Are post-treatment orthognathic patients attractive? A three-dimensional study.

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Summary

Background: The primary objective of orthognathic surgery is to improve facial aesthetics and function to an acceptable standard and to the patient's satisfaction. Exactly what constitutes an acceptable standard of facial aesthetics to a patient has been the topic of numerous studies and yet has so far remained elusive. The patient, as a lay person, is the final end user of orthognathic services; it is their idea of facial attractiveness that ultimately is more relevant as a treatment goal than pre-determined measurements and standards developed by the clinicians. The standards for facial attractiveness of a given population tend to reflect the arbitrary standards of beauty set by cultural background and the influence of the media and fashion trends of the time. In the past, studies on facial attractiveness have used two-dimensional photographs. Using a 3D stereophotogrammetry system to capture images presented in a 3D configuration is probably a more realistic method to replace the actual patient. The overall aim of the present study was to compare, using angular and linear measurements, 3D facial images of a group of post-surgical orthognathic patients to a group of "attractive" individuals which were selected by a lay panel as being attractive, from a population from the West of Scotland.

Part I

Aims: To determine the 3D soft tissue facial measurements of an "attractive" group of West of Scotland males and females between the age of 18 and 35 as selected by a panel of lay people.

Materials and Methods: Subjects for the attractive group were recruited from within the local population of West of Scotland on a voluntary basis. Inclusion criteria were that subjects had to be of Caucasian origin from the West of Scotland, without craniofacial defect or facial hair and had to be between 18-35 years of age. 61 females and 51 males took part in the study; the subjects were imaged using the Di3D stereophotogrammetry system. The images were assessed by a lay panel of 8 members for facial attractiveness using a VAS method. The VAS scores were ranked from most attractive to least attractive for each subject as recorded by each of the 8 lay panel members. The data was divided into three segments – most attractive, attractive and least attractive. Individuals who were thought of as being most attractive and attractive by at least 6 lay panel members were chosen to be part of the attractive control group. The attractive group comprised of 24 females and 16 males. Landmarks were placed on all the 3D images by the author. Angular and linear measurements were derived for comparison between groups. An error study of landmark localisation was performed which showed no systematic errors and all coefficients of reliability were above 90%.

Results and Conclusions: The comparison of female and male attractive groups showed that all female linear measurements were smaller then male measurements except for columella length. There was a statistical difference ($p<0.05$) between the majority of linear measurements for males and females except for columella length and lower lip length. In all cases except upper facial convexity and nasolabial angle, female angular measurements were smaller than male measurements. The difference in the mean for nasolabial angle was minimal. There was no statistical difference between the majority of angular measurements for males and females except for upper facial convexity ($p = 0.006$). Overall the results show that attractive females from this sample have smaller facial dimensions than the attractive males for the most part except for upper facial convexity where the females showed a slightly flatter upper face.

Part II

Aims: To determine whether post-operative orthognathic patients look attractive based on objective measurements of 3D soft-tissue facial landmarks.

Materials and Methods: 16 male orthognathic patients and 17 female orthognathic patients participated in the study. The post-operative orthognathic subjects were imaged using the Di3D stereophotogrammetry system. Angular and linear measurements were used for comparison between the attractive males and females to the male and female post-orthognathic groups.

Results and Conclusions: In the male orthognathic group, the only statistical difference in comparison of means to the male attractive control group was noted for the measurements lower lip length and lower lip prominence. The male orthognathic sample appeared to have longer and more prominent upper and lower lips compared with the male controls though only the measurements for lower lip were statistically different in this study.

In the female orthognathic group, the only statistical difference in comparison of means to the female attractive control group was noted for the measurements nose width, lower anterior face height, nasolabial angle, nasal tip convexity and facial convexity including nose. The values for nose width, lower anterior face height, nasal tip convexity and facial convexity angle including nose were larger in the orthognathic group than in the attractive control group whilst the value for nasolabial angle was smaller. These results suggest that the female orthognathic group in comparison to the female attractive group have more convex faces in the sagittal plane, more convex nasal tips, wider noses and smaller nasolabial angles.

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Declaration

This thesis is the original work of the author.

Chapter One

Literature Review

1 Literature Review

1.1 Introduction

Orthognathic surgery is defined as the surgical correction of dentofacial deformity (Proffit and White, 1990).

Recently there has been an increased demand for orthognathic surgery to treat severe dento-facial deformities (Proffit *et al*., 2007). It has been estimated that in the United Kingdom there may be up to a quarter of a million patients who may require orthognathic surgery (Sandy *et al*., 2001). Proffit and White (1990) investigated the demand for orthognathic surgery in an American population and extrapolating from the incidence of different types of malocclusion estimated that a total of 1.2 million individuals might require orthognathic surgery.

Orthognathic surgery has evolved over the past century from an emphasis on occlusal correction to an improvement of facial attractiveness. In recent decades there has been significant advancements in diagnosis, treatment planning, orthodontic mechanics and surgical techniques which now allow the use of bimaxillary procedures to correct anterior-posterior, vertical and transverse discrepancies of the facial skeleton. This improved manipulation of the skeletal hard tissue in three planes of space should allow the improvement of facial soft tissue disharmony to be corrected more readily.

1.2 Facial aesthetics

1.2.1 Motivation for seeking orthognathic treatment

The primary objective of orthognathic surgery is to improve facial and dental aesthetics to an acceptable standard and to the patient's satisfaction, sometimes with a secondary objective of improving function (Kiyak *et al*., 1981; Jacobson, 1984; Bell *et al*., 1985).

It has been well-established that the perception of facial attractiveness and improving dento-facial aesthetics makes profound contributions to a person's decision to seek orthodontic or orthognathic treatment (Baldwin, 1980; Shaw *et al*., 1980, Kiyak *et al*., 1981; Shaw, 1981a; Tedesco *et al*., 1983a; Tedesco *et al*., 1983b; Albino *et al*., 1984; Jacobson, 1984; Tulloch *et al*., 1984; Bell *et al*., 1985; Howells and Shaw, 1985; Shaw *et al*., 1985; Gosney, 1986; Pogrel, 1991; Phillips *et al*., 1992a; Burden *et al*., 1995; Giddon, 1995; Arpino *et al*., 1998; Cunningham, 1999; Spyropoulos and Halazonetis, 2001; Flores-Mir *et al*., 2004; Mugonzibwa *et al*., 2004; Kiekens *et al*., 2005; Knight and Keith, 2005; Schlosser *et al*., 2005; Soh *et al*., 2006).

The literature consistently shows that physical attractiveness plays a major role in social life and interaction among individuals. The development of aesthetic awareness begins very early in childhood with the attitude that "what is beautiful is good". As we grow older, we are all subjected to the incessant bombardment of the mass communication media. Such indoctrination has made society irrepressibly face and body conscious.

The role of the face is vital in social interactions between humans and a rich source of nonverbal communication. Considering the importance of society's emphasis on physical attractiveness the social and psychological implication of a facial handicap should not be underestimated. Public reaction to a facial anomaly depends on many factors including the nature of the disfigurement, the type of social interaction and the anticipated duration of the interaction (Sergl *et al.,* 1992). Teasing is one of the most destructive instruments people can use to cause anger, distress and low self-esteem in others. Dentofacial deformities can affect an individual's psyche especially in relation to the development of body image (Shalhoub, 1994). The psychosocial impact of a dentofacial deformity is usually more important to an individual than the related physical problems, and an individual's entire life can be altered as a result of improving his/her facial appearance (Proffit and White, 1990).

The motivational patterns of patients seeking orthognathic surgery have been found in the literature to be varied and often multiple in nature. The motivation for orthognathic surgery patients seeking treatment has been previously described as external or internal (Edgerton and Knorr, 1971). External motivations include the need to please others, having paranoid ideas and the belief that one's career or social ambitions are being hindered by physical appearance. External motivations require a change in the patient's personal environment rather than surgery to solve the problem (Cunningham *et al*., 1995). Internal motivation is usually a more valid form of motivation and includes long-established inner feelings about deficiencies in one's appearance. Such individuals may feel that their facial anomaly interferes with their enjoyment of life and they may have a sense of inadequacy. Individuals driven by internal motivations make better candidates for surgery (Ostler and Kiyak, 1991; Cunningham *et al*., 1995). Individuals with a long-standing history of unhappiness with a certain feature are usually better surgical candidates than those with short term distress which may be connected to a transient turmoil in their private lives, or those that display dysmorphophobia.

A previous study showed that many patients reported that their abnormal facial appearance was a significant concern and primary motivation for seeking surgical treatment (Stirling *et al.,* 2007). Patients were aware that they looked different from others. This difference in facial appearance did affect their behaviour and self-esteem negatively and they wanted to look more 'normal'. Whilst functional problems do play a major role in a patient's reasons for seeking orthognathic treatment, achieving a normal facial appearance was the key motivation, even by patients who initially expressed more concern about functional problems (Stirling *et al.,* 2007). An individual's decision to undergo orthognathic surgery can be based on multiple reasons. This was in agreement with earlier studies which reported that aesthetic improvement of facial and dental appearance was the prime motivating factor for 41% to 89% of orthognathic surgery patients (Kiyak *et al.,* 1981; Rivera *et al.*, 2000).

The factors related to health awareness and prevention of problems are likely to become more important to individuals with increasing age. Previous studies have shown that younger patients expressed greater concern for aesthetic improvement more frequently in their motivation compared with older patients (Garvill *et al.,* 1992). However, Rivera *et al.* (2000) found no significant age differences in the frequency of aesthetic reasons reported by the patients in their sample. The authors suggest that in the past, surgical treatment for cosmetic modifications was not as well-received and accepted as it is today and that there is no longer any stigma associated with seeking orthognathic surgery to correct facial appearance at any age.

1.2.2 Gender differences

There may be gender differences in motivation for patients undergoing orthognathic surgery. It has been found that more females than males assigned importance to facial appearance as the primary motivation for surgery (Flanary *et al.,* 1985; Shalhoub, 1994). However this difference was not significant and it was concluded that facial aesthetics was an important major motivating factor for both sexes more or less equally (Kiyak *et al.,* 1981; Rivera *et al*., 2000; Sadek and Salem, 2007).

In recent years, as society has become more accepting of surgical procedures to improve facial imperfections and abnormalities, orthognathic surgery has gained widespread acceptance and an ever increasing demand. Gender, age or ethnicity contribute to the make-up of the motivation behind patients who seek orthognathic surgery however the main motivating reasons are similar across the population, with the desire to improve one's facial appearance often being the primary motivating factor for seeking surgical correction of facial abnormalities.

1.3 Facial attractiveness

1.3.1 Perception of facial attractiveness

The meaning of beauty and facial attractiveness has been debated for centuries. Beauty is a mystery that has been with us for ages and it is something that is recognised in an instant, yet it is difficult to define. Beauty has been defined as a combination of qualities that give pleasure to the senses or to the mind (Naini *et al.,* 2006). People's perception of facial beauty are multifactorial with genetic, environmental and cultural foundations (Naini and Moss, 2004; Naini and Gill, 2008). Facial attractiveness is perhaps easier to define and is the time-static visual properties of a face that are pleasing to the visual sense of an observer (Bashour, 2006b).

Over the centuries the concept of facial aesthetics has grown to include emotional embellishments, such as judgements of beauty and attractiveness. The influence of social factors in perception of aesthetics can be particularly strong. Perception is the process by which patterns of environmental stimuli are organised and interpreted; it can be influenced by a variety of physical, physiological, psychological and social factors. The recognition of the huge importance of one's self-perception relative to others has led to the rapid emergence of indices in dentofacial and orthodontic treatment acknowledging perceptions of attractiveness by self and others. Prahl-Anderson *et al.* (1979) noted that the motivation for orthodontic treatment involved three main factors:

- Objective signs (deviations from established normal values).
- Subjective signs (recognition by the patient of problems).
- Social sufficiency (recognition by society that the patient's malocclusion creates a problem for the patient).

Incorporating society's values relative to one's perceived attributes can have a major impact on self-image and ultimately self-concept. Self-image includes the physical aspects of one's self, combined with how one understands and weighs the perceptions of others. Perception of facial attractiveness from the public depends on current socio-cultural norms in the relevant population. Attractive people are thought to be more intelligent and have a nicer personality and more socially desirable characteristics (Shaw, 1981b; Cunningham, 1986). Perception of appearance, particularly of the face, by oneself and others, affects mental health and social behaviour with significant implications for educational and employment opportunities and mate selection (Peck and Peck, 1970; Berscheid and Gangestad, 1982). Whether right or wrong, the social consequences of society's pernicious attitudes to facial appearance and attractiveness are pervasive.

Any feature that causes an individual's facial appearance to deviate from society's accepted norm of facial attractiveness can be considered a handicap (Cunningham, 1999). Studies have shown that people or children who are facially attractive are better received by their peers and the general public than those who are less attractive (Shaw, 1981b; Shaw *et al*., 1985). Thus concern for facial appearance is a serious mental as well as dental health issue and it is not surprising that it is the prime motivating factor that drives patients to seek orthodontic care or surgical correction. *Shaw et al.* (1980) found that patients with facial deformities are often subjected to teasing, nicknaming and social discrimination. A later study found that children with a normal dental appearance were judged by their peers to be better looking, more desirable as friends and less likely to behave aggressively than children with a dentofacial deformity; the attractive children were also judged by teachers as more competent and more intelligent (Shaw, 1981b; Cunningham, 1986).

It has been well-established through numerous studies that the perception of facial attractiveness and improving dento-facial aesthetics make profound contributions to a person's decision to seek orthodontic or orthognathic treatment (Baldwin, 1980; Shaw *et al*., 1980, Kiyak *et al*., 1981; Shaw, 1981a; Tedesco *et al*., 1983a; Tedesco *et al*., 1983b; Albino *et al*., 1984; Jacobson, 1984; Tulloch *et al*., 1984; Bell *et al*., 1985; Howells and Shaw, 1985; Shaw *et al*., 1985; Gosney, 1986; Pogrel, 1991; Phillips *et al*., 1992a; Burden *et al*., 1995; Giddon, 1995; Arpino *et al*., 1998; Cunningham, 1999;

Spyropoulos and Halazonetis, 2001; Flores-Mir *et al*., 2004; Mugonzibwa *et al*., 2004; Kiekens *et al*., 2005; Knight and Keith, 2005; Schlosser *et al*., 2005; Soh *et al*., 2006).

A common belief is that beauty is in the eye of the beholder, suggesting that judgements of facial aesthetics are a matter of individual taste and wholly subjective. Nevertheless some persons are universally regarded as attractive and a number of studies have shown good agreement between people on attractiveness ratings (Iliffe, 1960; Udry, 1965; Xu *et al*., 2008). Iliffe (1960) invited the British lay persons to rank the facial attractiveness of 12 photographs of English women published in a British newspaper and received over 4,000 replies that showed very similar preferences for facial attractiveness among the British general public. Udry (1965) published the same 12 photographs in an American newspaper and received over 10,000 replies which showed a remarkable consistency and similarity to the results derived from the British public (Iliffe, 1960). It has been more recently demonstrated that Chinese and American orthodontists when ranking facial attractiveness from post-treatment photographs of 43 Caucasian and 48 Chinese orthodontic patients showed good agreement of results (Xu *et al.,* 2008). These similarities were shown to be robust across differences in age, sex, ethnicity and cultural background. Thus the concept of facial attractiveness as entirely subjective might not be wholly correct and in fact may be based on universal features.

1.3.2 Features constituting facial attractiveness

Facial attractiveness involves the understanding and evaluation of beauty, proportions and symmetry. Facial beauty appears to be related to some quality of the whole observed face that tends to be universally accepted, rather than solely due to any single facial feature. However, each person's experiences in life, their ideas and feelings evolve into a conditioned response that affect's his or her judgement thus adding a subjective element to the perception of facial beauty. On the other hand, our perception of facial beauty might have its foundation in our heredity or environment or both. The evolutionary basis assumes that facial beauty is a prerequisite for sexual selection, leading to better chances for reproduction (Naini and Gill, 2008). Langlois *et al*. (1987) showed that infants as young as 3 months of age when shown two facial photographs simultaneously tend to show a preference for and stare longer at the face previously rated as more attractive by adults, showing support for a genetic influence to human perception of facial beauty. However considering how much modern society is fuelled by the media and obsession with the perfect and the most beautiful appearance, environmental influences certainly play a strong role in judgements of facial attractiveness.

Martin (1964) determined that there was a cultural basis for facial beauty and human perception of facial attractiveness. The results of the study showed that both white and black American men preferred black female faces with white features to them, while black African men preferred black female faces with Negroid features thus showing support to the basis for cultural and environmental triggers to human perception of facial beauty. However many studies have long since showed that the perception of facial beauty between different ethnic groups and between people from different countries is remarkably similar (Udry, 1965; Perrett *et al*., 1994; Xu *et al*., 2008). A meta-analysis by Langlois *et al.* (2000) concluded that there is cross-cultural agreement about facial attractiveness. It seems that there is a universal standard for beauty regardless of race, age, sex and cultural background. Faces judged to be very attractive in one society tend to be found equally attractive in other societies and that judges tend to be in good agreement about facial attractiveness, thus indicating that a universal standard of facial attractiveness does in fact exist.

1.3.3 Physical cues of facial attractiveness

Evolutionary psychology proposes that there are four main cues to influence facial attractiveness in the biologically significant assessments of mate value (Bashour, 2006a). These proposed cues are averageness, symmetry, youthfulness and sexual dimorphism.

1.3.3.1 Averageness

Studies in the late 1800s by Sir Francis Galton suggested that taking the mathematical averageness of a series of faces produced the ideal face (Galton, 1879). This was echoed in a study by Langlois and Roggman (1990) the results of which showed that composite facial photographs obtained higher attractiveness ratings than the individual facial photographs. In contrast, Perrett *et al.* (1994) showed that the mean face from a composite of very attractive faces was preferred to the mean face of the whole population sample from which the very attractive faces were selected. Furthermore the study also showed that by exaggerating shape differences from the sample mean the attractive composite faces were made more attractive. Thus while an average face is attractive, it is not the most optimally attractive face and that highly attractive faces are not necessarily average. The authors showed that beauty goes far beyond mere averageness and is far more complex. Therefore while averageness plays a part in facial beauty, there are many other varied components to facial attractiveness, such as proportions, symmetry, youthfulness and perhaps an indefinable elusive element that contributes to what makes up facial beauty to every human being.

1.3.3.2 Symmetry

Asymmetry in faces is readily perceived by others and perceived usually in a negative light, such as in individuals with craniofacial syndromes. Creating a mathematically average face which improves symmetry has been shown to be preferred to the individual faces that made up the composite (Langlois and Roggman, 1990). Thus there is clearly a direct positive relationship between averageness and symmetry. However, Langlois *et al.* (1994) looked at assessments of facial attractiveness of chimeric faces (faces made symmetrical by replacing one-half with the mirror image of the opposite side thus producing right and left chimeric faces), single-face composites (averaging a face only with its own mirror image so as to increase the symmetry of the face without using other faces), multiface composites and the original faces. The authors found that in this instance, the original faces were rated more attractive than the chimeric faces and the single-face composites were rated less attractive than the multiface composites. The authors felt that symmetry may not be the underlying cause of attractiveness in mathematically averaged faces. While it is intuitive in people that symmetry is important to facial attractiveness, there are certainly other factors that play a part in what constitutes facial attractiveness to an individual.

1.3.3.3 Youthfulness

Studies have shown that youthful faces are perceived as more attractive than older faces across populations and cultures (Mathes *et al*., 1985; Henss, 1991; Zebrowitz *et al*., 1993; Tatarunaite *et al*., 2005). Youthfulness indicates babyness and neonate features are large eyes, round cheeks, small nose, glossy hair, smooth skin and lighter colouration. Neonate features in the human face have been shown to be perceived as more attractive and preferred in many cultures (Jones and Hill, 1993; Cunningham *et al.*, 1995; Jones, 1995).

1.3.3.4 Sexual dimorphism and maturity

Male and female faces though similar at birth, begin to diverge from puberty. It is thought that the extremes of secondary sexual characteristics and sexual dimorphic traits are perceived as more attractive and indicative of more valuable heritable traits (Bashour, 2006a). Such desirable masculine features in males are larger jawbones, prominent cheekbones, large chins, square jaws, wide nose, wide mouth and thick eyebrows (Edler, 2001). Desired feminine features in females are high cheekbones, high forehead, smooth skin, shorter and narrower lower jaw, small nose and chin, large eyes spaced widely apart, high sweeping eyebrows and full lips (Edler, 2001). It is interesting to note that studies have shown that women's preferences for a masculine male face varied with the menstrual cycle with women preferring more masculine faces when they are near ovulation or likely to conceive so as to gain the most advantageous heritable genetic traits, while at other times women tend to prefer slightly feminised male facial shapes (Penton-Voak *et al.*, 1999, Penton-Voak and Perrett, 2000).

Summary

There is a wide range of factors that may contribute to facial attractiveness such as symmetry, averageness, youthfulness and perhaps also something that is elusive and indefinable but intuitive to the human eye. However it is interesting to note that it is the distinguishing factors that also contribute to extraordinary beauty. Facial attractiveness is also greatly influenced by fluctuations in fashion and is very media-driven. Although there appears to be a universal agreement over the standard of facial beauty, the debate rages on over what it is exactly that constitutes facial attractiveness.

1.4 Objective evaluation of facial attractiveness

1.4.1 Photographic measurements

At present the main method of recording soft tissue appearance is in the form of photographs. The main problem of using 2D techniques, e.g. photographs or radiographs, to assess 3D objects is the distortion of the perspective in the facial image. Conventional 2D photographs even when standardised lose depth information by projecting images of structures at different heights upon a single plane of film. There are also errors resulting from landmark identification (Baumrind & Frantz, 1971; Houston *et al.,* 1986).

Farkas *et al.* (1980) assessed the reliability of facial photographs compared with direct anthropometric measurements of the face. The study compared 104 direct facial measurements from 36 subjects with measurements taken from frontal and profile photographs. The study found that only 60% (62 out of 104) of the anthropometric measurements could be recorded from the photographs and out of these only 42% (26 out of 62) were deemed reliable and accurate (the same as or differing from the direct measurements by no more than 1mm or 2°). The authors found that errors were introduced by incorrect head positioning in both the vertical and horizontal planes and by measuring points on the photographs without previously indicated landmarks on the face. Of interest to note was that the greatest reliability was for measurements taken in the area of the mouth and lips. However the authors also found that even with identifying landmarks on the face these were not easily located on the photographs when it came to recording the measurements. Another source of error was that the profile line seen on the lateral photographs was not always identical with the true facial profile of the subjects. Further error was also caused by the distortion inherent in photographs especially with points on different planes and this error contributed to the greatest differences between the anthropometric and the photographic measurements.

Strauss *et al.* (1997) investigated the variability of measurements from frontal and lateral facial photographs and frontal dental photographs and found that some measurements from facial photographs are generally reproducible over time but significant individual variations did occur. The least reliability and lowest accuracy was seen with measurements taken from smile photographs, with the commissure-to-commissure width on smiling photographs being the least reliable of all the measurements taken. Measurement of lower lip length taken from all aspects was uniformly of low accuracy, especially on frontal photographs. This was thought to be due to the difficulty in locating soft tissue menton on the photographs. The authors suggested that because of their two-dimensional nature, photographs lack the fine clinical subtlety, precision and accuracy seen in the living subject.

A recent study investigated the accuracy of measurements of the face recorded by manual anthropometry (direct manual measurement of the face), 3D stereophotogrammetry and 2D photography (Ghoddousi *et al.,* 2007). The study concluded that the degree of accuracy of the 3D measurements was found to be very satisfactory and reliable enough for clinical use. The variability of 3D measurements was found to be only marginally less than that of manual measurements and significantly less than that of the 2D measurements.

