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Profile and Frontal Nasolabial Changes Following Le Fort I Maxillary Advancement or Impaction Surgery

by

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

Master of Science

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To my mother, again you have played an intricate role in my life, as well as Kim's, but especially Mya's. We are all fortunate to have you in our lives, we love you and thank you for helping us realize our dreams.

ABSTRACT

Profile and Frontal Nasolabial Changes Following Le Fort I Maxillary Advancement or Impaction Surgery.

Purpose: To determine if there were any measurable differences in nasolabial soft tissue features between surgical-orthodontic patients who received either maxillary advancement or maxillary posterior impaction in the profile and frontal view.
Methods: Records for 43 patients consisting of 22 patients for the maxillary advancement group, and 21 patients for the maxillary impaction group were obtained from the archives of the graduate orthodontic program, at the University of Manitoba in Winnipeg, Canada. The profile analysis for nasolabial changes was performed on lateral cephalograms before surgery and post-treatment. Changes in soft and hard tissue landmarks were made on an X-Y axis system centered on Sella Turcica. The four profile nasolabial variables included vertical and horizontal changes in pronasale and labrale superious. The four frontal nasolabial variables included alar base width, nose length, upper lip length, and vermillion display which were measured relative to the patient's intercanthal distance from pre-surgical and post-treatment photos in repose. **Results:** *Maxillary Advancement:* The maxillary advancement surgical group had the greatest overall profile and frontal soft tissue changes. All profile variables except vertical height of pronasale showed a statistically significant change ($p<0.05$). Profile nasolabial changes included forward movement of the nasal tip by 2.5 mm, and forward and upward movement of labrale superious by 3.8 mm and 0.6 mm respectively. All frontal variables except upper lip length showed a statistically significant change ($p<0.05$). Significant frontal nasolabial changes included widening of the nasal base by 9% ($p<0.0001$), shortening of the frontal appearance of the nose by 4% ($p<0.05$), and increase in vermillion display by 19% ($p<0.05$). *Maxillary Posterior Impaction:* The maxillary posterior impaction surgical group had the least overall profile and frontal soft tissue changes. All profile and frontal soft tissue nasolabial variables in the maxillary posterior impaction showed no statistically significant changes except alar base which widened by 4% ($p<0.05$).

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CHAPTER 1

INTRODUCTION

1.1 Forward

For more than 30 years, orthodontics with combined orthognathic surgery has been able to improve the quality of life for patients with a dentofacial deformity (Jacobson and Sarver, 2002). Esthetic success is primarily determined by the patient and their expectations are typically very high, a trend that will likely continue due to heightened facial esthetic awareness, perhaps a result of plastic surgery in today's celebrity pop culture and current "makeover" reality television programs.

A Pubmed search with key words "profile" and "orthodontics" resulted in over 20 pages and 500 articles identified. Orthodontists and surgeons are highly concerned with the patient's facial esthetics, possibly now more than ever, due to advances in surgical techniques and an increased esthetic awareness of the general public. A paradigm shift in orthodontics has once again led the specialty to focus on soft tissue esthetics as the main determinant in choosing surgical treatment options. Orthodontists however, evaluate patients in profile to aid in surgical treatment planning, a perspective in which patients rarely observe themselves.

Orthodontics and orthognathic surgery are elective procedures which patients can accept or reject. However, orthodontics and combined orthognathic surgery has gained a greater acceptance level over the last two decades (Romani et al, 1993). A major reason why patients choose to undergo orthognathic surgery versus camouflage is to achieve a positive change in facial esthetics which is often portrayed in modern computer software programs . Patients also accept a surgical orthodontic treatment option based on a combination of esthetics with functional and dental health reasons (Phillips et al, 1995). Perhaps not surprisingly, the most frequently stated motive for accepting a surgical orthodontic treatment plan is due to the advice of an orthodontist (Kiyak et al, 1985). This could be problematic, since professional opinions may not coincide with the patient's self perception and subsequent end treatment expectations. This is further complicated if a chosen surgical treatment option is based solely upon professional advice.

Studies have shown that lay people are more likely to assign normal ratings to various profile drawings (Bell et al, 1985) and of course the corollary being that orthodontists are far more critical in classifying facial profiles that deviate slightly from the ideal (Prahl-Anderon et al, 1979). Correction of a dentofacial deformity may appear significantly improved to the surgeon and orthodontist, but an untrained person may have little appreciation for the result. In fact, it has been reported that some orthognathic surgery patients may even fail to notice major changes in their own appearance or even be disappointed with the end result (Burcal et al, 1987; Tsang et al, 2006).

Typically, following orthognathic surgery the surgeon and orthodontist report an improvement in the patient's profile, and base the success on achieving a more orthognathic profile. Why then do some patients fail to notice this change? Is it simply that they don't ever look at their profile? Perhaps an important question to ask, especially from a patient's standpoint; does a change in profile translate into visible and measurable facial changes in the frontal view? Are there different profile and frontal nasolabial outcomes with different maxillary movements? The frontal view is how we view ourselves in the mirror, and thus any postsurgical changes will first be scrutinized this way by the patient.

There is currently very little literature on changes in frontal features following maxillary surgery, none that compare profile changes following maxillary advancement to maxillary posterior impaction surgeries, let alone frontal soft tissue changes. Perhaps the change in the nose and upper lip are minimal in frontal view compared to a more noticeable change in profile. This information could be useful for the clinician to share with a patient in conjunction with a computer generated profile prediction.

1.2 Objectives

The main objective of this study was to determine if any measurable differences in soft tissue changes (specifically nasal and labial) exist between two different maxillary surgical movements (maxillary advancement and maxillary posterior impaction) in the profile and frontal view. Soft tissue and hard tissue variables for each patient in the two surgical groups were measured before and after surgery within each group and between the two groups. Differences in soft tissue nasolabial characteristics following surgery were expected since the two groups were selected on very different criteria involving surgical manipulation of the maxilla, although, soft tissue responses are not linear and are highly unpredictable (Rosenburg et al, 2002).

1.3 Null Hypotheses

1.3.1 Null Hypothesis H01

There is no significant difference in *profile* nasolabial changes following surgery in the *maxillary advancement group*.

1.3.2 Null Hypothesis H02

There is no significant difference in *profile* nasolabial changes following surgery in the *maxillary posterior impaction group*.

1.3.3 Null Hypothesis H03

There is no significant difference in *frontal* nasolabial changes following surgery in the *maxillary advancement group*.

1.3.4 Null Hypothesis H04

There is no significant difference in *frontal* nasolabial changes following surgery in the *maxillary posterior impaction group*.

1.3.5 Null Hypothesis H05

There is no significant difference in *profile* nasolabial changes following surgery *between the maxillary advancement group and the maxillary posterior impaction group*.

1.3.6 Null Hypothesis H06

There is no significant difference in *frontal* nasolabial changes following surgery *between the maxillary advancement group and the maxillary posterior impaction group*.

CHAPTER 2

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CHAPTER 2

LITERATURE REVIEW

2.1 History of Maxillary Surgery

Maxillofacial surgery is a relatively young specialty of medicine and dentistry. It was not established as an acknowledged specialty until the second half of the 20th century. It was developed by general surgeons with a particular interest in this field and by extremely talented dentists (Hausemen , 2001).

Orthognathic surgery is an original and proper field of maxillofacial surgery. Over the last one hundred years there have been many techniques employed for the correction of dentofacial deformities, the authorships of which were not always clear (Hausemen, 2001). It has been reported that the first Le Fort I osteotomy of the maxilla goes back to Langenbeck in the mid 19th century (1859). In 1864, Cheever reported the Le Fort I osteotomy technique with downfracture in order to resect a nasopharyngeal mass in two patients (Moloney and Worthington, 1981).

Wassmund (1927) described a maxillary osteotomy technique to correct the malposition of a maxilla due to trauma (Hausemen, 2001). However, instead of completely mobilizing the maxilla, he utilized orthopedic traction to position the maxilla postsurgically (Proffit et al, 2003). Then in 1934, a student of Wassmund's named Axhausen first performed a total mobilization of the maxilla (Hausemen, 2001). But it wasn't until 1954 that an American surgeon by the name of Converse, and then again in 1964 by Obwegeser, that detailed reports were provided for describing the surgical techniques for different maxillary osteotomies in the Le Fort I plane (Hausemen, 2001; Proffit, 2003).

Before 1965, correction of dentofacial deformities was performed by mandibular procedures alone, although the skeletal problem may have been due to, in part or completely, a retruded or small maxilla. Important reasearch by Bell in 1969 on the Le Fort 1 downfracture that had been developed in Europe, along with interesting suggestions and efforts regarding planning and performing maxillary orthognathic procedures from Epker, Stoker, Wilmar, and Wolford, led to bimaxillary techniques that now allow surgeons to address the deformity where it truly exists (Hausemen, 2001, Proffit et al, 2003). Although maxillary surgery was introduced in the 1960's, it wasn't until the mid 1980's that maxillary osteotomies were being utilized more routinely for surgical correction of Class III patients, instead of the less stable and less esthetic mandibular setback. By the 1990's, rigid internal fixation (RIF) allowed for greater refinement of orthognathic surgical movements, improved patient's post operative recovery in terms of speech and diet by making immobilization of the jaws with intermaxillary fixation (IMF) unnecessary, and increased longterm stability (Proffit et al, 2003).

Currently, more than 90% of Class III patients have maxillary surgery either alone or in conjunction with mandibular surgery. This change occurred since maxillary surgery either alone or in conjunction with mandibular surgery is more esthetic and stable than a mandibular surgical setback. Combined surgical-orthodontic treatment with conventional techniques or distraction devices can now be applied for correction of any type of dentofacial deformity including the most severe problems (Proffit, 2000; Proffit et al, 2003).

2.2 Prevalence of Dentofacial Deformities

Proffit et al (2003) discussed the difficulty in attaining accurate information on the prevalence of dentofacial deformity, since almost no large scale population data exists. However, by using the data form the large scale evaluation of health of the United States population; the National Health and Nutrition Estimates Survey (NHANES-III) from 1989-94, dentofacial deformities are inferred by estimates of malocclusion from a sample of 14,000 individuals. This sample was to provide weighted estimates for approximately 150 million people in black, white and Mexican ethnic groups between the ages of 8 and 50 years (Proffit et al, 2003).

Dentofacial deformity is inferred from this data set since extreme values for overjet, negative overjet and openbite imply an underlying skeletal Class II, Class III and long face problem respectively. Class II, III and longface problems were categorized as either extreme or severe. Class II individuals had a severe overjet when it was measured at 7 to 10 mm, while extreme overjet was considered to be greater than 10mm for Class II patients. Class III individuals were characterized as having extreme negative overjet if it measure greater than –4 mm, and severe negative overjet if it measured –3 mm to –4 mm. Extreme openbites were grouped as greater than –4 mm, while severe openbites were measured at –3 mm to –4 mm.

Based on the data obtained from the NHANES-III study, it was possible to extrapolate from the information that approximately 2% of the U.S. population has mandibular deficiency or maxillary excess severe enough to be handicapping, about 0.3% have mandibular excess and/or maxillary deficiency this severe, and about 0.3% have a longface deformity. Therefore, approximately 2.6% of the U.S. population studied have facial disproportions and severe malocclusions that would put these individuals into the dentofacial deformity category (Proffit, 2000; Proffit et al, 2003).

2.3 Psychological Implications of Dentofacial Deformity

Over the last couple of decades, there has been a dramatic increase in the number of orthodontic patients, especially adults, choosing orthognathic surgery. Treatment presented by the doctor to the patient must include sufficient information so that the patient can make their own informed decision. This is especially true for combined surgical orthodontic treatment since a change in facial appearance, both positive and negative, can be a very stressful event, especially if a patient is not mentally prepared for such a change (Proffit, 2000; Proffit et al, 2003). Treatment options can be difficult for patients to understand which may result in unattainable presurgical expectations or heightened presurgical anxiety, and have been shown to contribute to postsurgical dissatisfaction (Phillips et al, 1995). Patients may not only experience a psychological disturbance, but they may also express verbal and written complaints, as well as threatened or actual malpractice lawsuits (Flanary, 1992; Chen et al, 2002).

Dentofacial deformities can affect a patient's psyche, particularly the development of body image. It has been reported that a dentofacial deformity can have a greater psychosocial impact on an individual than any other physical deformity. Fortunately, with proper treatment, an individual's life can be positively altered as a result of improving facial and dental appearance (Proffit et al, 2003). Currently, there is an increased interest in studying emotional and behavioral factors that influence the acceptance and response to combined orthodontic-surgical treatment. In one particular study, it has been reported that half the Class III patients had a nickname related to their facial appearance. Many surgical patients reported that their anxiety would have been reduced if they had been able to talk to someone who had undergone a similar orthognathic surgical procedure. (Zhou et al, 2001).

There is a close relationship that exists between facial appearance and psychological parameters such as self-esteem and self-confidence. Severe psychological distress may result if patients dislike their appearance following an orthognathic procedure (Gerzanic et al, 2002). In an early study by Kiyak et al in 1982, it was reported that a high level of neuroticism, and other personality traits studied were predictive of patient dissatisfaction and the development of problems with eating and speech during the early postoperative period.

Another study by Auerbach et al in 1984, found that the postsurgical satisfaction may not correlate with the surgeon's skill as much as it correlates with the level of communication between the surgeon and patient. However, more recent authors have found no significant correlation of personality profiles with patients satisfaction after orthognathic surgery (Bertolini et al, 2000; Scott et al, 2000).

A study by Chen et al (2002) showed that postoperative satisfaction was high and increased with time to reach 86% at 1 year, which was consistent with the range of satisfaction from 84% to 92% that Flanary and Alexander obtained in 1983. In this earlier study, male and female patients had similar rates of satisfaction with surgical outcome, and age and marital status also did not affect outcome. Patients with more education and more severe deformities reported an increase in satisfaction. Patients with a high degree of interpersonal sensitivity deemed by psychologic tests, whose relatives did not support surgery, or who accepted surgery passively tended to be more dissatisfied (Chen et al, 2002).

Gerzanic et al (2002) showed patients with Class III malocclusion felt significantly less attractive, paid more attention to their physical appearance, and had stronger feelings of insecurity regarding their facial appearance compared to patients with Class II malocclusions. Preoperatively Class II and III patients had a similar grading of attractiveness when judged by their relatives and friends. However postoperatively, Class III patients were judged significantly more attractive than Class II patients by their respective friends and family. The study concluded that orthognathic surgery has an overall beneficial effect on Class III patients. Class II patients in contrast, may gain attractiveness but remain unchanged with regard to their body image (Gerzanic et al, 2002).

These results suggest thorough preparation is critical for orthognathic surgery patients, including psychological interviews and a higher level patient-doctor communication prior to surgery, as well as continued counseling after surgery (Chen, 2002). Contact with previous patients may be of benefit and should be suggested routinely rather than waiting for patients to request it (Derwent et al, 2002).

2.4 Indications for Le Fort I Surgery

LeFort I maxillary osteotomies in orthognathic surgery have many indications in combined surgical orthodontic cases. These indications include a concave profile due to a midfacial deficiency beyond the scope and age that would allow for orthopedic correction first described by Delaire (Baccetti et al, 1998). Generally, the indication for surgery is when a dentofacial problem is too severe for successful camouflage, resulting in unstable tooth positions and unaesthetic facial outcomes (failure to camouflage), and when growth modification is no longer a viable option due to growth completion.

Proffit has outlined the limitations of orthodontic treatment in a diagrammatic form he describes as the "envelope of discrepancy" which considers factors such as extent and direction of tooth movement (teeth can be moved further in some directions than others) and the patient's age (for potential growth modification) (Fig. 1). He points out that the envelope of discrepancy sets general limits of the hard tissue movements and does not reflect soft tissue goals, which is a major factor in treatment planning when deciding on orthodontic camouflage or combined surgical-orthodontic treatment (Bailey et al, 1999; Proffit, 2001)

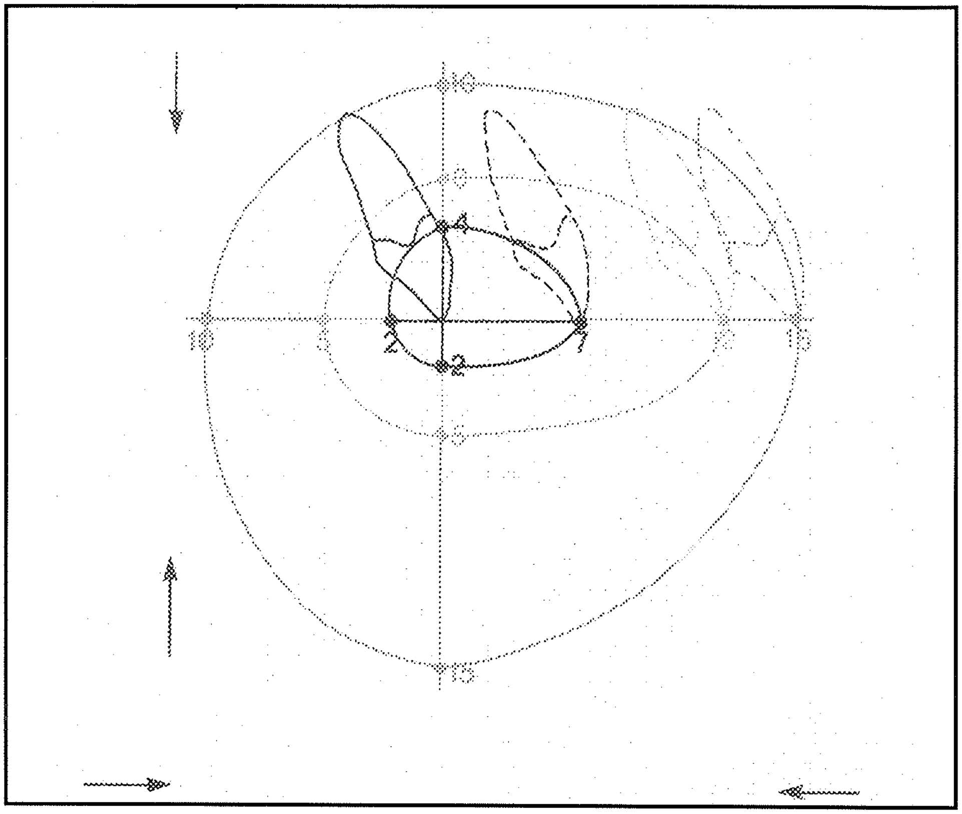

Figure 1. The envelope of discrepancy shows the amount of change that could be produced by orthodontic tooth movement alone (the inner envelope); orthodontic tooth movement combined with growth modification (middle envelope), and orthognathic surgery (outer envelope) (Proffit WR, Fields HW. Contemporary Orthodontics, 3rd ed. St. Louis: Mosby. 2000; p676.).

2.4.1 Maxillary Superior Repositioning (Impaction)

LeFort I maxillary osteotomies with superior repositioning (impaction) have many indications which include the reduction of lip incompetence, excessive gingival display, and increased lower anterior face height, as well as correction of an anterior open bite. The most common soft-tissue changes with Lefort I osteotomies are elevation of the nasal tip with an increase in nasolabial angle, increase in alar base width, shortening of the upper lip, and changes in lip position (Sarver and Weissman, 1991).

Maxillary deficiency is three dimensional, so that the maxilla is narrow transversely relative to the mandible and positioned superiorly, in addition to being deficient anteroposteriorly (Proffit et al, 2003). Excessive anterior maxillary growth resulting in an increase in facial convexity rarely occurs and is usually due to a deficient mandible (Proffit et al, 2003). However, excessive vertical growth with subsequent relative mandibular retrognathia (mandible rotates down and back) is quite common, contributing to a third of Class II skeletal problems. Thus superior repositioning of the maxilla alone, or in conjunction with mandibular bilateral sagittal split osteotomy (BSSO) is required for orthognathic correction (Bailey et al, 2001).

2.4.2 Maxillary Advancement

Maxillary advancement procedures are typically performed in Class III dental and skeletal patients with a retruded or small maxilla and an average size mandible, mandibular prognathism (a two jaw surgery), cleft lip and palate patients, or syndromic Class III dental and skeletal problems such as Crouzon, Apert, Binders, Van der Woude's, Pfeiffer, etc (Figueroa et al, 2004; Cheung et al, 2006; Suda et al, 2006; Boutros et al, 2007).

In Class III patients, it is sometimes difficult, but extremely important to determine in which jaw the skeletal problem lies. This is particularly true for growing patients since surgical procedures have little effect on subsequent growth. If the patient has significant growth remaining, then his or her problem will likely recur if the dentofacial problem is due to excessive growth of the mandible. (Costa et al, 2001; Chang and Tseng, 2006).

