any differences in perception of the nasolabial angle between layperson and clinician's and if the perception changed depending on the viewing media. The clinician group of raters were selected as they were commonly involved in orthodontic, orthognathic or a combination treatment. Similar rating groups have been used in previous studies (Naini et al., 2015; Todd et al., 2005).

The laypeople group comprised of first year undergraduate science students who were not current orthodontic patients. There is potential for bias as the laypeople group was a convenience sample rather than a "true random sample" of the population; given the COVID-19 pandemic it was not possible to use the larger population, as a result a local University of Birmingham convenience sample was used. The mean age of this group was lower than the clinician group. Previous studies have shown that there is minimal difference in the perception of facial aesthetics between varying age groups (Salehi et al., 2019).

Ideally a group of pre-treatment patients should have been used in the present study to determine their nasolabial angle preference. It could be argued that this group could be bias as they may have had a prior conversation about their nasolabial during the informed consent process. However, it is this group of individuals whose nasolabial angle may be affected by treatment and as such should be consulted. Given the COVID-19 pandemic it was not possible to use NHS patients and so they were not included.

5.7 Rating 2D silhouette images and 3D grey non-textured images

Two-dimensional silhouette images are profile images which lack texture, anatomy, and gender. Three-dimensional grey images also lack texture, and as a result gender, but have a surface that is illuminated to produce the effect of depth and highlight facial anatomy, for example nasal form, lip shape and vermillion border outline. They are viewed on a flat monitor screen and are not actually 3D; the illusion of 3D depth is obtained by the addition of lighting and shadowing. So, by comparing 2D silhouette images and 3D grey non-textured images, the effect of 3D perception and facial anatomy on facial attractiveness was being investigated. The results indicate that the addition of depth and facial anatomy does influence the facial attractiveness score.

In the layperson group, nasolabial angles of 90°, 100° and 110° were perceived as less attractive based on the 3D grey non-textured images compared to the 2D silhouette images. The clinician group also rated 3D grey non-textured images as less attractive compared to 2D silhouette images for nasolabial angles of 100° and 110°. There was a consensus view that laypeople and clinicians rated nasolabial angles of 100° and 110° less attractive using 3D grey non-textured images over 2D silhouette images. For nasolabial angles of 70°, 80° and 90° the clinician group rated the facial attractiveness comparable for 2D silhouette and 3D grey non-textured images. Whilst laypeople rated a 70° nasolabial angle as more attractive and 90° nasolabial angle as less attractive and on 3D non-textured grey images compared to the 2D silhouettes. The differences between the laypeople and clinician group may be because the clinician group routinely view profile images as photographs and cephalograms and can interpret the 2D silhouette images whilst laypeople are not familiar with 2D silhouette images and relying more on the additional visual cues during the rating process. Given that the historical norms for the nasolabial angle in the literature, are predominantly derived from 2D images, the results of the present study suggest that use of 2D images may not be clinically valid as they do not represent the true clinical picture. Some nasolabial angles that were once thought to be attractive using 2D silhouettes may not be seen as attractive in 3D i.e., in real life. This is not surprising as 3D images have depth and address most of the limitations of 2D images (Souccar and Kau, 2012). This is an important finding as it may impact patient's perception of treatment outcomes or may influence their desire to undergo treatment.

5.8 Willingness to seek treatment regarding the nasolabial angle

The willingness to seek treatment in relationship to the nasolabial angle is dependent on the images being viewed, in particular the gender. The results of the present study show that both clinicians and laypeople followed a similar trend of when they would seek treatment. Generally nasolabial angles of 100° and 110° were thought of as unattractive enough to seek treatment, irrespective of the viewing media, by both rater groups. The only exception was with clinicians viewing 3D male textured images compared to laypeople; a greater number of clinicians (41.7%) would seek treatment for a 70° nasolabial than 100° and 110°. There was a tendency for clinicians to seek treatment for a 70° nasolabial regardless of viewing media. This is an important finding as it suggests there is marked difference between clinicians and laypeople, emphasising the importance of seeking full patient involvement and understanding of their wishes and concerns and not treating individuals to a standard, or clinician preferences, particularly when invasive treatment, such as orthognathic surgery. This study also shows the influence of gender and nasolabial angle on perceived facial attractiveness and confirms the use of 3D textured images, male and female, can change the perceived attractiveness and the desire to seek treatment. These results question the use of 2D silhouette in studies to rate perceived facial attractiveness (Naini et al., 2015).

5.9 Effect of rater gender on outcome

Historically, studies have found no association between the gender of the rater and facial attractiveness rating score (Tedesco et al., 1983b). The results of the present study supported this finding and found there were no statistical difference in the facial attractiveness rating between male and female clinicians when rating 3D non-textured grey and 3D textured female images, for all the nasolabial angles. However where using 2D silhouettes and 3D textured male images, there were statistical differences in the facial attractiveness rating scores between male and female clinician raters only when viewing images with nasolabial angles of 110°. Male clinicians rated these images as more attractive than female clinicians. This would suggest that female clinicians were more critical of obtuse nasolabial angles when assessing 3D male textured images, whilst males were more accepting.