1.4.2 Cephalometric measurements

Cephalometric norms are used for providing clinical guidance during diagnosis and treatment planning during orthodontic treatment. These values are even more important in orthognathic surgical treatment where there is an obvious need to identify the underlying skeletal discrepancy and soft-tissue facial disharmony by comparing the individual to the normative values. The majority of studies to date have attempted to objectively evaluate facial attractiveness based on linear, angular and ratio measurements from lateral cephalometric radiographs using a “normal” group of subjects i.e. soft tissue analysis, often based on beautiful or idealized faces, or on author’s preferences (Peck and Peck, 1970; Cox and van der Linden, 1971; Lines *et al.,* 1978; Ricketts, 1982a; Ricketts, 1982b; Jacobson, 1984; Powell and Humphreys, 1984; McNamara *et al.,* 1988; Proffit and White*,* 1990; Arnett and Bergman 1993a; Arnett and Bergman 1993b; El-Mangoury *et al.,* 1996; Nanda *et al.,* 1996; Nguyen and Turley, 1998; Auger and Turley, 1999). The data that is produced is obviously two dimensional in origin and is used to analysis soft tissue profiles only.

1.4.3 Overlay mask measurements - Phi mask

A recent mathematical model has been developed to measure human facial attractiveness. The system uses a facial overlay mask variously called the phi, archetypal, golden, or golden ratio mask (Figure 1.1 and 1.2). This mask has been claimed as being used to create an objective system for measuring facial attractiveness (Marquardt, 1999; Marquardt, 2001). The phi mask is based on the golden ratio phi, first derived by the ancient Greeks. The Golden Proportion is a geometrical proportion whereby a line AB is divided at a point C in such a way that AB/AC=AC/CB. The ratio of the shorter segment of the line to the longer segment is

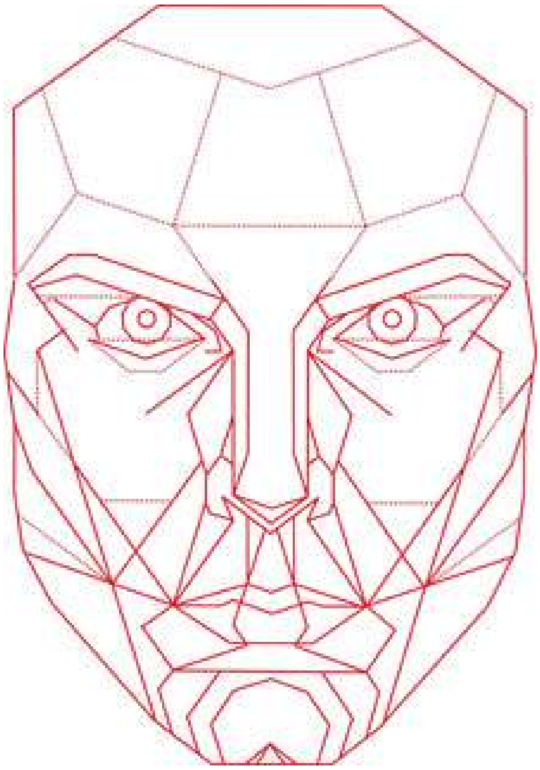

Figure 1.1 Marquardt's Phi Mask

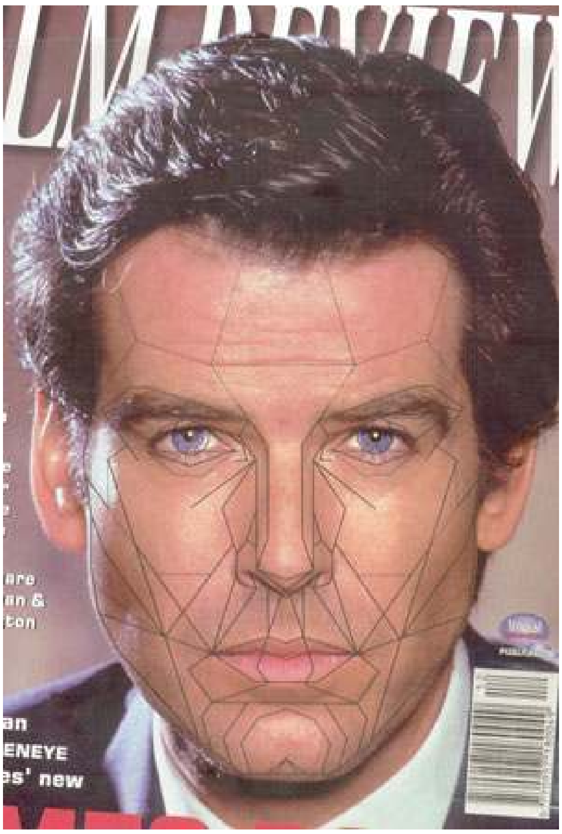

Figure 1.2 Marquardt's Phi Mask superimposed on a famous face

equal to the ratio of the longer segment to the whole line. This numerical value obtained is 1.618 and is indicated by the Greek letter phi (Φ). The Golden Proportion, also known as the Divine Proportion, re-named by the mathematician Luca Pacioli (1509), was taken to be the ratio that is most attractive to the human mind and eye.

In a recent study to validate the phi mask, 68 male faces and 66 female faces were subjectively evaluated by raters and compared to the phi mask (Bashour, 2006b). Using the phi mask model as a template for "attractiveness," a quantitative system was devised by measuring the numerical divergence of the real anthropometric landmarks from their equivalent mask points. The study found the deviation of the landmarks from the phi mask significantly correlates with attractiveness, explaining from 25 to 75 percent of the variance in attractiveness. The problem with the phi mask is that it is based on 2D photographs and there is only one phi mask irrespective of age, sex or ethnicity.

1.4.4 3D measurements

1.4.4.1 Direct manual measurement

Direct manual measurement of the face or direct anthropometry has been a widely accepted method for quantitative assessment of facial surface anatomy. Anthropometry relies on the identification of standard facial soft tissue landmarks and direct measurements of distances, arcs and angles between these points (Farkas, 1973).

Direct anthropometry has several limitations as a method of clinical documentation of the face. The technique is restricted to direct measurement of linear distances between landmarks and subject to operator errors from different degrees of deformation of soft tissue by direct contact of instruments. The technique is also inadequate for the task of three-dimensional surface characterisation and shape measurement. Conventional manual methods of point-to-point displacements and landmark identification are laborious, error prone and lack sufficient information to quantify complex deformities. Some measurements, such as those around the eyes, are difficult to obtain directly without risk of discomfort or injury to the patient. Clinically applicable and acceptable systems for three-dimensional facial surface imaging and digitisation offer the means to define facial surface morphology and facial soft tissue landmarks rapidly and accurately without discomfort to the patient. Indirect methods of facial anthropometry are easier, quicker and less dependent on the patient's behaviour or the need for the patient to keep still for long periods, particularly advantageous when children are being assessed. It also eliminates the need for direct contact with the subject's soft tissues thus avoiding deformation of the soft tissue which is a source of error in direct anthropometry.

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1.4.4.2 Facial three dimensional morphometry

This system uses two charge-coupled device (CCD) cameras that image the subject, using real time hardware for the recognition of markers placed on a patient's face. Appropriate software reconstructs the x,y,z coordinates of the landmarks relative to a reference system and provides 3D data. Placing landmarks on the face is time- and labour-consuming and cannot be performed consistently between consecutive sessions due to movement of facial features. Although the system has been used extensively to investigate facial changes, no lifelike models have been produced to show the natural soft tissue appearance of faces (Ferrario *et al.,* 1994; Ferrario *et al.,* 1996). This system could not be used as a 3D treatment-planning tool or as a communication medium with orthognathic surgery patients. An interesting point to note is that none of the studies include an error study in landmark placement.

1.4.4.3 Measurements from 3D images

Following recent advances in technology and the introduction of digital imaging it has become possible to introduce stereophotogrammetric camera systems that generate 3D facial images with photorealistic rendering (Ayoub *et al.,* 1998). These new systems produce a natural photorealistic appearance of the face which should then in theory allow more accurate landmark placement compared with many previous 3D imaging systems which did not have photorealistic rendering. As with cephalometric evaluation basic linear, angular and ratio measurements can be made based on landmarks, but also more complex morphometrics.

Ayoub *et al.* (1998) found error of facial landmark localisation to be within 0.5mm however the precise landmarks selected were not highlighted. In a later study however, the same system (C3D) was used to scan 21 facial casts of infants with cleft lip where 5 landmarks across the mouth and nose had been pre-labelled on each cast (Ayoub *et al*., 2003). The results showed that the operator error for manual localisation of landmarks using a co-ordinate measuring machine was on average 0.2mm while the operator error for landmark localisation on the digitised facial model generated by the C3D system was accurate within 0.4mm. Even though the error associated with the C3D system was double that of the co-ordinate measuring machine the difference was not clinically significant.

The use of the system was expanded and the pre- and post-operative scans of five orthognathic patients were assessed to determine surgical soft tissue change (Hajeer *et al.,* 2002). Twenty-four landmarks were identified on each image covering areas such as the cheeks, gonial angles, the chin and the ear which were not included in previous studies (McCance *et al.,* 1992; Moss *et al.,* 1994; Ras *et al.,* 1996). Landmark identification of 30 facial landmarks was repeated three times by the same operator with a 1 week interval between each session of digitisation. Intra-operator error for landmark localisation was taken at the cut-off point of 0.5mm for high reproducibility. Using the set criteria 20 landmarks were found to be highly reproducible within the 0.5mm cut-off. A further 4 had standard deviations between 0.5-1mm (glabella, right and left otobasion inferius, left zygion). Six landmarks had standard deviations that exceeded 1mm and were considered inappropriate for use in studying facial soft tissue morphology (right and left gonion, right and left tragion, right zygion and menton). The authors suggested that the reproducibility of gonion and zygion was poor due to the difficulty in locating these points precisely on the computer screen. To improve accuracy of gonion and zygion would require palpation and pre-labelling on the face prior to capture. Soft tissue menton was difficult to locate especially where the patient had a double chin or retrognathia. A further study using the same landmarks was conducted to assess facial soft tissue asymmetry before and after orthognathic surgery (Hajeer *et al.,* 2004).

In a more recent study Gwilliam *et al.* (2006) chose 24 landmarks that were selected to represent those used most commonly in previous studies of 3D facial imaging (Farkas, 1994; Hajeer *et al.,* 2002). Six 3D stereophotogrammetric facial images were selected from an archive. If the gold standard for intra-operator error is taken as 0.5mm (Hajeer *et al,* 2002), then this study showed only 4 out of the 24 landmarks to be within this error margin and thus highly reproducible for all images (right and left cheilion, labrale superius and exocanthion). If the intra-operator error margin is increased to 1mm then 12 landmarks were identified. This compares unfavorably with the data of Hajeer et al.

(2002) data in which 20 out of the 30 landmarks were found to be highly reproducible. One of the possible reasons suggested is that it is important to become familiar with the software program used to view the images in order to improve landmark reproducibility.

Considering other 3D stereophotogrammetry systems, Weinberg *et al.* (2004) evaluated the precision and accuracy of measurements obtained from digital 3D images using a Genex 3D stereophotogrammetry camera system (Rainbow 3D Imaging System). The authors assessed the precision and accuracy of the system for a series of 19 standardised linear measurements derived from 17 landmarks (Farkas, 1994) taken from the face of 20 Caucasian females and males aged 16 to 62 years with no obvious craniofacial abnormalities. Measurements were recorded directly from the face with digital callipers and indirectly from the 3D images, both when the landmarks were pre-labelled as dots on the face and when there was no pre-labelling. Their results showed that measurements obtained from the 3D images had higher precision compared with direct anthropometry, largely irrespective of whether the landmarks were pre-labelled on the subject's face or not. However, measurements from the 3D images of subjects with pre-labelled landmarks showed the highest precision. The authors concluded that indirect anthropometry will always show better precision than direct anthropometry as the latter requires direct physical contact with the pliable soft tissues of the face leading to tissue deformation which is one of the major sources of measurement error in direct anthropometry (Farkas, 1994). The error magnitude scores for the 3D measurements were generally in the submillimetre range, rarely exceeding 2mm. Overall error magnitudes tended to be higher in variables of greater size (glabella-subnasale distance, nasal height), variables containing difficult to see landmarks (e.g. exocanthion) and variables crossing the labial fissure (e.g. lower facial height, total facial height). Smaller error magnitudes tended to be associated with smaller variables (e.g. endocanthion-endocanthion) and variables centred on the nasal and upper lip region (inter-phitral distance).

Aldridge *et al.* (2005) assessed the precision, error and repeatability associated with landmarks derived from 3D stereophotogrammetric digital images of the faces of 15 children and adults obtained by the 3dMDface system. The results showed that on average, landmarks were located with a very high degree of precision with fourteen of the twenty landmarks selected displaying a very high degree of precision, showing an error of less than 1mm along each of the three coordinate axes averaged over subjects and scans. Out of the remaining six landmarks, three showed an error greater than 1mm but less than 2mm (nasion, left and right tragion) and the other three had an error magnitude of greater than 2mm (glabella, left and right gonion). Nasion showed error greater than 1mm only along one axis with lower error along the other two axes, showing that nasion is easily located on the mediolateral and anteroposterior axes but less consistently located superoinferiorly. Glabella was found to have the same problems in accurate landmark localisation as nasion. Gonion however was inconsistently located along all three axes, this is in agreement with previous studies (Weinberg *et al.,* 2004). The study also reported increased error in linear distances crossing the labial fissure and attributed this to the children in their sample altering their facial expressions between the first and second image capture. The mean error due to digitisation across all 190 linear distances was 0.9% meaning that on average less than 1% of the total observed variance is explained by error due to digitisation. Seven of the linear distances showed an error due to digitisation in excess of 5%, these were mainly measurements that included the landmarks glabella and gonion. In addition, the mean error averaged across all 190 linear distances due to the imaging system was 1.5%. Eleven linear distances had error due to the imaging system in excess of 5% and these were distances that included the landmarks glabella, gonion, tragion and nasion. Repeatability was found to be high for all landmarks.

Summary

The ability to document accurately a complex three-dimensional surface via 3D imaging systems provides an unprecedented means for evaluation of craniofacial morphology. The face, as a three-dimensional structure, has been analysed extensively in the literature (Ferrario *et al*., 1994; Ferrario *et al*., 1996; Hajeer *et al*., 2002; Ayoub *et al*., 2003; Kau *et al*., 2005a; Kau *et al*., 2005b; Kau *et al*., 2006). Three-dimensional coordinates for facial soft tissue landmarks are produced by these systems in the x, y and z axis. By using these three-dimensional coordinates it is possible using computer programs to define lines and planes, and calculate distances and angles between the landmarks, lines and planes. As the digitised images are permanent, they can be looked at repeatedly long after the patient is gone and determination of 3D coordinates for landmarks can be repeated and new landmarks can be added.

The choice and number of 3D facial landmarks used in previous studies have varied widely in the literature. Most studies have concentrated on reliably measuring distances between manually selected digitised facial soft tissue landmarks against corresponding points on live subjects as a form of validation (Aung *et al*., 1995; Ayoub *et al*., 1998;). Some studies use complex mathematics to derive and analyse shapes (Coombes *et al*., 1991). Mathematically constructed landmarks have been used in some studies based on the location of anatomical facial landmarks (Techalertpaisarn and Kuroda, 1998; Nute and Moss, 2000). In order to reduce the error associated with landmark identification the concept of automated facial landmark extraction has been proposed (Yamada *et al*., 1999).

1.5 3D normative data

The use of normative values was first suggested by Downs (1956), who based his two dimensional normative values on a group of subjects with untreated excellent occlusions. The problem still exists of recent studies either still assuming that an ideal occlusion relates to an ideal facial appearance or a single individual is in a position to pick an ideal facial appearance (Scheideman *et al.,* 1980; Holdaway, 1983; Holdaway, 1984; Connor and Moshiri, 1985; Alcalde *et al.,* 1998; Alcalde *et al.,* 2000; Erbay & Caniklioğlu, 2002; Moate *et al.,* 2002; Al-Jasser, 2003; Al-Gunaid *et al.,* 2007; Beugre *et al.,* 2007; Nakahara & Nakahara, 2007; Kalha *et al.,* 2008; Taki *et al.,* 2009). For instance Scheideman et al. (1980) derived cephalometric norms from 56 individuals selected according to class I canines and molars, an ANB value between 0 and 4^o and stating “no attempt was made to select subjects with “ideal” facial aesthetics”.

Ferrario *et al.* (1996) was one of the earliest studies attempting to objectively identify 3D reference standards and aesthetic features in facial proportion of an adult male and female sample. The study utilised three-dimensional facial morphometry (3DFM) to analyse two different groups. The “normal” reference group of 40 healthy male and female Caucasian Northern Italians were selected from dental students aged 19-32 years. All subjects had sound dentitions with bilateral Angle Class I molar relationship, absence of crossbites and no previous history of craniofacial abnormalities, orthodontic treatment or orthognathic surgery. A number of subsequent studies have compared normal Italian adolescents or adult women to adolescents or women who were deemed attractive. Ferrario *et al.* (1995) compared the facial morphology of 10 white Italian television actresses selected on the basis that their facial appearance was judged to be beautiful to the 40 normal Caucasian Italian women group. The same authors have compared the facial aesthetics of 71 normal white Northern Italian women to beautiful women selected from national beauty competitions over 2 years (Sforza *et al.,* 2007; Sforza *et al.,* 2009). Sforza *et al.* (2008) also compared normal white Northern Italian adolescents (boys and girls) chosen on the same criteria as the above studies to beautiful adolescents judged to be very attractive by a commercial casting company and suitable for cinema, television or the fashion industry. These studies use normative data that could be based on extremely subjective opinion. Another interesting point to note is that the normal values for the 40 dental students and the 71 reference normal women are not similar even though the inclusion criteria was the same, Table 1.1 and 1.2. This again shows the subjective nature of facial aesthetics.

Two further studies that looked at normal reference groups using 3D stereophotogrammetry were Weinberg *et al.* (2004) and Wong *et al.* (2008). These studies compared facial soft tissue linear measurements recorded by 3D stereophotogrammetry and direct anthropometry. Weinberg *et al.* (2004) used a normal sample comprising of 14 females and 6 males who were healthy Caucasians with no obvious craniofacial dysmorphology. Wong *et al.* (2008) assessed 8 females and 12 males, five of whom were Asian and the rest were Caucasian (but there was no mention of which subjects in particular were Asian). Unfortunately no further clarification was provided on exactly how they defined "normal" for their sample.

		Ferrario *et al.* (1996)				Ferrario *et al.* (1995)		Sforza *et al.* (2009)					
		Male (40)		Female (40)		Television actresses (10)		Reference group (71)		2006 Beauty contest winners (12)		2007 Beauty contest winners (12)	
Measurements	Landmarks												
Linear		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Upper face height	N-Sn	64.30	5.04	61.96	3.96	52.38	2.76	-	-	-	-	-	-
Lower face height	Sn-Pg	50.41	4.04	46.31	3.39	47.71	3.71	-	-	-	-	-	-
Upper third face depth	N-(Tr_r-Tr_l)	99.14	5.20	95.06	3.83	91.40	5.91	-	-	-	-	-	-
Middle third face depth	Sn-(Tr_r-Tr_l)	101.45	5.73	96.27	3.81	95.50	5.63	102.5	4.8	103.8	4.0	100.5	3.5
Lower third face depth	Pg'-(Tr_r-Tr_l)	120.07	6.60	111.84	4.94	110.11	5.71	-	-	-	-	-	-
Upper face width	Can-Can	116.93	5.92	111.47	6.74	101.59	4.97	90.2	3.8	95.2	3.3	92.5	3.5
Middle face width	Tr_r-Tr_l	142.97	9.20	132.45	10.06	135.10	5.05	134.4	5.7	136.2	5.2	130.8	4.7
Lower face width	Go_r-Go_l	111.86	10.26	104.69	7.59	111.18	4.11						
Mouth width	Com_r-Com_l	54.90	3.97	51.20	3.80	52.40	4.51	48.5	3.5	49.2	2.1	48.2	2.9
Mandibular body length	Pg'-(Go_r-Go_l)	82.23	5.62	77.21	4.96	76.67	5.09	-	-	-	-	-	-
Mandibular ramus height	Tr-Go	61.39	5.27	54.67	5.86	52.68	4.05	-	-	-	-	-	-

Table 1.1 Comparison of the linear measurements from the main comparative studies.

		Ferrario *et al.* (1996)				Ferrario *et al.* (1995)		Sforza *et al.* (2009)					
		Male (40)		Female (40)		Television actresses (10)		Reference group (71)		2006 Beauty contest winners (12)		2007 Beauty contest winners (12)	
Measurements	Landmarks												
Angular		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Facial convexity exc. nose	N-Sn-Pg	168.03	5.70	166.82	5.26	164.02	3.71	160.4	6.3	160.2	5.0	162.7	4.6
Facial convexity inc. nose	N-Pn-Pg	134.21	5.47	134.04	5.02	131.76	3.59	-	-	-	-	-	-
	B-N-Sn	5.86	2.17	6.19	1.95	8.48	1.72	-	-	-	-	-	-
	Tr_l-N-Tr_r	71.60	5.02	69.68	4.90	73.03	3.76	-	-	-	-	-	-
	Tr_l-Pn-Tr_r	63.63	4.64	62.41	3.83	64.43	3.02	-	-	-	-	-	-
	Tr_l-Pg-Tr_r	61.58	4.82	61.23	4.20	63.07	2.98	-	-	-	-	-	-
Upper facial convexity	Can_l-N-Can_r	109.78	7.62	110.00	7.94	120.29	5.24	120.2	5.6	124.9	3.5	120.8	4.2
	Go_l-Pg-Go_l	68.32	6.14	68.26	5.34	71.94	4.63	-	-	-	-	-	-
	Tr_r-Go_r-Pg	117.92	6.37	119.97	6.07	119.72	5.83	-	-	-	-	-	-
	Tr_l-Go_l-Pg	120.09	6.98	122.13	5.26	120.42	7.13	-	-	-	-	-	-
Nasolabial	Prn-Sn-LS	-	-	-	-	-	-	127.2	8.0	137.7	6.4	159.0	7.7

Table 1.2 Comparison of the angular measurements from the main comparative studies.

1.6 Subjective evaluation of facial attractiveness

Several authors have attempted to evaluate facial attractiveness using a variety of scoring systems and involving panel assessments, in which rating or ranking by a group of professional or lay individuals or both is undertaken (Roberts-Harry, 1992; Peerlings *et al.,* 1995; Knight and Keith, 2005; Tatarunaite *et al.,* 2005; Shafiee *et al.,* 2008). The early studies concluded that the use of standardised photographs as a means of judging facial appearance was deemed to be necessary if meaningful results were to be achieved.

Knight and Keith (2005) investigated the relationship between ANB differences and anterior lower face height (ALFH) percentages with respect to facial attractiveness using a ranking system. Two panels, one panel of six orthodontists and dentists and the other panel of six lay people were asked to rate the facial attractiveness of each group of 30 photographs by ranking the photographs in a line from most attractive to least attractive. The study concluded that the most attractive profile was found to be the Class I profile and there was complete agreement between the clinicians and lay people about the most and least attractive faces. As such the authors recommend that the collection of 30 male and 30 female photographs can be taken as a standardised spectrum of facial attractiveness, against which orthognathic treatment outcomes could be compared.