Class III patients typically present with two types of dental compensation. They can present with upright or retroclined lower incisors with at least some degree of crowding and upper incisors that are proclined and protruded with spacing or crowding. A Class III dentofacial problem that is mainly due to maxillary deficiency will typically show greater maxillary dental crowding, whereas, excessive mandibular growth will result in greater retroclination and crowding of lower incisors. If maxillary advancement is indicated due to maxillary deficiency, then the surgery can be performed earlier since postsurgical growth of the maxilla will not be a problem, and normal mandibular growth is less likely to undo the surgical correction (Proffit et al, 2003).

2.5 Stability of Le Fort I Surgery

During the last decade, oral and maxillofacial surgeons and orthodontists have increasingly preferred to do a one piece LeFort 1 osteotomy to advance the maxilla. This is done sometimes in isolation to treat maxillary retrusive skeletal Class III patients, or in combination with mandibular surgery to treat various dentofacial deformities (Arpornmaeklong et al, 2003; Arpornmaeklong et al, 2004).

Many studies have investigated the stability of surgical movement of the maxilla and mandible (Bundgaard et al,1986; Bundgaard et al,1986; Costa et al, 2001; Jacobson and Sarver, 2002; Arpornmaeklong et al, 2003; Hoffman and Brennon , 2004). Recently, there has been much focus on the hierarchy of stability in surgical orthodontic treatment. Bailey et al (2004) pointed out that it is highly misleading to use statistics based on normal distribution to describe posttreatment changes, since the mean of a normal distribution is a good indicator of what a given patient would experience (Bailey et al, 2004). Since what is observed in practice is that there is essentially no change in three quarters of the patients who undergo surgery. Thus, the mean is a highly misleading indicator of a typical treatment response (Bailey et al, 2004). She suggested reporting the data in terms of percentage of patients that have changes of a given magnitude. Responses can therefore be grouped as highly stable (less than a 10% chance of a significant posttreatment change; stable (less than a 20% chance of a posttreatment change and almost no chance of a major posttreatment change); stable only if modified with rigid internal fixation; and problematic (a considerable probability of a major posttreatment change).

Superior repositioning of the maxilla is the most stable orthognathic surgery, followed closely by mandibular advancement in patients with short or normal face height and less than 10 mm advancement. These procedures are highly stable and have a 90% chance of less than a 2mm change anterposteriorly, and almost no chance of a >4mm change during the first postsurgical year. Advancement of the maxilla falls into the second category and is described as stable. With forward movement of distances less than 8mm, there is an 80% chance of less than a 2mm relapse, a 20% chance of a 2-4mm relapse, and almost no chance of more than a 4mm relapse. The downward movement of the maxilla falls into the problematic category. If the maxilla is moved both forward and downward, the vertical component has a higher chance of relapse with the horizontal component likely remaining unchanged (Proffit et al, 2003; Bailey et al, 2004). Table 1 summarizes the hierarchy of stability for orthognathic procedures.

	Maxilla up
More	Mandible forward
↑	Maxilla forward
	Mx up + Mn forward
Stable/ Predictable	Mx forward + Mn back
↓	Asymmetry
	Mandible back
	Maxilla down
Less	Maxilla wider

Table 1. Hierarchy of predictability for orthognathic surgical procedures (reproduced from Proffit WR, White RP, Sarver DM. Contemporary Treatment of Dentofacial Deformity. St. Louis: Mosby, 2003 pp288,658.).

2.6 Nasal and Upper Lip Profile and Frontal Responses to Maxillary Surgery

Correction of dentofacial deformities through surgical correction results in major changes in facial appearance. The beneficial facial changes anticipated by the surgeon, orthodontist and patient/parents must be weighed against potential unfavorable changes. The Le Fort I osteotomy is a very common orthognathic procedure to correct dentofacial deformity, and a number of authors have described subsequent adverse findings from this surgery, albeit the esthetic changes are somewhat variable in each study. The postoperative nasolabial changes include widening of the alar bases of the nose, up and forward movement of the nasal tip, flattening and thinning, and/or shortening of the upper lip, and a downward turning of the commissures of the mouth. Although movement of the nasal tip and upper lip has been documented to occur to various degrees during maxillary Le Fort I osteotomies, it is very difficult to predict the extent of change, and even more difficult to surgically control (Carlotti et al, 1986; Mansour et al, 1983; McFarlane et al, 1995; Mommaerts et al, 2000; O'Ryan and Schendel, 1989; Radney and Jacobs, 1981; Schendel et al, 1976; Rosen, 1988; Rosenburg et al, 2002; Sarver and Weissman, 1991; Schendel and Carlotti, 1991; Starck and Epker , 1996; Stella et al,1989; Teitelbaum et al, 2002; Tomlak et al, 1984).

In 1981, Radney and Jacobs evaluated the soft tissue profile response to total maxillary impaction performed to reduce vertical maxillary excess. From the sample size of 10 patients, they used simple and multiple regression equations and found that the nasal tip moved superiorly 1mm for every 6 mm of maxillary intrusion. Freihofer (1977) investigated predicting nasal changes in advancement surgeries in cleft and non-cleft patients and derived an approximate ratio of 2:7 for nasal tip advancement to maxillary advancement. The author cited this was only an approximation due to a small sample size and a number of extreme values. Mansour et al (1983) described the upper lip to move superiorly approximately 40% of the vertical maxillary change and for the advancement group there was a progressive increase in the horizontal soft-tissue movement from the tip of the nose to the free end of the upper lip. This study however, included 14 impaction patients (that also had an anterior component) and 7 advancement patients and could not achieve reliability in predicting the extent of nasal tip movement. McFarlane et al (1995) investigated nasal tip morphology and investigated its importance in determining nasal response with maxillary movement and devised a deflection resistance index (DRI) to be used as a potential indicator of individual nasal tip deflection.

A prospective study by Rosen (1988) of 41 patients made the observation that there had to be anterior advancement of the maxilla for nasal tip elevation, and thus superior repositioning alone would not cause significant nasal tip elevation. It was observed that alar base width increases with either anterior or superior repositioning of the maxilla. Although no significant correlation could be demonstrated for lip shortening, 80 percent of patients who underwent maxillary impaction, had lip shortening ranging from 20 to 50 percent.

A high degree of variation in the literature on nasal changes with maxillary movements led authors to suggest that an understanding of nasal anatomy was important if successful prediction of nasal tip change is desired (Gassman et al, 1989; O'Ryan et al, 1989; Schendel and Carlotti, 1991). Initial studies assessing lip length following maxillary advancement and impaction suggested that the upper lip shortened (Schendel 1976). The cause of lip shortening that was often observed was thought to be due to scarring from the suture technique used at the time, which eventually led to the V-Y closure technique. The V-Y closure technique is believed to maintain lip length, alar base width, and vermillion display (Proffit et al 2003). Schendel (1983) proposed that transected muscles of facial expression resulted in the undesirable nasolabial changes. Guymon, Crosby, and Wolford (1988) suggested that an alar base cinch be performed during surgical closure, since the adverse alar width change is due to alteration of the bony architecture supporting the alar base when the maxilla is repositioned.

2.7 Surgical Treatment Planning with Computer Imaging Prediction Software.

There are several surgical prediction software applications (Dentofacial Planner©, Dolphin's Treatment Planning©, Maxilim©, etc) that provide 2-D and 3-D imaging, but generally lack a scientific basis for many of the soft tissue changes as a result of hard tissue manipulations. Although, this technology has many advantages in that it allows the surgeon, orthodontist, and patient/parent instant visualization for treatment planning and possibly informed consent, it cannot as yet accurately predict the real behavior of individual's unique soft tissue drape. Currently, there is a situation where much more scientific evidence on soft tissue changes during surgery is needed in order to apply it to the progressive software applications that are available today, especially on frontal view (Gladilin et al, 2001; Marchetti et al, 2006)

There is no doubt that 3 dimensional computerized tomography of the hard and soft tissue offers many advantages (primarily visual) compared to the 2-D plane radiographs and photographs, in that there is important volumetric information loss with 2-D (Moyers and Bookstein, 1979). Computerized tomography furnishes large quantities of data which can be highly useful for more complicated surgical cases. However, for more straightforward orthognathic cases, there is typically superfluous data which is never analyzed or interpreted. Furthermore, the valuable data obtained are often difficult to evaluate for quick comparison before and after surgery (Ferrario et al, 1999).

The computerized instrumentation and corresponding software applications are very expensive and there are ethical concerns regarding the unnecessary use of ionizing diagnostic tools in non-surgical patients in order to establish three dimensional norms (although data bases are being compiled on routine orthodontic patients). Three dimensional optoelectric devices that have been developed offer the advantages of being noninvasive and allows for objective evaluation of soft tissue changes before and after surgery. Although, because only soft tissue data is obtained, the relationship of hard tissue to soft tissue change during surgery in three dimensions is unavailable with this technique (Ferrario et al, 1999).

The main function of surgical prediction software is to allow the surgeon to experiment with different surgical procedures (maxillary advancement, impaction, grafts, etc.) in a virtual simulated environment in order to evaluate generalized esthetic outcomes before the actual surgery. This can be extremely useful in clinical practice and has shown to be relatively reliable for surgical predictions (Marchetti et al, 2006). However, more refined facial changes such as alar base widening, nasal tip elevation, and vermillion changes are often indiscriminately overlooked. If relationships of soft tissue change to different surgical manipulations can be found, then this information could prove to be very useful in surgical treatment planning and more relevant to patient's actual results thereby meeting their esthetic expectations.

CHAPTER 3

MATERIALS AND METHODS

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CHAPTER 3

MATERIALS AND METHODS

3.1 Sample Selection

This was a retrospective study that consisted of a final patient sample of 43 patients who had undergone a Le Fort I osteotomy and maxillary repositioning. The records utilized from the patients charts consist of pre-surgical and post-treatment lateral cephalograms, and frontal photos with patients smiling and in repose. Patient records were obtained from the archives of the graduate orthodontic program, at the University of Manitoba in Winnipeg, Canada. Of 126 charts collected, only 50 could be utilized due to not meeting specific inclusion criteria (for example; a multiple piece maxilla may have been performed, patients with asymmetries or syndromes were eliminated, or there were missing or incomplete records) and subdivided into two groups of 25 patients each, consisting of a maxillary advancement group, and a posterior maxillary impaction group.

Subsequently, charts that didn't meet the specific inclusion criteria (3.1.1) for either group with respect to surgical maxillary movements (showed elements of both an impaction and advancement) were eliminated to give a final sample of 22 patients for the maxillary advancement group, and 21 patients for the maxillary impaction group. Surgery was performed between 1990 and 2006 on all patients at the Health Sciences Center in Winnipeg, Manitoba, Canada by the same oral and maxillofacial surgeon and resident staff. Patient consent was obtained and permission from the Research Ethics Board at the University of Manitoba was granted (Protocol Reference Number: H2005:211).

3.2 Inclusion Criteria and Exclusion Criteria

The selected charts consisted of well documented cases consisting of 43 Caucasian patients. All patients received preoperative and postoperative orthodontic treatment and were categorized to the advancement or impaction group based upon the horizontal movement of the central incisal edge and the change in palatal plane angulation before and after surgery. Patients in the maxillary advancement group were selected based on a maxillary incisor advancement of 3mm or greater measured by the change in horizontal forward movement of the upper central incisal edge between presurgery and post-treatment (change in I-Y $\geq$ 3mm), a change in the vertical position of the upper incisal edge of 2mm or less (change in I-X $\leq$ 2mm), and a change of palatal plane to the X-axis of less than 3 degrees (change in PP-X $< 3°$). The maxillary posterior impaction group had a maxillary advancement of less than 3mm (change in I-Y $<$ 3mm), a change in the vertical position of the upper incisal edge of 2mm or less (change in I-X $\leq$ 2mm), and a greater differential posterior impaction component measured by a change in palatal plane greater than 3 degrees (change in PP-X $> 3°$).

The patients had complete presurgical and post-treatment (deband) records including photos that were in focus and cephalograms that were of high quality such that soft tissue could be easily identified and the perioral soft tissue relaxed. The patients were excluded if they had undergone any maxillary surgery in which the maxilla was inferiorly positioned or had been segmented during surgery, as well as any advancement of the maxilla greater than 10 mm. Patients were excluded if adjunctive rhinoplasty was performed in conjunction with the orthognathic surgery or if facial asymmetries were present. Any patients with dentofacial deformities such as cleft lip and/or palate, craniofacial synostosis, or syndromes were also excluded.

3.3 Le Fort I Surgery

The total sample was operated on by one surgeon and resident staff, thereby minimizing inter-operator variability and the Le Fort I technique was done in a conventional way. Under general anesthesia, local anesthetic was infiltrated into the vestibular tissue along maxillary surface to provide soft tissue anesthesia and to minimize bleeding. The horizontal incision was made high on the vestibule and extended from first molar on one side to the first molar on the other side with subperiosteal degloving including the nasal spine and rim of the piriform aperture for maximum soft tissue retraction. The lateral wall of the maxilla was exposed superiorly with a periosteal elevator from the zygomatic maxillary buttress to the anterior nasal spine. The osteotomy was then performed through the lateral wall of the maxillary sinus, rim of the piriform aperture, nasal septum, and the pterygoid plates. The maxilla was then mobilized, repositioned according to the treatment protocol and fixed with transosseous rigid internal fixation (RIF) with contoured plates and additional wire osteosynthesis. An alar base cinch suture was placed, then the incision was closed with a continuous suture and a V-Y (the "V" shaped wound in the vestibule is closed with a "Y", with the base of the

"Y" in the midline of the upper lip) closure technique was performed in the midline. The anterior nasal spine was resected in some patients which were not specified.

3.4 Cephalometric Analysis and Acquisition of Data

The various landmarks that were used in this study to determine linear and angular measurements are defined in Table 2. The measurements were recorded on the custom-made Profile Analysis- Lateral Cephalogram form (Table. 3) and the Frontal Analysis form (Table. 4). The profile analysis was performed on lateral cephalograms before and after surgery, and changes in soft and hard tissue landmarks were made on an X-Y axis system previously published by Rosenberg et al (2002). The X-axis runs through Sella at 7 degrees from Sella-Nasion (SN) which represents an alternative for the Frankfort Horizontal (FH) line (McFarlane 1995, Rosenberg et al 2002), then a Y-axis was constructed at 90 degrees to the X-axis. Vertical changes in Pronasale (Pn-X) (Fig. 2), Labrale Superious (Ls-X) (Fig. 3), and the incisal edge (I-X) (Fig. 4) were measured in relation to the X-axis. These linear vertical measurements as well as two angular measurements which include the upper incisor angulation (UIA) and the palatal plane (PP-X) (Fig. 5) were also recorded relative to the X-axis on the Profile Analysis. Horizontal changes on the Profile Analysis form were made relative to a Y-axis that runs down from the X-axis at Sella. The measurements made relative to the Y-axis included Pronasale (Pn-Y) (Fig. 2), Labrale Superious (Ls-Y) (Fig. 3), and the incisal edge (I-Y) (Fig. 4). The patient's sex and treatment time (in months) was also recorded on the Profile Analysis at presurgery and post-treatment.

The Frontal Analysis was performed for all patients at presurgical records and at deband. All facial photos were taken at approximately 2 feet by one of three assistants at the graduate orthodontic clinic at the University of Manitoba. Only the frontal photo at repose was used to record frontal nasal and labial changes. The intercanthal distance (ICD) of the patients at presurgery and post-treatment photos were recorded and used to standardize linear measurements made on the photos. The frontal features recorded included alar base width (Alae-Alae/ICD), nose length (Nose Length/ICD) (Fig. 6), lip length (Upper Lip Length/ICD), and vermillion (Vermillion Display/ICD) (Fig. 7).

All cephalograms were taken with the same radiographic unit (Gendex Gx 900 @ 90 KVp) at the graduate orthodontic clinic. Nasal and upper lip profile characteristics, such as nasal tip projection and elevation, and upper lip changes were evaluated cephalometrically by superimposing on a maximum of structures in the anterior cranial base. Linear horizontal and vertical measurements were taken with reference to the X and Y axis. Angular measurements were also recorded for the palatal plane and upper incisor. Frontal photos were taken by one of three photographers at approximately the same distance of 30 cms. However, in order to account for minor differences in distance between the presurgical and postreatment photos, the measurements of frontal features were taken as a ratio of the patient's intercanthal distance and recorded as a percentage on the Frontal Analysis form. The measurements were taken by one evaluator with a Chicago Brand ™ Digital Caliper in millimeters to the one hundredth decimal place, and a protractor for angular measurements. Pre-surgical and post-treatment measurements were taken for all 12 variables for each of the 43 patients, for a total of 1032 recordings.

3.5 Reliability

The reproducibility of measurements was assessed by repeating 20 analyses on 10 patients of the studied sample (10 profile analysis forms each with 8 variables, and 10 frontal analysis forms each with 4 variables) which were randomly chosen for re-evaluation by the same principle examiner. The profile and frontal analysis were repeated 6 weeks following the initial measurements taken. Intra-examiner calibration was verified by Intra-class Correlation coefficients (ICC) with it's 95% confidence interval.

3.6 Statistical Analysis

Statistical significance was determined for each profile and frontal variable (8 profile and 4 frontal) following surgery within each patient surgical group and between groups. Unpaired *t*-tests were used to determine statistical significance in changes recorded following surgery for each variable between the maxillary advancement and maxillary posterior impaction surgical groups. Repeated measures analysis of variance (ANOVA) was performed to determine if interactions exists between the two groups over time for each variable. Finally, when interactions are significant, a pair wise comparison was performed to compare differences in pre-surgical and post-treatment changes for each variable within and between the two groups. Significance level was set at $p=0.05$.

Table 2. Cephalometric landmarks and definitions.

Ala- the flaring cartilaginous expansion forming the outer side of each of the nares.

Intercanthal distance- the distance in mms between the angle formed by the meeting of the upper and lower eyelids at the medial aspect of the eye.

Labrale superious (Ls) – the mucocutaneous junction of the upper lip (usually the most anterior point).

Nasion (N) – the most anterior point of the fronto-nasal suture.

Nose Length- the vertical linear distance measured from the mid intercanthal line to the most inferior part of the columella of the nose.

Pronasale (Prn) – the most anterior point of the nose.

Sella-nasion (SN) – a horizontal line constructed between S and N.

Sella Turcica (S) – the geometric center of the pituitary fossa.

Stomion Superious (Stms) – the most inferior point of the upper lip.

Upper Incisor Angulation (UIA) – Angle formed by the upper incisor and cranial base SN

Upper Incisal Edge (I) – the most inferior anterior point on the incisal edge.

Upper Lip Length- the vertical linear distance from the most inferior part of the columella of the nose to the vermillion in the center of the cupids bow.

Vermillion Display- the red margin of the upper lip measured as the vertical linear distance between the center of the cupids bow to stomion superious.

X-Axis – a horizontal reference line constructed at 7 degrees above sella-nasion at nasion

Y-Axis- a vertical reference line constructed 90 degrees to the X-axis at Sella.

Table 3. Profile Analysis form to record measurements taken from the lateral cephalogram.

Profile Analysis - Lateral Cephalogram

Patient # ____

Max advance (Group 1)/ Max post impact (Group 2)

Upper premolar : *non exo* **or** *exo*

	Pre-Sur	Post-Tx
Pn-X (Vert mm)		
Pn-Y (Horiz mm)		
Ls-X(Vert)		
Ls-Y(Horiz)		
I-X(Vert)		
I-Y(Horiz)		
UIA-X		
PP-X		
Time(mo)		

Table 4. Frontal Analysis form to record nasal and labial measurements.