Male and female laypeople rated all the nasolabial angles similarly based on 3D non-textured grey, 3D textured female and 2D silhouette images. Statistical differences in facial attractiveness scores between male and female laypeople were observed for 80°, 90° and 100° nasolabial angles using 3D male textured images. For all three nasolabial angles female laypersons rated the images as more attractive than male layperson raters. This showed that male raters were more critical of male images than female raters. This is contrary to previous studies that have found no specific gender differences when rating 2D and 3D images, specifically when assessing Class I skeletal base profiles (Todd et al., 2005).

The reasons for this are not fully understood and there is conflicting evidence in the literature regarding the association of gender and perception of profile attractiveness. Many studies found no difference between gender and aesthetic perception (Johnston et al., 2005; Todd et al., 2005; Abu Aqoub & Al-Khateeb, 2011). One study however, found that although rating between genders were similar, male subjects preferred female profiles that were more convex, whilst females had a preference to more concave female profiles (Turkkahraman and Goklap 2004).

5.10 Raters preference for image rating

Across the orthodontist and lay person group the results were consistent. All groups preferred the 3D images compared with the 2D silhouette images. There was a marginal preference for use of textured 3D images compared with the 3D grey images in both groups. These findings are consistent with the findings of previous studies in which participants found 3D images to be more beneficial than 2D images (Zhu et al., 2017; Stebel et al., 2016). However, raters reported 3D textured images were more informative and beneficial when compared with 2D images, which correlates with the results of the present study

5.11 Limitations of the study

There are several limitations with the current study, and include:

- As this study was carried out during the COVID-19 pandemic, recruiting raters was challenging and the clinician group rating needed to be carried out virtually. This resulted in everyone using a different viewing screen to view and rate the images. This may have had an effect on the quality of the image and thus the rating outcome.

- The clinician group consisted of individuals of varying clinical experience including orthodontic speciality registrars in training, specialist orthodontists and consultant orthodontists. Therefore, again this may have had an impact on the outcomes of the results. Previous studies however have subdivided their groups into orthodontists and maxillofacial surgeons and collectively used the umbrella term of "professionals" (Todd et al., 2005).
- This study was carried out using 3D male and female textured Caucasian images only. Therefore, this study is not generalisable to other ethnic groups in terms of perceived aesthetics of the nasolabial angle as we know from previous studies that racial norms vary between ethnicities (Weng et al., 2015).
- The images in this study included male and female gender 3D textured images. The male and female images were rated differently, and this has been historically the case in terms of acceptability or norms for the nasolabial angle (Guyuron, 1993; Orten and Hilger, 2002). However, in a changing age with gender neutrality and not identifying as either male or female, this may not be fully relevant to all groups of patients presenting for treatment. However, the use of 3D grey non textured images may be of use in such instances as they are not gender specific.

CHAPTER 6

CONCLUSIONS

Conclusions

This study showed that the use of different image types (2D facial profile silhouette, 3D female textured, 3D male textured and 3D grey non textured) with the same nasolabial angle, resulted in different facial attractiveness ratings by both clinicians and laypeople. Two-dimensional facial profile silhouette underestimated the facial attractiveness of images with 100° and 110° nasolabial angles when compared with 3D images in both clinician and laypeople groups.

Both clinicians and laypeople rated the 3D male and female textured images with 70°, 100° and 110° nasolabial angles as the least attractive, whilst rating the males with a nasolabial angle of 90° and females with nasolabial angles of 80° as most attractive. Several factors affected the ratings of facial attractiveness including, laypeople rated images more unattractive than clinicians, however clinicians were still more likely to seek treatment to improve aesthetics. The facial attractiveness ratings of the nasolabial angle was also affected by the gender of the texture applied to the 3D image.

The type of images influences the facial attractiveness scores. Both clinicians and laypeople rated 3D grey non-textured images with nasolabial angles of 100° and 110° as less attractive than 2D facial profile silhouette images. Laypeople rated 3D grey non-textured images with a 70° nasolabial angle as more attractive than 2D facial profile silhouette images; clinicians rated 70°, 80° and 90° nasolabial angles similarly for both types of image.

Both clinicians and laypeople preferred the use of 3D textured images, followed closely by the 3D grey non-textured images. Both groups indicated that the 2D facial profile silhouette images are the least preferred and least beneficial image type for rating the perception of nasolabial angle aesthetics and facial attractiveness.

The primary null hypothesis was therefore rejected as there was a statistically significant difference ($p < 0.05$) in facial attractiveness rating score between clinicians and laypeople when assessing 5 different nasolabial angles using 2D facial profile silhouette, 3D female textured, 3D male textured and 3D grey non-textured images.

The secondary null hypothesis was also rejected as there was a statistically significant difference ($p < 0.05$) in the rating of the nasolabial angles between 3D grey non-textured image and 2D facial profile silhouette images for both laypeople and clinicians.