It has been reported that specific features of a face i.e. eyes, the mouth and the complexion may significantly contribute to facial attractiveness (Lerner, 1973; Helm *et al*., 1985). In a recent study, Tatarunaite et al. (2005) investigated the various factors that might affect facial attractiveness. A lay panel was asked to rate overall facial attractiveness as well as the cheeks, chin, eyes, hair, lips, nose, skin and teeth of the 60 subjects using a nine-point rating scale based on colour photographs. It was found that the facial feature most strongly associated with overall attractiveness were the cheeks and those least associated with attractiveness were the nose and teeth. The study concluded that overall facial attractiveness does not however depend on any single facial feature. The authors also determined that although the lay panel did not agree on the exact same facial attractiveness score, they tended to rank the photographs in a similar fashion. The consistency of results supports the idea that facial attractiveness is less subjective than is generally thought.

1.7 Lay panel versus expert panel in assessing facial attractiveness

Perception of facial attractiveness is an individual response and is shaped by personal, cultural and social experiences. Thus the perception and evaluation of facial aesthetics by dental professionals may not coincide with the perceptions and expectations of lay people.

A number of studies have demonstrated that orthodontists are more critical of facial appearance than lay people (Shaw *et al.,* 1975; Prahl-Anderson *et al.,* 1979; Bell *et al.,* 1985; Dunlevy *et al.,* 1987; Kerr and O'Donnell, 1990; Espeland and Stenvik, 1991; Cochrane *et al.,* 1997; Cochrane *et al.,* 1999; Flores-Mir *et al.,* 2004; Kiekens *et al.,* 2005).

These differences have been attributed to the subjective judgement involved in the evaluation of dentofacial appearance between lay people and professionals and to the difference in knowledge and experience between the two groups (Prahl-Anderson *et al.,* 1979; Phillips *et al.,* 1992b). It has also been suggested that the age and socio-economic status of the judges should match the stimulus photographs in the sample (Howells and Shaw, 1985; Phillips *et al.,* 1992b). More importantly, one study showed that there was no significant difference when the ratings of facial attractiveness by a 2 person lay panel were compared with those of the larger lay panel of 122 lay people, suggesting that a small panel of judges can provide valid, reproducible and representative ratings of facial aesthetics (Howells and Shaw, 1985). This is supported by a recent study investigating the influence of panel composition on aesthetic evaluation of adolescent faces (Kiekens *et al*, 2007). The study concluded that a panel of about seven randomly selected lay men and/or orthodontists (males and/or females) would be sufficient to yield reliable results, using the VAS as the outcome measure in clinical and epidemiological studies of facial aesthetics of adolescents. The use of larger panels is unnecessary, more time-consuming, and more expensive

Although some studies have found dental professionals were actually less critical when assessing facial aesthetics compared to the lay people (Tedesco *et al.,* 1983a; Tedesco *et al.,* 1983b; Phillips *et al.,* 1992b; Spyropoulos and Halazonetis 2001), other investigations did not find any difference between the two groups (Lines *et al.,* 1978; Peerlings *et al.,* 1995; Kiekens *et al.,* 2005; Maple *et al.,* 2005). Controversy remains in the literature as to whether lay people and professionals agree in their perceptions of facial attractiveness.

Different facial views have been utilised in many different combinations in studies of facial aesthetics using photographs. Phillips *et al.* (1992b) showed two full face (smiling and non-smiling) and one profile colour views of 18 orthodontic patients to 16 orthodontic residents, 17 dental students and 71 undergraduate non-dental students. The ratings for facial attractiveness (using a 100mm visual analogue scale with the anchors 'very unattractive' and 'very attractive') and the ranking of these ratings differed significantly among the three views for 80% of the patients, showing that the rating of facial attractiveness for a given subject may differ significantly depending on the facial view presented. It has been suggested that the simultaneous presentation of frontal and profile views to imitate a three-dimensional viewing of the face was the best way to overcome this limitation (Phillips *et al.,* 1995).

In investigations of facial aesthetics, use of panels to rate facial attractiveness has been widely established (Tedesco *et al.*, 1983a; Kerr and O'Donnell, 1990; Phillips *et al.*, 1992a; Phillips *et al.*, 1992b; Peerlings *et al.*, 1995; Giddon, 1995; Spyropoulos and Halazonetis, 2001; Kiekens *et al.*, 2005; Kiekens *et al.*, 2007). However there has been a wide variation in panel composition throughout the studies, with no particular agreement on the optimal panel characteristics for such investigations. Judgements of panels have often been compared; however conflicting results have been reported due to the many differences in panel composition between studies. Factors related to the individual characteristics of the panel members such as age, gender, socio-economic background and of course professional versus lay background can significantly influence the ratings made, and this has been showed in a number of studies (De Smit and Dermaut, 1984; Howells and Shaw, 1985).

Summary

The importance of facial attractiveness in society cannot be overlooked. It has been established that clinicians and the lay public tend to view facial aesthetics differently.

Controversy still surrounds this issue; however the fact that differences are found between professionals and lay people does not mean that their opinions of facial attractiveness are completely mutually exclusive. It simply means that some groups are more critical than others in the evaluation of facial aesthetics. Ultimately it must be remembered that it is the views of the patient undergoing treatment that has a high priority. It is essential that clinicians who are involved in the management and treatment planning of orthodontic and orthognathic surgery patients are aware of how the patient perceives his or her own appearance and society's standards for normal facial attractiveness. Any differences in the perception of facial attractiveness between clinicians and the lay person should be more thoroughly understood in the further development of patient-centred treatment goals. A failure to communicate and align the patient's perceptions of facial attractiveness and treatment expectations with the clinical parameters of improving a malocclusion may result in patient dissatisfaction with the end result despite technically well planned and executed procedures.

1.8 Use of the Visual Analogue Scale (VAS)

The Visual Analogue Scale (VAS) is a reliable, valid and sensitive measurement tool used for measuring a variety of subjective phenomena (Scott and Huskisson, 1976; Morrison, 1983; McCormack *et al.,* 1988; Wewers and Lowe, 1990; Mottola, 1993). It is one of the most frequently used measurement scales in health care research (McCormack *et al.,* 1988; Wewers and Lowe, 1990; Miller and Daron, 1993). The VAS is a concept readily understood by the general public and clinicians alike, it is quick, simple to construct, simple and easy to use (Morrison, 1983; Howells and Shaw, 1985; Phillips *et al.,* 1992a; Mottola, 1993). Its ease of construction, use and scoring makes it a viable tool for use in clinical situations (Little and McPhail, 1973; Scott and Huskisson, 1976; Morrison, 1983; Ahles *et al.,* 1984).

The VAS is an instrument that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot be directly measured. It has been used in clinical and research settings since the 1920's but it gained widespread use in the assessment of mood (Aitken, 1969; Zealley and Aitken, 1969; Aitken and Zealley, 1970).

Description

The VAS is a straight line anchored by word descriptors at each end which are labelled as the extreme boundaries of the sensation, feeling or response to be measured. Subjects respond to the VAS by placing a mark through the line at a position which best represents their current perception of a given phenomenon between the labelled extremes. A score is obtained by measuring the distance from the minimal end point to the subject's mark on the line.

The VAS may be a horizontal or a vertical line of any length as determined by the investigator. The most common form is a horizontal line usually 100 millimetres in length, producing a 100-point scale (McCormack *et al.,* 1988; Wewers and Lowe, 1990). A horizontal VAS has been shown to produce a more uniform distribution of scores than a vertical VAS. This was shown by Scott and Huskisson (1976) who also showed that 7% of their patients failed to complete a vertical VAS mainly because they were unable to understand the concept. Some authors have found that subjects expressed a preference for the horizontal VAS as compared to the vertical VAS

(Sriwatanakul *et al.,* 1983). It has been suggested that the scores obtained when using a vertical VAS may be subject to error as a function of the angle at which the subject views the scale (Dixon and Bird, 1981). Joyce *et al.* (1975) showed that patients using the horizontal VAS to evaluate their pain from chronic inflammatory arthropathy found it no more difficult than the traditional four-point-descriptive scale to understand and complete properly. The VAS was also preferred by the patients and was shown to be more sensitive compared with the traditional rating scale. Whether vertical or horizontal scales are used, it is suggested that the direction of the scale remain constant during a given study (Scott and Huskisson, 1979b; Wewers and Lowe, 1990).

Although word labels define the end points of the VAS, it has been shown that neither numbers or word descriptors should be used to define intermediate points as this may cause a clustering of scores around a preferred number (Scott and Huskisson, 1976) or around the word descriptor (Huskisson, 1974).

Revill *et al.* (1976) showed that lines shorter than 100mm tend to produce greater error variance. They also noted that there were minimal differences in mean error for horizontal lines of 5, 10, 15 and 20cm; however the largest error was noted for the 5cm VAS.

Construction of the VAS

The VAS is simple to construct via a number of steps (Scott and Huskisson, 1976),

1. Define the subjective phenomenon or response to be observed.
2. Determine the extremes of that response and choose the appropriate descriptive end-phrases.

3. Use an appropriate question and explanation to introduce the scale.
4. Make definite cut-off points, determining the length and direction of the scale.

Decisions should be made for each individual VAS based on the experimental design of the phenomenon being studied, distribution of scores during pilot studies, the variable being measured and the population being tested. It is essential that the researcher provide a clear and careful definition of the subjective phenomenon that is to be assessed by the VAS.

Uses of the VAS

The VAS was originally developed as a tool used for the evaluation of individuals by raters, but has now been extended to the rating of subjective phenomena by individuals experiencing the phenomena of interest. The VAS has been shown to be successfully used by both health professionals and lay persons (Morrison, 1983).

The VAS is mostly used as a single item measurement strategy but in the recent years it has also been used to measure multiple constructs in a study or used as a response format to produce summative scores on a given subjective phenomenon. For example, the VAS has been used to measure overall quality of life of cancer patients (Coates *et al.,* 1983), the subjective effects of medication (Hart *et al.,* 1976) and the response to smoking cessation treatment (Glassman *et al.,* 1984).

In general, the VAS has been used to measure mood (Aitken, 1969; Zealley & Aitken, 1969; Aitken & Zealley, 1970), pain (Joyce *et al.,* 1975; Scott and Huskisson, 1976; Revill *et al.,* 1976; Scott and Huskisson, 1979a; Sriwatanakul *et al.,* 1983; Ahles *et al.,* 1984), anxiety (Hornblow and Kidson, 1976), depression (Little and McPhail, 1973), alertness (Hart *et al.,* 1976), change in function (Guyatt *et al.,* 1987), quality of sleep (Aitken, 1969), behaviour of the elderly (Morrison, 1983) and health state valuations from the general public (Gudex *et al.,* 1996) to name a few examples.

In the dental context, the VAS has been used to measure:

- perception of facial attractiveness/aesthetics (Tulloch *et al.,* 1984; Howells and Shaw, 1985; Phillips *et al*., 1992b; Phillips *et al*., 1995; Flores-Mir *et al*., 2004; Kiekens *et al.,* 2005; Maple *et al*., 2005).
- perception of dental aesthetics (Schlosser *et al.,* 2005; Soh *et al.,* 2006).
- facial and body image satisfaction (Newton and Minhas*,* 2005).
- treatment need for orthodontics (Ashley *et al.* 2001; Ngom *et al*., 2005).
- treatment outcome (Proffit *et al*., 1992).
- the effect of treatment on facial attractiveness (Paquette *et al.,* 1992; Phillips *et al.,* 1992a; Shell *et al.,* 2003).
- dental anxiety (Luyk *et al.,* 1988).
- patient's perspective of orthognathic surgery (Cheng *et al.,* 1998).
- health-related quality of life values for oral cleft patients (Wehby *et al.,* 2006).

In the vast majority of these dentofacial studies, the VAS used was a 100mm horizontal scale with word descriptors such as:

- very unattractive face – very attractive face (Phillips *et al*., 1992b).
- least attractive imaginable – most attractive imaginable (Flores-Mir *et al*., 2004).
- least attractive – most attractive (Ngom *et al.,* 2005).

- very unattractive – most attractive (Tulloch *et al.,* 1984; Howells and Shaw, 1985; Phillips *et al.,* 1992a; Phillips *et al.,* 1995; Kiekens *et al.,* 2005, Maple *et al.,* 2005; Edler *et al.,* 2006).
- no need for dental treatment – most urgent need for dental treatment (Ashley *et al.,* 2001).

1.9 Use of VAS to score facial attractiveness

Howells and Shaw (1985) reported good validity and reliability with the VAS in rating facial attractiveness from photographs. The study showed high correlation between the VAS scores given to the photographs and the live patient (correlation coefficient 0.67) as well as a high correlation between the first and second rating of the photographs by each of the two lay judges (correlation coefficient 0.78 and 0.86 respectively). The study recommended the VAS as a simple, quick, valid, reliable, easily understood and economical tool in studies of rating facial aesthetics. This is in agreement with several more recent studies (Phillips *et al*., 1992a; Kiekens *et al*., 2005; Kiekens *et al*., 2007).

However it has suggested that the VAS method of scoring can introduce a level of precision beyond the discriminatory ability of the judges and can be affected by the training and experience of the assessor (Phillips *et al.,* 1992b). It has been previously noted that one of the limitation of the VAS was that comparable positioning of marks on the scale by two observers does not necessarily imply the same feeling, and that intensity of feeling is not necessarily a simple multiple of the score (Aitken, 1969). A later study remarked on the uncertainty present in determining how many millimetres of difference in facial attractiveness would be required to be clinically meaningful (Maple *et al.,* 2005). It was therefore recommended that the VAS scores be transformed to rankings to improve the statistical validity of the VAS tool (Phillips *et al.,* 1992b). The use of ranks also removes the problem of non-even distribution of ratings among judges which can occur when certain parts of the scale are neglected by some judges or when intervals in the rating scale are not viewed as of equal value. Doing so would allow relative changes rather than absolute values to be investigated (Edler *et al.,* 2006).

Advantages of using the VAS

- Simple and quick to construct.
- Quick and easy to administer and score.
- Useful in a wide variety of clinical and research settings for measuring subjective phenomena.
- Easily understood by most subjects.
- Requires little motivation for completion by subjects.
- Enables the rater to make fine discriminations without the constraints of direct quantitative terms.
- Provides options for fineness of the score.
- High levels of reliability, validity and sensitivity (Faure *et al.,* 2002; Kiekens *et al.,* 2005; Maple *et al*., 2005).
- Good inter-rater and intra-rater reliability (Howells and Shaw 1985; Faure *et al*., 2002; Maple *et al*., 2005; Kiekens *et al*., 2005).
- Good level of reliability when used by both professionals and lay persons (Morrison, 1983; Maple *et al.,* 2005, Kiekens *et al.,* 2005).
- More sensitive than a graphic rating scale or a four-point descriptive rating scale for pain (Joyce *et al*., 1975).

- Allows the use of numerical values and/or normalisation of data thus making VAS data suitable for a variety of statistical analysis.
- No impediment to problems of sight impairment or manual dexterity.
- Independent of language, vocabulary and learning since only a few words are used with the VAS.
- Avoidance of subjects putting individual interpretations to a wide variety of descriptors as only a few words are used.

Disadvantages

- Difficulty in conceptual understanding of the method, some subjects find it difficult to convert a subjective sensation to a straight line.
- Comparable positioning of marks on the scale by two observers or by the same observer on two separate occasions does not necessarily imply the same feeling.
- Intensity of the subjective phenomena is not necessarily a simple summation of the score.
- Uncertainty in determining how many millimetres of score represents a meaningful clinical change in the subjective phenomena.
- The angle at which the subject views the VAS may alter the placement of the mark.
- Accurate reproduction of the scale is essential – photocopying distorts the length of the scale (Wewers and Lowe, 1990).
- Mark placed along the VAS is totally dependent on the subject's unique interpretation of the maximal value (which could be argued to be immeasurable e.g. greatest pain) and based on the subject's experience to date – thus the VAS is totally ipsative with no normative basis.

- Reproducibility of previous marks varies along the length of the VAS – subjects tend to estimate accurately along the extremes or in the centre while the region ±2cm of the midpoint is the least reproducible (Dixon and Bird, 1981).

Summary

The VAS is a simple, quick to construct, valid, reliable, convenient, easily understood, readily accepted and easy to administer measurement strategy that can be used by both lay persons and professionals. While the VAS as a measurement tool is not without certain drawbacks, there is a growing amount of evidence that has shown the VAS to be a fairly reliable, valid and sensitive tool in the measurement of subjective phenomena, allowing scores on a large number of stimuli to be readily obtained by a panel of judges.

1.10 Recording facial images

In the literature there have been numerous studies reported and various techniques used to evaluate facial attractiveness:

- Silhouettes (Lines *et al.,* 1978, DeSmit and Dermaut, 1984).
- Line drawings (Prahl-Anderson *et al.,* 1979; Kiyak and Zeitler, 1988).
- Photographs (Iliffe, 1960; Udry, 1965; Shaw, 1980; Tedesco *et al.,* 1983a; Tedesco *et al.,* 1983b; Tulloch *et al.,* 1984; Bell *et al.,* 1985; Shaw *et al.,* 1985; Howells and Shaw, 1985; Kerr and O'Donnell, 1990; Phillips *et al.,* 1992a; Phillips *et al.,* 1992b; Roberts-Harry *et al.,* 1992; Phillips *et al.,* 1995; Peerlings *et al.,* 1995; Cochrane *et al.,* 1997; Spyropoulos and Halazonetis, 2001; Flores-Mir *et al.,* 2004; Tatarunaite *et al.,* 2005; Knight and Keith, 2005; Kiekens *et al.,* 2005; Kiekens *et al.,* 2007; Xu *et al.,* 2008).
- Artist sketches (Burcal *et al.,* 1987).

Lateral photographs and silhouettes have the advantage of reducing or eliminating the influences of confounding variables (such as hairstyle) but they do not represent the whole face (Maple *et al.,* 2005). In addition the profile view is one that lay persons and the patients themselves rarely see when assessing facial aesthetics. Maple *et al.* (2005) concluded that although the use of profile outlines or silhouettes would eliminate subjective variables, in the study of facial attractiveness it is necessary to judge the attractiveness of the entire face. Frontal photographs have been rated as more attractive than profile views (Kerr and O'Donnell 1990). Phillips *et al.* (1995) suggested that the best presentation of facial attractiveness from photographs is the simultaneous presentation of frontal and profile views so as to imitate the three-dimensional face from all aspects. Howells and Shaw (1985) showed that there is good relationship between judgements of facial aesthetics on live stimuli and single colour photographs. However ultimately, any two-dimensional photograph still does not have the ability to express a person's whole facial attractiveness since dynamic characteristics and skin texture are not taken into account (Kiekens *et al.,* 2005), nor can any given photograph showcase all aspects of the face within it.

Digital imaging gives a more realistic representation of facial aesthetics than silhouettes or line drawings. Photo-realistic colour three-dimensional images that can be rotated to be viewed from any angle provide the most realistic and life-like representation of a subject's face, much more than what can be gleaned from two-dimensional photographs of any view of the face. There are very few studies on assessing facial attractiveness by means of three-dimensional imaging techniques, which is surprising as the human face is ultimately a dynamic three-dimensional structure and considering the plethora of advancements in three-dimensional imaging systems (Baik *et al.,* 2007, Sforza *et al.,* 2007, Sforza *et al.,* 2008).

Previous studies investigating facial attractiveness have generally been carried out using conventional two-dimensional photographs. Todd *et al.* (2005) attempted to ascertain whether viewing two-dimensional or three-dimensional images had any effect on the ranking of facial attractiveness. The study concluded that there appeared to be a large variation in both professional and lay men's attitudes to facial attractiveness, irrespective of the format in which the image is presented and suggested further investigation of these findings but with larger sample sizes. Another point to note is that the images used in this study were black and white which may have introduced a bias against natural facial appearance.

1.11 Three-dimensional soft tissue imaging methods

1.11.1 3D Cephalometry

The first attempt at obtaining 3D soft tissue utilised the 3D reconstruction of craniofacial morphology from stereo X-ray projections using orthogonal X-ray sources (Broadbent, 1931). This technique involved extrapolating 3D data from 2 radiographs taken at 90° to each other, usually a lateral skull radiograph and an anteroposterior radiograph (Broadbent, 1931; Baumrind *et al.,* 1983; Dean *et al.,* 2000). These films are easily obtained, relatively inexpensive and provided fairly adequate information on skeletal and dental hard tissues. However this technique exposed the patient to ionising radiation, shows little soft tissue definition and provides no photorealistic soft tissue texture. The extrapolation technique obviously means that data in between the two radiographs is not necessarily accurate and this will provide a source of error.

1.11.2 Conventional 3D Spiral CT Scanning

Computed tomography (CT) was developed by Godfrey Hounsfield in 1967 and since the first prototype there has been a gradual evolution to produce five generations of CT. Computed tomography captures multiple slices of the human head which can be stacked together, it is then possible to reconstruct a 3D image using the appropriate computer software (Kau *et al.,* 2007). Three dimensional CT images are capable of providing an accurate representation of the osseous structures of the craniofacial region. These images enhance the accuracy of analytical measurements typically used with traditional 2D/3D cephalometry and allow for elimination of the inherent errors associated with plain radiograph cephalometry. A high precision level and accuracy in measurement of hard tissues, 3D visualisation of the facial skeleton, accurate landmark identification, quantitative analysis of craniofacial structures and simulation of CT model osteotomies are among the reported benefits of 3D CT (Chan *et al*., 2007). However this technique exposes the patient to a high radiation dose. It is also expensive, time-consuming and can easily have artefacts created from metal objects within the mouth (Ayoub, 1998; Bearcroft, 2007; Kau *et al.,* 2007). It also lacks the ability to capture natural photographic facial appearance or skin texture.

1.11.3 Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) was developed in the 1990s to counter some of the limitations of the conventional CT scanning systems. CBCT allows a single rotation of the radiation source to capture an entire region of interest. Total radiation for CBCT has been reported at approximately 20% of conventional CT systems and equivalent to a full mouth periapical radiograph exposure (Mah *et al.,* 2003). CBCT is less expensive and smaller, while producing images comparable to conventional CT

(Kau *et al.,* 2005c). As with conventional spiral CT, CBCT soft tissue images do not capture the true colour and texture of skin and thus does not provide photorealistic rendering of the images, Figure 1.3 (Kau *et al.,* 2005c; Kau *et al.,* 2007).

1.11.4 Magnetic Resonance Imaging MRI

MRI is an imaging modality that does not use ionising radiation and that can generate cross-sectional images in any arbitrary plane which can then be generated into 3D images with the appropriate computer software (Bearcroft, 2007). The images are acquired by placing the patient into a strong homogeneous magnetic field for over several minutes during which time the patient must remain still or else errors will be introduced into the resulting images. The advantage of MRI is that there is much better soft tissue definition compared to CT scanning but there is still limited resolution of facial soft tissues due to slice spacing. Natural photographic facial appearance or skin texture are not captured by this technique and while it is a relatively safe procedure, the cost involved is very high, Figure 1.4 (Ayoub *et al.,* 1998). This method of imaging is predominately utilised for internal soft tissue capture since its ability to capture hard tissue is inferior to CT.