Frontal Analysis

Patient # ____

Pre-Surg Intercanthal Distance (ICD) ____
Post-Tx Intercanthal Distance (ICD) ____

	Pre-Sur mm-%	Post-Tx mm-%
Ala-Ala/ICD		
Nose Length/ICD		
Upper lip Length)/ICD		
Vermillion Display/ICD		

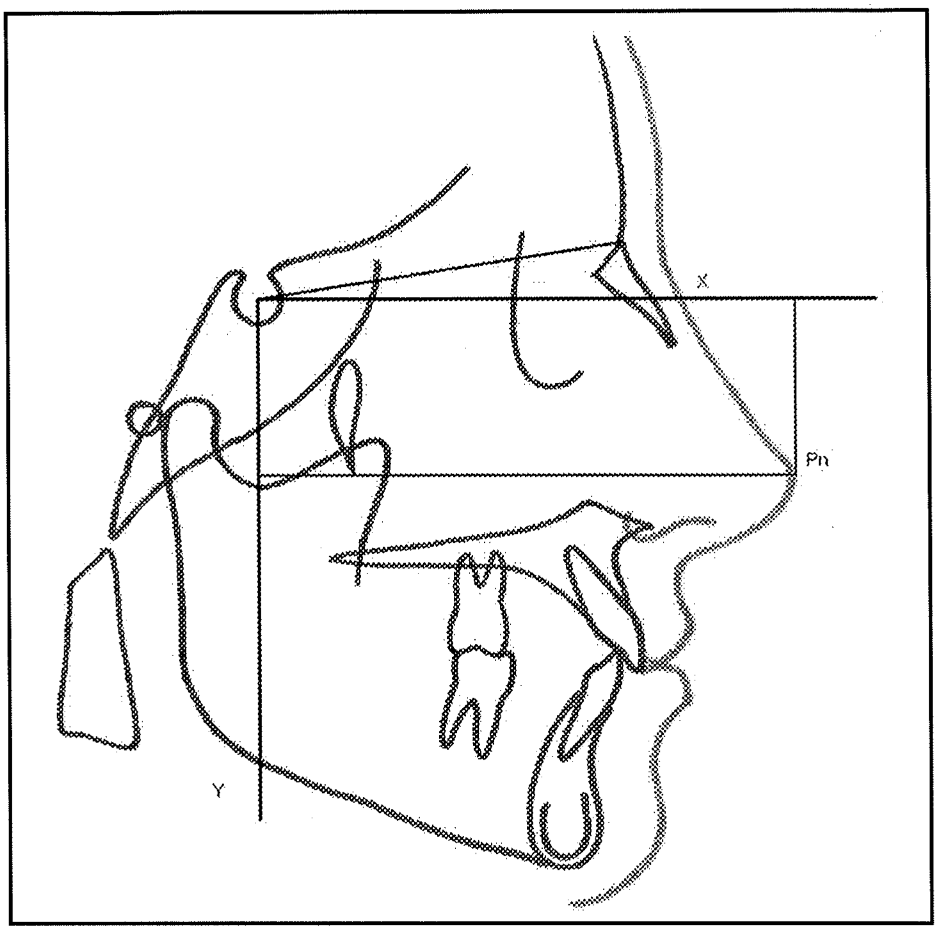

Figure 2. X-Y axis was used to record vertical changes in Pronasale relative to the X-axis (Pn-X) and horizontal changes relative to the Y-axis (Pn-Y).

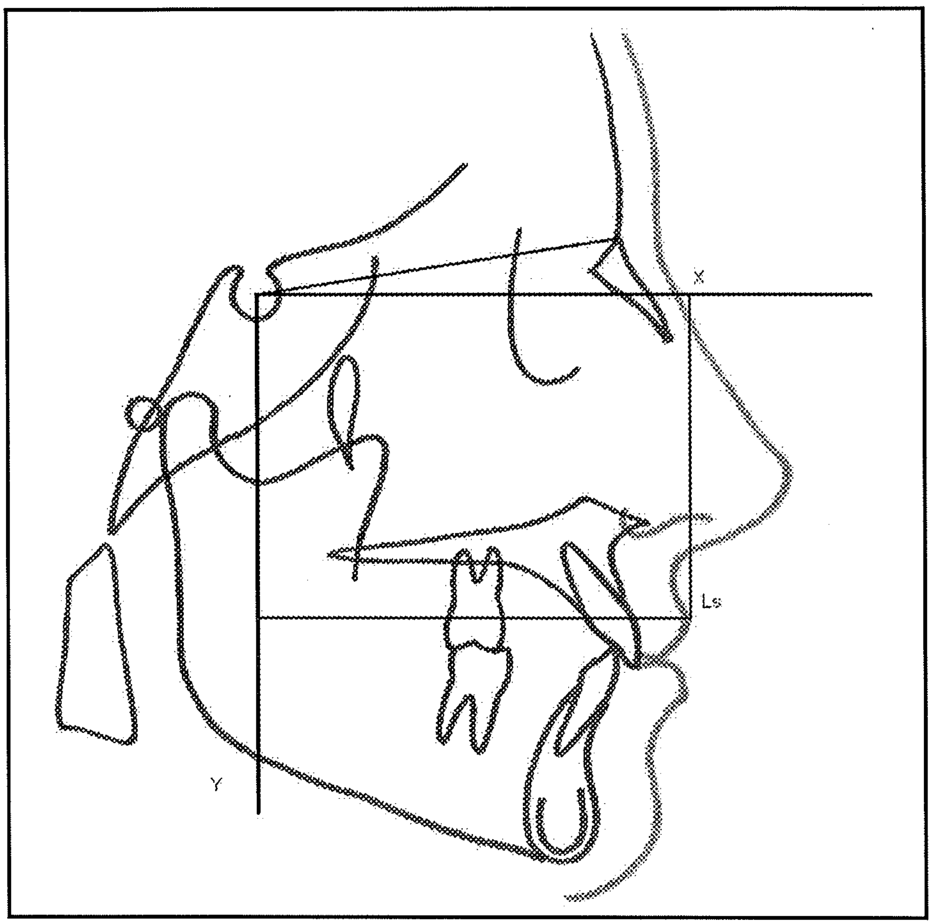

Figure 3. X-Y axis was used to record vertical changes in Labrale Superious relative to the X-axis (Ls-X) and horizontal changes relative to the Y-axis (Ls-Y).

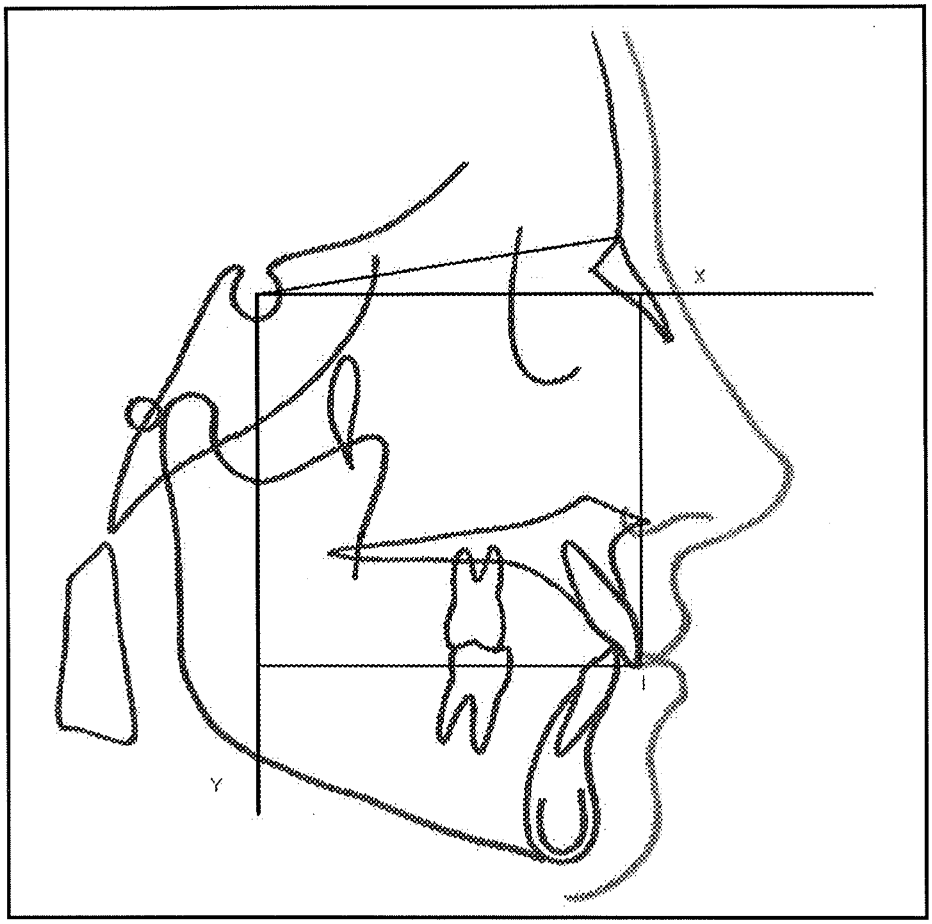

Figure 4. X-Y axis was used to record vertical changes in the upper incisal edge relative to the X-axis (I-X) and horizontal changes relative to the Y-axis (I-Y).

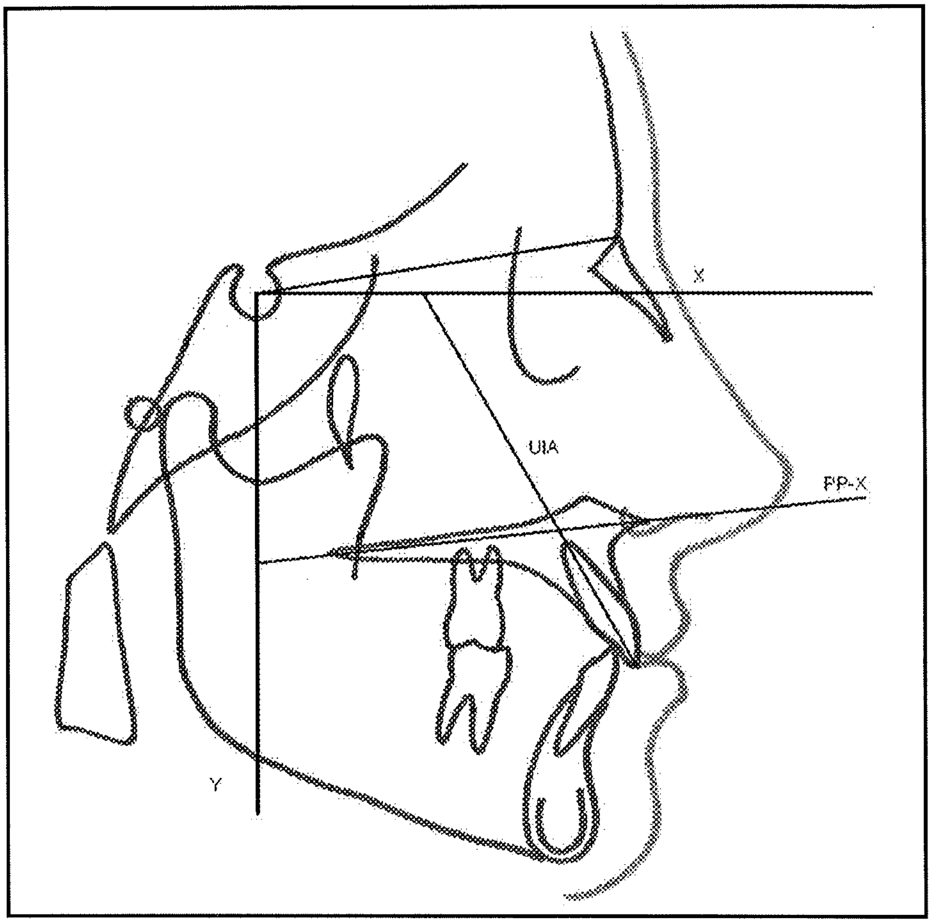

Figure 5. Two angular measurements which include the upper incisor angulation (UIA) and the palatal plane (PP-X) were recorded relative to the X-axis.

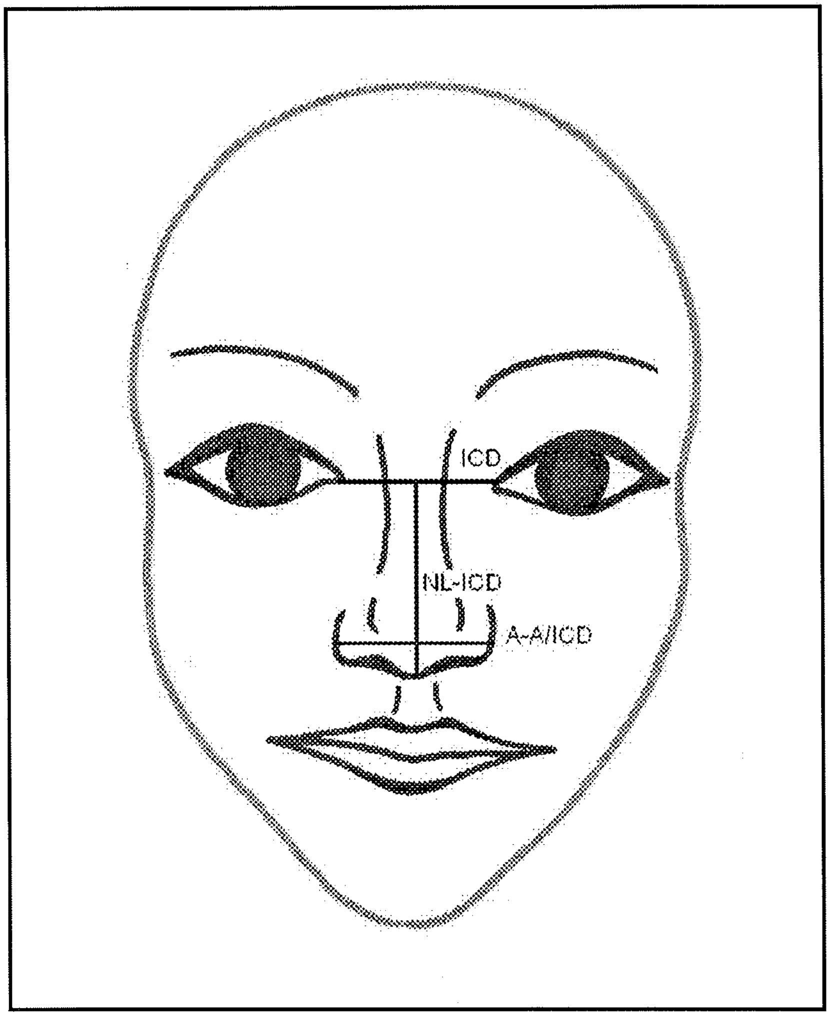

Figure 6. The intercanthal distance (ICD) of the patients at presurgery and post-treatment photos were recorded and used to standardize linear measurements made on the photos. The frontal nasal features recorded included alar base width (A-A/ICD), nose length (NL/ICD).

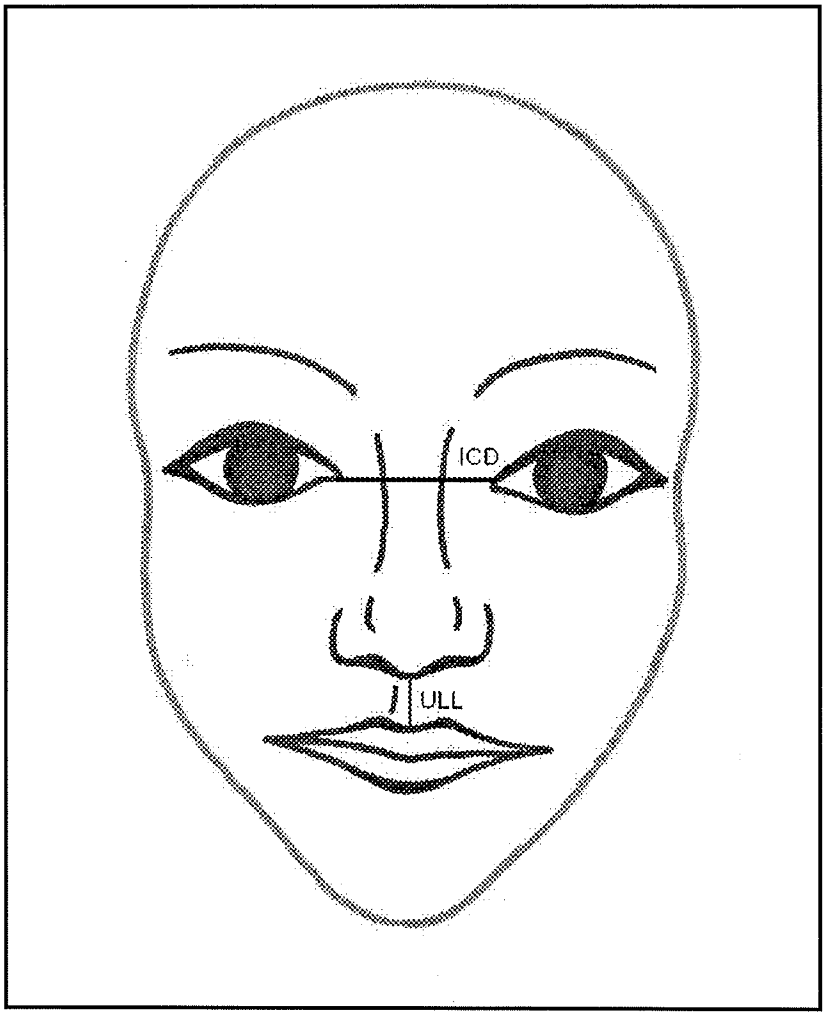

Figure 7. Upper Lip Length (ULL) was recorded relative to the intercanthal distance (ICD) on the Frontal Analysis.

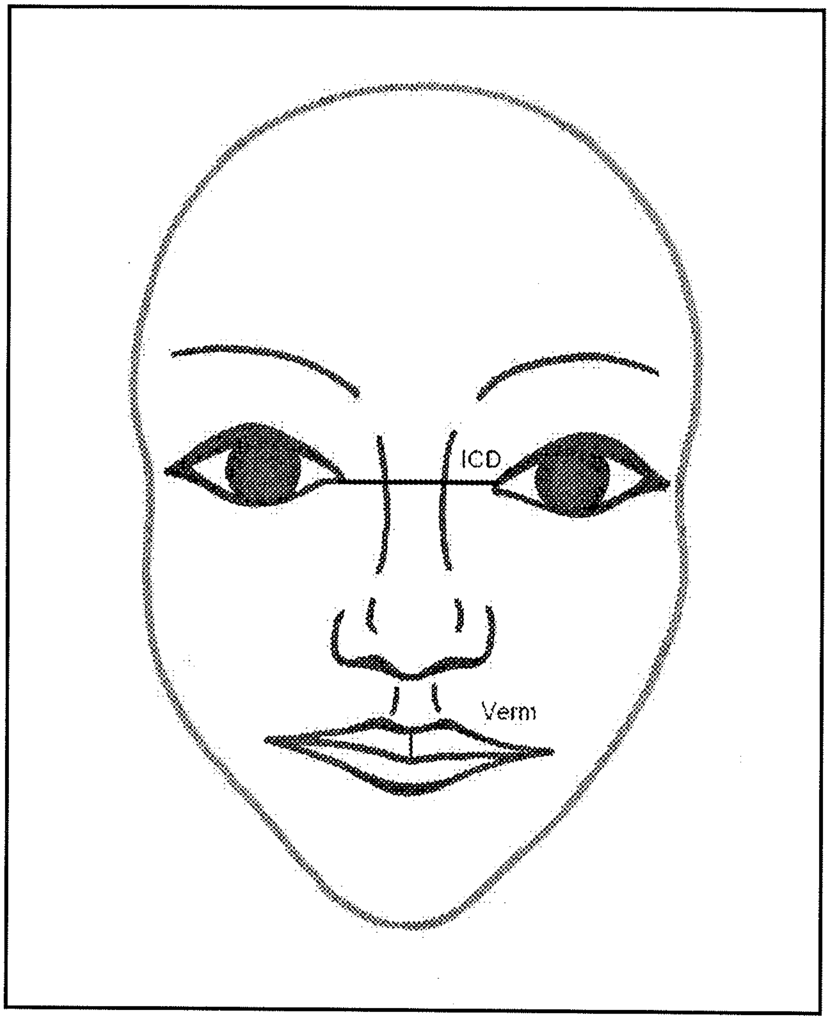

Figure 8. Vermillion display (Verm) was recorded relative to the intercanthal distance (ICD) on the Frontal Analysis.

CHAPTER 4

RESULTS

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CHAPTER 4

RESULTS

4.1 Calibration

Intra-examiner calibration was verified by Intra-class Correlation coefficients (ICC) and set at 95% agreement. ICC values for cephalometric and photographic measurements by the operator are listed in Table 5. All measurements demonstrated reliability and reproducibility above 95%.

Table 5. Repeated measurements taken from 10 randomly selected patients to determine intra-class correlation coefficients (ICC) set at 95% confidence limits.