CHAPTER 7

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CHAPTER 8

APPENDICES

Appendix I

UNIVERSITY OF BIRMINGHAM

Participant Information Sheet

The influence of nasolabial angle on perceived facial aesthetics

Version 1.1, 24th November 2020

University of Birmingham Sponsor Reference: Awaiting

Ethics Reference: ERN 20-1332

You can speak to a member of the research team for more information using the details below

You can change your mind about participating in the study at any time; you do not need to give a reason for your decision.

Enquiries & Correspondence:

The Chief Investigator of this study is Professor Balvinder Khambay

If you want to discuss this study further, please call [redacted] or email [redacted]

Professor Balvinder Khambay
Birmingham Dental Hospital
5 Mill Pool Way
Birmingham
B5 7EG

Thank you for considering volunteering.

We do a lot of research at the University of Birmingham that needs volunteers to look at images of faces. We need all types of volunteers to be able to compare differences between them.

Your decision to participate is completely voluntary. If you decide to withdraw, all identifiable data will be removed from the research data set and will not be analysed. Any data that has already been analysed will not be removed from the data set as it will be anonymised and numerical, and difficult to remove. Just tell either the researcher or email us (see bottom of page). You have 2 weeks are the rating session to
contact the researcher and ask them to remove your data, after this time it will not be possible.

Information

1. **Introduction**
   We would like to invite you to take part in a research study. You are free to decide whether or not to take part. Please take time to read the following information carefully.

2. **What is the research about?**
   The purpose of this research project is to assess whether lay adults and professional orthodontists rate the appearance of the nose-upper lip region the same. This is important as orthodontic treatment and facial surgery can change the appearance of this region. It is important to know what would be pleasing appearance to lay adults and is it the same as orthodontists.

3. **Why have we been asked?**
   We are looking for healthy volunteers aged 18 - 65 to assess 3D images of faces.

4. **What will happen if I decide to take part?**
   We want to give you time to consider the information in this leaflet. We will contact you at least one week after you receive the leaflet to see if you wish to take part.

   If you decide you would like to participate you will be sent a consent form to sign that you need to return to us, either electronically (emailed, scanned or photographed) or as hard copy via the post. We will then arrange to show you a series of short videos of a 3D facial image and ask you to rate the images using a scale. You maybe contacted around 2 weeks later to repeat the rating of a fewer number of images.

5. **What are the advantages of taking part?**
   You will be helping with research that may lead to better treatment for patients in the future.

6. **What are the disadvantages of taking part?**
   You would need to give up some of your time. There are no known risks to taking part in the study.

7. **Has this research been reviewed?**
   This project has been reviewed and approved by the University of Birmingham's Research Ethics Committee .

8. **How can I obtain more information about this study?**
   You can speak to the researcher when they contact you or if you attend an appointment. Alternatively you can contact the research team using the details on the cover of this information sheet.

CONSENT FORM

Please initial each box you agree with and sign and date the form at the bottom.

		Initials
1	I confirm that I have read the information sheet dated XX September 2020 (version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2	I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
3	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.	
4	The data from this research might be useful to future research; by initialling this box you give us permission to use it as part of other ethically approved research projects. These projects may be in collaboration with other institutes outside the university but all the information used will be anonymised by research teams at the University of Birmingham.	
5	I agree to be contacted after around 2 weeks to view the images for a second time.	
6	I agree to take part in the above study.	

______________________ ____________________________ __________

Your name	Signed	Date

I have discussed this study with this participant who has agreed to give informed consent.

______________________	___________________________	_________
Name of person taking consent	Signed	Date

Appendix II

Please mark X on one outcome for each image as numbered

Image Number	Extremely Unattractive	Very Unattractive	Slightly Unattractive	Neither Attractive nor Unattractive	Slightly Attractive	Very Attractive	Extremely Attractive	Would you consider seeking treatment if this represented your own appearance?
Image 1								Yes / No
Image 2								Yes / No
Image 3								Yes / No
Image 4								Yes / No
Image 5								Yes / No
Image 6								Yes / No
Image 7								Yes / No
Image 8								Yes / No
Image 9								Yes / No
Image 10								Yes / No

Image Number	Extremely Unattractive	Very Unattractive	Slightly Unattractive	Neither Attractive nor Unattractive	Slightly Attractive	Very Attractive	Extremely Attractive	Would you consider seeking treatment if this represented your own appearance?
Image 11								Yes / No
Image 12								Yes / No
Image 13								Yes / No
Image 14								Yes / No
Image 15								Yes / No
Image 16								Yes / No
Image 17								Yes / No
Image 18								Yes / No
Image 19								Yes / No
Image 20								Yes / No

Image Number	Extremely Unattractive	Very Unattractive	Slightly Unattractive	Neither Attractive nor Unattractive	Slightly Attractive	Very Attractive	Extremely Attractive	Would you consider seeking treatment if this represented your own appearance?
Image 21								Yes / No
Image 22								Yes / No
Image 23								Yes / No
Image 24								Yes / No
Image 25								Yes / No
Image 26								Yes / No
Image 27								Yes / No
Image 28								Yes / No

Please tick the type of image you found easier to rate?

☐ **2D silhouette profile**

☐ **3D non textured (grey)**

☐ **3D textured**