1.11.5 Laser Scanning

Laser scanning is a method that utilises optical principles to capture surface topography of the human face in 3D (Moss *et al*., 1987). Laser technology is an active technique in which the distance of an object is computed by means of a directional light source and a detector. A laser beam is deflected by a mirror onto the subject’s face. As the laser beam is projected onto the face the beam is scattered and then captured by a detector. The resultant distortion of the laser light pattern on the subject’s face is captured by the

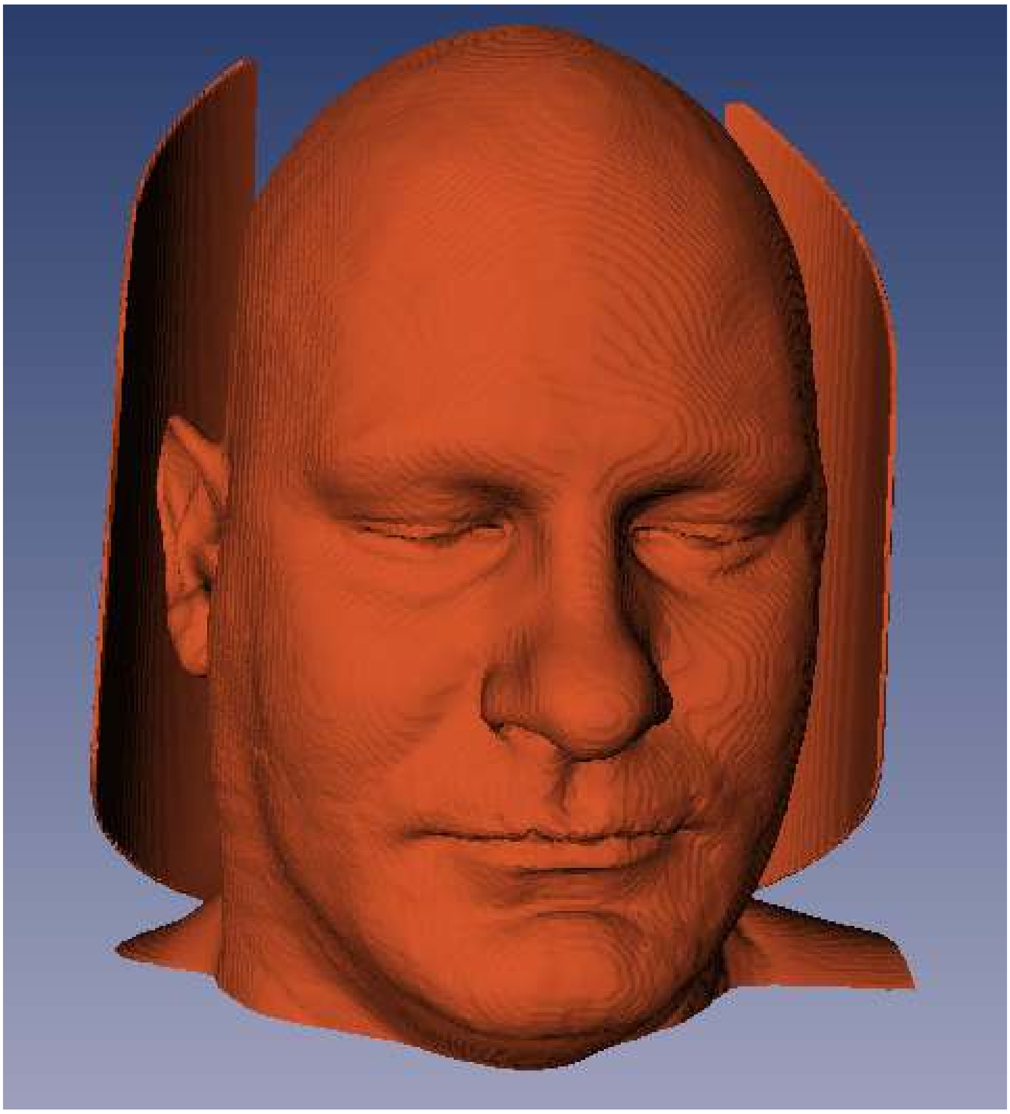

Figure 1.3 Photograph showing the image of a face captured by CBCT scanning.

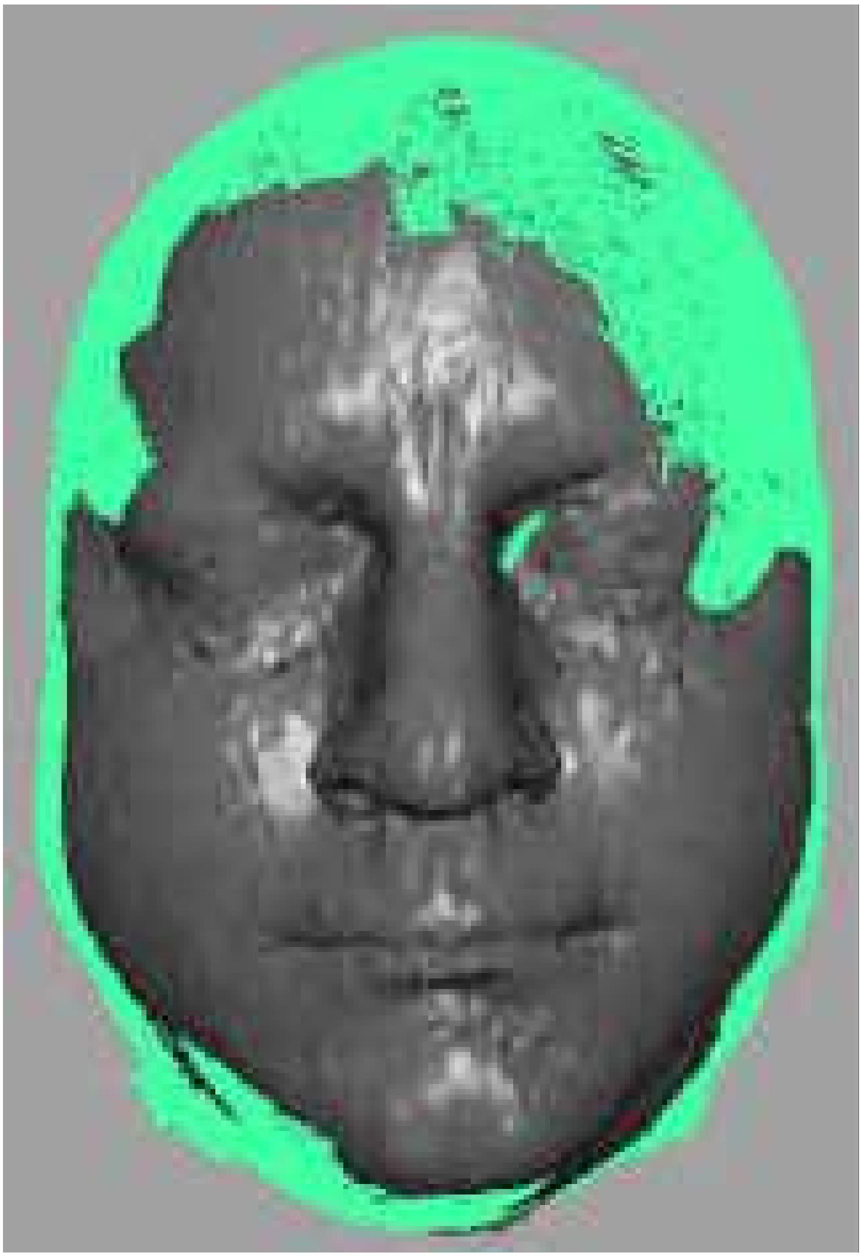

Figure 1.4 Photograph showing the image of a face captured by an MRI scan with a soft tissue overlay.

detector and converted into a computer generated 3D image. This technique is simple, easy to use and non-invasive to the patient. 3D laser scanning can provide an efficient, valid and reproducible method of recording a subject's face with the reproduction of 90% of facial morphology reported as accurate to within 0.7mm for females and 0.8mm for males (Arridge *et al*., 1985; Kau *et al.,* 2005b; Kau *et al.,* 2006). The 3D laser scanning system has been used clinically to assess soft tissue changes with orthognathic surgery in Class III surgical cases (McCance *et al.,* 1992), Class II surgical cases (Moss *et al.,* 1994) and adult cleft palate patients (McCance *et al.,* 1997).

There are, however, a number of disadvantages with the 3D laser system, including the time taken to capture the face, this is a slow process taking minutes rather than milliseconds, in which time any changes to the patient's head or facial muscles will distort the captured image (Kau *et al*., 2004). This may make laser scanning unsuitable for imaging children, but it has been reported that the laser scans obtained from children are in general as good as those of adults (Kau *et al.,* 2004). However it was also showed that the tolerance level for the adults was more uniform than the children to the laser scanning process and that the children scanned were prone to minor muscular responses in the eyelid region and near the lips and chin. In addition, as a laser beam is used, the patient's eyes must be closed due to safety issues related to exposing the eyes to a laser beam but with the eyes closed the identity of the captured 3D image would be affected. The early laser scanners were unable to capture soft tissue texture, with the new generation of scanners this is no longer the case, Figure 1.5.

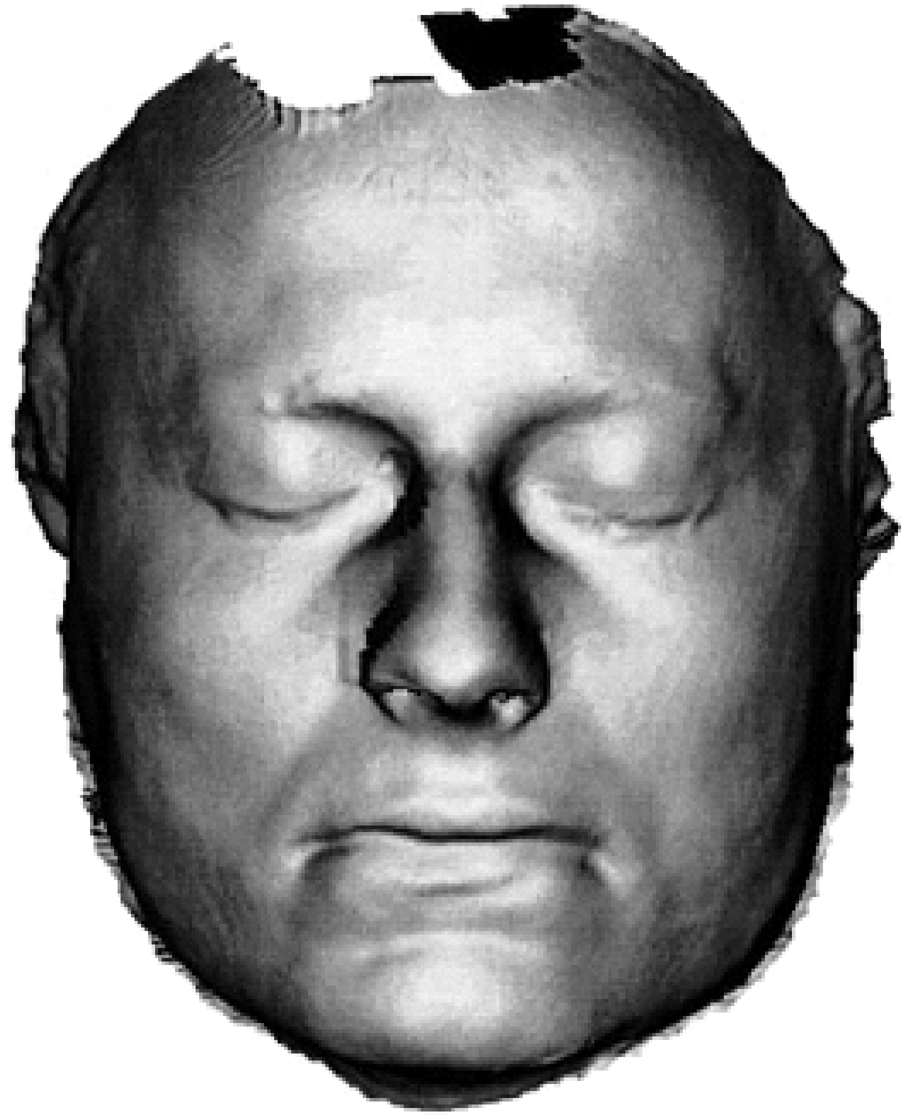

Figure 1.5 Photograph showing the image of a face captured by laser scanning.

1.11.6 3D Ultrasonography

This technique uses high frequency pulses of sound to generate cross-sectional images through the body and has been developed for craniofacial imaging (Hell, 1995). A high frequency sound wave, normally 3.5 – 7.0 MHz, is emitted from a special probe placed in contact with the area of interest. These waves do not pass through air which acts as an absolute barrier and thus a specific contact probe with a coupling media is needed to generate the 3D data from the face. The sound waves produced reflect off internal structures and the echoes are received and recorded by a transducer and converted into an image (Bearcroft, 2007). Ultrasonography captures soft tissues well but is not able to visualise bone abnormalities (Bearcroft, 2007). It is non-invasive, does not involve ionising radiation, is painless to the patient and has no known adverse side effects. This technique has been used by maxillofacial surgeons for visualisation of soft tissues and organs. However the accuracy of the resultant image depends largely on the operator in a way that is not mirrored with other imaging techniques. The fact that the probe contacts the skin in measurement can produce errors of distortion. This technique can be time-consuming and does not capture natural photographic facial appearance or skin texture. Movement of the head or touching the facial soft tissue introduces errors.

1.11.7 Morphoanalysis

Morphoanalysis is a method whereby 3D measurements are extrapolated from photographs, radiographs and study casts of the patient (Rabey, 1971). The study suggested that morphoanalysis was a useful, valid and accurate 3D measurement tool for assessing facial appearance. This method however requires expensive equipment and is complex and time-consuming. It is not practical for everyday clinical use and did not gain wide acceptance.

1.11.8 Moiré Topography and Contour Photography

A non-invasive method employing a light sectioning technique in which equal width grids of light are projected onto the side of the face producing a standardised contour pattern (Leivesley, 1983). The pattern consists of alternate light and dark bands which fall on the subject and can captured on camera, Figure 1.6. Measurements made on the resulting photographs are extrapolated to generate 3D images. Moire topography obtains 3D measurements from contour fringes and fringe intervals (Takasaki, 1970). The imaging technique involves positioning a grating close to a subject and observing its shadow on the subject through the grating. The resultant light and shadow bands are distorted by the curvature of the subject's face producing Moire fringes, Figure 1.6. This resultant contour-mapping pattern on the subject's face corresponds to a contour line system of the subject under certain conditions. Difficulties arise when a surface has sharp features, the best results with this method are produced only when used on smoothly contoured objects. Careful and exact head positioning is also required as a small change in head position produces a large change in fringe pattern thus introducing errors. This technique is time-consuming in analysis and does not capture natural photographic facial appearance or skin texture.

1.11.9 Structured Light Technique

The structured light technique is a non-invasive technique based on triangulation principles whereby a projector shines a pattern of structured light onto a surface to be scanned. When the light illuminates the surface, the light pattern distorts and bends.

The reflected light is captured by a system of cameras at a fixed distance away and this information is translated via computer software to generate a 3D image of the subject. Nguyen *et al.* (2000) reported good accuracy on a system where the 3D surface of the

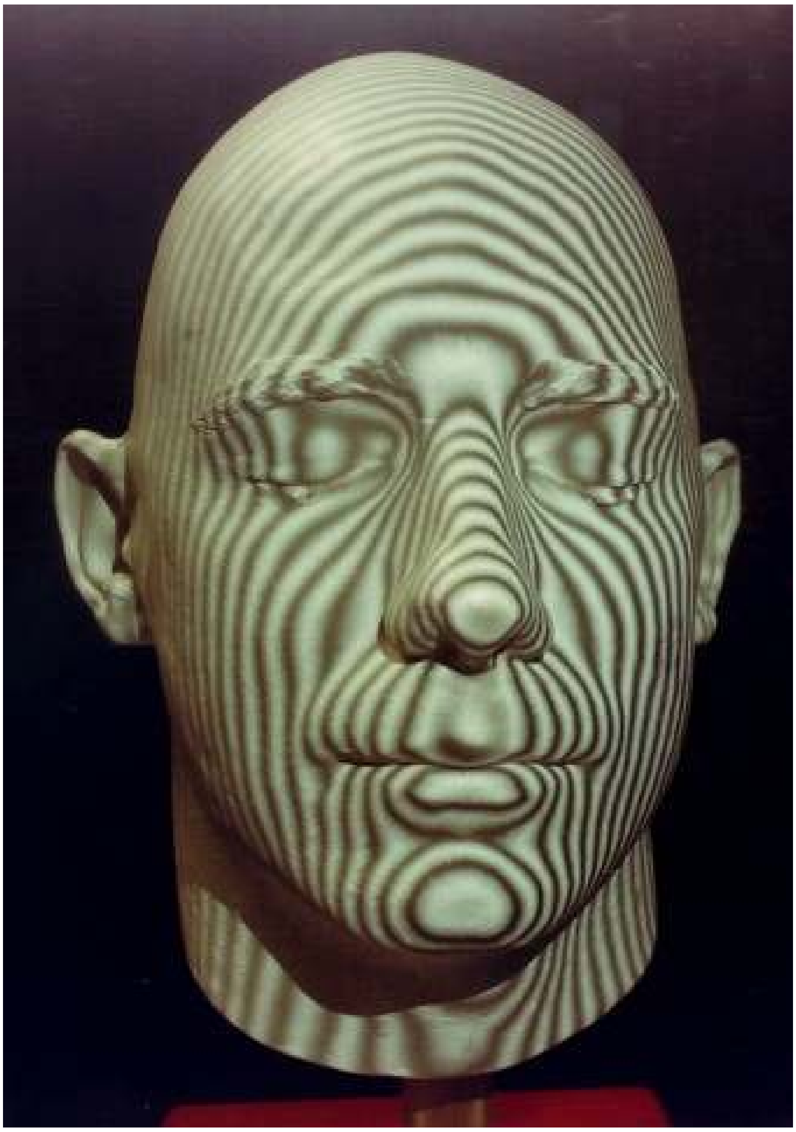

Figure 1.6 Photograph showing the image of a face captured by the technique of Moiré Topography .

face is captured with structured light and integrated with the 3D tracings of standard cephalometric films. The face needs to be illuminated several times with random patterns of light which is time-consuming and this method is also susceptible to patient movement which introduces errors. Thus it may not be a practical consideration with children. Techalertpaisarn and Kuroda (1998) used two LCD projectors, cameras and a computer to obtain a 3D image of the face that can be rotated in any direction but image capture is slow and again may not be a practical method when dealing with the child patient. The structured light technique does not produce photorealistic images nor does it capture natural skin texture, Figure 1.7.

1.11.10 3D Facial Morphometry

Reflective markers are placed on landmarks of the face and 2 charge-coupled-device cameras are used to capture the image of the human face. Real-time hardware for recognition of the markers is used together with software for 3D reconstruction of the landmarks according to a reference system. Landmark placement on the face is a time- and labour-consuming process which shows poor reproducibility due to movement of the facial features. Movement of facial features and changes in facial expression introduces error. No life-like models can be produced to show the natural soft tissue appearance of a face or photorealistic rendering; as such this method cannot be used as a 3D treatment planning tool (Ferrario *et al.,* 1996; Ferrario *et al.,* 1997).

1.11.11 Stereophotogrammetry

Facial stereophotogrammetry refers to the special case where two cameras, configured as a stereopair, are used to recover 3D distances of features on the surface of the face by means of triangulation (Hajeer *et al.,* 2002). Stereophotogrammetry is a non-invasive

Figure 1.7 Photograph showing the image of a face captured by the Structured Light technique.

technique and the images obtained are then used to build a 3D image of the face using the appropriate calibration data. Calibration in stereophotogrammetry is an automatic process that is performed by imaging a target object of accurately known dimensions in the field of view. The information obtained is then used to determine the intrinsic camera imaging parameters and the relative orientation of each camera to the other cameras during subsequent image capture, and this allows for computerised calculation of 3D coordinates. This technology allows conversion of simple two-dimensional photographs taken from the two cameras into a three-dimensional computer image that can be rotated in any direction and allow three-dimensional measurements of facial morphology. The ideal is to achieve high quality lifelike visualisation of the imaged face from any desired viewpoint; this is known as photorealistic rendering. The craniofacial image is portrayed as a collection of pixels in 3D space resulting from the reconstructed craniofacial surface. The surface data comprises of a collection of points interconnected to one another by their position along an x, y and z coordinate system. The distances among these points can be readily computed to allow three-dimensional measurements of facial morphology. Landmarks have reference coordinates that can be saved for subsequent measurement session.

Early stereophotogrammetric systems used complicated, elaborate and expensive equipment and complex analyses. In spite of these shortcomings, stereophotogrammetry was used increasingly throughout medicine and dentistry to assess facial morphology and changes to the facial soft tissue form (Burke and Beard, 1967; Ras *et al.,* 1996).

The first clinical use of stereophotogrammetry to measure the face was reported in 1944 by Thalman-Degen who measured facial changes induced by growth and orthodontic treatment. Stereophotogrammetry has been previously used to measure facial swelling (Bjorn *et al.,* 1954) and in anthropometry and growth studies (Hertzberg and Daniels, 1952). Burke and Beard 1967 simplified the technique and developed a portable version of cameras to record a stereo pair of photographs from which contour maps of the face could be plotted to provide 3D analysis of the facial surface. The contour mapping process was complex and analysis of the contours was elaborate and complicated. This technique did not gain wide acceptance but was used to assess extent of facial asymmetry and facial soft tissue changes after orthognathic surgery (Burke, 1971; Burke, 1983; Burke, 1992). Berkowitz and Cuzzi (1977) advanced the technique using 3 stereometric cameras to give full coverage of the face and head in their analysis of changes of facial form due to growth and surgery. The technique has been used to capture patients with minor forms of clefts (Dixon and Newton, 1972; Ras *et al*., 1996).

Advances in computer technology has led to this technique becoming easier to implement and more popular. Kobayashi *et al.* (1990) placed subjects' heads in a metal reference frame with known three dimensional values before and after orthognathic surgery. The system employed two cameras each at an angle of 25° to simultaneously capture a photograph; from these photographs two dimensional coordinates were measured. These measurements were combined with the known three dimensional coordinates from the reference frame and together used to generate a mathematical 3D coordinate system of the face via a computer. These co-ordinates were connected to produce a wire frame model of the subject's face which could be viewed from any aspect on a computer screen. However there was no capture of the natural skin surface or photorealistic rendering of the image.

Instead of simultaneously capturing both sides of the face it is possible to capture one side of the face and then the other and merge the two images together. Ferrario *et al.* (1996) used two infrared cameras mounted on the same vertical axis but at different angles to the subject to analyse soft tissue facial morphology. This system allowed two photographs to be captured simultaneously but of only one side of the subject's face. A second pair of photographs was taken of the other side of the face once the subject was rotated on a stool. Each subject had reflective markers placed on their face before image capture and the coordinates of these landmarks in each photograph were combined and used to mathematically reconstruct 3D image coordinates of the face via computer software. However this technique will potentially have greater errors involved due to the independent images and did not capture natural skin texture or photorealistic rendering.

Geng (1996) introduced the Rainbow 3D stereophotogrammetry imaging system. This system uses a structured light design to project colour patterns onto the surface of an object and pixel values are assigned by calculating the exact distance between the points on the object's surface and the focal plane of the camera. The projecting light is a spatially continuously varying wavelength light and its colour is encoded with information of the corresponding light projection angle. All visible surface points are captured in a single life-like image lasting less than a second using one digital high resolution colour camera. This system allows 3D images to be obtained directly at the camera frame rate. The system uses only one camera, and eliminates the feature finding problem of normal binocular multiple camera 3D imaging systems.

In an effort to improve 3D image capture and achieve photorealistic rendering of images so as to obtain real-life visualisation of the subjects, a new stereophotogrammetric camera system C3D was developed (Ayoub *et al.,* 1996, Ayoub *et al.,* 1998). The C3D system used two pairs of calibrated low resolution stereo video cameras and a projected texture pattern linked to a computer to generate photorealistic 3D images of the face. Stereo-pair images were captured from each side of the face simultaneously. The subject was illuminated either with a texture pattern to facilitate stereo matching or with plain light to facilitate capture of the natural appearance of the face. C3D software then matched the images captured to recover triangulated distances to each surface point imaged by the pair of cameras. The textured illumination provided sufficient information in the images to match the two sides of the face and accurately construct the 3D facial model. The system also captured the natural surface appearance of skin and this data is translated into the skin texture being draped over the reconstructed 3D model. It took 50 milliseconds to capture the full face and less than 5 minutes for the computer to produce a photorealistic 3D facial model. This model could then be measured in all three dimensions and rotated or enlarged, providing invaluable information to aid the clinician in diagnosis, treatment planning, patient information and communication, surgical outcome analysis and in obtaining informed consent (Ayoub *et al*., 1996; Ayoub *et al*., 1998; Hajeer *et al*., 2002; Ayoub *et al*., 2003; Hajeer *et al*., 2004). The C3D system was shown to have good validity and accuracy, with the overall error for landmark localisation found to be within 0.4mm which was satisfactory in the assessment of facial soft tissue changes. Operator error when locating the landmarks by hand was found to be within 0.2mm of the true coordinates of the landmarks (Ayoub *et al.,* 2003).