Measurements	ICC	95% Confidence Limits
Pn-X	0.9925	0.9458 - 0.9992
Pn-Y	0.9793	0.9629 - 0.9840
I-X	0.9967	0.9758 - 0.9996
I-Y	0.9960	0.9710 - 0.9996
Ls-X	0.9987	0.9901 - 0.9999
Ls-Y	0.9876	0.9118 - 0.9987
UIA	0.9888	0.9204 - 0.9988
PP-X	1	
Alae/Alae	0.9798	0.9619 - 0.9846
Nose Length	0.9634	0.9288 - 0.9731
Upper Lip Length	0.9716	0.9407 - 0.9867
Vermillion	0.9665	0.9334 - 0.9806

4.2 Sample Description

The maxillary advancement group consisted of 8 males and 14 females (n=22) with a mean age of 22.1 years (SD= 5.6 years), a mean orthodontic treatment time prior to surgery of 12.2 months (SD= 6.8 months), and a mean total active treatment time of 30.7 months (SD= 7.7 months). The maxillary impaction group consisted of 7 males and 14 females (n=21) with a mean age of 22.6 years (SD= 6.3 years), a mean orthodontic treatment time prior to surgery of 15.0 months (SD= 8.2 months), and a mean total active treatment time of 32.7 months (SD= 7.9 months). The pre-surgical orthodontic treatment time and total active treatment time was slightly longer (by 2.8 months and 2 months respectively) for the maxillary posterior impaction group.

4.3 Profile Analysis

4.3.1 Vertical Changes in Pronasale (Pn-X)

This variable in the vertical plane showed a non significant decrease ($p>0.05$) in the maxillary advancement group following surgery from a mean (x) of 39.57mm (SD=4.10mm) at pre-surgical to 37.94mm (SD=4.29mm) at post-treatment, with a mean change (Δ) of -1.64mm (SD 1.31mm). There was also no statistically significant difference ($p>0.05$) in the vertical position of pronasale in the maxillary impaction group following surgery although in contrast to the maxillary advancement group, an increase was noted from 38.38mm (SD=4.04mm) at pre-surgical to 41.21mm (SD=15.32mm) at post-treatment, a change of 2.83mm (SD=15.19mm) ($p>0.05$). The changes (Δ) that occurred between the two surgical groups, although in different directions, were not statistically significant ($p>0.05$) (Fig. 9).

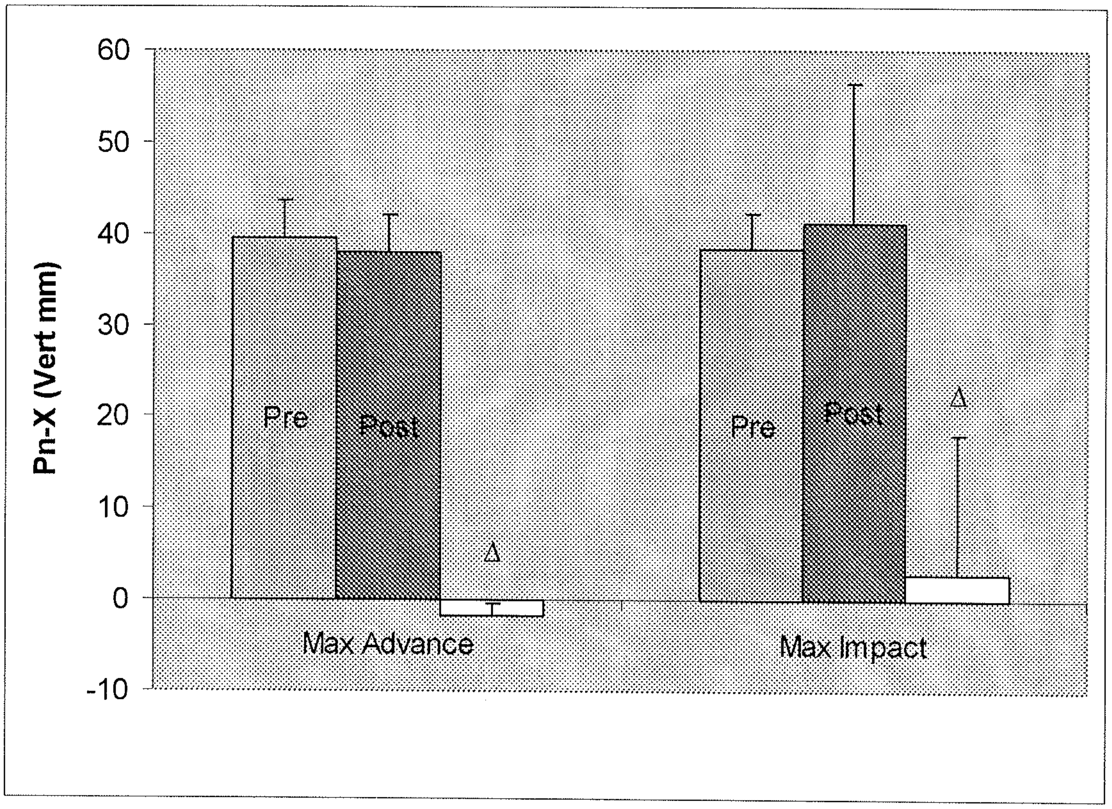

Figure 9: The mean positions and mean differences of Pn-X (Vert mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.2 Horizontal Changes in Pronasale (Pn-Y)

Horizontal changes in pronasale showed a highly statistically significant increase in the maxillary advancement group following surgery, from 102.44mm (SD=5.35mm) at pre-surgical to 104.94mm (SD=5.59mm) at post-treatment ($p<0.0001$), with a mean change (Δ) of 2.50mm (SD 1.07mm). However, there was no statistically significant difference in the horizontal position of pronasale in the maxillary impaction group following surgery, from 105.17mm (SD=4.33mm) at pre-surgical to 105.67mm (SD=4.30mm) at post-treatment, a change of 0.50mm (SD=0.88mm) ($p>0.05$). The changes (Δ) that occurred between the two surgical groups were highly statistically significant ($p<0.0001$) (Fig. 10).

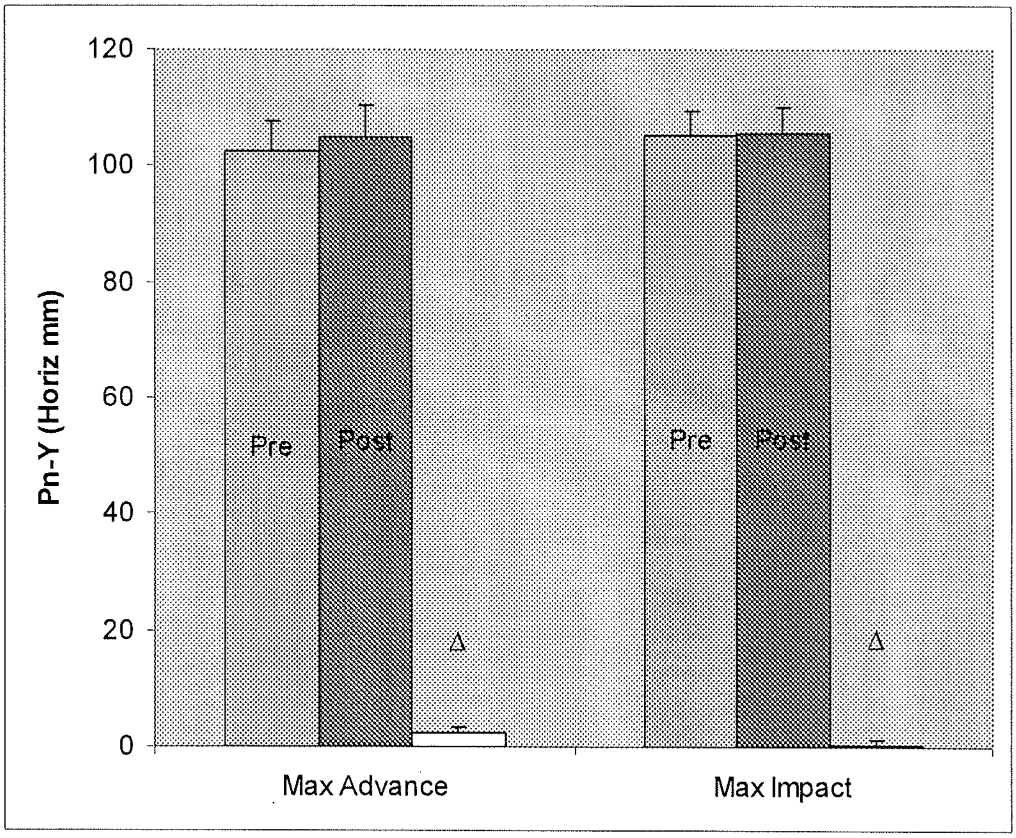

Figure 10: The mean positions and mean differences of Pn-Y (Horiz mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.3 Vertical Changes in Labrale Superious (Ls-X)

Vertical changes in this variable showed a statistically significant decrease ($p=0.0173$) in the maxillary advancement group following surgery from 66.81mm

(SD=4.89mm) at pre-surgical to 66.19mm (SD=4.54mm) at post-treatment, with a mean change (Δ) of -0.624mm (SD 0.99mm). However, there was no significant difference in the vertical position of labrale superious in the maxillary impaction group following surgery from 68.14mm (SD=5.45mm) at pre-surgical to 68.65mm (SD=6.07mm) at post-treatment, a change of 0.51mm (SD=1.35mm) (p=0.053). The changes (Δ) that occurred between the two surgical groups were highly statistically significant (p<0.003) (Fig. 11).

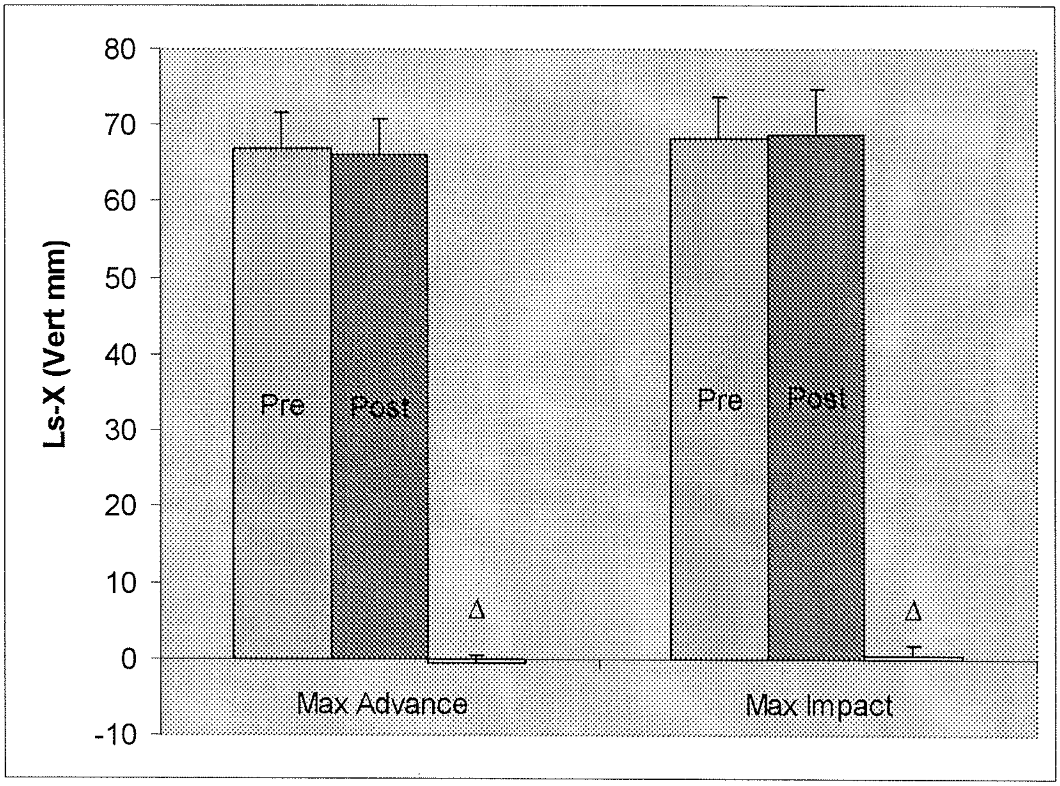

Figure 11: The mean positions and mean differences of Ls-X (Vert mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.4 Horizontal Changes in Labrale Superious (Ls-Y)

Horizontal changes in this variable showed a highly statistically significant increase (p<0.0001) in the maxillary advancement group following surgery from

86.61mm (SD=5.48mm) at pre-surgical to 90.36mm (SD=6.04mm) at post-treatment, with a mean change (Δ) of 3.76mm (SD 1.69mm). However, there was no significant difference in the horizontal position of labrale superious in the maxillary impaction group following surgery from 88.57mm (SD=4.27mm) at pre-surgical to 88.05mm (SD=3.83mm) at post-treatment, a change of -0.52mm (SD=1.99mm) ($p=0.21$). The changes (Δ) that occurred between the two surgical groups were highly statistically significant ($p<0.0001$) (Fig. 12).

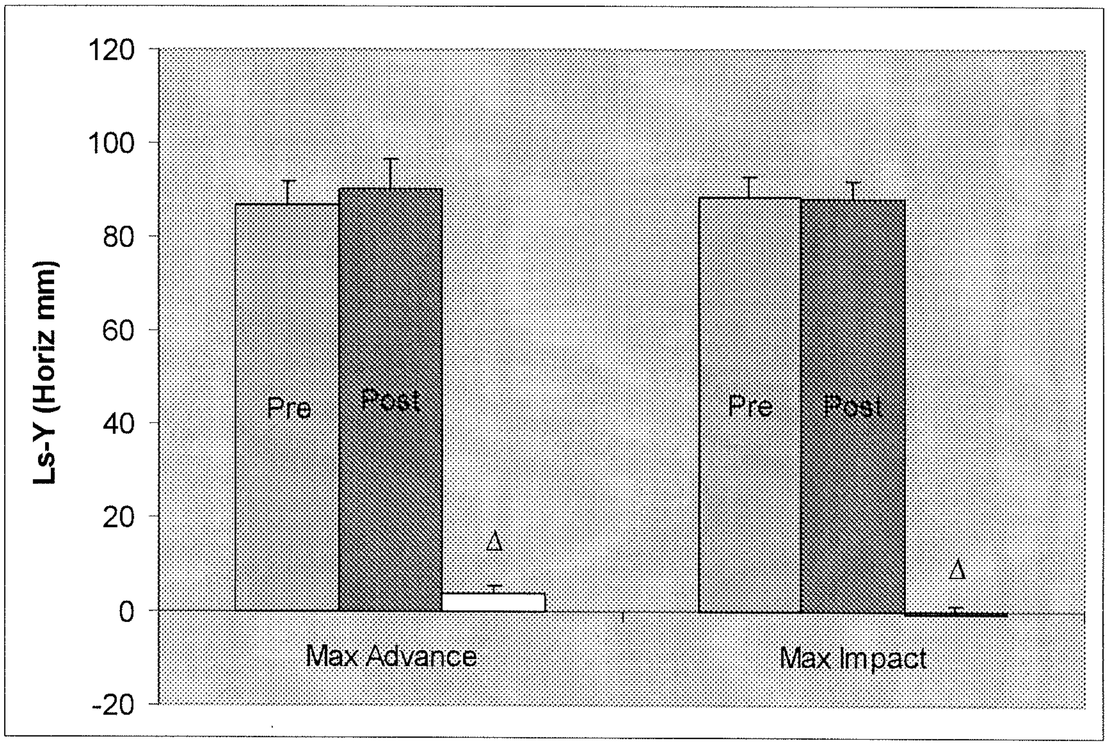

Figure 12: The mean positions and mean differences of Ls-Y (Horiz mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.5 Vertical Changes in Upper Central Incisal Edge (I-X)

Vertical changes in this variable showed a highly statistically significant decrease ($p<0.0013$) in the maxillary advancement group following surgery from 78.29mm

(SD=5.55mm) at pre-surgical to 77.58mm (SD=5.62mm) at post-treatment, with a mean change (Δ) of -0.71mm (SD 0.95mm). There was also a significant difference in the vertical position of upper central incisal edge in the maxillary impaction group following surgery from 78.91mm (SD=5.36mm) at pre-surgical to 78.18mm (SD=5.52mm) at post-treatment, a change of -0.73mm (SD=0.98mm) ($p<0.0013$). The changes (Δ) that occurred between the two surgical groups were not statistically significant ($p>0.05$) (Fig. 13).

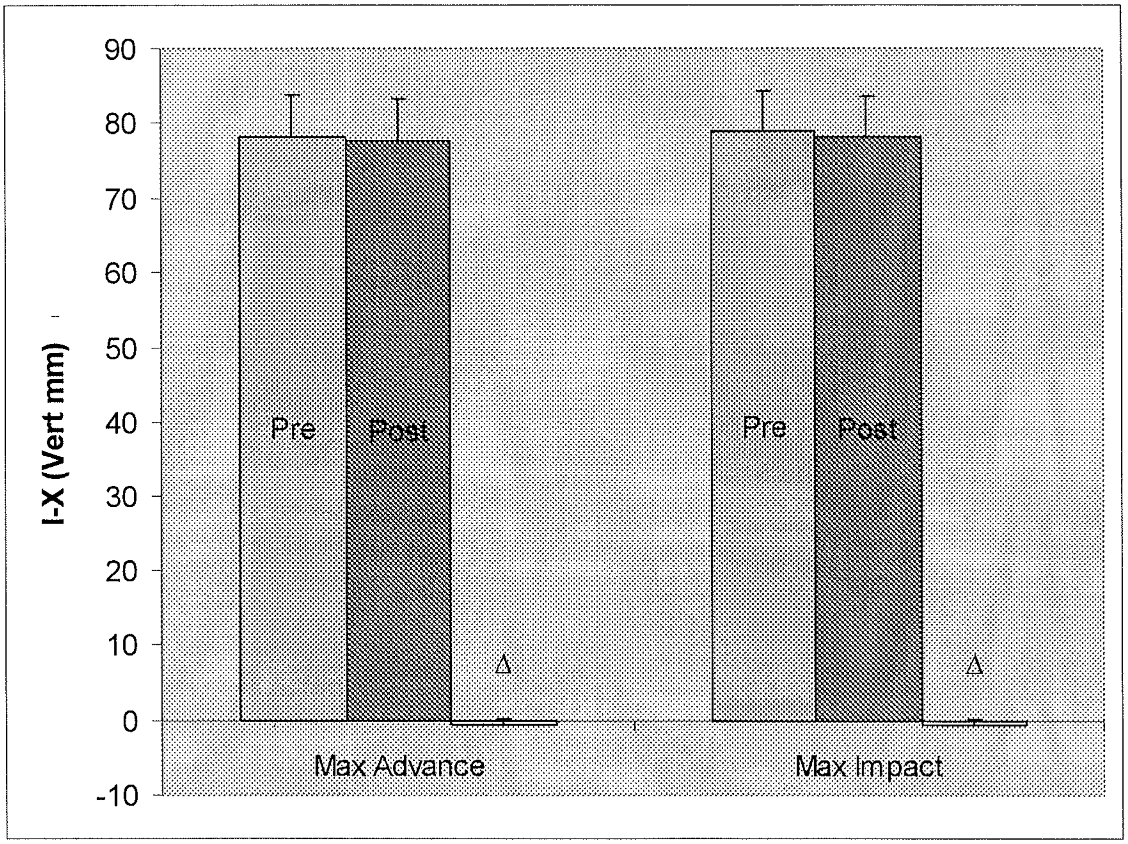

Figure 13: The mean positions and mean differences of I-X (Vert mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.6 Horizontal Changes in Upper Central Incisal Edge (I-Y)

Horizontal changes in this variable showed a statistically significant increase ($p<0.05$) in the maxillary advancement group following surgery from 71.64mm (SD=6.87mm) at pre-surgical to 75.15mm (SD=11.86mm) at post-treatment, with a mean change (Δ) of 3.51mm (SD 5.62mm). There was no statistically significant difference in the horizontal position of upper central incisal edge in the maxillary impaction group following surgery from 74.71mm (SD=4.38mm) at pre-surgical to 74.51mm (SD=4.20mm) at post-treatment, a change of -0.20mm (SD=1.45mm) ($p>0.05$). The changes (Δ) that occurred between the two surgical groups were also statistically significant ($p<0.05$) (Fig. 14).

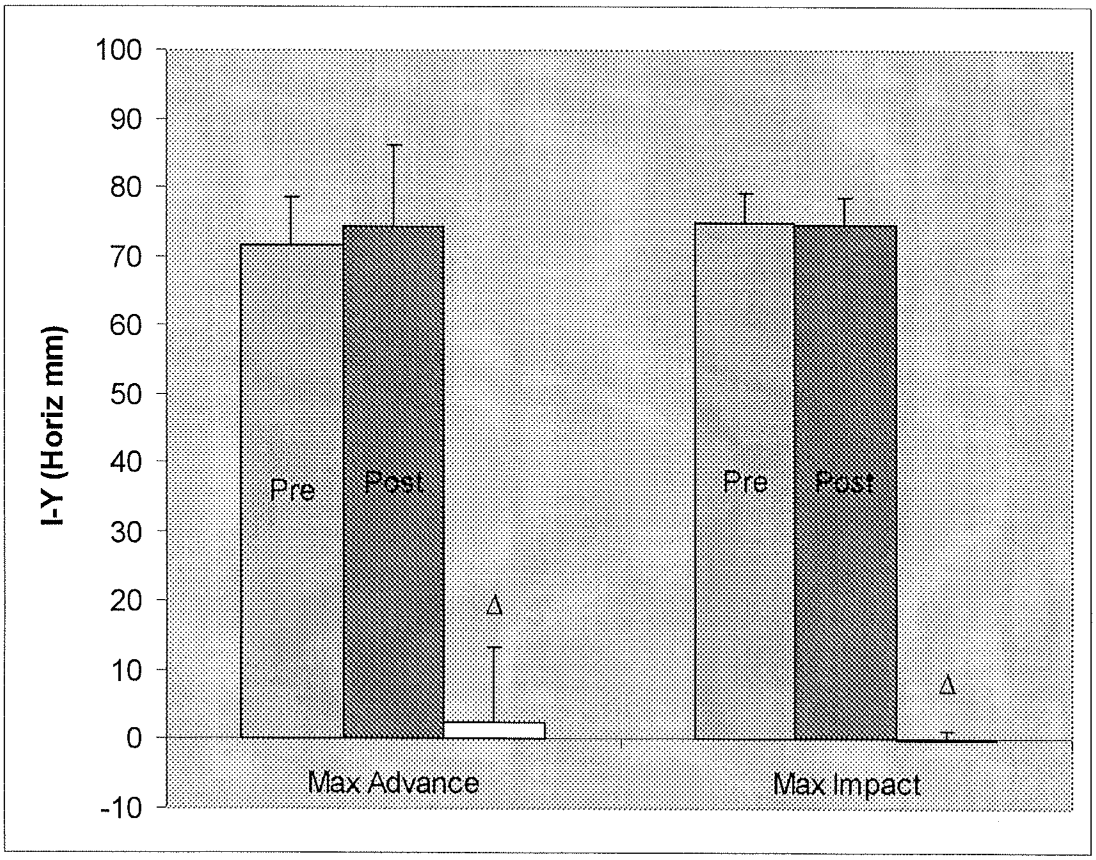

Figure 14: The mean positions and mean differences of I-Y (Horiz mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.7 Upper Central Incisor Angle (UIA-X)

Angular changes in this variable showed no statistically significant difference (p=0.39)in the maxillary advancement group following surgery from 110.09° (SD=5.67°) at pre-surgical to 110.95° (SD=6.81°) at post-treatment, with a mean change (Δ) of 0.86° (SD 5.46°). However, there was a highly statistically significant decrease in angulation of the upper central incisor in the maxillary impaction group following surgery from 111.81° (SD=5.33°) at pre-surgical to 104.90° (SD=5.49°) at post-treatment, a change of -6.91° (SD=3.73°) (p<0.0001). The changes (Δ) that occurred between the two surgical groups were also highly statistically significant (p<0.0001) (Fig. 15).

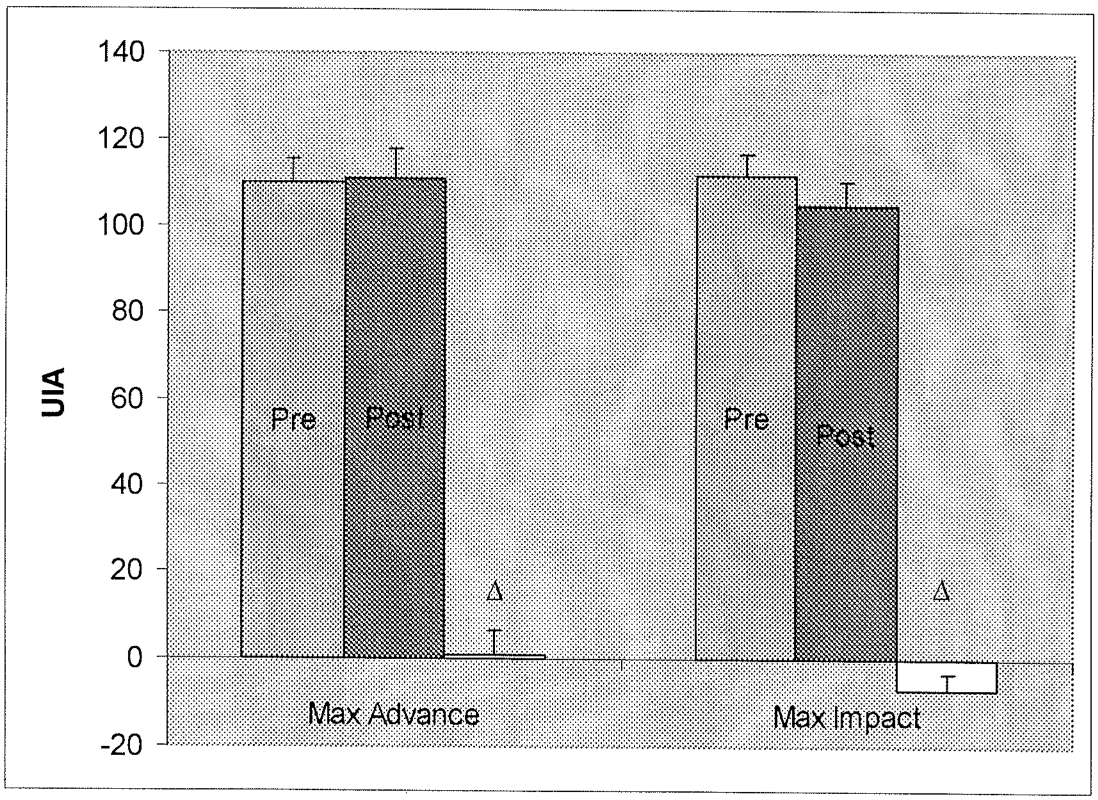

Figure 15: The mean positions and mean differences of UIA pre-surgery and post-treatment. Error bars represent the standard deviation.

4.3.8 Palatal Plane Angle (PP-X)

Angular changes in this variable showed no statistically significant difference ($p=0.26$) in the maxillary advancement group following surgery from 0.36° (SD=2.50°) at pre-surgical to 0.82° (SD=2.67°) at post-treatment, with a mean change (Δ) of 0.45° (SD 1.53°). However, there was a highly statistically significant increase in angulation of the palatal plane in the maxillary impaction group following surgery from –0.24° (SD=2.47°) at pre-surgical to 5.67° (SD=3.57°) at post-treatment, a change of 5.91° (SD=1.92°) ($p<0.0001$). The changes (Δ) that occurred between the two surgical groups were also highly statistically significant ($p<0.0001$) (Fig. 16).

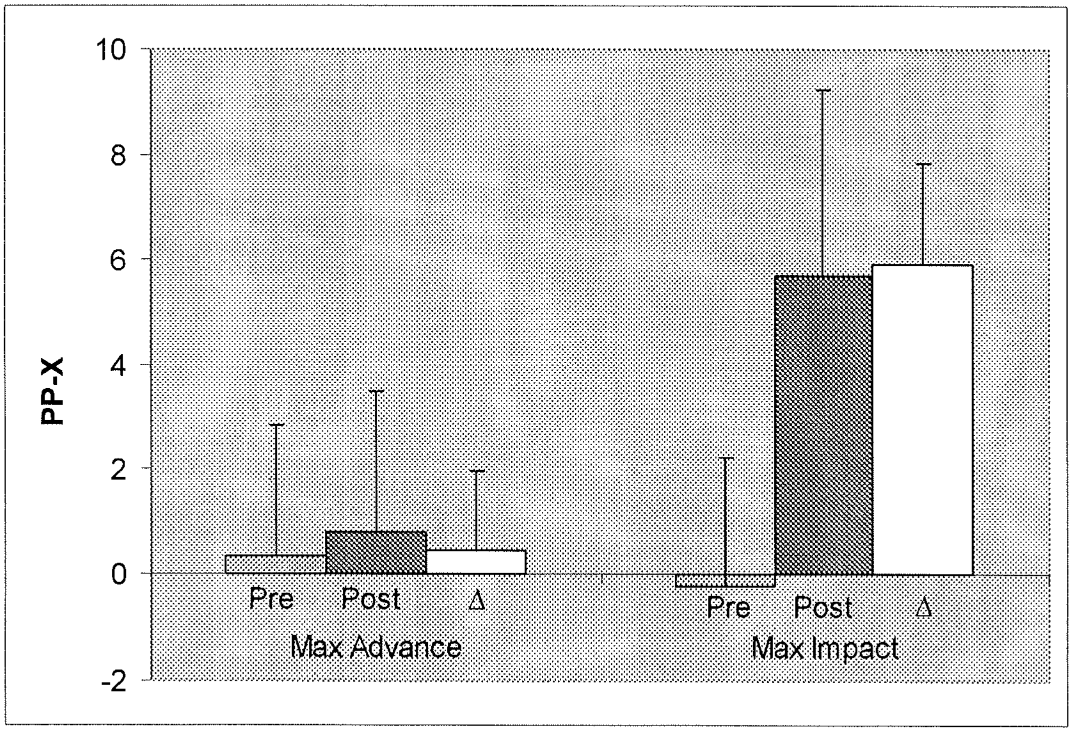

Figure 16: The mean positions and mean differences of PP-X pre-surgery and post-treatment. Error bars represent the standard deviation.

4.4 Frontal Analysis

4.4.1 Alar Base Width Relative to Intercanthal Distance (Ala-Ala/ICD)

Changes in alar base width showed a highly statistically significant increase ($p<0.0001$) in the maxillary advancement group following surgery from a ratio of 1.05 (SD=0.18) at pre-surgical to a ratio of 1.14 (SD=0.11) at post-treatment, with a mean change (Δ) of 0.09 (9%) (SD 0.12). There was also a statistically significant increase in the alar base width in the maxillary impaction group following surgery (although, not at the same probability level) from a ratio of 1.07 (SD=0.09) at pre-surgical to a ratio of 1.11 (SD=0.08) at post-treatment, a change of 0.04 or 4% (SD=0.12) ($p=0.033$). The changes (Δ) that occurred between the two surgical groups were not statistically significant ($p=0.08$) (Fig. 17).

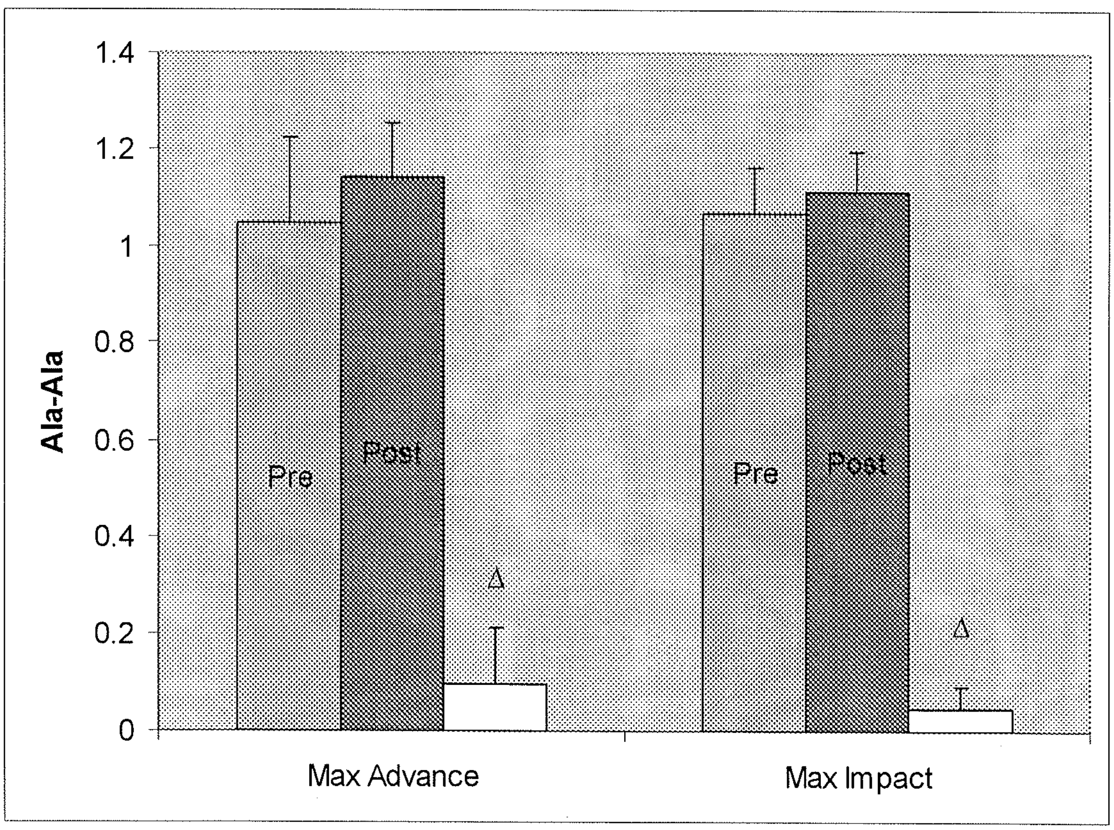

Figure 17: The mean positions and mean differences of Ala-Ala pre-surgery and post-treatment. Error bars represent the standard deviation.

4.4.2 Nose Length Relative to Intercanthal Distance (Nose Length/ICD)

Changes in nose length showed a statistically significant decrease (p=0.03) in the maxillary advancement group following surgery from a ratio of 1.37 (SD=0.11) at pre-surgical to a ratio of 1.33 (SD=0.10) at post-treatment, with a mean change (Δ) of -0.04 or 4% decrease (SD 0.09mm). However, there was no statistically significant decrease in nose length in the maxillary impaction group following surgery from a ratio of 1.31 (SD=0.16) at pre-surgical to a ratio of 1.29 (SD=0.14) at post-treatment, a change of -0.02 or 2% decrease (SD=0.08) (p=0.27). The changes (Δ) that occurred between the two surgical groups were not statistically significant (p=0.46) (Fig. 18).

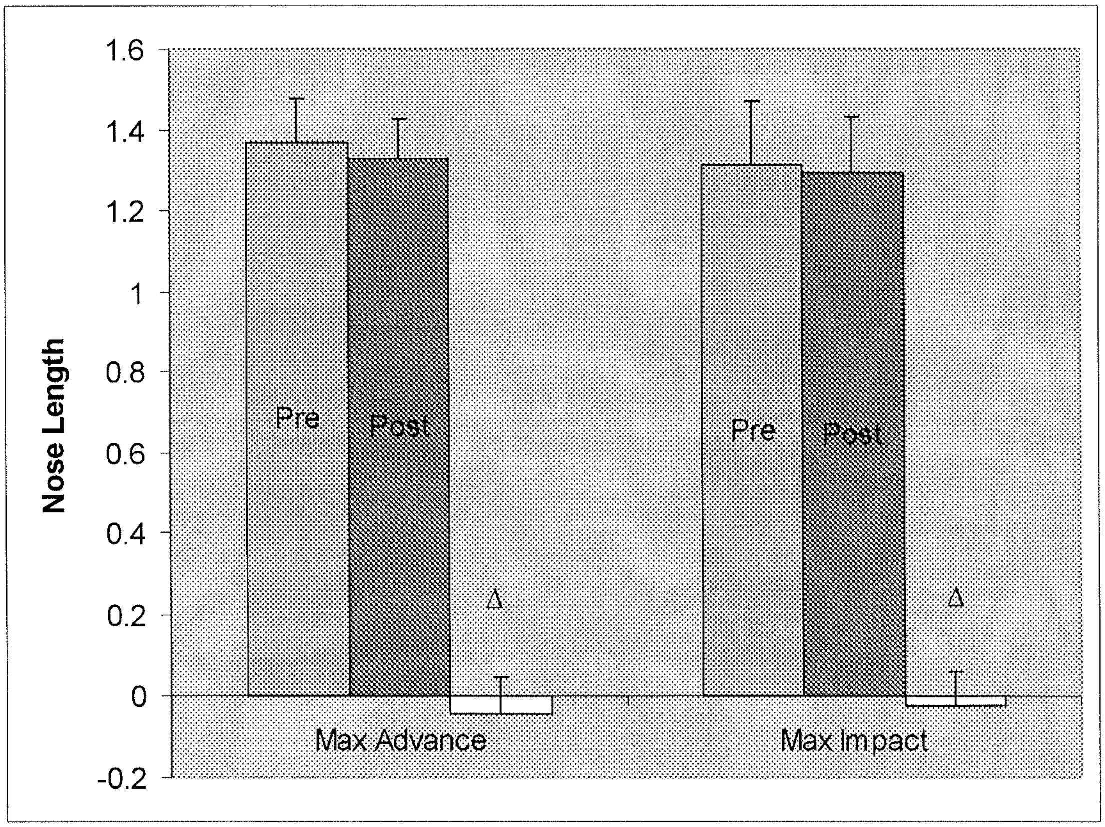

Figure 18: The mean positions and mean differences of Nose Length pre-surgery and post-treatment. Error bars represent the standard deviation.

4.4.3 Upper Lip Length Relative to Intercanthal Distance (Upper Lip Length/ICD)

Changes in upper lip length showed no statistically significant increase (p=0.09) in the maxillary advancement group following surgery from a ratio of 0.46 (SD=0.09) at pre-surgical to a ratio of 0.48 (SD=0.08) at post-treatment, with a mean change (Δ) of 0.02 or 2% (SD 0.06). Also, there was no statistically significant increase in lip length in the maxillary impaction group following surgery from a ratio of 0.50 (SD=0.10) at pre-surgical to a ratio of 0.51 (SD=0.11) at post-treatment, a change of 0.01 or 1% (SD=0.05) (p=0.71). The changes (Δ) that occurred between the two surgical groups were not statistically significant (p=0.35) (Fig. 19).

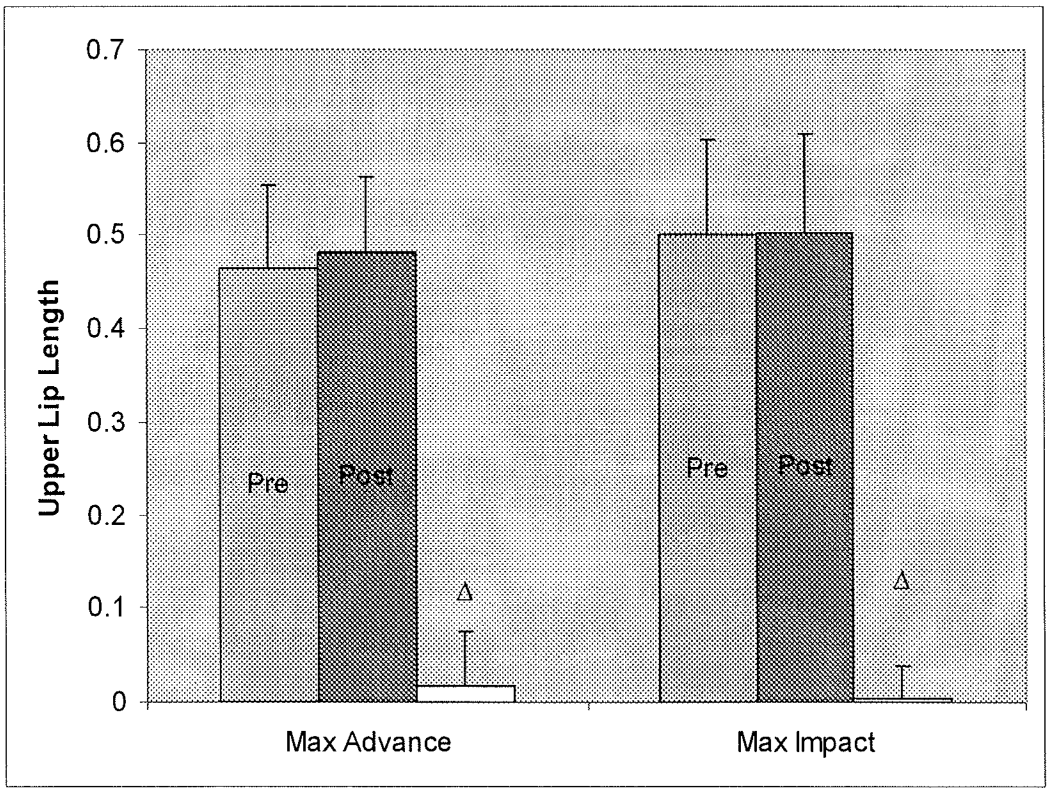

Figure 19: The mean positions and mean differences of Upper Lip Length pre-surgery and post-treatment. Error bars represent the standard deviation.