The release of a high resolution commercial digital camera based system (Di3D, Dimensional Imaging, Glasgow, UK) allowed accurate capture of the natural surface appearance of skin and image was of high enough resolution to provide sufficient information about the skin texture to allow for immediate and reliable area-based stereo matching of facial coordinates from both pairs of photographs (4 images) without the need for a projected skin texture pattern over the subject's face to facilitate stereo matching. As with the previous C3D system, the high resolution Di3D system produced high quality full face lifelike photorealistic rendering of the 3D facial model. The system was reported to be valid, reproducible and accurate with the overall system error found to be within 0.21mm and the reproducibility error of the Di3D image capture to be within 0.13mm. Operator error of landmark localisation on the 3D image was found to be within 0.07mm (Khambay *et al.,* 2008).

Winder *et al.* (2008) also looked at the geometric accuracy of the Di3D imaging system. They compared direct anthropometric measurements of physical linear distances from a mannequin's head with digital measurements of the same distances using images captured by the Di3D system. The landmarks on the mannequin's head were pre-labelled with black dots less than 0.5mm in size. The mean error in the three-dimensional surfaces for the Di3D stereophotogrammetry system was found to be 0.057mm. The variance or repeatability error was found to be 0.0016mm and the mean error in linear measurements compared with the direct manual measurements was found to be 0.6mm. These results show that the Di3D system is capable of measuring the same object to a high degree of repeatability. The authors also determined that the field of view of the system was 170° horizontally and 102° vertically, making it sufficient for imaging the head, neck and face, supporting the claims made by the Di3D system that ear-to-ear coverage can be provided with Di3D images, Figure 1.8 to 1.10.

Another 3D stereophotogrammetry camera system reported in the literature is the 3dMDface system. The 3dMDface system works by projecting random light patterns on the subject and the subject is then captured with multiple precisely synchronised digital cameras set at various angles in an optimum configuration. Image capture occurs in less then two milliseconds and is non-invasive. Three dimensional surface geometry and texture are acquired almost simultaneously and 3dMD computer software then integrates the various images obtained to produce a single life-like 3D image which can be analysed and archived using the 3dMD software. Littlefield *et al.* (2004) tested the 3dMD system against a high precision coordinate measuring machine (CMM) in the measurement of an infant's face and cranium. Accuracy was determined to be within +/- 0.236mm and the 3dMD system was demonstrated to be highly accurate, safe and non-invasive and impervious to motion, with a capture time of 0.008 seconds.

Requirements for an optimum 3D image capture system – as exemplified by the advantages of Di3D (Ayoub *et al.,* 1998; Ayoub *et al.,* 2003; Khambay *et al.,* 2008).

- Simple and easy to use, portable equipment available, practical for clinical use.
- Professional high resolution colour digital cameras used that can capture images of high quality accurate enough to resolve local details of linear densities within 0.1mm/pixel on human faces – providing sufficient information about natural skin texture to achieve reliable area-based stereo matching, thus obviating the need for

Figure 1.8 Photograph showing the image of a face captured by the technique 3D stereophotogrammetry using the Di3D system.

Figure 1.9 Photograph showing the image of a face (tilted at an angle) captured by the Di3D system – to show depth.

Figure 1.10 Photograph showing the image of a face captured by the Di3D system with the wire mesh overlaid to show depth and the quality of the three-dimensional model building.

the projected skin texture for stereo matching of images and all its inherent problems.

- Projection of texture no longer necessary to obtain a valid and accurate lifelike 3D facial model.
- True three dimensional image visualisation from any aspect.
- Immediate generation of a 3D facial image (within 5 minutes).
- Non-invasive.
- Rapid capture of facial image, suitable for imaging children and infants (1ms).
- Integrated capture of the natural facial soft tissue surface texture.
- Accuracy of measurements found to be within 0.2mm.
- Cost effective, good data storage and retrieval.

Summary

Three-dimensional imaging can provide the means by which facial morphology can be accurately assessed and avoid the measurement errors that occur with 2D representations of 3D surfaces. The ability to document accurately a complex three-dimensional surface provides an unprecedented means for evaluation of craniofacial morphology.

The advantages of 3D stereophotogrammetry are near-instantaneous and non-invasive image capture which reduces the risk of motion artefact and reduces the need for subject compliance over a prolonged period of time, collection of 3D co-ordinates, high resolution lifelike texture images and provision of archived image data for repeated measurements without inconveniencing the patient. It eliminates the need for direct contact with the subject's soft tissues thus avoiding deformation of the soft tissue which is a source of error in direct anthropometry. Landmarks can be easily localised on the

3D images which can be magnified and rotated to facilitate their viewing and identification. Since the data points are in the form of 3D coordinates, the application of new and powerful statistical shape analyses is possible.

As with any imaging system there are some limitations. The equipment is expensive. There are inherent difficulties in accurately imaging transparent, shiny or shadowed surfaces. Interactive landmark localisation from 3D images relies primarily on visual cues and certain landmarks that are covered by hair or defined in reference to the underlying bone and therefore need to be palpated may present problems in accurate localisation. Only surface soft tissue is captured by 3D stereophotogrammetry and not any bony landmarks.

The four ideal properties of a 3D measurement system for the craniofacial complex include (Motoyoshi *et al*., 1992):

1. Little cooperation should be required from the patient and there should be low patient burden at the time of measurement.
2. There should be a simple input operation and high precision measurements should be obtained.
3. Calculation of co-ordinates for a substantial number of points by a non-invasive, non-ionising technique that allows for repeated registration and the inclusion of control groups.
4. High speed 3D display based on the 3D co-ordinates obtained, high quality visualisation of the imaged face from any desired viewpoint.

The variety of applications with 3D imaging systems has resulted in a better understanding of the craniofacial form. Recently, 3D craniofacial images have been used to establish a database for normal children as control data for cleft surgery (Yamada *et al*., 2002), cross-sectional growth changes (Kau *et al*., 2005a) and also as a possible tool in the assessment of clinical outcomes in orthognathic surgery (McCance *et al*., 1992; Ayoub *et al*., 1996; Ayoub *et al*., 1998; Khambay *et al*., 2008) and non-surgical treatments (Ismail *et al*., 2002; Moss *et al*., 2003). The advances in 3D imaging systems mean that soft tissues of the face can be evaluated in a faster, more accurate and non-invasive three-dimensional manner than with conventional direct anthropometric techniques.

In investigating what constitutes normal facial attractiveness in the way human beings view one another in nature, carrying out a comprehensive three-dimensional assessment is the only strategy to providing the most accurate information required. The Di3D imaging system is to date the most suitable, practical and accurate 3D measurement technique that captures the patient's lifelike image to a high degree of accuracy with photo-realistic soft tissue definition. These 3D images can then be collated for perusal by the lay panel of judges as to what constitutes normal facial attractiveness from an entirely natural point of view.

Chapter Two

Aims & Null Hypotheses

2 Aims & Null Hypotheses

Statement of the aims

In recent years, as society has become more accepting of surgical procedures to improve facial imperfections and abnormalities, orthognathic surgery has gained widespread acceptance and an ever increasing demand. However, in most, if not all cases, the patient is solely interested in the esthetic outcome of the treatment (Kiyak *et al*., 1981; Jacobson, 1984; Bell *et al*., 1985). The soft tissue change as a result of orthognathic surgery is of utmost importance to the patient, and dental professionals must bear that in mind when planning treatment. However, an orthognathic surgical outcome that is successful in the eyes of the professional does not always improve facial aesthetics (Arnett and Bergman, 1993a; Arnett and Bergman, 1993b; Al Yami *et al*., 1998), or facial balance (Bergman, 1999), and therefore might be considered to be less satisfying in the eyes of the patient (Kiekens *et al.,* 2005). It is essential to make sure that when selecting a normal group of subjects for comparison, they are chosen by lay people since it is their opinion as end-users of orthodontic / orthognathic surgery services that has the most value in determining the appropriateness of aesthetic results. It is also essential that the control group are from the same population as the treatment group.

In investigating what constitutes normal facial attractiveness in the way human beings view one another in nature, carrying out a comprehensive three-dimensional assessment is the only strategy to providing the most accurate information required. The Di3D imaging system is practical and accurate as a 3D measurement technique that captures the patient's lifelike image to a high degree of accuracy with photo-realistic soft tissue definition. These 3D images can then be viewed at a later date and used for analysis.

The aims of the study are as follows;

1) To determine the 3D soft tissue facial measurements of an "attractive" group of West of Scotland males and females between the age of 18 and 35 as selected by a panel of lay people. The null hypothesis being that there is no difference between the 3D soft tissue measurements between males and females.

2) To determine whether post-operative orthognathic patients look attractive based on objective measurements of 3D soft-tissue facial landmarks. The null hypothesis being that there is no difference between the 3D soft tissue measurements obtained from a group of attractive subjects and those of the post surgical treatment group.

Chapter Three

Materials & Methods

3 Materials & Methods Part I

3.1 Study design

The over all aim of the study was to compare, using angular and linear measurements, the 3D facial images obtained by stereophotogrammetry of a group of post surgical orthognathic patients to a group of attractive individuals. The aim of part I of the study was to determine which individuals were thought of as attractive by a lay panel and to determine if males are different to females.

Ethical approval was obtained from the Local Area Dental Ethics Committee of North Glasgow University Hospitals NHS Trust, Appendix I.

3.2 Subjects

Subjects for the attractive group were recruited from within the local population of West of Scotland on a voluntary basis. These subjects were recruited over a ten month period from April 2008 to January 2009. In total 61 females and 51 males agreed to take part in the study. Consent was obtained from each volunteer for participation in the study.

3.2.1 Inclusion criteria

- Caucasian origin from the West of Scotland.
- Both parents from the West of Scotland.
- Patients between 18-35 years of age
- Consented to participate in study.

3.2.2 Exclusion criteria

- Craniofacial defect or syndrome.
- Facial hair present.
- Not of Caucasian origin.
- Not from the West of Scotland

3.3 Materials

3.3.1 The 3D Imaging System

The subjects were imaged using the Di3D system (Di3D, Dimensional Imaging, Hillington Park, Glasgow, UK), which consisted of two camera stations placed at each side of the face to take a stereo image. Each station contained only a pair of colour high-resolution digital cameras (Eastman Kodak Company, Rochester, New York) (Figure 3.1). The subject was simultaneously illuminated by commercial white-light studio flash units (Esprit Digital DX1000, Bowens, Essix, UK). It took 1 millisecond to capture the full face using the two camera stations. The resolution of the cameras was 4500 by 3000 pixels, with a focal length of 50 mm. A personal computer required less than 5 minutes to produce a 3D model of the captured subject.

3.3.2 Calibration

Prior to image capture the Di3D system requires calibration. The purpose of the calibration is to determine the intrinsic camera parameters and the special orientation of each camera to the other. The process it self is fully automated but requires a target of accurately known dimensions to be imaged. The target consisted of black circles of known size and separation on a white background. In order to capture the entire

Figure 3.1 Photograph showing a subject being imaged using the Di3D stereophotogrammetry system

three dimensional space several images of the target were captured, the target was captured at different positions within the imaging space. The calibration software extracts the co-ordinates of the circles on the image and from this information the software can determine the relative positions of all four cameras with out any further operator intervention. The system was calibrated prior to each capture session, Figure 3.2.

3.3.3 Image capture

For all captures, subjects were seated on a dental chair directly in front of the camera system. The dental chair was positioned to ensure that the subject was in the correct position relative to all four cameras. To standardise the images each subject was captured in natural head position, Figure 3.3. For image capture subjects were asked to:

- remove spectacles,
- remove jewellery,
- keep all hair completely off the face and neck,
- remove all make-up,
- keep their eyes open,
- achieve natural head position, by gently oscillating their head up and down whilst looking into their own eyes in a mirror positioned in the midline of the beam supporting the cameras,
- remain still during image capture,
- say “Mississippi”, then told to swallow once and say “N” (guidelines to obtaining rest position natural facial expression as proposed by Zachrisson, 1998).

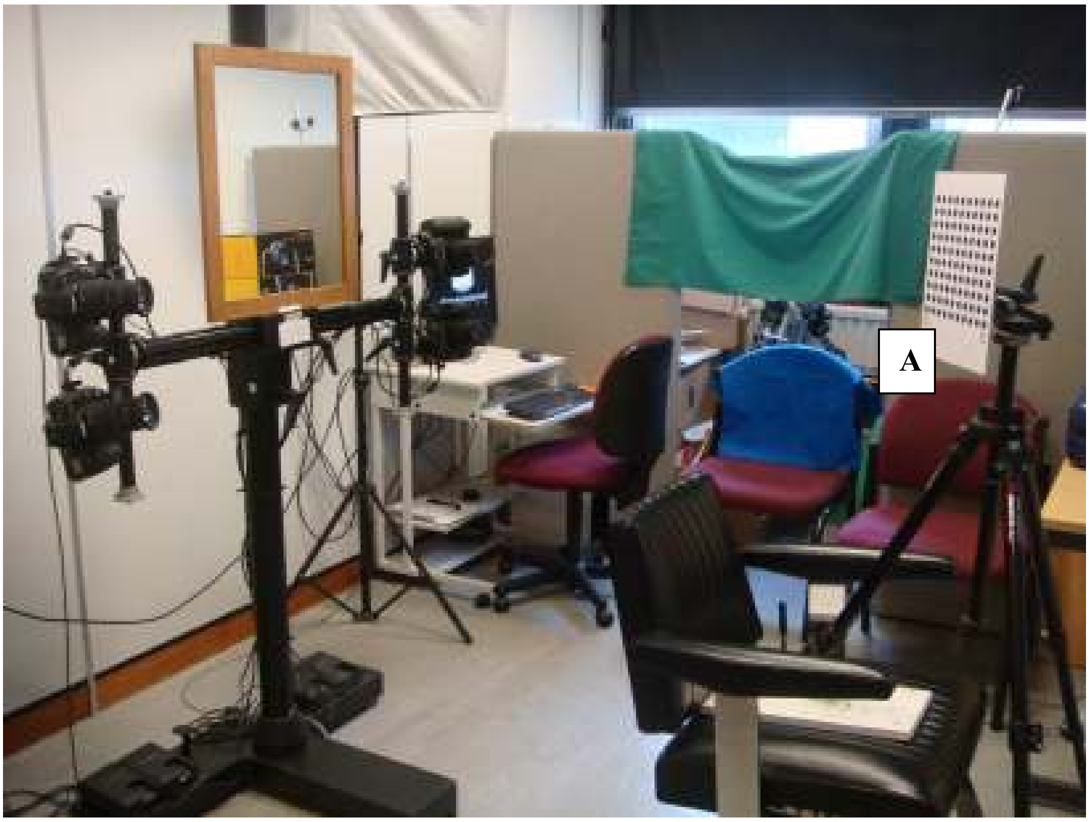

Figure 3.2 Photograph showing the calibration process for the Di3D system.
A - Calibration target.

Figure 3.3 Photograph showing the positioning of the mirror with respect to the subject's position

Once the subject had found natural head position and the lips were in rest position the facial image was captured using DiCapture software (Di3D, Dimensional Imaging, Hillington Park, Glasgow, UK).

3.3.4 Model building

A three dimensional model of the subjects face was built using Di3D software (Di3D, Dimensional Imaging, Hillington Park, Glasgow, UK). This fully automated process involves three main stages. The first stage involved finding the points of correspondence between stereo pairs of images, this is termed matching. This matching process generates a disparity map for each image point with in each pair of images. The second stage uses the principle of photogrammetry based on triangulation to convert the disparity maps into distances, range maps. The third stage relies on the calibration data to compute through back projection, the intersection of the matched image points to their dimensional intersections in reality.

In real terms this process took about five minutes to build a three-dimensional image of each subject. The software is capable of producing and displaying a variety of model types. These include wire frames, a silver model or a full face with photo realistic rendering. These models were viewed on a monitor and could be easily rotated to view them from different view points. For this study only the photo-realistic models were used, Figure 3.4.

3.4 Panel members

In this study a panel of 4 males and 4 females lay people were randomly selected between the ages of 18-35 years. All were of Caucasian origin from the West of

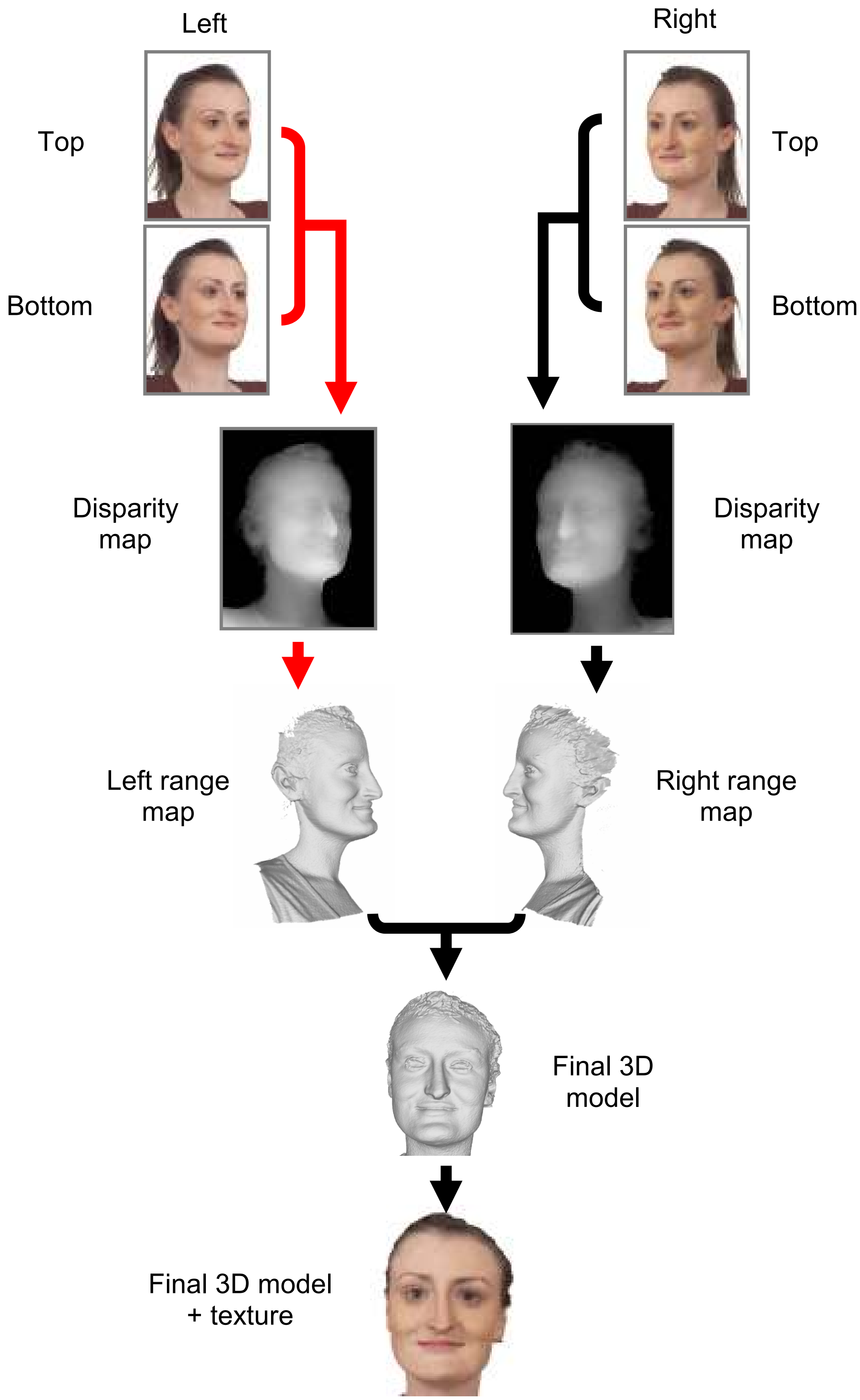

Figure 3.4 Systematic diagram showing the process of 3D model construction.

Scotland. None of the lay panel had a dental background.

3.5 Rating of Images

Each individual was imaged according to the protocol above. Each image was viewed in the frontal view and then rotated slowly to the left and then to the right using GLview software (http://home.snafu.de/hg/). During the viewing the screen was captured as a video clip using screen recording software, Auto Screen Recorder (Wisdom Software Inc, Victoria, Canada). Each image was recorded for 30 seconds and the video clip was saved as an Audio Video Interleaved file (*.avi) for viewing later. This procedure was repeated for all 112 individuals.

Each video file was embedded into a Powerpoint presentation (Microsoft® Powerpoint 2000, Microsoft Corporation, USA). Images were embedded alternately male and female were possible. The presentation was saved onto a DVD (Imation, Schiphol, The Netherlands). Prior to viewing the lay panel were given basic instructions on how to rate the images. They were instructed to ignore skin complexion, hair, position of ears and to concentrate on facial attractiveness with respect to facial balance and harmony. Each lay panel member viewed the Powerpoint presentation in a single sitting.

The lay panel member rated each image for facial attractiveness on a 100mm horizontal VAS scale marked with the anchors “least attractive” and “most attractive”, Appendix II.

3.6 Ranking of the images

The VAS scores were ranked from most attractive to least attractive for each subject as recorded by each of the 8 lay panel members. The data was divided into three segments – most attractive, attractive and least attractive. Individuals who were thought of as being most attractive and attractive by at least 6 lay panel members were chosen to be part of the attractive control group. In this way, 16 attractive males and 24 attractive females were selected based on the lay panel members.

3 Materials & Methods Part II

3.7 Study design

The study was designed to compare the 3D facial images obtained by stereophotogrammetry of a group of post surgical orthognathic patients to a group of attractive patients. The study was based on angular and linear measurements as an objective form of assessment. The attractive patients were selected by a lay panel as previously indicated.

Ethical approval was obtained from the Local Area Dental Ethics Committee of North Glasgow University Hospitals NHS Trust.

3.8 Subjects

Subjects were recruited from the Dentofacial Deformity clinics at the Glasgow Dental Hospital and from the Maxillofacial department of the Southern General Hospital Glasgow. Subjects were recruited over a two and a half-year period from October 2005 to June 2008. All subjects underwent surgery under the care of one Consultant Oral Surgeon at the Southern General Hospital.

3.8.1 Inclusion criteria

- Dentofacial deformities treated by orthognathic surgery.
- Caucasian origin.
- Patients between 18-35 years of age.

3.8.2 Exclusion criteria

- Craniofacial defect or syndrome.
- Facial hair present.

3.8.3 Sample size calculation

Estimation of sample size is dependant on a number of factors:

- The level of desired power.
- The type of the intended statistical test.
- The smallest clinical significant difference that needs to be detected.
- The variability of the observed data.

The clinical significance was derived from the results of a previous study and was set at 3 mm (Jones *et al.,* 2007). A search of the literature indicated that the majority of soft tissue facial landmarks of potential interest had a standard deviation of ± 3.0 mm (Sforza *et al.,* 2007; Sforza *et al.,* 2009). Applying a significance level of 0.05 and a power of 80% a sample size of 16 subjects would be required (Gardner *et al.,* 1986). This means that within each group a minimum of 16 patients are required.