4.4.4 Vermillion Display Relative to Intercanthal Distance (Vermillion/ICD)

Changes in vermillion display showed a statistically significant increase (p=0.04) in the maxillary advancement group following surgery from a ratio of 0.18 (SD=0.05) at pre-surgical to a ratio of 0.37 (SD=0.59) at post-treatment, with a mean increase (Δ) of 0.19 or 19% (SD 0.60). Although a decrease was noted in vermillion thickness in the maxillary impaction group, the decrease was not statistically significant following surgery from a ratio of 0.16 (SD=0.04) at pre-surgical to a ratio of 0.14 (SD=0.05) at post-treatment, a change of -0.02 or 2% decrease (SD=0.03mm) (p=0.83). The changes (Δ) that occurred between the two surgical groups were statistically significant (p=0.02) (Fig. 20).

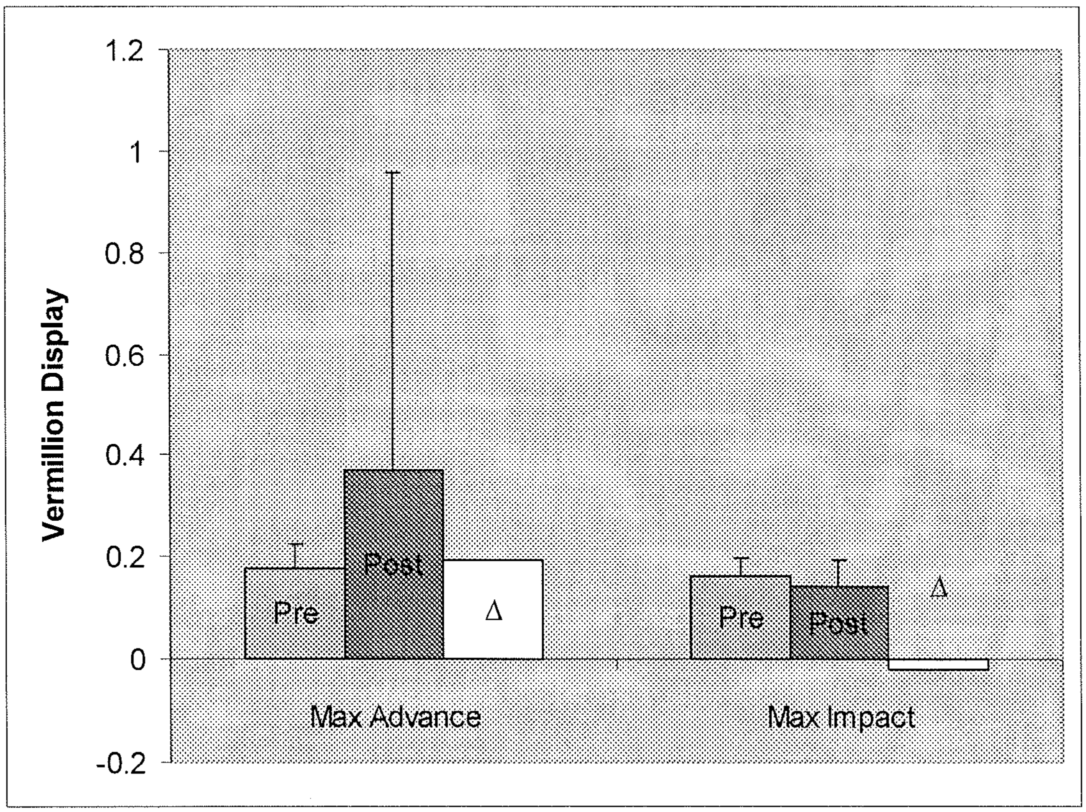

Figure 20: The mean positions and mean differences of Vermillion Display pre-surgery and post-treatment. Error bars represent the standard deviation.

CHAPTER 5

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CHAPTER 5

DISCUSSION

5.1 Profile Changes

The number of patients who are highly concerned with facial esthetics and who are potential candidates for a combined orthodontic-surgical procedure are increasing, Furthermore, computer imaging prediction software programs are becoming used more routinely in treatment planning and for patient education presentations (Romani et al, 1993). This places greater responsibility on the clinician to fully understand the limitations and potential inaccuracies of computer software programs, and then make inferred image corrections based upon scientific studies of soft tissue response with different surgical maxillary movements. The intent of the present study was to contribute to current knowledge on profile nasolabial changes, and to reveal relatively new information on frontal nasolabial changes following two very different maxillary surgical movements.

The vertical position of the nasolabial variables were measured relative to the horizontal X-axis, which was constructed at 7 degrees to Frankfurt Horizontal at Sella. The horizontal changes for the nasolabial variables were measured to the Y-axis constructed at 90 degrees to the X-axis also at Sella. The XY- axis constructed in this study to measure soft and hard tissue changes from lateral cephalograms was similar to previous studies investigating profile changes from Le Fort 1 osteotomies (Hack et al, 1993; Rosenburg et al, 2002). The XY-axis centered on Sella that was used in this study encompassed all the landmarks that were investigated in profile for all patients in both surgical groups.

5.1.1 Soft Tissue (Nasolabial) Changes

5.1.1.1 Nasal Tip Changes (Vertical and Horizontal)

The nasal tip landmark pronasale was selected in this study since it is relatively easy to identify, and was shown to be repeatable with above 97% reliability. The nasal tip (pronasale) in the vertical plane (Pn-X) was measured before surgery and at the end of surgical-orthodontic treatment. For both surgical groups (maxillary advancement and maxillary posterior impaction) no statistical difference in the vertical position of pronasale from pre-surgical to post-treatment records was found. Vertical movement of the nasal tip as a result of maxillary surgery has been reported by previous studies which included anterosuperior movement of the maxilla (Engel et al, 1979; Radney and Jacobs, 1981; Mansour et al, 1983; Carlotti et al, 1986; Rosen et al, 1988; Gassmann et al, 1989; Sarver and Weissman, 1991; Betts et al, 1993; Hack et al 1993;). However in our study, no elevation in the nasal tip was likely due to the selection criteria that restricted vertical change in the upper incisal edge for both groups to 2 mm or less.

The present study design made it possible to compare profile and frontal nasolabial changes in two surgical groups with two very different surgical movements of the upper incisor, but similar surgical incisions and soft tissue closure protocols. The protocol upon closure in the present study included a V-Y suture technique (the "V" shaped wound in the vestibule is closed with a "Y", with the base of the "Y" in the midline of the upper lip), alar base cinch, and in some patients resection of the anterior nasal spine was performed. Although only some patients had the anterior nasal spine removed, a study by Mommaerts et al (2000) showed that the advancing piriform aperture pushing on the alae, and not the nasal spine, is responsible for the increase in nasal tip projection and the columello-labial angle was, on average, unchanged by the surgery.

Although the vertical change in the nasal tip was not significant, a trend was observed in that pronasale moved superiorly in the advancement group and inferiorly in the impaction group following surgery. Surprisingly, even though pronasale moved in different directions, there was no significant difference between the change in maxillary advancement and maxillary impaction. This was due to a large standard deviation (SD) in the post-treatment impaction group (SD 15.3 mm). Standard deviations were similar for the pre-surgical and post-treatment advancement group means and the pre-surgical impaction group mean at approximately 4 mm.

There was a highly statistically significant forward movement in the horizontal position of the nasal tip (pronasale) at the post-treatment time for the maxillary advancement group. The mean forward movement of pronasale was 2.5 mm with a standard deviation of 1.07 mm. There was no significant difference in the horizontal position of pronasale in the maxillary posterior impaction group. This indicates that forward surgical movement of the maxilla was required to have the nasal tip move forward. Rosen et al (1988), suggested that there must be anterior movement of the maxilla for nasal tip projection which was consistent with this study, since only the advancement group showed a significant change in the horizontal position of pronasale post-treatment. The anterior structures of the maxilla include the upper incisor and overlying cortical bone, anterior nasal spine and the piriform aperture. Surgical movement of these structures, as well as soft tissue management, all play an intricate role in soft tissue nasal changes in profile with questionable predictability (although Mommaerts (2000) showed the anterior nasal spine may not influence nasal soft tissue changes) (Rosen et al, 1988; Betts et al, 1993; McFarlane et al, 1995; Mommaerts et al, 2000). Interestingly, different nasal structures and morphology also play a major role in the variation of nasal tip deflection as a result of maxillary osteotomy (McFarlane, 1995).

5.1.1.2 Upper Lip Changes (Vertical and Horizontal)

Labrale superious was used as a landmark since it is relatively easy to identify on a lateral cephalogram and was shown to be repeatable above 98% reliability in this study. Changes in labrale superious following maxillary surgery have been well documented. However, a comparison of the two different types of maxillary surgical movements and labial position changes from the profile and frontal aspect has not been studied. Betts et al (1993) suggested that soft tissue changes associated with maxillary surgery may be more affected by the position of the soft tissue incision and methods used in closure than by the surgically induced hard tissue change. Both surgical groups in this study were operated on by one surgeon and had similar surgical soft tissue management with VY sutural closure and alar base cinch techniques performed.

There was a statistically significant superior movement of labrale superious of the upper lip at the post-treatment time in the maxillary advancement group, a mean change of 0.6 mm and a standard deviation of 0.99 mm. Although there was no significant difference in the vertical position of labrale superious in the posterior impaction from pre-surgical to post-treatment records, a trend was observed (similar to the nasal tip) in that labrale superious moved inferiorly. The nasolabial complex, although showing no statistical change, showed a trend to move in a clockwise direction in the maxillary posterior impaction group. The inferior movement of labrale superious was not statistically significant but a probability value of 0.053 was determined, which was very close to statistical significance. Nevertheless, the changes that occurred in the vertical position of labrale superious was highly statistically significant between the two groups at the end of treatment, and were not statistically different pre-surgically. Therefore, surgery had a significant effect on the lip with different maxillary movements, although this change may not be clinically significant (0.6 mm). Previous reports suggest that superior repositioning of labrale superious could also be due to shortening of the upper lip. Proffit et al (2003) suggests the upper lip shortens by 1-2 mm.

The lip moved forward significantly in the maxillary advancement group at the end of treatment by 3.8 mm. Since the mean duration following surgery was 18.5 months for the maxillary advancement group, any swelling from the surgery had long since resolved. The upper lip antero-posterior (A-P) position is often compared to A-P movement of the incisor. Proffit et al (2003) also showed the upper lip moves forward 60% of the forward movement of the upper incisor. The mean advancement of the upper incisor was 3.5 mm and the mean advancement of the upper lip (labrale superious) was 3.7 mm for a ratio of roughly 1:1 for the upper incisor to upper lip advancement. This finding agrees with a recent study by Peled et al (2004), who showed a hard to soft tissue movement ratio of 1.0:0.9 for Le Fort 1 surgical patients that had a V-Y surgical closure, the same surgical soft tissue closure protocol used in this study. Mansour et al (1983) showed that for the advancement group, a progressive increase in the horizontal soft-tissue movement from the tip of the nose to the free end of the upper lip was observed.

5.1.2 Hard Tissue (Upper Incisor and Palatal Plane) Changes

Angular cephalometric change of the upper incisor was chosen in order to compare incisor angle changes for each group. The change observed in the upper incisor angulation should be relatively consistent with palatal plane changes following surgery. The maxillary advancement group was selected based on the fact that patients had a straight advancement with little change in palatal plane and thus the upper incisor. The posterior (differential) impaction group was selected based on a change in palatal plane of 3 degrees or greater. For the advancement group, there was no significant difference in upper incisor angulation following surgery. However, in the posterior impaction group, there was a statistically significant difference of the upper incisor angulation following surgery. The same observation was made for the palatal plane in each surgical group. In the advancement group there was a significant change in the horizontal position of the upper incisor. This was expected since the advancement group required 3 mm or greater advancement of the upper incisor.

These findings were expected since the surgical patients were selected on upper incisor and palatal plane changes and categorized accordingly. The fact that these variables are consistent shows that there was little orthodontic movement of the upper incisor from pre-surgical to post-treatment records. Therefore, surgical maxillary posterior impactions greater than 3 degrees reflects a significant change in upper incisor angulation (significantly more upright), but no statistically significant change in vertical or A-P position.

Soft tissue change as a result of the change in upper incisor and palatal plane angulation was reflected in soft tissue change with no significant change of the upper lip, nasal tip, lip length, nor vermillion display. The only soft tissue change found following the maxillary impaction surgical group, was an increase in alar base width which was also found by Betts et al (1993). Sarver and Weissman (1991) did not find evidence to support the contention that many soft tissue changes occur with maxillary impaction in the long term analysis. However, the authors mentioned it would be inappropriate to say that other soft tissue changes with maxillary impaction do not occur, such as widening of the alar base from the frontal aspect, since it was not looked at in their profile cephalometric study.

5.2 Frontal Analysis

5.2.1 Alar Base Width Relative to Intercanthal Distance

A statistically significant increase in alar base width relative to intercanthal distance was observed in both groups. A highly statistically significant increase was observed ($p<0.0001$) in the maxillary advancement group with a mean increase of nasal base width of 9%, and a statistically significant increase ($p<0.033$) in the posterior impaction group, with a mean increase of nasal base width of 4%. For a patient with a pre-surgical nasal base width of 21 mm, a 9% increase would result in nasal base widening (on average) of 1.9mm in the advancement group and 0.8mm for the posterior impaction group. The changes that occurred between the two surgical groups are not statistically significant. These findings suggest that maxillary surgery does not necessarily require forward repositioning of the maxilla in order to create a statistically significant increase in nasal base width. The findings in our study also agree with a study by Betts et al (1993) who found that in general, the base of the nose widened in all patients regardless of the vector of surgical maxillary movement an average of 9%. Interestingly, these authors also found that alar cinch suturing widened the alar base even more by10.6% (1.6% more than those who did not receive an alar cinch), although the sample group was small (only seven patients). They suggest the reasons for this could be the surgeon's inability to include the periosteum near the midline during closure, or perhaps distortion from the nasopharyngeal tubes, resulting in a more lateral and superior position of the alar base. Rosen et al (1988) also found that alar rim width increases with anterior and/or superior repositioning of the maxilla an average of 3.4 ±1 mm.

5.2.2 Nose Length Relative to Intercanthal Distance

There was a statistically significant decrease (or shortening) in nose length in the maxillary advancement group following surgery of 4%. However, in the maxillary posterior impaction group the nose decreased in length 2% but was not statistically significant and the change that occurred between the two groups was also not statistically significant. No information was found in the literature on changes in nose length following Le Fort 1 osteotomy.

5.2.3 Upper Lip Length Relative to Intercanthal Distance

The changes in lip length showed no statistically significant difference following surgery in both surgical groups. Upper lip length was measured from the base of the columella to labrale superious in the center of the philtrum and the vermillion was studied independently. Previous studies reported that the upper lip shortens with varying degrees with maxillary advancement, but in these studies, a superior vertical component was present with the maxillary advancement (Schendel et al, 1976; Rosen et al, 1988). However, other studies found similar results that support the findings in our study, in that the upper lip length does not change following Le Fort 1 osteotomy with impaction and/or advancement (Schendel et al, 1983; Tomlak et al, 1984, Carlotti et al, 1986; Sarver and Weissman, 1991). The technique utilized by the surgeon in this study placed the vestibular incision low, adjacent to the attached gingival, in order to prevent shortening of the upper lip. The findings in this study for lip length support using this technique in order to prevent lip shortening.

5.2.4 Vermillion Display Relative to Intercanthal Distance

Changes in the thickness of vermillion showed a statistically significant increase in the maxillary advancement group following surgery of 19%. This can be clinically significant as well, since a pre-surgical vermillion thickness of 8 mm would result in an average increase of 1.5 mm. In today's society of popular cosmetic lip procedures, this may likely be perceived as an esthetic improvement for many individuals. Although a decrease in vermillion thickness was observed in the maxillary posterior impaction procedure, it was not a statistically significant change (2%). However, the changes that occurred between the two surgical groups were statistically significant. Sarver and Weissman (1991) stated that the upper lip does not shorten, and that the clinical axiom that anterior movement of the maxilla rolls the upper lip superiorly (lip eversion) is incorrect. The present study agrees with Sarver and Weissman in that there were no significant changes in upper lip length in either surgical group measured from the base of the columella to labrale superious (philtrum height). However, labrale superious moved significantly forward and upward, and vermillion thickness increased in the maxillary advancement group. These findings support the clinical axiom that maxillary advancement results in lip eversion thereby increasing the thickness of the vermillion.

5.3 Study Limitations

Limitations of this study possibly include the sample size for each surgical group. There were 22 patients in the maxillary advancement group, and 21 patients in the maxillary posterior impaction group which could be used in our final assessment. By applying very strict surgical parameters, only 43 of 126 charts obtained from the legal storage at the University of Manitoba were suitable for inclusion. The parameters included changes in the upper incisor position and palatal plane angulation, one piece maxillary surgery with rigid internal fixation, and all surgeries performed by one surgeon (section 3.2 in Materials and Methods). That said, from a statistical standpoint, we had adequate power from our sample size to make relevant conclusions.

The results from our study only pertain to those patients that had maxillary surgeries similar to one of the two surgical groups. The maxillary advancement group had an anterior movement of the upper incisor of 3mm or greater, a change in palatal plane of less than 3 degrees, and a vertical change in the upper incisor of 2 mm or less. The maxillary posterior impaction group had an anterior movement of the upper incisor of less than 3mm, a change in palatal plane of 3 degrees or greater, and also a vertical change in the upper incisor of 2mm or less. Therefore, any patient that has Le Fort I surgery resulting in an anterosuperior movement of the maxilla by which the upper incisal edge is positioned superiorly by more than 2mm, would mean that the results of this study cannot be applied. Further research would be required to find and investigate patients with surgical procedures resulting in surgical dimensional changes other than those investigated in the present research project.

The male and female ratios for each surgical group were similar (8 males and 14 females in the maxillary advancement group, 7 males and 14 females for the maxillary posterior impaction group). Profile and frontal nasolabial surgical changes were not determined by sex since the sample size for females and males in each group was too small.

Finally, although resolution of edema and soft tissue adaptation to maxillary osteotomy is generally described as a 12 month process, nasolabial changes at that time may not represent final soft-tissue adaptation as a result of surgery (Sarver and Weissmas, 1991). The present study evaluated patients a mean time of 18 months following surgery which may not represent surgical outcome 2 or more years following surgery. A 5 year follow up study by Lee et al (1996) revealed that long-term changes in soft tissue landmarks exceeded hard tissue changes, meaning soft tissue points tended to move downward even if hard tissue points were stable and moved down more than the corresponding hard tissue points when skeletal changes occurred (which is likely related to aging as opposed to long term surgical changes). A study by Hack et al (1993) suggested that soft tissue settling or equilibrium following Le Fort 1 surgery may take several years to complete. A further research project evaluating long term soft tissue change after 10 years or more, may produce interesting results.

5.4 Evaluation of the Null Hypotheses

5.4.1 Null Hypothesis H01

There is no significant difference in *profile* nasolabial changes following surgery in the *maxillary advancement group.*

This statement was **rejected** as there were statistically significant ($p<0.05$) nasolabial profile changes found following surgery in the maxillary advancement group. The nasolabial complex had a trend to move anterosuperior following maxillary advancement.

5.4.2 Null Hypothesis H02

There is no significant difference in *profile* nasolabial changes following surgery in the *maxillary posterior impaction group.*

This statement was **accepted** as there were no statistically significant differences ($p>0.05$) found in the nasolabial complex in profile following maxillary posterior impaction surgery.

5.4.3 Null Hypothesis H03

There is no significant difference in *frontal* nasolabial changes following surgery in the *maxillary advancement group.*

This statement was **rejected** as there were statistically significant ($p<0.05$) nasolabial frontal changes following surgery in the maxillary advancement group. Overall nasolabial frontal changes included alar base widening, nose shortening, and an increase in vermillion display following maxillary advancement surgery.

5.4.4 Null Hypothesis H04

There is no significant difference in *frontal* nasolabial changes following surgery in the *maxillary posterior impaction group.*

This statement was **accepted** as there were no statistically significant ($p>0.05$) nasolabial frontal changes following surgery in the posterior maxillary impaction group.

5.4.5 Null Hypothesis H05

There is no significant difference in *profile* nasolabial changes following surgery *when comparing the maxillary advancement group and the maxillary posterior impaction group.*

This statement was **rejected** as there were statistically significant ($p<0.05$) nasolabial profile changes between the two surgical groups.

5.4.6 Null Hypothesis H06

There is no significant difference in *frontal* nasolabial changes following surgery *when comparing the maxillary advancement group and the maxillary posterior impaction group*.

This statement was **accepted** as there were no statistically significant ($p>0.05$) nasolabial frontal changes between the two surgical groups.

CHAPTER 6

CONCLUSIONS

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CHAPTER 6

CONCLUSIONS

6.1 Nasolabial Profile and Frontal Changes with Maxillary Advancement Surgery.

1. The maxillary advancement surgical group displayed the greatest overall profile and frontal soft tissue changes.
2. All the profile variables except vertical height in pronasale (Pn-X) showed significant changes. Profile nasolabial changes included anterior movement of the nasal tip and anterosuperior movement of labrale superious of the upper lip.
3. All frontal variables except upper lip length, showed a statistically significant change. Frontal nasolabial changes included widening of the nasal base, shortening of the frontal appearance of the nose, and an increase in vermillion display.

6.2 Nasolabial Profile and Frontal Changes with Maxillary Posterior Impaction Surgery.

1. The maxillary posterior impaction surgical group had the least overall profile and frontal soft tissue changes.

2. None of the profile nor frontal soft tissue nasolabial variables showed any statistically significant changes, with the exception of alar base width. The alar base widened following maxillary posterior impaction.

6.3 Concluding remarks.

Pre-surgical identification of potential profile and frontal nasolabial changes could offer useful clinical information for the orthodontist and maxillofacial surgeon during treatment planning. The patient will also benefit from knowing in advance, what potential impact these surgeries could have on facial changes post-surgically and form an important part of informed consent for medicolegal reasons. The findings of this study form a valuable additional adjunct to predictions gleaned from computerized visual treatment ojectives.

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ARTICLE FOR PUBLICATION

Profile and Frontal Nasolabial Changes Following Le Fort I Maxillary Advancement or Impaction Surgery.

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ABSTRACT

Profile and Frontal Nasolabial Changes Following Le Fort I Maxillary Advancement or Impaction Surgery.

Purpose: To determine if there were any measurable differences in nasolabial soft tissue features between surgical-orthodontic patients who received either maxillary advancement or maxillary posterior impaction in the profile and frontal view. **Methods:** Records for 43 patients consisting of 22 patients for the maxillary advancement group, and 21 patients for the maxillary impaction group were obtained from the archives of a graduate orthodontic program. Changes in profile soft and hard tissue cephalometric landmarks were made on an X-Y axis system centered on Sella. The frontal nasolabial variables were measured relative to the patient's intercanthal distance from pre-surgical and post-treatment photos in repose. **Results:** *Maxillary Advancement:* All profile variables except vertical height of pronasale showed a statistically significant change ($p<0.05$). Changes included anterior movement of the nasal tip by 2.5 mm, and anterosuperior movement of labrale superious by 3.8 mm and 0.6 mm respectively. All frontal variables except upper lip length showed a statistically significant change ($p<0.05$). Significant frontal nasolabial changes included widening of the nasal base by 9% ($p<0.0001$), shortening of the frontal appearance of the nose by 4% ($p<0.05$), and increase in vermillion display by 19% ($p<0.05$). *Maxillary Posterior Impaction:* All profile and frontal soft tissue nasolabial variables in the maxillary posterior impaction showed no statistically significant changes except alar base which widened by 4% ($p<0.05$). **Conclusions:** The maxillary advancement surgery group showed more frontal and profile soft tissue changes than the posterior impaction group. Widening of the nasal base was the only consistent change displayed by both groups.

INTRODUCTION

Orthodontists and surgeons are highly concerned with the patient's facial esthetics, possibly now more than ever due to advances in surgical techniques and an increased esthetic awareness of the general public. A paradigm shift in orthodontics has once again led the specialty to focus on soft tissue esthetics as the main determinant in choosing surgical treatment options. Orthodontists however, evaluate patients in profile to aid in surgical treatment planning, a perspective in which patients rarely observe themselves[1].

Orthodontics and orthognathic surgery are elective procedures which patients can accept or reject. However, orthodontics and combined orthognathic surgery has gained a greater acceptance level over the last two decades[2]. Patient's rational for choosing orthognathic surgery is to achieve an esthetic improvement combined with functional and dental health reasons[3]. Perhaps not surprisingly, the most frequently stated motive for accepting a surgical orthodontic treatment plan is due the advice of an orthodontist[4]. This could be problematic, since professional opinions may not coincide with the patient's self perception and subsequent end treatment expectations. This is further complicated if a chosen surgical treatment option is based solely upon professional advice.

The beneficial facial changes anticipated by the surgeon, orthodontist and patient/parents must be weighed against potential unfavorable changes. The Le Fort I osteotomy is a very common orthognathic procedure to correct dentofacial deformity, and a number of authors have described subsequent adverse findings from this surgery, albeit the esthetic changes are somewhat variable in each study. The postoperative nasolabial changes include widening of the alar bases of the nose, up and forward movement of the nasal tip, flattening and thinning, and/or shortening of the upper lip, and a downward turning of the commissures of the mouth. Although movement of the nasal tip and upper lip has been documented to occur to various degrees during maxillary Le Fort I osteotomies, it is very difficult to predict the extent of change, and even more difficult to surgically control[5-19].

The purpose of this study was to evaluate profile nasolabial changes, and to reveal relatively new information on frontal nasolabial changes by comparing the soft tissue effects from two different maxillary surgical movements. Correction of a dentofacial deformity may appear significantly improved to the surgeon and orthodontist, but an untrained person may have little appreciation for the result. In fact, it has been reported that some orthognathic surgery patients may even fail to notice major changes in their own appearance or even be disappointed with the end result[20].

MATERIALS AND METHODS

Patient records were obtained from the archives of a North American graduate orthodontic program. Forty-three patients who had undergone a Le Fort I osteotomy and maxillary repositioning were selected. The records consisted of pre-surgical and post-treatment lateral cephalograms and frontal photos. Of the 43 patients, 22 were categorized to the maxillary advancement group, and 21 patients to the maxillary posterior impaction group.

Surgery was performed between 1995 and 2006 by the same oral and maxillofacial surgeon. All patients received the same soft tissue management which included a V-Y closure technique, an alar base cinch suture, and the anterior nasal spine was removed in some patients. The patients were excluded if they had undergone: maxillary segmental surgery, advancement of the maxilla greater than 10 mm, or adjunctive rhinoplasty. Any patients with cleft lip and/or palate, craniofacial synostosis, facial asymmetries, or syndromes were also excluded.

The vertical and horizontal position of the profile variables were measured relative to the horizontal X and Y-axis respectively. The upper incisor and palatal plane angulation was measured relative to the X-axis which was constructed at 7 degrees to Frankfurt Horizontal at Sella. The horizontal changes for the nasolabial variables were measured to the Y-axis constructed at 90 degrees to the X-axis also at Sella. The XY-axis constructed in this study to measure soft and hard tissue changes from lateral cephalograms was similar to previous studies investigating profile changes from Le Fort 1 osteotomies and was utilized since it encompassed all the landmarks and planes that were investigated in profile for all patients in both surgical groups[13,21](Figure 1).

Patients in the maxillary advancement group were selected based on a maxillary incisor advancement of 3mm or greater. This was measured by the change in horizontal forward movement of the upper central incisal edge relative to the Y-axis at presurgery and post-treatment (change in I-Y $\geq$ 3mm), a change in the vertical position of the upper incisal edge of 2mm or less (change in I-X $\leq$ 2mm), and a change in angulation of the upper incisor and palatal plane to the X-axis of less than 3 degrees (change in PP-X < 3°). The maxillary posterior impaction group had a maxillary advancement of less than 3mm (change in I-Y < 3mm), a change in the vertical position of the upper incisal edge of 2mm or less (change in I-X $\leq$ 2mm), and a greater differential posterior impaction component measured by a change in palatal plane and upper incisor angualtion of greater than or equal to 3 degrees (change in PP-X $\geq$ 3°) (Table 1).

Frontal photos were taken by one of three photographers at approximately the same distance of 30 cms. However, in order to account for minor differences in distance between the presurgical and postreatment photos, the measurements of frontal nasolabial features were taken as a ratio of the patient's intercanthal distance and recorded as a percentage (Figure 2). The measurements were taken by one evaluator with a Chicago Brand ™ Digital Caliper in millimeters to the one hundredth decimal place, and a protractor for angular measurements. Pre-surgical and post-treatment measurements were taken for all 12 variables for each of the 43 patients, for a total of 1032 recordings.

The reproducibility of measurements was assessed by repeating 20 analyses on 10 patients of the studied sample six weeks following the initial measurements, which were randomly chosen for re-evaluation by the same principle examiner. Intra-examiner calibration was verified by Intra-class Correlation coefficients (ICC) with it's 95% confidence interval.

Statistical significance was determined for each profile and frontal variable following surgery within each patient surgical group and between groups. Unpaired *t*-tests were used to determine statistical significance in changes recorded following surgery for each variable between the maxillary advancement and maxillary posterior impaction surgical groups. Repeated measures analysis of variance (ANOVA) was performed to determine if interactions exists between the two groups over time for each variable. Finally, when interactions were significant, a pair wise comparison was performed to compare differences in pre-surgical and post-treatment changes for each variable within and between the two groups. Significance level was set at p=0.05.

RESULTS

Calibration

Intra-examiner calibration was verified by Intra-class Correlation coefficients (ICC) and set at 95% agreement. ICC values for cephalometric and photographic measurements by the operator are listed in Table 2. All measurements demonstrated reliability and reproducibility above 95%.

Sample Description

The maxillary advancement group consisted of 8 males and 14 females (n=22) with a mean age of 22.1 years (SD= 5.6 years), a mean orthodontic treatment time prior to surgery of 12.2 months (SD= 6.8 months), and a mean total active treatment time of 30.7 months (SD= 7.7 months). The maxillary impaction group consisted of 7 males and 14 females (n=21) with a mean age of 22.6 years (SD= 6.3 years), a mean orthodontic treatment time prior to surgery of 15.0 months (SD= 8.2 months), and a mean total active treatment time of 32.7 months (SD= 7.9 months). The pre-surgical orthodontic treatment time and total active treatment time was slightly longer (by 2.8 months and 2 months respectively) for the maxillary posterior impaction group. The two surgical groups were categorized based upon specific surgical movements of the upper incisor and palatal plane. The results of these hard tissue movements for the maxillary advancement and maxillary posterior impaction are outlined in Table 3.

Profile Nasolabial Analysis

Vertical Changes in Pronasale (Pn-X)

This variable in the vertical plane showed a non significant decrease ($p>0.05$) in the maxillary advancement group following surgery from a mean (x) of 39.57mm

(SD=4.10mm) at pre-surgical to 37.94mm (SD=4.29mm) at post-treatment, with a mean change (Δ) of -1.64mm (SD 1.31mm). There was also no statistically significant difference ($p>0.05$) in the vertical position of pronasale in the maxillary impaction group following surgery although in contrast to the maxillary advancement group, an increase was noted from 38.38mm (SD=4.04mm) at pre-surgical to 41.21mm (SD=15.32mm) at post-treatment, a change of 2.83mm (SD=15.19mm) ($p>0.05$). The changes (Δ) that occurred between the two surgical groups, although in different directions, were not statistically significant ($p>0.05$) (Fig. 3).

Horizontal Changes in Pronasale (Pn-Y)

Horizontal changes in pronasale showed a highly statistically significant increase in the maxillary advancement group following surgery, from 102.44mm (SD=5.35mm) at pre-surgical to 104.94mm (SD=5.59mm) at post-treatment ($p<0.0001$), with a mean change (Δ) of 2.50mm (SD 1.07mm). However, there was no statistically significant difference in the horizontal position of pronasale in the maxillary impaction group following surgery, from 105.17mm (SD=4.33mm) at pre-surgical to 105.67mm (SD=4.30mm) at post-treatment, a change of 0.50mm (SD=0.88mm) ($p>0.05$). The changes (Δ) that occurred between the two surgical groups were highly statistically significant ($p<0.0001$) (Fig. 4).

Vertical Changes in Labrale Superious (Ls-X)

Vertical changes in this variable showed a statistically significant decrease ($p=0.0173$) in the maxillary advancement group following surgery from 66.81mm (SD=4.89mm) at pre-surgical to 66.19mm (SD=4.54mm) at post-treatment, with a mean change (Δ) of -0.624mm (SD 0.99mm). However, there was no significant difference in the vertical position of labrale superious in the maxillary impaction group following surgery from 68.14mm (SD=5.45mm) at pre-surgical to 68.65mm (SD=6.07mm) at post-treatment, a change of 0.51mm (SD=1.35mm) ($p=0.053$). The changes (Δ) that occurred between the two surgical groups were highly statistically significant ($p<0.003$) (Fig. 5).

Horizontal Changes in Labrale Superious (Ls-Y)

Horizontal changes in this variable showed a highly statistically significant increase ($p<0.0001$) in the maxillary advancement group following surgery from 86.61mm (SD=5.48mm) at pre-surgical to 90.36mm (SD=6.04mm) at post-treatment, with a mean change (Δ) of 3.76mm (SD 1.69mm). However, there was no significant difference in the horizontal position of labrale superious in the maxillary impaction group following surgery from 88.57mm (SD=4.27mm) at pre-surgical to 88.05mm (SD=3.83mm) at post-treatment, a change of -0.52mm (SD=1.99mm) (p=0.21). The changes (Δ) that occurred between the two surgical groups were highly statistically significant (p<0.0001) (Fig. 6).

Frontal Nasolabial Analysis

Alar Base Width Relative to Intercanthal Distance (Ala-Ala/ICD)

Changes in alar base width showed a highly statistically significant increase (p<0.0001) in the maxillary advancement group following surgery from a ratio of 1.05 (SD=0.18) at pre-surgical to a ratio of 1.14 (SD=0.11) at post-treatment, with a mean change (Δ) of 0.09 (9%) (SD 0.12). There was also a statistically significant increase in the alar base width in the maxillary impaction group following surgery (although, not a the same probability level) from a ratio of 1.07 (SD=0.09) at pre-surgical to a ratio of 1.11 (SD=0.08) at post-treatment, a change of 0.04 or 4% (SD=0.12) (p=0.033). The changes (Δ) that occurred between the two surgical groups were not statistically significant (p=0.08) (Fig. 7).

Nose Length Relative to Intercanthal Distance (Nose Length/ICD)

Changes in nose length showed a statistically significant decrease (p=0.03) in the maxillary advancement group following surgery from a ratio of 1.37 (SD=0.11) at pre-surgical to a ratio of 1.33 (SD=0.10) at post-treatment, with a mean change (Δ) of -0.04 or 4% decrease (SD 0.09mm). However, there was no statistically significant decrease in nose length in the maxillary impaction group following surgery from a ratio of 1.31 (SD=0.16) at pre-surgical to a ratio of 1.29 (SD=0.14) at post-treatment, a change of -0.02 or 2% decrease (SD=0.08) (p=0.27). The changes (Δ) that occurred between the two surgical groups were not statistically significant (p=0.46) (Fig. 8).

Upper Lip Length Relative to Intercanthal Distance (Upper Lip Length/ICD)

Changes in upper lip length showed no statistically significant increase (p=0.09) in the maxillary advancement group following surgery from a ratio of 0.46 (SD=0.09) at pre-surgical to a ratio of 0.48 (SD=0.08) at post-treatment, with a mean change (Δ) of 0.02 or 2% (SD 0.06). Also, there was no statistically significant increase in lip length in the maxillary impaction group following surgery from a ratio of 0.50 (SD=0.10) at pre-surgical to a ratio of 0.51 (SD=0.11) at post-treatment, a change of 0.01 or 1% (SD=0.05) (p=0.71). The changes (Δ) that occurred between the two surgical groups were not statistically significant (p=0.35) (Fig. 9).

Vermillion Display Relative to Intercanthal Distance (Vermillion/ICD)

Changes in vermillion display showed a statistically significant increase (p=0.04) in the maxillary advancement group following surgery from a ratio of 0.18 (SD=0.05) at pre-surgical to a ratio of 0.37 (SD=0.59) at post-treatment, with a mean increase (Δ) of 0.19 or 19% (SD 0.60). Although a decrease was noted in vermillion thickness in the maxillary impaction group, the decrease was not statistically significant following surgery from a ratio of 0.16 (SD=0.04) at pre-surgical to a ratio of 0.14 (SD=0.05) at post-treatment, a change of -0.02 or 2% decrease (SD=0.03mm) (p=0.83). The changes (Δ) that occurred between the two surgical groups were statistically significant (p=0.02) (Fig. 10).

DISCUSSION

The number of orthodontic-surgical patients who are highly concerned with facial esthetics are increasing, and computer imaging prediction software programs are becoming used more routinely in treatment planning and for patient presentations. This places greater responsibility on the clinician to understand the limitations and inaccuracies of computer software programs, and to make required image corrections base upon scientific studies of soft tissue response with different maxillary movements.

In this study, all surgical patients were operated on by the same surgeon and thus received similar surgical incisions and soft tissue closure protocol. The protocol upon closure in the present study included a V-Y suture technique, alar base cinch, and in some patients resection of the anterior nasal spine was performed. Although only some patients had the anterior nasal spine removed, a study by Mommaerts et al (2000) [8] showed that the advancing piriform aperture pushing on the alae, and not the nasal spine, is responsible for the increase in nasal tip projection and the columello-labial angle was, on average, unchanged by the surgery.

Profile Nasolabial Changes

There was a significant forward movement in the horizontal position of the nasal tip (pronasale) at the post-treatment time for the maxillary advancement group of 2.5 mm. However, there was no significant difference in the maxillary posterior impaction group. This indicates that forward surgical movement of the maxilla was required to have the nasal tip move forward. Rosen et al (1988) [12] suggested that there must be anterior movement of the maxilla for nasal tip projection which was consistent with this study since only the advancement group showed a significant change in the horizontal position of pronasale post-treatment. Besides surgical forward repositioning of the maxilla, different nasal structures and morphology also play a major role in the variation of nasal tip deflection as a result of maxillary osteotomy[7].

Changes in labrale superious following maxillary surgery have been well documented. However, a comparison of two different types of maxillary surgical movements and labial position changes from the profile and frontal aspect has not been studied. Betts et al (1993) [22] suggested that soft tissue changes associated with maxillary surgery may be more affected by the position of the soft tissue incision and methods used in closure than by the surgically induced hard tissue change. However, in this study, both surgical groups were operated on by one surgeon and had similar surgical soft tissue management with V-Y sutural closure and alar base cinch techniques performed.

There was a significant superior movement of labrale superious of the upper lip at the post-treatment time in the maxillary advancement group (although clinically, the mean change of 0.6mm is likely negligible), and the lip moved forward significantly by 3.8 mm. Since the mean duration following surgery was 18.5 months for the maxillary advancement group, any swelling from the surgery had long since resolved. The upper lip antero-posterior (A-P) position is often compared to A-P movement of the incisor. Proffit et al (2003) [23] also showed the upper lip moves forward 60% of the forward movement of the upper incisor. However, in our study, the mean advancement of the upper incisor was 3.5 mm and the mean advancement of the upper lip (labrale superious) was 3.7 mm for a ratio of roughly 1:1 for the upper incisor to upper lip advancement. This finding agrees with a recent study by Peled et al (2004) [24], who showed a hard to soft tissue movement ratio of 1.0:0.9 for Le Fort 1 surgical patients that had a V-Y surgical closure, the same surgical soft tissue closure protocol used in our study. Mansour et al (1983)[6] showed that for the advancement group, a progressive increase in the horizontal soft-tissue movement from the tip of the nose to the free end of the upper lip was observed.

In the posterior impaction group, a significant change in angualtion of the upper incisor and palatal plane was not reflected in soft tissue change in that there were no significant changes of the upper lip, nasal tip, lip length, nor vermillion display. The only soft tissue change found following maxillary posterior impaction surgical was an increase in alar base width which was also found by Betts et al (1993) [22]. Sarver and Weissman (1991) [14] did not find evidence to support soft tissue changes with maxillary impaction in their long term analysis. However, the authors mentioned it would be inappropriate to say that soft tissue changes from the frontal aspect with maxillary impaction do not occur, such as widening of the alar base, since it was not looked at in their profile cephalometric study.