3. 9 Materials

As previously described the post surgical Orthognathic group patients were imaged using the standardised capture protocol (section 3.3.3). Following model building the images were viewed using software which allowed landmarks to be placed and measurements between them calculated (DiView4, Dimensional Imaging, Hillington Park, Glasgow, UK). The software allowed simultaneous viewing of the single image in three different “windows”, allowing rotation and magnification of the image (Figure 3.5).

The landmarks and measurements recorded are shown in Figure 3.6 and Table 3.1 to 3.3 respectively. This procedure was carried out for the attractive male and female images and the male and female post orthognathic surgery images.

3.9.1 Error study

The validity and reproducibility of the method was assessed by an error study. Six images were randomly selected from each of the 4 groups. Each of the 24 images was landmarked two weeks apart and the data used in the error study.

Table 3.1 Landmark definitions (* **Indicates bilateral left & right landmarks.)**

Landmark	Definition
Nasion (N)	The point in the midline of both the nasal root and the nasofrontal suture, always above the line that connects the two inner canthi, identical to bony nasion.
Exocanthion (Exc)*	The point at the outer commissure of the eye fissure, located slightly medial to bony exocanthion.
Endocanthion (Enc)*	The point at the inner commissure of the eye fissure, located lateral to the bony landmark.
Subtragion (Sbtr)*	The most anterior inferior point on the anterior inferior margin of the helix attachment to the face, just above the earlobe.
Alar curvature (Ac)*	The most lateral point on the curved base line of each ala, indicating the facial insertion of the nasal wingbase.
Pronasale (Prn)	The most protruded point of the apex nose identified in lateral view of the rest position of the head.
Subnasale (Sn)	The midpoint of the angle at the columella base where the lower border of the nasal septum and surface of the upper lip meet.
Soft tissue A point	The deepest midline point on the upper lip, which is located usually halfway between Sn and Ls.
Cheilion (Ch)*	The point located at each labial commissure.
Crista philtre (Cphi)*	The peak of Cupid's bow of the upper lip inferior.
Crista philtre (Cphs)	The top of the phitral crest at the level of a line drawn superior transversely through Subnasale.
Labrale superius (Ls)	A point indicating the muco-cutaneous junction of the upper lip and philtrum.
Inferior Labrale Superius (ILs)	A landmark on the upper lip located midway between Labrale Superius and Stomion Superius.
Superior Labrale Inferius (SLi),	A landmark on the lower lip located midway between Stomion Inferius and Labrale Inferius.
Soft tissue B point	The deepest midline point on the labiomental fold, which determines the lower border of the lower lip or the upper border of the chin.
Labrale inferius (Li)	A point indicating the muco-cutaneous border of the lower lip.
Pogonion (Pog)	The most anterior midpoint of the chin, located on the skin surface in front of the identical bony landmark of the mandible.

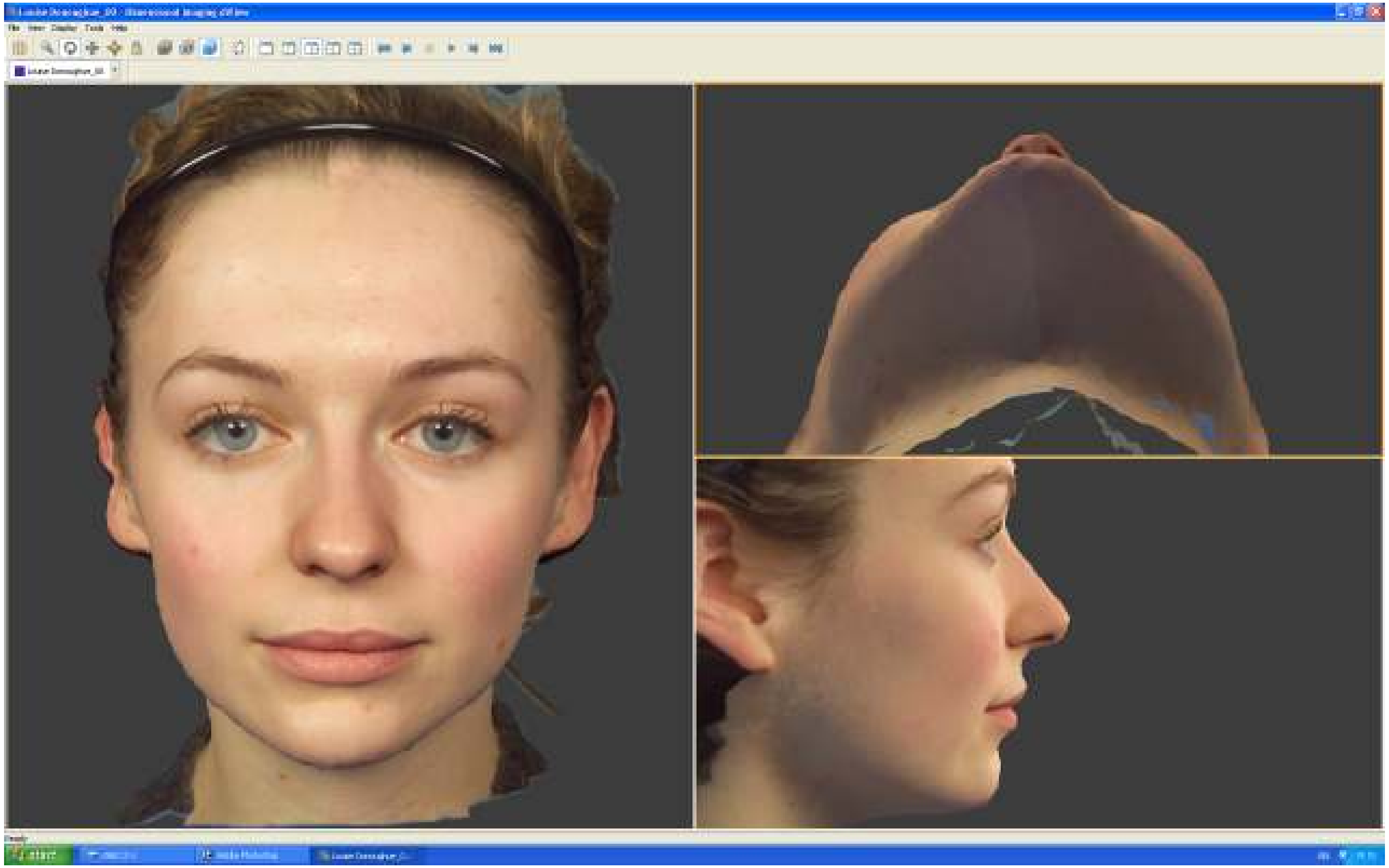

Figure 3.5 Photograph showing the screen capture when an image is viewed simultaneously in three "windows", showing magnification and rotation.

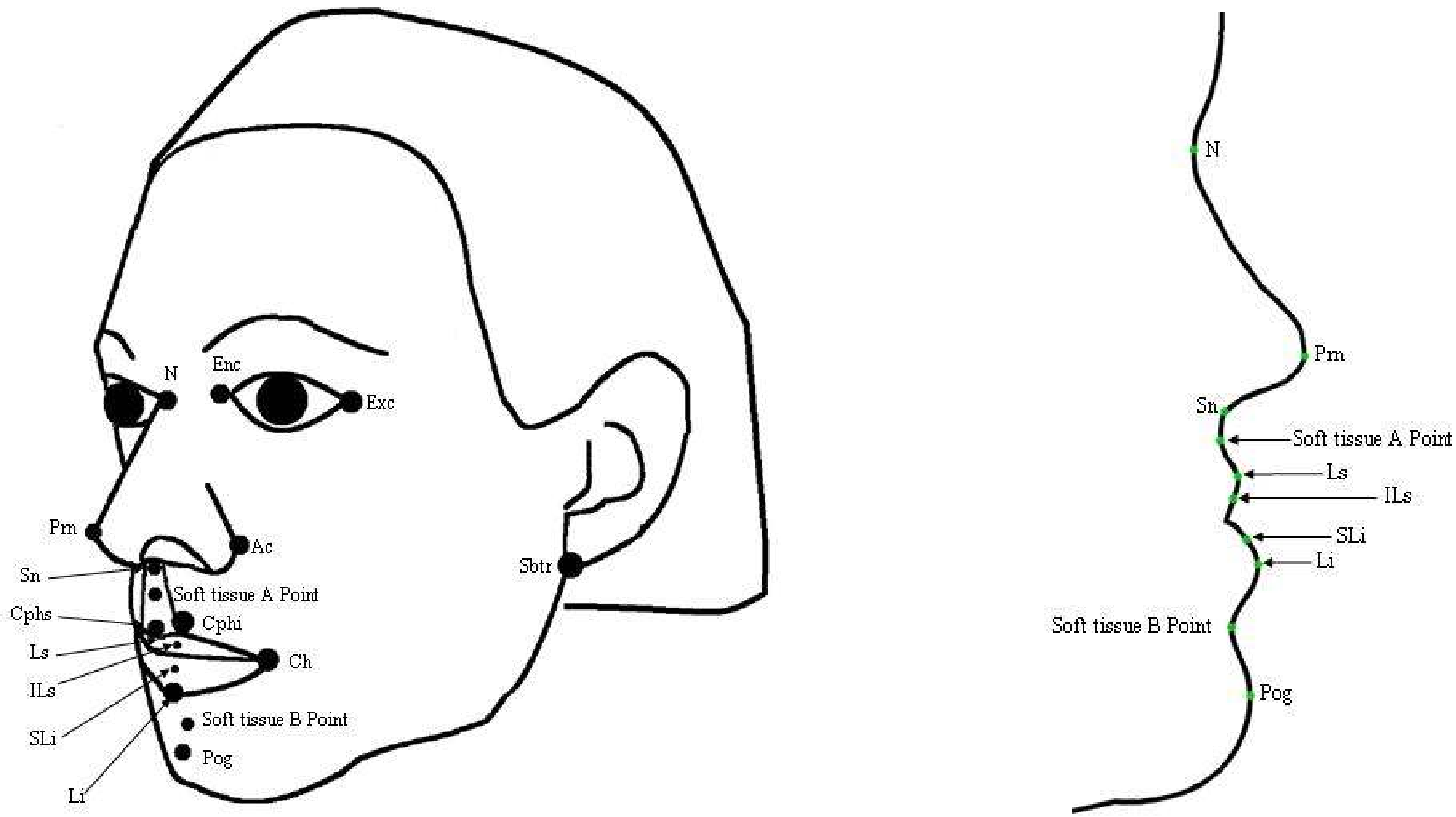

Figure 3.6 Diagram showing Landmark locations

Table 3.2 Landmarks used to define clinical linear measurements.

Landmarks	Measurements
N-Sn	Upper anterior face height
Ex(R) -Ex(L)	Upper face width
Sbtr(R)-Sbtr(L)	Middle face width
Ac(R)-Ac(L)	Nose width
Sn-Prn	Columella length
Ch(R)-Ch(L)	Mouth width
Sn-ILs	Upper lip length
SLi-Soft tissue B	Lower lip length
En(R)-En(L)	Nasal bridge width
Cphil(R)-Cphil(L)	Philtrum width
Sn-Cphs	Philitrum length
Sn-Pog	Lower anterior face height

Table 3.3 Landmarks used to define clinical angular measurements.

Landmarks	Measurements
Ex(R)-N-Ex(L)	Upper facial convexity
Prn-Sn-LS	Nasolabial angle
Sbtr(R)-Sn-Sbtr(L)	Mid facial convexity
Ac(R)-Prn-Ac(L)	Nasal tip convexity
N-Sn-Pog	Facial convexity exc. nose
N-Prn-Pog	Facial convexity inc. nose
LS-Sn-Pog	Upper lip prominence
Li-Sn-Pog	Lower lip prominence

Chapter Four

Results

4 Results Part I

4.1 Sample characteristics

During the period of data collection a total 61 females and 51 males agreed to take part in the study and were viewed by the lay panel. After dividing the data into three segments – most attractive, attractive and least attractive and choosing individuals who were thought of as being most attractive and attractive by at least 6 lay panel members, 16 “attractive” males and 24 “attractive” females were selected.

Gender	Number (n)	Mean age (Yrs)	Range (Yrs)
Male	16	25.4	19 - 32
Female	24	21.3	18 - 30

4.2 Error of the method

The results of the error of the method are presented in Tables 4.1 – 4.3. Systematic error was assessed by paired t-tests and random error assessed by coefficients of reliability (Houston, 1983).

No systematic errors were observed. All coefficients of reliability were above 90%.

Table 4.1 Reproducibility of landmark identification, X coordinates.

Landmark	Mean[1]	SD	p-value[2]	CR[3]
N	-0.51	0.36	0.622	0.95
Exc (R)	0.30	0.21	0.632	0.99
Enc (R)	0.01	0.01	0.462	0.99
Enc (L)	0.28	0.19	0.292	0.99
Exc (L)	0.08	0.05	0.744	1.00
Sbtr (R)	0.05	0.04	0.300	0.99
Ac (R)	0.22	0.16	0.230	1.00
Prn	0.71	0.29	0.750	1.00
Ac (L)	0.13	0.09	0.255	0.99
Sbtr(L)	-0.40	0.28	0.376	0.99
Sn	-0.22	0.16	0.933	1.00
Soft tissue A point	-0.02	0.02	0.872	0.99
Ch (R)	0.14	0.10	0.194	1.00
Cphi (R)	0.23	0.16	0.191	1.00
Cphs	-0.18	0.12	0.943	1.00
Cphi (L)	0.40	0.28	0.446	1.00
LS	0.00	0.00	0.306	0.99
ILs	0.21	0.15	0.231	0.99
Ch (L)	-0.13	0.09	0.188	0.99
Li	0.29	0.21	0.198	1.00
SLi	-0.19	0.13	0.277	0.99
Soft tissue B point	0.00	0.00	0.728	1.00
Pog	-0.43	0.30	0.501	1.00

1. Mean difference between repeat landmark identification (mm)
2. Testing for significant differences from zero using paired t-tests
3. CR = Pearson's coefficient of reliability

Table 4.2 Reproducibility of landmark identification, Y coordinates.

Landmark	Mean[1]	SD	p-value[2]	CR[3]
N	-0.70	0.49	0.493	0.99
Exc (R)	0.15	0.11	0.173	0.99
Enc (R)	0.36	0.25	0.708	1.00
Enc (L)	0.08	0.06	0.608	0.99
Exc (L)	-0.39	0.28	0.725	1.00
Sbtr (R)	-0.23	0.16	0.151	0.99
Ac (R)	0.20	0.14	0.436	1.00
Prn	-0.38	0.27	0.160	1.00
Ac (L)	0.24	0.17	0.538	0.99
Sbtr(L)	-0.96	0.68	0.206	0.99
Sn	-0.09	0.06	0.773	1.00
Soft tissue A point	-0.03	0.02	0.374	0.99
Ch (R)	0.31	0.22	0.374	1.00
Cphi (R)	0.06	0.05	0.270	0.99
Cphs	-0.06	0.04	0.903	0.99
Cphi (L)	-0.08	0.06	0.912	0.99
LS	0.00	0.00	0.551	1.00
ILs	-0.19	0.13	0.251	0.99
Ch (L)	0.02	0.01	0.817	1.00
Li	-0.29	0.21	0.178	1.00
SLi	-0.21	0.15	0.230	0.99
Soft tissue B point	0.00	0.00	0.835	1.00
Pog	-0.15	0.11	0.462	1.00

1. Mean difference between repeat landmark identification (mm)
2. Testing for significant differences from zero using paired t-tests
3. CR = Pearson's coefficient of reliability

Table 4.3 Reproducibility of landmark identification, Z coordinates.

Landmark	Mean[1]	SD	p-value[2]	CR[3]
N	0.11	0.08	0.174	0.99
Exc (R)	0.18	0.13	0.268	1.00
Enc (R)	-0.21	0.15	0.833	0.99
Enc (L)	-0.43	0.30	0.896	1.00
Exc (L)	-0.40	0.28	0.925	0.99
Sbtr (R)	-0.35	0.25	0.271	0.99
Ac (R)	0.59	0.42	0.271	0.99
Prn	-0.17	0.12	0.276	1.00
Ac (L)	-0.60	0.23	0.562	0.99
Sbtr(L)	0.64	0.46	0.664	0.99
Sn	-0.05	0.04	0.481	1.00
Soft tissue A point	0.00	0.00	0.816	0.99
Ch (R)	0.15	0.11	0.137	1.00
Cphi (R)	0.02	0.01	0.378	0.99
Cphs	0.00	0.00	0.300	0.99
Cphi (L)	-0.07	0.05	0.146	0.99
LS	0.00	0.00	0.210	1.00
ILs	-0.23	0.16	0.195	0.99
Ch (L)	0.00	0.00	0.243	1.00
Li	-0.08	0.06	0.291	1.00
SLi	0.04	0.03	0.357	0.99
Soft tissue B point	0.00	0.00	0.682	1.00
Pog	0.00	0.00	0.492	1.00

1. Mean difference between repeat landmark identification (mm)
2. Testing for significant differences from zero using paired t-tests
3. CR = Pearson's coefficient of reliability

4.3 Attractive Group

Tables 4.4 - 4.7 show the results for the attractive male and female control groups. Descriptive statistics and tests for significant differences between the males and females are presented in Table 4.8 and Table 4.9.

In all cases except columella length female linear measurements were smaller then male measurements. There was a statistical difference ($p<0.05$) between the majority of linear measurements for males and females except for: columella length ($p = 0.395$) and lower lip length ($p = 0.154$). Columella length was found to be larger in females than males. Whilst the lower lip length this was larger in males than females. The 95% confidence for the mean difference was also greater than 3mm for all the linear measurements except columella length and lower lip length. It was interesting to note that even though upper lip length, nasal bridge width, philtrum width and philtrum length were significantly statistically different, the differences would not be clinically significant in this sample.

In all cases except upper facial convexity and nasolabial angle female angular measurements were smaller then male measurements. The angular measurements generally had larger standard deviations compared to the linear measurements in both males and females. There was no statistical difference between the majority of angular measurements for males and females except for upper facial convexity ($p = 0.006$). This measurement was larger in females than males. Thus females had a greater upper facial convexity compared to males in this sample.

Table 4.4 Linear measurements (mm) for the male attractive group, showing means and standard deviations.

Landmark	Mean	S.D.
N-Sn	52.8	2.2
Ex(R) -Ex(L)	92.1	4.0
Sbtr(R)-Sbtr(L)	148.2	8.0
Ac(R)-Ac(L)	35.1	2.6
Sn-Prn	19.8	2.1
Ch(R)-Ch(L)	52.2	3.5
Sn-ILs	19.9	2.2
SLi-Soft tissue B	15.3	2.1
En(R)-En(L)	33.1	3.2
Cphil(R)-Cphil(L)	14.3	2.6
Sn-Cphs	16.5	2.0
Sn-Pog	55.4	5.2

Table 4.5 Angular measurements (^{o}) for the male attractive group, showing means and standard deviations.

Landmark	Mean	S.D.
Ex(R)-N-Ex(L)	124.8	5.2
Prn-Sn-LS	131.2	10.3
Sbtr(R)-Sn-Sbtr(L)	73.3	5.0
Ac(R)-Prn-Ac(L)	64.1	9.7
N-Sn-Pog	164.7	4.7
N-Prn-Pog	132.8	9.0
LS-Sn-Pog	8.1	6.5
Li-Sn-Pog	3.1	2.7

Table 4.6 Linear measurements (mm) for the female attractive group, showing means and standard deviations.

Landmark	Mean	S.D.
N-Sn	49.4	2.6
Ex(R) -Ex(L)	89.0	3.1
Sbtr(R)-Sbtr(L)	135.7	5.8
Ac(R)-Ac(L)	31.7	1.7
Sn-Prn	20.3	1.2
Ch(R)-Ch(L)	48.8	2.2
Sn-ILs	17.7	1.4
SLi-Soft tissue B	14.5	1.3
En(R)-En(L)	30.9	2.2
Cphil(R)-Cphil(L)	12.4	1.6
Sn-Cphs	14.3	1.3
Sn-Pog	50.6	2.7

Table 4.7 Angular measurements (^{o}) for the female attractive group, showing means and standard deviations.

Landmark	Mean	S.D.
Ex(R)-N-Ex(L)	129.6	4.8
Prn-Sn-LS	133.1	8.6
Sbtr(R)-Sn-Sbtr(L)	72.1	3.0
Ac(R)-Prn-Ac(L)	61.5	5.1
N-Sn-Pog	163.5	4.6
N-Prn-Pog	128.1	3.6
LS-Sn-Pog	7.6	4.5
Li-Sn-Pog	3.0	2.0

Table 4.8 Linear measurements (mm) comparing male & female control groups. Tests for significant differences between males and females attractive groups.

Landmark[1]	Male		Female		Difference between means	P-value[2]	95% CI for Mean Difference[3]	
	Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
N-Sn	52.8	2.2	49.4	2.6	3.4	<0.001*	1.8	4.9
Ex(R) -Ex(L)	92.1	4.0	89.0	3.1	3.1	0.012*	0.7	5.6
Sbtr(R)-Sbtr(L)	148.2	8.0	135.7	5.8	12.5	<0.001*	7.7	17.3
Ac(R)-Ac(L)	35.1	2.6	31.7	1.7	3.4	<0.001*	1.8	4.9
Sn-Prn	19.8	2.1	20.3	1.2	-0.5	0.395	-1.7	0.7
Ch(R)-Ch(L)	52.2	3.5	48.8	2.2	3.4	0.002*	1.4	5.5
Sn-ILs	19.9	2.2	17.7	1.4	2.2	0.002*	0.9	3.4
SLi-Soft tissue B	15.3	2.1	14.5	1.3	0.8	0.154	-0.3	2.1
En(R)-En(L)	33.1	3.2	30.9	2.2	2.2	0.027*	0.3	4.1
Cphil(R)-Cphil(L)	14.3	2.6	12.4	1.6	1.9	0.013*	0.4	3.5
Sn-Cphs	16.5	2.0	14.3	1.3	2.2	0.001*	0.9	3.3
Sn-Pog	55.4	5.2	50.6	2.7	4.8	0.003*	1.8	7.7

1. Full names of landmarks and abbreviations are listed in the appendix.
2. p-values using Student's t-test.
3. 95% confidence interval for the mean difference.

Symbols used: * statistically significant difference at $p<0.05$.

Table 4.9 Angular measurements (°) comparing male & female control groups. Tests for significant differences between males and females attractive groups.

Landmark[1]	Male		Female		Difference between means	P-value[2]	95% CI for Mean Difference[3]	
	Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Ex(R)-N-Ex(L)	124.8	5.2	129.6	4.8	-4.8	0.006*	-8.1	-1.5
Prn-Sn-LS	131.2	10.3	133.1	8.6	-1.9	0.55	-8.3	4.5
Sbtr(R)-Sn-Sbtr(L)	73.3	5.0	72.1	3.0	1.2	0.418	-1.7	4.0
Ac(R)-Prn-Ac(L)	64.1	9.7	61.5	5.1	2.6	0.335	-2.9	8.1
N-Sn-Pog	164.7	4.7	163.5	4.6	1.2	0.416	-1.8	4.3
N-Prn-Pog	132.8	9.0	128.1	3.6	4.7	0.061	-0.2	9.7
LS-Sn-Pog	8.1	6.5	7.6	4.5	0.5	0.78	-3.3	4.4
Li-Sn-Pog	3.1	2.7	3.0	2.0	0.1	0.887	-1.5	1.7

1. Full names of landmarks and abbreviations is listed in the appendix.
2. p-values using Student's t-test.
3. 95% confidence interval for the mean difference.
   Symbols used: * statistically significant difference at $p<0.05$.

4 Results Part II

4.4 Sample characteristics

During the period of data collection a total 17 females and 16 males agreed to take part in the study.

Gender	Number (n)	Mean age (Yrs)	Range (Yrs)
Male	16	22.4	16 - 34
Female	17	23.8	17 - 35

4.5 Attractive male group compared with male orthognathic group

Tables 4.10 and 4.11 show the results for the attractive male control group compared with the male orthognathic group. Descriptive statistics and tests for significant differences between the two groups are presented in Table 4.12 and Table 4.13.

In the majority, the following measurements were larger in the control group than in the orthognathic group: upper face width, middle face width, mouth width, nasal bridge width and philtrum width. However these differences were not statistically significant. The last remaining width measurement, nose width, was larger in the orthognathic group, this again was not statistically significant.

Table 4.10 Linear measurements (mm) for the male orthognathic group, showing means and standard deviations.

Landmark	Mean	S.D.
N-Sn	53.0	4.2
Ex(R) -Ex(L)	91.2	4.6
Sbtr(R)-Sbtr(L)	143.5	7.6
Ac(R)-Ac(L)	36.9	2.9
Sn-Prn	20.8	1.7
Ch(R)-Ch(L)	51.0	3.9
Sn-ILs	20.3	2.8
SLi-Soft tissue B	16.9	2.1
En(R)-En(L)	32.1	3.5
Cphil(R)-Cphil(L)	14.1	2.0
Sn-Cphs	17.0	2.7
Sn-Pog	55.9	5.1

Table 4.11 Angular measurements (^{o}) for the male orthognathic group, showing means and standard deviations.

Landmark	Mean	S.D.
Ex(R)-N-Ex(L)	127.2	5.2
Prn-Sn-LS	129.7	9.0
Sbtr(R)-Sn-Sbtr(L)	71.4	3.3
Ac(R)-Prn-Ac(L)	65.4	5.8
N-Sn-Pog	164.0	6.2
N-Prn-Pog	129.8	5.3
LS-Sn-Pog	8.5	4.9
Li-Sn-Pog	5.2	2.0

Table 4.12 Linear measurements (mm) comparing attractive male & orthognathic male groups. Tests for significant differences between the attractive male & orthognathic male groups.

Landmark[1]	Attractive male		Orthognathic male		Difference between means	P-value[2]	95% CI for MeanDifference[3]	
	Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
N-Sn	52.8	2.2	53.0	4.2	-0.2	0.852	-2.2	2.7
Ex(R) -Ex(L)	92.1	4.0	91.2	4.6	0.9	0.517	-4.1	2.1
Sbtr(R)-Sbtr(L)	148.2	8.0	143.5	7.6	4.7	0.099	-10.3	0.9
Ac(R)-Ac(L)	35.1	2.6	36.9	2.9	-1.8	0.074	-0.2	3.8
Sn-Prn	19.8	2.1	20.8	1.7	-1	0.150	-0.4	2.4
Ch(R)-Ch(L)	52.2	3.5	51.0	3.9	1.2	0.372	-3.9	1.5
Sn-ILs	19.9	2.2	20.3	2.8	-0.4	0.608	-1.4	2.3
SLi-Soft tissue B	15.3	2.1	16.9	2.1	-1.6	0.039*	0.1	3.1
En(R)-En(L)	33.1	3.2	32.1	3.5	1	0.411	-3.4	1.4
Cphil(R)-Cphil(L)	14.3	2.6	14.1	2.0	0.2	0.781	-1.9	1.5
Sn-Cphs	16.5	2.0	17.0	2.7	-0.5	0.503	-1.1	2.3
Sn-Pog	55.4	5.2	55.9	5.1	-0.5	0.765	-3.2	4.3

1. Full names of landmarks and abbreviations are listed in the appendix.
2. p-values using Student's t-test.
3. 95% confidence interval for the mean difference.

Symbols used: * statistically significant difference at $p<0.05$.

Table 4.13 Angular measurements (^{o}) comparing attractive male & orthognathic male groups. Tests for significant differences between the attractive male & orthognathic male groups.

Landmark[1]	Attractive male		Orthognathic male		Difference between means	P-value[2]	95% CI for Mean Difference[3]	
	Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Ex(R)-N-Ex(L)	124.8	5.2	127.2	5.2	-2.4	0.197	-1.3	6.1
Prn-Sn-LS	131.2	10.3	129.7	9.0	1.5	0.660	-8.5	5.5
Sbtr(R)-Sn-Sbtr(L)	73.3	5.0	71.4	3.3	1.9	0.212	-5.0	1.2
Ac(R)-Prn-Ac(L)	64.1	9.7	65.4	5.8	-1.3	0.668	-4.6	7.1
N-Sn-Pog	164.7	4.7	164.0	6.2	0.7	0.735	-4.6	3.3
N-Prn-Pog	132.8	9.0	129.8	5.3	3	0.257	-8.4	2.3
LS-Sn-Pog	8.1	6.5	8.5	4.9	-0.4	0.836	-3.7	4.6
Li-Sn-Pog	3.1	2.7	5.2	2.0	-2.1	0.023*	0.3	3.7

1. Full names of landmarks and abbreviations are listed in the appendix.
2. p-values using Student's t-test .
3. 95% confidence interval for the mean difference.

Symbols used: * statistically significant difference at $p<0.05$.

The only length measurement that showed a statistical difference ($p<0.05$) was lower lip length and this was larger in the orthognathic group. The difference for this measurement was not clinically significant in this sample, but the 95% confidence for the mean difference was greater than 3mm. Upper lip length, columella length, philtrum length, upper anterior face height and lower anterior face height were all larger in the orthognathic group than in the control group though there was no statistical difference between the groups for these measurements. The 95% confidence for the mean difference was greater than 3mm for the following measurements – upper face width, middle face width, nose width, mouth width, lower lip length, nasal bridge width and lower anterior face height.

Table 4.13 shows that the following angular measurements are larger in the control group than in the orthognathic group: nasolabial angle, mid facial convexity, facial convexity excluding the nose and including the nose. The angular measurements generally had larger standard deviations compared to the linear measurements in both the male control and the orthognathic male group. There was no statistical difference between the majority of angular measurements between the groups except for lower lip prominence ($p = 0.023$). Lower lip prominence was larger in the orthognathic group. Upper lip prominence, nasal convexity and upper facial convexity were also larger in the orthognathic group compared to the control group though there was no statistical difference between the groups. The male orthognathic sample appeared to have longer and more prominent upper and lower lips compared with the male controls though only the measurements for lower lip were statistically different in this study.

4.6 Attractive female group compared with female orthognathic group

Tables 4.14 and 4.15 show the results for the attractive female control group compared with the female orthognathic group. Descriptive statistics and tests for significant differences between the two groups are presented in Table 4.16 and Table 4.17.

In the majority of cases the following measurements were larger in the control group than in the orthognathic group: columella length, lower lip length, philtrum width and philtrum length. However these differences were not statistically significant. The only measurements that showed a statistical difference ($p<0.05$) were lower anterior face height and nose width. Both these measurements were larger in the orthognathic group. The differences for both these measurements were not clinically significant in this sample, but the 95% confidence for the mean difference was greater than 3mm. The 95% confidence for the mean difference was also greater than 3mm for middle facial width. Upper anterior face height, upper face width, middle face width, mouth width, upper lip length and nasal bridge width were larger in the orthognathic group though these measurements were not statistically different between the groups.

Table 4.17 shows that the following angular measurements are larger in the control group than in the orthognathic group: nasolabial angle, upper facial convexity and mid facial convexity. The angular measurements generally had larger standard deviations compared to the linear measurements in both groups. There was no statistical difference between the majority of angular measurements between the

Table 4.14 Linear measurements (mm) for the female orthognathic group, showing means and standard deviations.

Landmark	Mean	S.D.
N-Sn	50.0	3.3
Ex(R) -Ex(L)	89.6	4.1
Sbtr(R)-Sbtr(L)	136.4	5.9
Ac(R)-Ac(L)	33.6	2.7
Sn-Prn	19.8	1.9
Ch(R)-Ch(L)	49.0	4.2
Sn-ILs	17.9	2.5
SLi-Soft tissue B	14.3	2.2
En(R)-En(L)	31.3	2.3
Cphil(R)-Cphil(L)	12.1	1.6
Sn-Cphs	14.0	2.2
Sn-Pog	53.3	3.5

Table 4.15 Angular measurements (°) for the female orthognathic group, showing means and standard deviations.

Landmark	Mean	S.D.
Ex(R)-N-Ex(L)	125.7	23.1
Prn-Sn-LS	124.7	7.3
Sbtr(R)-Sn-Sbtr(L)	70.5	8.9
Ac(R)-Prn-Ac(L)	67.4	7.4
N-Sn-Pog	166.5	5.2
N-Prn-Pog	131.9	4.5
LS-Sn-Pog	10.2	4.2
Li-Sn-Pog	3.8	2.2

Table 4.16 Linear measurements (mm) comparing attractive female & orthognathic female groups. Tests for significant differences between the attractive female & orthognathic female groups.

Landmark[1]	Attractive female		Orthognathic female		Difference between means	P-value[2]	95% CI for Mean Difference[3]	
	Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
N-Sn	49.4	2.6	50.0	3.3	-0.6	0.565	-1.4	2.5
Ex(R) -Ex(L)	89.0	3.1	89.6	4.1	-0.6	0.613	-1.8	3.0
Sbtr(R)-Sbtr(L)	135.7	5.8	136.4	5.9	-0.7	0.710	-3.1	4.5
Ac(R)-Ac(L)	31.7	1.7	33.6	2.7	-1.9	0.017*	0.4	3.4
Sn-Prn	20.3	1.2	19.8	1.9	0.5	0.378	-1.6	0.6
Ch(R)-Ch(L)	48.8	2.2	49.0	4.2	-0.2	0.816	-2.1	2.6
Sn-ILs	17.7	1.4	17.9	2.5	-0.2	0.832	-1.3	1.5
SLi-Soft tissue B	14.5	1.3	14.3	2.2	0.2	0.755	-1.4	1.0
En(R)-En(L)	30.9	2.2	31.3	2.3	-0.4	0.574	-1.1	1.9
Cphil(R)-Cphil(L)	12.4	1.6	12.1	1.6	0.3	0.522	-1.3	0.7
Sn-Cphs	14.3	1.3	14.0	2.2	0.3	0.613	-1.5	0.9
Sn-Pog	50.6	2.7	53.3	3.5	-2.7	0.011*	0.7	4.8

1. Full names of landmarks and abbreviations is listed in the appendix.
2. p-values using Student's t-test.
3. 95% confidence interval for the mean difference.

Symbols used: * statistically significant difference at $p<0.05$.

Table 4.17 Angular measurements (^{o}) comparing attractive female & orthognathic female groups. Tests for significant differences between the attractive female & orthognathic female groups.

Landmark[1]	Attractive female		Orthognathic female		Difference between means	P-value[2]	95% CI for Mean Difference[3]	
	Mean	**S.D.**	**Mean**	**S.D.**			**Lower Limit**	**Upper Limit**
Ex(R)-N-Ex(L)	129.6	4.8	125.7	23.1	3.9	0.500	-15.9	8.1
Prn-Sn-LS	133.1	8.6	124.7	7.2	8.4	0.002*	-13.5	-3.4
Sbtr(R)-Sn-Sbtr(L)	72.1	3.0	70.5	8.9	1.6	0.481	-6.3	3.1
Ac(R)-Prn-Ac(L)	61.5	5.1	67.4	7.4	-5.9	0.008*	1.6	10.2
N-Sn-Pog	163.5	4.6	166.5	5.2	-3	0.062	-0.2	6.3
N-Prn-Pog	128.1	3.6	131.9	4.5	-3.8	0.006*	1.2	6.6
LS-Sn-Pog	7.6	4.5	10.2	4.2	-2.6	0.065	-0.2	5.4
Li-Sn-Pog	3.0	2.0	3.8	2.2	-0.8	0.265	-0.6	2.1

1. Full names of landmarks and abbreviations is listed in the appendix.
2. p-values using Student's t-test.
3. 95% confidence interval for the mean difference.

   Symbols used: * statistically significant difference at $p<0.05$.

groups except for nasolabial angle ($p = 0.002$), nasal tip convexity ($p = 0.008$) and facial convexity including the nose ($p = 0.006$). The latter two measurements were larger, more obtuse, in the orthognathic group.

Facial convexity excluding nose and upper and lower lip prominence were larger in the orthognathic group though these measurements were not statistically different in this sample.

Chapter Five

Discussion

5 Discussion Part I

5.1 The normal group

Our standards for facial attractiveness reflect arbitrary standards of beauty set by cultural background and the influence of the media and fashion trends of the time. Averageness, symmetry, youthfulness and sexual dismorphism are all cues for facial attractiveness yet they do not account for the whole picture, with secular trends and cultural variations influencing the perception of facial aesthetics.

The overall aim of the study was to compare, using angular and linear measurements, the 3D facial images obtained by stereophotogrammetry of a group of post surgical orthognathic patients to a group of "attractive'' individuals. The aim of part I of the study was to determine which individuals were thought of as attractive by a lay panel from a population from the West of Scotland. Studies on the objective assessment of facial attractiveness based on three-dimensional facial adult morphology are presently scarce. The main studies at present are limited to direct anthropometry (Farkas, 1994) and three-dimensional facial morphometry at the University of Milan (Ferrario *et al.,* 1995; Sforza *et al.,* 2007; Sforza *et al.,* 2008; Sforza *et al.,* 2009).

In their assessment of female attractiveness, Sforza *et al.* (2007, 2009) selected their normal control group of Northern Italian female adults between the ages of 18-30 years who were judged to conform to dentofacial normality. This reference group was judged by the authors to be normal on the basis that they had normal dentofacial dimensions and proportions, with no previous history of craniofacial trauma or congenital anomalies. However no further clarification of what constituted normal dentofacial dimensions was given. All these women were either staff or students at the University of Milan. This control group was selected purely on the subjective opinion of the author, which could result in a very biased sample. For comparative analysis this sample is limited to an Italian population and the facial features may not be indicative of a West of Scotland population.

Since the ultimate aim of this study was determine whether post surgical orthognathic patients from the West of Scotland were attractive, the comparison group would need to be from the same population. Hence, recruitment of the attractive control group was based on a voluntary basis from within the local Caucasian population of the West of Scotland. The age range of the sample was chosen to reflect the common age range of patients who uptake of orthognathic surgery. Caucasian volunteers from the West of Scotland were chosen to reflect the ethnicity of the local patient population. Volunteers were not included if they possessed a craniofacial defect or syndrome, facial hair or were not of Caucasian origin.

5.2 3D images versus 2D photographs

The soft tissues of the craniofacial complex are in a three-dimensional configuration and any facial soft tissue analysis ideally should be carried out via three-dimensional measurement techniques for accurate representation. The use of 3D images is more realistic of the clinical situation and prior to this imaging modality it was suggested that the simultaneous presentation of frontal and profile views to imitate a three-dimensional viewing of the face was the best way to overcome this limitation (Phillips *et al.,* 1995).

The accuracy of facial measurements recorded by manual anthropometry, 3D stereophotogrammetry and 2D photography has been previously assessed (Ghoddousi *et al.,* 2007). The 3D measurements were found to compare well with the manual measurements while the 2D measurements were found to be more variable. Hence the use of 3D images in this study is probably the most realistic technique to replace the actual patient.

5.3 Lay panel

The final soft tissue appearance produced as a result of orthognathic surgery is the primary outcome measure of success for the patient and their peers. An orthognathic surgical outcome that is successful in the eyes of the professional does not always improve facial aesthetics (Arnett and Bergman, 1993a; Arnett and Bergman, 1993b; Al Yami *et al*., 1998; Bergman, 1999). Many patients expressed their facial appearance as the main reason for seeking surgical treatment (Stirling *et al.,* 2007) and their desire to look "normal", i.e. similar to their peers. Patients themselves are generally laypeople and are not experts at examining facial form. Therefore, it is essential to make sure that when selecting a normal group of subjects for comparison, they are chosen by laypeople since it is their opinion as end-users of orthodontic / orthognathic surgery services that has the most value in determining the appropriateness of aesthetic results.

Panel composition was a key element in this study. It has been suggested that the age and socio-economic status of the judges should match the stimulus photographs in the sample (Phillips *et al.,* 1992b; Howells and Shaw, 1985). Howells and Shaw (1985) also showed that there was no significant difference when the ratings of facial attractiveness by a 2 person lay panel was compared with those of the larger lay panel of 122 laypeople, suggesting that a small panel of judges can provide valid, reproducible and representative ratings of facial aesthetics. This is supported by the work of Kiekens *et al.* (2007) which concluded that a panel of about seven randomly selected laymen and/or orthodontists (males and/or females) would be sufficient to yield reliable results, using the VAS as the outcome measure in clinical and epidemiological studies of facial aesthetics. Therefore, in this study a panel of 8 lay people to assess the facial images was randomly selected (4 males and 4 females) between the ages of 18-35 years and all having had university education. All were of Caucasian origin from the West of Scotland. None of the lay panel had a medical or dental background.

5.4 Rating of images

The lay panel rated each image for facial attractiveness on a 100mm horizontal VAS scale marked with the anchors "least attractive" and "most attractive". They were instructed to ignore skin complexion, hair, position of ears and to concentrate on facial attractiveness with respect to facial balance and harmony. Each lay panel member viewed the Powerpoint presentation showing the three-dimensional images rotating in a video presentation in a single sitting.

5.4.1 Ranking of the VAS scores

As previously highlighted, it has been recommended that VAS scores be transformed to rankings to improve the statistical validity of the VAS tool (Philips *et al.,* 1992b). Doing so would allow relative changes rather than absolute values to be investigated (Edler *et al.,* 2006) and would thus improve the sensitivity of the VAS as a measurement tool.

In this study, the VAS scores were ranked from most attractive to least attractive for each subject as recorded by each of the 8 lay panel members. The data was divided into three segments – most attractive, attractive and least attractive. Where there was agreement between the lay panel members for a subject's facial attractiveness as being either "most attractive" or "attractive", the subject was chosen to be part of the "attractive" control group to which the post surgical orthognathic patients could be compared. In this way, 16 "attractive" males and 24 "attractive" females were selected based on agreement between 6 or more of the lay panel members. The sample size for the attractive males and females matched the desired sample size for the orthognathic group (minimum 16 subjects). This sample of 40 attractive individuals was selected from 112 volunteers by the lay panel. An alternative method of selecting the control group would have been to pick them at random from the 112 volunteers but this would have included volunteers that would not have been thought of as attractive by laypeople and introduced greater variation and error. A previous study has described a similar selection process based on the facial profile of 72 Chinese subjects (Lew *et al.,* 1992). The study used a lay panel of four men and four women to score the images who had been pre-selected by a professional panel on the basis of harmonious facial profiles and having an intact dentition. However there was no clarification on what exactly constituted a harmonious facial profile. The lay panel was asked to rate each profile as very pleasing, pleasing, average and below average which corresponded to the numerical scores of 4, 3, 2 and 1 respectively. Profiles which were scored with 16 or more points were taken as good profiles. The maximum score a profile could obtain was 32 points, if all 8 lay panel members gave a score of 4, meaning that profiles which scored 50% of maximum were described as good. The present study has refined this process further and eliminated the pre-selection bias of the lay panel by eliminating the expert panel pre-screening and only included images where 6 out of 8 lay panel members agreed that an image was attractive.

5.5 3D facial landmarks

A wide variety of different linear distances and angular measurements have been used in the literature in the 3D measurement of facial soft tissue morphology. The 20 variables chosen in this study were taken to represent the facial areas most commonly affected by orthognathic surgery, mainly the middle and lower facial regions, based on the landmarks highlighted and including aspects of the Legan-Burstone (1980) facial soft tissue analysis with a number of variables which were used in other studies (Ferrario *et al.,* 1996; Weinberg *et al.,* 2004; Sforza *et al.,* 2009; Wong *et al.,* 2008).

For purposes of this study, the landmarks used by Hajeer *et al.* (2002) and Gwilliam *et al.* (2006) were combined with the classic points defined by Farkas (1994) to produce a total of 23 landmarks, some of which have been previously shown to have high reproducibility to within 0.5mm (Hajeer *et al.,* 2002, Hajeer *et al.,* 2004). One of the landmarks used was crista philtri superior, a reference point in labial anthropometry first quoted in Mulliken *et al.* (2001) and since used in a number of studies including Wong *et al.* (2008) who also defined the bilateral landmark crista philtri inferior to determine philtrum width. The landmarks selected were a representative subset of anatomic facial landmarks comprising of both midline and sagittal points. Landmark identification was repeated by the author 2 weeks after the first session of localisation on 6 male and 6 female subjects from both the attractive and orthognathic groups to determine intra-operator error. In the literature there has been no agreement on how long an interval between landmark identification is required to reduce any effect of memory on landmark reproducibility (Gwilliam *et al.,* 2006).

5.5.1 Reproducibility of landmarks: Intra-operator reliability

As there is no universal gold standard for landmark reproducibility, this study took the guidelines suggested by Hajeer *et al.* (2002). Therefore, in taking the standard deviation for reproducibility of intra-operator landmark identification as 0.5mm or less in all three planes of space, only one landmark in this study did not fit within this category and only in one Cartesian plane – Left Subtragion in the y axis which had a standard deviation of 0.68mm. Overall, reproducibility of landmark identification was very high. Random error assessed by coefficients of reliability showed values well above 90% for all landmarks. This was similar to the findings of Hajeer *et al.* (2002) who reported four landmarks with standard deviations between 0.5-1mm (glabella, right and left otobasion inferius, left zygion) and six landmarks with standard deviations that exceeded 1mm (right and left gonion, right and left tragion, right zygion and menton). These landmarks were considered inappropriate for use in studying facial soft tissue morphology. The authors suggested that the reproducibility of gonion and zygion was poor due to the difficulty in locating these points precisely on the computer screen. This is in contrast to Gwilliam *et al.* (2006) who showed only 4 out of the 24 landmarks to be within a 0.5mm error margin (right and left cheilion, labrale superius and exocanthion).

A possible reason for the differences in the present study are the very high resolution digital images with high quality colour and photorealistic rendering which facilitated landmark positioning and contributed to the excellent result found for intra-operator landmark reproducibility. Also the ability to view the same image in three planes of space simultaneously greatly increased landmarking precision.

5.6 Analysis of the attractive group

In the attractive sample, all female linear measurements were smaller then male measurements except for columella length. There was a statistical difference ($p<0.05$) between the majority of linear measurements for males and females except for columella length and lower lip length. This would tend to indicate that females have smaller faces then males, however many of the differences were minimal and not clinically significant in this sample. However, the 95% confidence for the mean difference was greater than 3mm for all the linear measurements except columella length and lower lip length.

In all cases, except upper facial convexity and nasolabial angle, female angular measurements were smaller then male measurements. The difference in the mean for nasolabial angle was minimal. There was no statistical difference between the majority of angular measurements for males and females except for upper facial convexity ($p = 0.006$).

Overall the results show that attractive females from this sample have smaller facial dimensions than the attractive males for the most part except for upper facial convexity where the females showed a slightly flatter upper face. This is to be expected as in human beings females are in general of smaller physical dimensions than males. This means that the two groups could not be combined, in other words males are different to females. Some studies have overlooked this fact and combined the two groups and as such, comparison of results from this study to these two studies would not be applicable (Weinberg *et al.,* 2004; Wong *et al.,* 2008).

Ferrario *et al.* (1995) was one of the earliest studies attempting to objectively identify reference standards and aesthetic features in facial proportion of an adult (female) sample. The "normal" reference group comprised of 40 healthy Caucasian Northern Italian female dental students aged 19-32 years. All subjects had sound dentitions with bilateral Angle Class I molar relationship, absence of crossbites and no previous history of craniofacial abnormalities, orthodontic treatment or orthognathic surgery. The "attractive" group comprised of 10 Caucasian Italian television actresses aged 19-28 years chosen during a television screen test by casting specialists based on the appearance of the woman's face on a television monitor. The study compared upper face height, lower face height, upper face width, middle face width (defined as right tragion – left tragion), mouth width, upper facial convexity and facial convexity including and excluding nose. The results showed that the television actresses had more acute facial convexity angles in the sagittal plane (smaller angle of facial convexity excluding nose) and that this difference was statistically significant. The television actresses had wider upper face widths than the normal Italian reference group, this would tend to indicate that the eyes were larger in the television actresses or they were further apart. Comparing these measurements to the present study, Table 5.1 and Figures 5.1 and 5.2, all the measurements highlighted above were larger in the Italian normal group and television actresses group except for upper facial convexity and lower face height in both groups. Middle face width of the normal group and actresses group were of similar values to the present study's reference group. The value for facial

		Present study		Ferrario *et al.* (1996)		Ferrario *et al.* (1995)		Sforza *et al.* (2009)					
		Female (24)		Female (40)		Television actresses (10)		Reference group (71)		2006 Beauty contest winners (12)		2007 Beauty contest winners (12)	
Measurements	Landmarks												
Linear		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Upper face height	N-Sn	49.4	2.6	61.96	3.96	52.38	2.76	-	-	-	-	-	-
Lower face height	Sn-Pg	50.6	2.7	46.31	3.39	47.71	3.71	-	-	-	-	-	-
Upper face width	Can-Can	89.0	3.1	111.47	6.74	101.59	4.97	90.2	3.8	95.2	3.3	92.5	3.5
Middle face width	Tr_r-Tr_l	135.7	5.8	132.45	10.06	135.10	5.05	134.4	5.7	136.2	5.2	130.8	4.7
Mouth width	Com_r-Com_l	48.8	2.2	51.20	3.80	52.40	4.51	48.5	3.5	49.2	2.1	48.2	2.9
Angular													
Facial convexity exc. nose	N-Sn-Pg	163.5	4.6	166.82	5.26	164.02	3.71	160.4	6.3	160.2	5.0	162.7	4.6
Facial convexity inc. nose	N-Pn-Pg	128.1	3.6	134.04	5.02	131.76	3.59	-	-	-	-	-	-
Upper facial convexity	Can_l-N-Can_r	129.6	4.8	110.00	7.94	120.29	5.24	120.2	5.6	124.9	3.5	120.8	4.2
Nasolabial	Prn-Sn-LS	133.1	8.6	-	-	-	-	127.2	8.0	137.7	6.4	159.0	7.7
Ratio													
Lower to upper facial height	Sn-Pg/N-Sn	102.4	-	74.4	-	91.1		101.2	8.4	104.0	8.6	100.2	7.7

Table 5.1 Comparison of linear and angular measurements from the main comparative studies and the present study

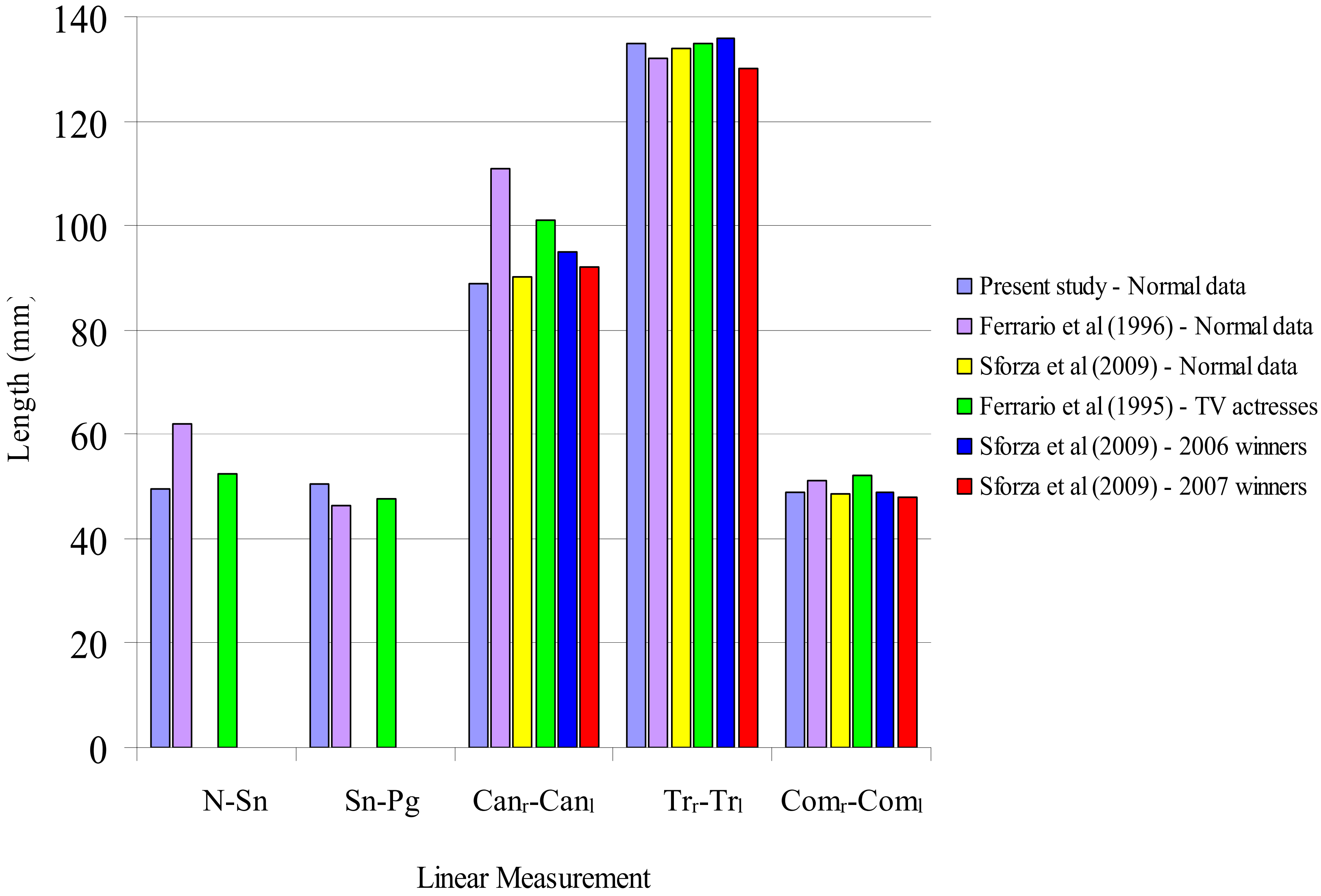

Figure 5.1 Comparison of the linear measurements from the main comparative studies and the present study

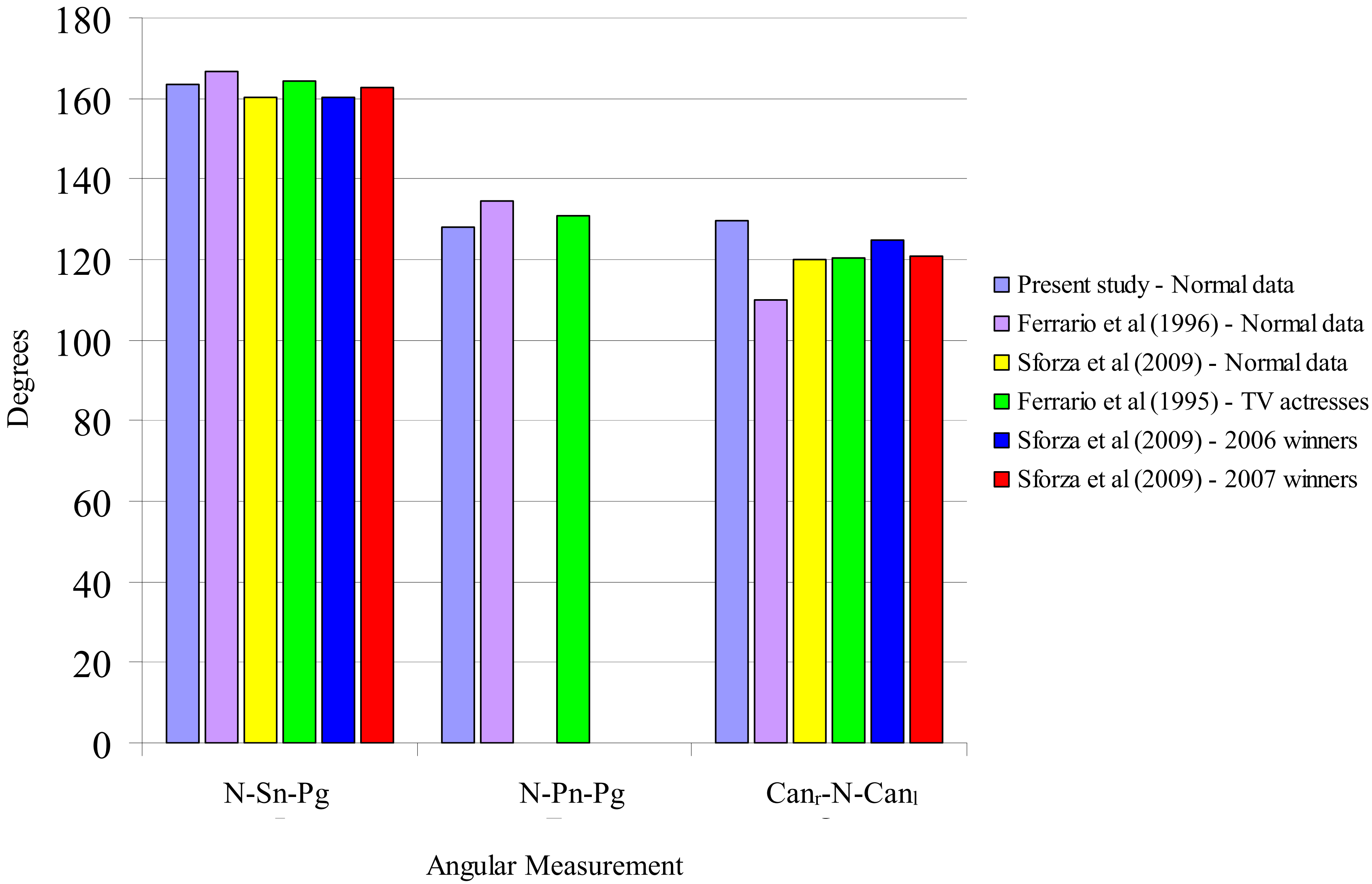

Figure 5.2 Comparison of the angular measurements from the main comparative studies and the present study

convexity excluding nose for the actresses group was similar to the present study's reference group.

In common with the present study, Ferrario *et al.* (1996) investigated the following linear and angular measurements: upper anterior face height, lower anterior face height, upper face width, mouth width, upper facial convexity and facial convexity including and excluding nose. The sample was based on a previous Italian normal reference group (Ferrario *et al.,* 1995). The study found all measurements were smaller in females than males and the differences showed statistical significance, which was in agreement with the present study. However, both the Italian male and female dental students had larger angular and linear measurements, except for upper facial convexity and lower face height. However it was interesting to note that some of the values were considerably larger in the Italian sample, for example, upper face width (mean value for males: 116.93mm, mean value for females: 111.47mm). The values for upper facial convexity on the other hand were considerably smaller in the Italian sample (mean value for males: 109.78°, mean value for females: 110°). This may represent true differences between Italian and West of Scotland individuals or may be a result of the inclusion criteria. The other reason for the differences between the two studies, Ferrario *et al.* (1996) and Sforza *et al.* (2009) may be that thirteen years had passed and an individual's opinion of the features of attractiveness may have changed over that time period.

Sforza *et al.* (2009) compared 71 healthy Caucasian Northern Italian women aged 18-30 years (women with normal dentofacial dimensions and no craniofacial trauma or congenital anomalies taken to represent their normal reference group) to an "attractive" group comprising of 24 national beauty pageant finalists. These women were deemed attractive or beautiful because they had been chosen subjectively by a panel of beauty pageant judges to reach the finals of two national beauty competitions that occurred in 2006 and 2007. The authors used similar facial measurements to this study: upper face width, middle face width (right tragion – left tragion), mouth width, nasolabial angle, upper facial convexity and facial convexity excluding the nose. Only upper face width and upper facial convexity showed statistical difference between the beauty pageant group and the normal Italian reference group. The 2006 beauty pageant finalists had larger angles of upper facial convexity, a wider middle facial third and had faces that were much flatter in the horizontal plane in contrast to the normal Italian group. The authors concluded that the beauty pageant women in their study shared common characteristics indicative of youthfulness such as relatively large foreheads and increased upper facial width compared to the normal reference women. In comparison to the measurements of the attractive reference group in the present study, the values for middle face width and mouth width in both the beauty pageant and normal Italian groups and the upper face width in the normal Italian group were very similar. Upper face width for the beauty pageant Italian group was larger. Upper facial convexity, nasolabial angle and facial convexity excluding nose were all smaller for both groups (beauty pageant and normal) in Sforza *et al.* (2009) compared to the attractive reference group in the present study. It is interesting to note that in terms of certain linear width measurements, the attractive reference group from the West of Scotland in this study was actually remarkably similar to the Italian normal reference group in Sforza *et al.* (2009). The attractive group from the West of Scotland appear to have more convex faces in the sagittal plane (facial convexity excluding nose) and in the transverse plane (upper facial convexity) and a more obtuse mean nasolabial angle compared to both the attractive and normal Italian groups.

The attractive group in this study was determined by a lay panel evaluation based on ranked VAS scores with agreement between 6 or more lay panel members. However it is to the “normal reference” group and not the “attractive” group in the Sforza *et al.* (2009) study that the “attractive” group in our study shows the similarity in measurements. This supports the idea that there is a universal standard of facial attractiveness and agreement between populations, with the Scottish females and Northern Italian females showing remarkable similarities in terms of some facial soft tissue measurements. Sforza *et al.* (2007) in their study comparing normal 71 Caucasian Northern Italian women to 48 “beautiful” women from a national beauty competition including the winner, the women in the “Beauties” group had mean measurements that deviated from the normal reference group with the winner having the most deviated scores. Beauty is often perceived in individuals with the greatest deviation from the normal averageness and normal facial attractiveness.

5.7 Future considerations

- The images from the attractive sample were viewed by the lay panel only in one sitting. Thus intra-rater reproducibility in rating of facial attractiveness could not be determined. Not many studies have included assessment of intra-rater reproducibility of attractiveness ratings. One of the studies that did so was Kiekens *et al.* (2005) and they found the median intra-observer consistency between the first and second ratings of the photographs was 0.68 for the lay panel which was acceptable. Whilst the studies on three-dimensional facial soft tissue morphology by Sforza *et al.* (2007, 2008, 2009) and Wong *et al.* (2008) also did not look at intra-rater reproducibility, this could be assessed in future studies of facial attractiveness using three-dimensional images to determine consistency of lay assessment of subjects in their most natural form.

- Among the limitations of the current study is that other facial cues thought to be involved in determining facial attractiveness such as symmetry and averageness were not assessed and neither was shape or volume change. These images can be further assessed for these aspects together with a wider set of angles and distances. This study has only scratched the surface of three-dimensional facial morphometrics and more comprehensive analyses to obtain a deeper insight to what constitutes facial attractiveness would be the direction of future studies.

- Clinical significance for angular facial measurements has not been determined in the literature and as such clinical significance of the differences in angular measurements between the groups in this study could not be commented on. Future studies could focus on determining the extent to which a difference in angular measurement values could translate to a clinically significant difference.

5 Discussion Part II

5.8 The orthognathic group

5.8.1 Patient recruitment

Random recruitment of post-surgical orthognathic patients took place from October 2005 to June 2008 from the dentofacial clinic at Glasgow Dental Hospital. The patients were all of Caucasian origin from the West of Scotland and were at least six months post-surgery. Recruitment was on a voluntary basis and irrespective of surgical procedure. 16 males with an age range of 16-34 years (mean age 22.4 years) consented to take part in the study. 17 females with an age range of 17-35 years (mean age 23.8 years) consented as well. All the male patients were clean shaven.

5.8.2 Surgical procedures

The surgical procedure was not part of the inclusion criteria for this study since it was the end result that was of interest. It is assumed that the surgical procedure that was chosen was on the grounds that it would address the soft tissue concerns of the patient. Orthognathic surgery is undertaken to correct dentofacial deformity and deficiency; with surgery, the goal is to restore normal function and appearance. Whether maxillary, mandibular or bimaxillary surgery had to be undertaken to correct the deficit is irrelevant. However for completeness the spread of surgical procedures was determined. For the male orthognathic group, 13 males had maxillary advancement procedures, 6 males had mandibular setback procedures and 4 males had mandibular advancement procedures. For the female orthognathic group, 12 females had maxillary advancement procedures and 8 females had mandibular advancement procedures. Only 1 female had a mandibular setback procedure in this sample.

5.9 The male orthognathic group versus the male attractive reference group

Overall, in the orthognathic group, the only statistical difference in comparison of means to the male attractive control group was noted for the measurements lower lip length and lower lip prominence. While the difference for lower lip length did not show clinical significance in this sample, the 95% confidence for the mean difference was greater than 3mm. The male orthognathic sample appeared to have longer and more prominent upper and lower lips compared with the male controls though only the measurements for lower lip were statistically different in this study. Given the fact that the majority of surgical procedures were maxillary advancement procedures this might suggest that surgery was only dealing with the main issue, that is a retrusive maxilla, but was not dealing with the subtleties of the lower lip position. In fact it might not even be possible to deal with this issue adequately with surgery.

The values for nose width and nasal tip convexity were larger in the orthognathic group than in the attractive control group while the value for nasolabial angle was smaller. This could be due to the consequences of maxillary advancement surgery, since this would probably broaden and flatten the nose and move the nasal tip forward. The facial convexity angle including the nose was smaller in the orthognathic group than the control group suggesting the orthognathic group had less convex faces in the sagittal plane. However these measurements were not statistically different between the groups.

5.10 The female orthognathic group versus the female attractive reference group

Overall, in the orthognathic group, the only statistical difference in comparison of means to the female attractive control group was noted for the measurements nose width, lower anterior face height, nasolabial angle, nasal tip convexity and facial convexity including nose. The values for nose width, lower anterior face height, nasal tip convexity and facial convexity angle including nose were larger in the orthognathic group than in the attractive control group while the value for nasolabial angle was smaller. Nose width and lower anterior face height measurements were not clinically significant in this sample but the 95% confidence for the mean difference was greater than 3mm. These results suggest that the female orthognathic group in comparison to the female attractive group have more convex faces in the sagittal plane, more convex nasal tips, wider noses and smaller nasolabial angles. A possible inference is that the nose has flattened and broadened but has become more posteriorly positioned possibly due to the up turning of the nose tip, likely due to the consequences of a maxillary advancement procedure. This would tend to suggest that the female orthognathic group could be seeing adverse nasal features as a result of over advancement of the maxilla.

5.11 Future considerations

- The present study only uses linear and angular measurements to determine soft tissue differences but this only scratches the surface of three-dimensional facial morphometrics and more comprehensive analyses are required to assess the shape differences and surface curve differences that exist between the attractive and post treatment orthognathic group.

- Another area of investigation should be whether pre-surgery orthognathic patients are different to the attractive group and in which areas. This would perhaps allow development of a diagnostic software tool to determine the specific area of deformity and the steps required to “normalise” the individual.

- Studies could also be conducted to determine the correlation between subjective and objective evaluation and an outcome score could be assigned to the final result.

Chapter Six

Conclusions

6 Conclusions

6.1 First Aim

To determine the 3D soft tissue facial measurements of an "attractive" group of West of Scotland males and females between the ages of 18 and 35 as selected by a panel of laypeople.

Conclusions

- A database of 3D images of 24 females and 16 males from the West of Scotland has been created based on the selection of 8 laypeople. Simple angular and linear measurements have been recorded.

- Males and females are different with respect to the angular and linear measurements recorded.

- The null hypothesis that there is no difference between the 3D soft tissue measurements between males and females in the attractive group in this study was not upheld.

6.2 Second Aim

To determine whether post-operative orthognathic patients look attractive based on objective measurements of 3D soft-tissue facial landmarks.

Conclusions

- A database of 3D images of 17 females and 16 males post orthognathic surgery and from the West of Scotland was collated from the Dentofacial Clinics at Glasgow Dental Hospital.

- The facial morphology of the male orthognathic sample was found to be similar to the male attractive group except for lower lip length and lower lip prominence which were both greater in the orthognathic group.

- The facial morphology of the female orthognathic group was similar to the female attractive group except that the female orthognathic group had more convex faces in the sagittal plane, more convex nasal tips, wider noses and smaller nasolabial angles. These effects may be attributed to over advancement of the maxilla.

- The null hypothesis that there is no difference between the 3D soft tissue measurements obtained from a group of attractive subjects and those of the post surgical treatment group in this study was not upheld.

Chapter Seven

Appendices

7 Appendices

7.1 Appendix I – Copy of the Ethics letter

Acute Services Division

NHS
Greater Glasgow and Clyde

West Glasgow Ethics Committee 2
Western Infirmary
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20 May 2008

Dr Balvinder Khambay
Level 5,
Orthodontic Department,
Glasgow Dental Hospital & School,
378 Sauchiehall Street,
Glasgow
G2 3JZ

Dear Dr Khambay

Study title:	**A pilot study to investigate the two & three dimensional features of the вЂњnormalвЂќ West of Scotland face and the development of an assessment tool to evaluate the success of orthognathic surgery.**
REC reference:	**07/S0709/59**
Amendment number:	
Amendment date:	**20 April 2008**

The above amendment was reviewed at the meeting of the Committee held on 20 May 2008.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date
Notice of Substantial Amendment (non-CTIMPs)		20 April 2008
Covering Letter		20 April 2008

Membership of the Committee

The members of the Committee who were present at the meeting are listed on the attached sheet.

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Acute Services Division

NHS Greater Glasgow and Clyde

R&D approval

All investigators and research collaborators in the NHS should notify the R&D office for the relevant NHS care organisation of this amendment and check whether it affects R&D approval of the research.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

07/S0709/59:	**Please quote this number on all correspondence**

Yours sincerely

Sharon Jenner

PP **Andrea Torrie, Manager - West Glasgow LREC's**

E-mail: andrea.torrie@ggc.scot.nhs.uk

Enclosures List of names and professions of members who were present at the meeting and those who submitted written comments

Copy to: *R & D Department*

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7.1 Appendix II - Rating VAS instructions

Thank you for agreeing to take part in this study.

You will be shown 112 images of peoples faces, each will be on the screen for about 30 seconds and each will rotate to provide you with a "3D view" of the face.

Using the line below please indicate with a vertical line where you would place the face on the line given that one end represents "very unattractive" and the other "very attractive".

For example

We are interested in "facial harmony" since attraction encompasses many other factors; therefore please **<u>IGNORE</u>** the following facial features whilst carrying out the assessment.

- Skin condition
- Hair
- Eyes
- Ears

Many thanks

Dr B.S.Khambay

Thank you for agreeing to take part in this study.

You will be shown 112 images of peoples faces, each will be on the screen for 30 seconds and each will rotate to provide you with a “3D view” of the face.

Using the line below please indicate with a vertical line where you would place the face on the line given that one end represents “very unattractive” and the other “very attractive”.

For example

vertical line

Very unattractive — Very attractive

No.1

Very unattractive — Very attractive

No.2

Very unattractive — Very attractive

No.3

Very unattractive — Very attractive

No.4

Very unattractive — Very attractive

Chapter Eight

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