Frontal Nasolabial Changes

A significant increase in alar base width relative to intercanthal distance was observed in both groups. In the maxillary advancement group, a significant increase of nasal base width of 9% was observed, and a significant increase of 4% in the posterior impaction group. A clinical example for a patient with a pre-surgical nasal base width of 21 mm, a 9% increase would result nasal base widening (on average) of 1.9mm in the advancement group and 0.8mm for the posterior impaction group. The changes that occurred between the two surgical groups are not statistically significant. These findings suggest that maxillary surgery does not necessarily require forward repositioning of the maxilla in order to create a statistically significant increase in nasal base width. Rosen et al (1988) [12] also found that alar rim width increases with anterior and/or superior repositioning of the maxilla.

There was a statistically significant decrease (or shortening) in nose length in the maxillary advancement group following surgery of 4%. However, in the maxillary posterior impaction group the nose decreased in length 2% but was not statistically significant and the change that occurred between the two groups was also not statistically significant. The changes in lip length showed no statistically significant difference following surgery in both surgical groups. Upper lip length was measured from the base of the columella to labrale superious in the center of the philtrum and the vermillion was studied independently. Previous studies reported that the upper lip shortens with varying degrees with maxillary advancement, but in these studies, a superior component was present with the maxillary advancement[12,13]. However, other studies support the findings in this study, in that the upper lip length does not change following Le Fort 1 osteotomy with impaction and/or advancement[6,15,16,20]. Vermillion thickness showed a significant increase in the maxillary advancement group following surgery of 19%, which in today's society may be perceived as an esthetic improvement for many individuals. There was no change in vermillion thickness for the posterior impaction group. There has been no previous literature comparing vermillion thickness of the upper lip following Le Fort 1 advancement compared to posterior impaction surgery.

Pre-surgical identification of potential profile and frontal nasolabial changes could offer useful clinical information for the orthodontist and maxillofacial surgeon during treatment planning. The patient will also benefit from knowing in advance, what potential impact these surgeries could have on facial changes post-surgically, and constitute an important part of informed consent for medicolegal reasons. The findings of this study form a valuable additional adjunct to predictions gleaned from computerized visual treatment objectives.

CONCLUSIONS

Maxillary Advancement Surgical Group.

1. The maxillary advancement surgical group displayed the greatest overall profile and frontal soft tissue changes.
2. All the profile variables except vertical height in pronasale (Pn-X) showed significant changes. Profile nasolabial changes included anterior movement of the nasal tip and anterosuperior movement of labrale superious of the upper lip.
3. All frontal variables except upper lip length, showed a statistically significant change. Frontal nasolabial changes included widening of the nasal base, shortening of the frontal appearance of the nose, and an increase in vermillion display.

Maxillary Posterior Impaction Surgical Group.

1. The maxillary posterior impaction surgical group had the least overall profile and frontal soft tissue changes.

2. None of the profile nor frontal soft tissue nasolabial variables showed any statistically significant changes, with the exception of alar base width. The alar base widened following maxillary posterior impaction.

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Table 1. Specific criteria for movement of hard tissue variables following Le Fort 1 osteotomy for the maxillary advancement and maxillary posterior impaction groups.

Hard Tissue Variables	Maxillary Advancement	Maxillary Posterior Impaction
I-X	≤2mm	≤2mm
I-Y	≥3mm	<3mm
UIA	<3°	≥3°
PP-X	<3°	≥3°

Table 2. Repeated measurements taken from 10 randomly selected patients to determine intra-class correlation coefficients (ICC) set at 95% confidence limits.

Measurements	ICC	95% Confidence Limits
Pn-X	0.9925	0.9458 - 0.9992
Pn-Y	0.9793	0.9629 - 0.9840
I-X	0.9967	0.9758 - 0.9996
I-Y	0.9960	0.9710 - 0.9996
Ls-X	0.9987	0.9901 - 0.9999
Ls-Y	0.9876	0.9118 - 0.9987
UIA	0.9888	0.9204 - 0.9988
PP-X	1	
Alae/Alae	0.9798	0.9619 - 0.9846
Nose Length	0.9634	0.9288 - 0.9731
Upper Lip Length	0.9716	0.9407 - 0.9867
Vermillion	0.9665	0.9334 - 0.9806

Table 3. Mean change (Δ) of hard tissue variables and p value (significance level set at 0.05) to determine statistical significance for the maxillary advancement and maxillary posterior impaction surgical groups.

Hard Tissue Variables	Maxillary Advancement		Maxillary Posterior Impaction	
	mean Δ	p=0.05	mean Δ	p=0.05
I-X	0.71mm	p<0.05	0.73mm	p<0.05
I-Y	3.51mm	p<0.05	0.20mm	p>0.05
UIA	0.86°	p>0.05	6.91°	p<0.05
PP-X	0.45°	p>0.05	5.67°	p<0.05

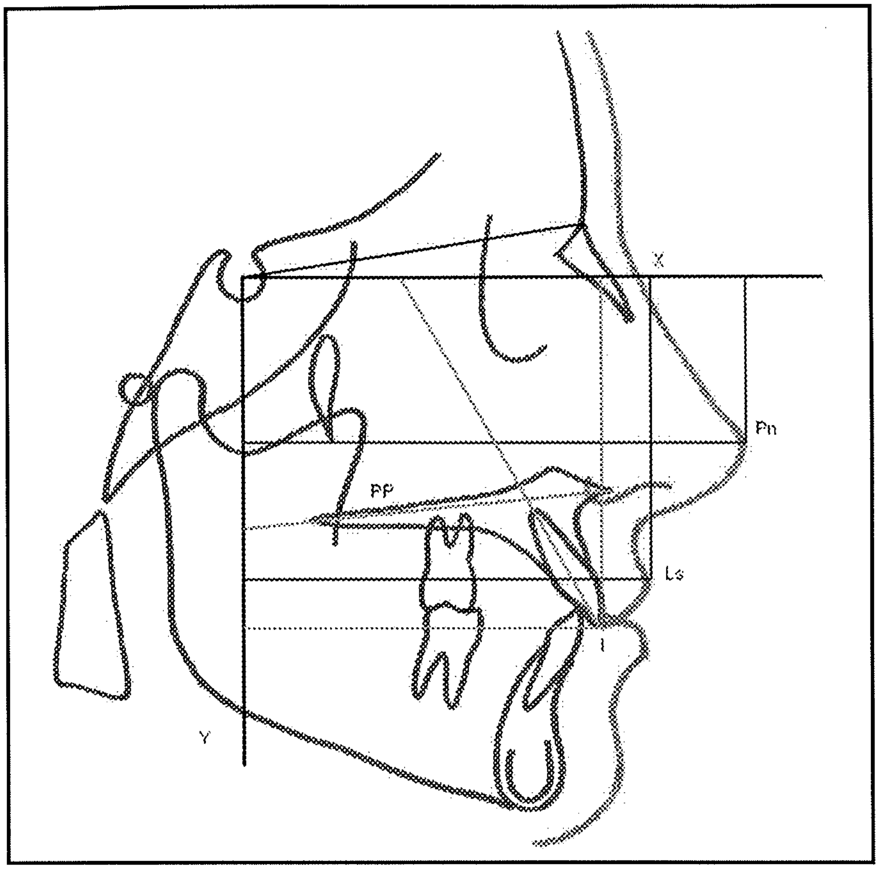

Figure 1. An X-Y axis system was utilized to record vertical and horizontal changes in hard and soft tissue variables. Blue lines represent linear vertical and horizontal changes in soft tissue nasolabial variables Pronasale (Pn) and Labrale Superious (Ls) relative to the X and Y-axis respectively. Green vertical and horizontal lines represent the linear changes in the incisal edge to the X and Y-axis respectively. Change in angulation of the upper incisor and palatal plane were recorded relative to the X-axis (green lines).

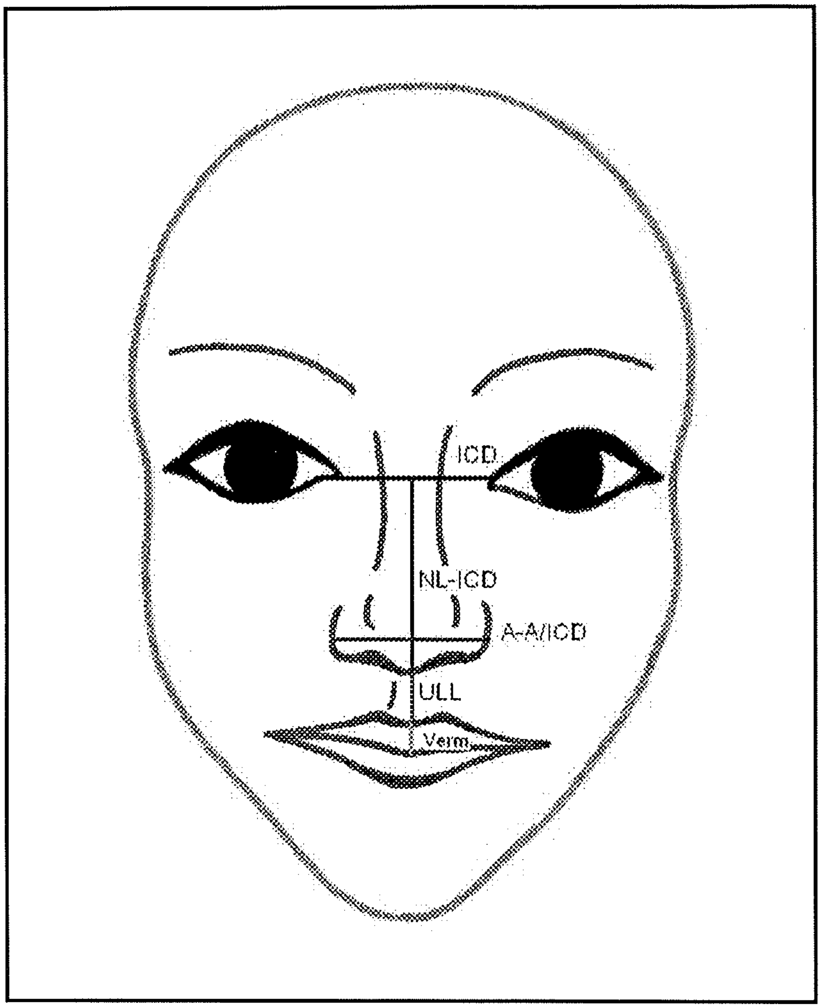

Figure 2. The intercanthal distance (ICD) of the patients at presurgery and post-treatment photos were recorded and used to standardize linear measurements made on the frontal photos. The blue lines demonstrate frontal nasal features that were recorded which included alar base width (A-A/ICD), nose length (NL/ICD). Red line represents upper lip length measured from base of the columella to labrale superious. Green line represents vermillion display measured from labrale superious to stomion superious in the midfacial plane.

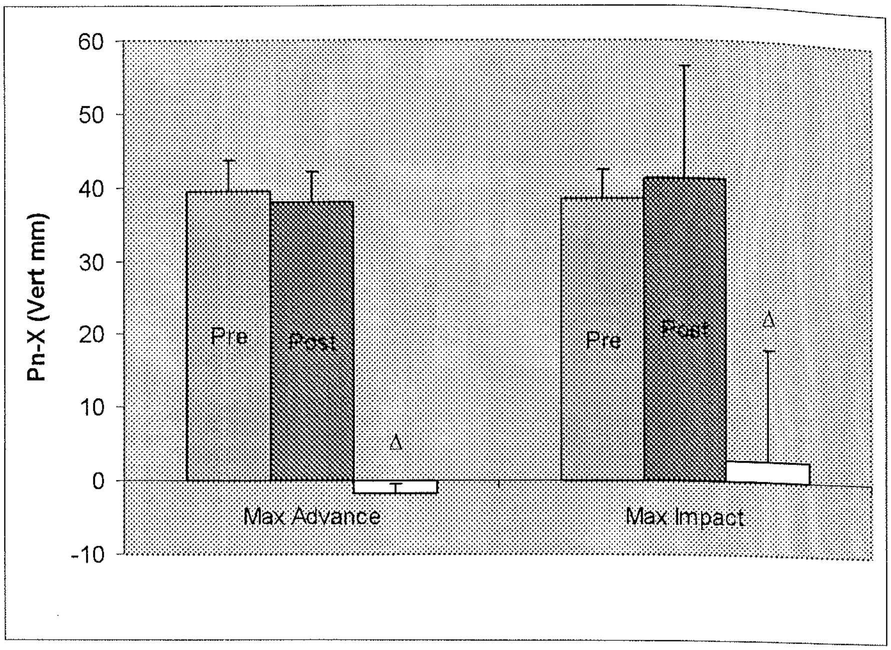

Figure 3. The mean positions and mean differences of Pn-X (Vert mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

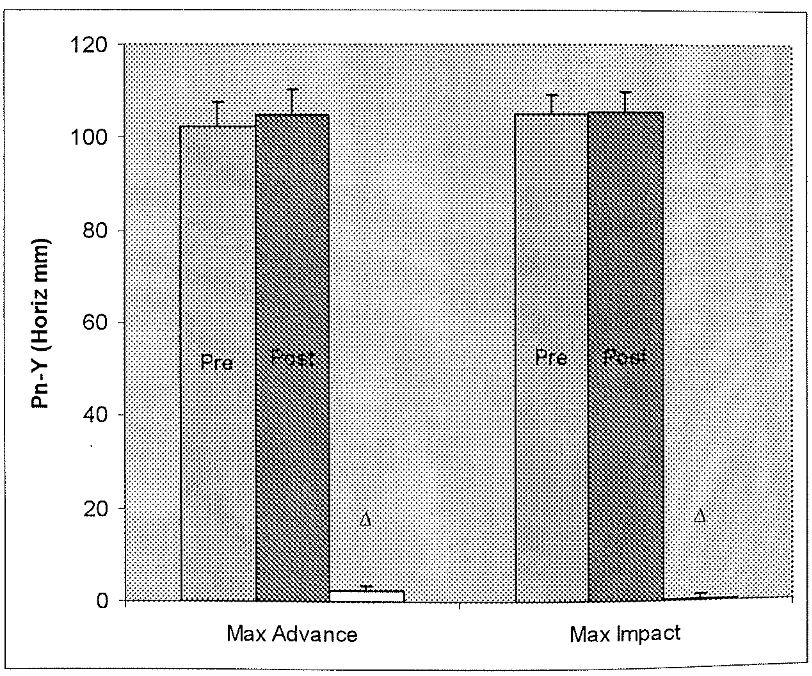

Figure 4. The mean positions and mean differences of Pn-Y (Horiz mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

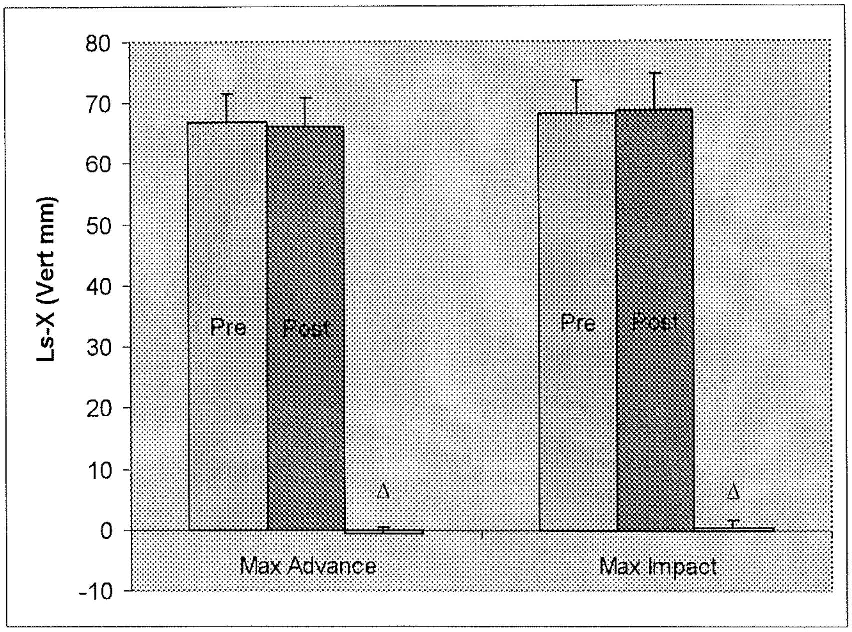

Figure 5. The mean positions and mean differences of Ls-X (Vert mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

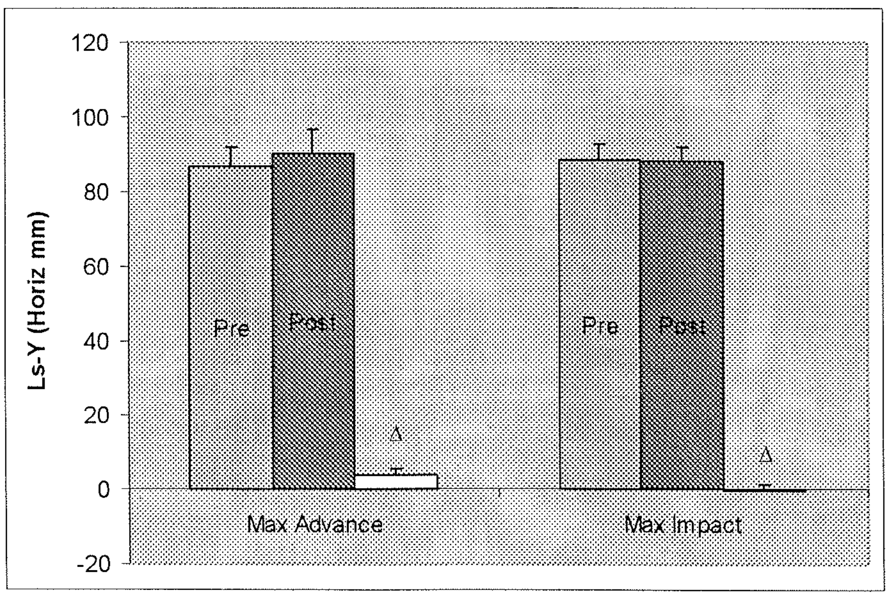

Figure 6. The mean positions and mean differences of Ls-Y (Horiz mm) pre-surgery and post-treatment. Error bars represent the standard deviation.

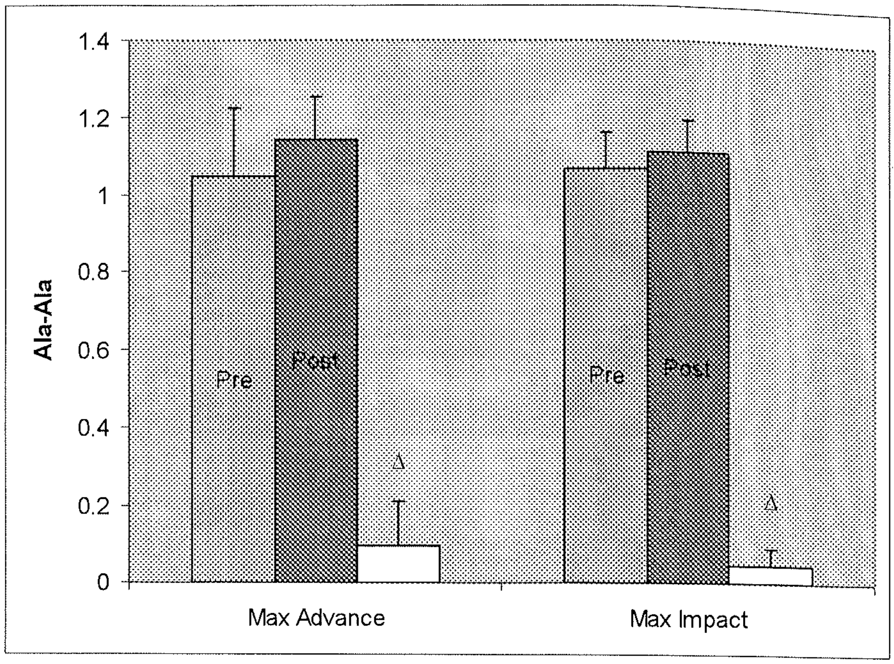

Figure 7. The mean positions and mean differences of Ala-Ala pre-surgery and post-treatment. Error bars represent the standard deviation.

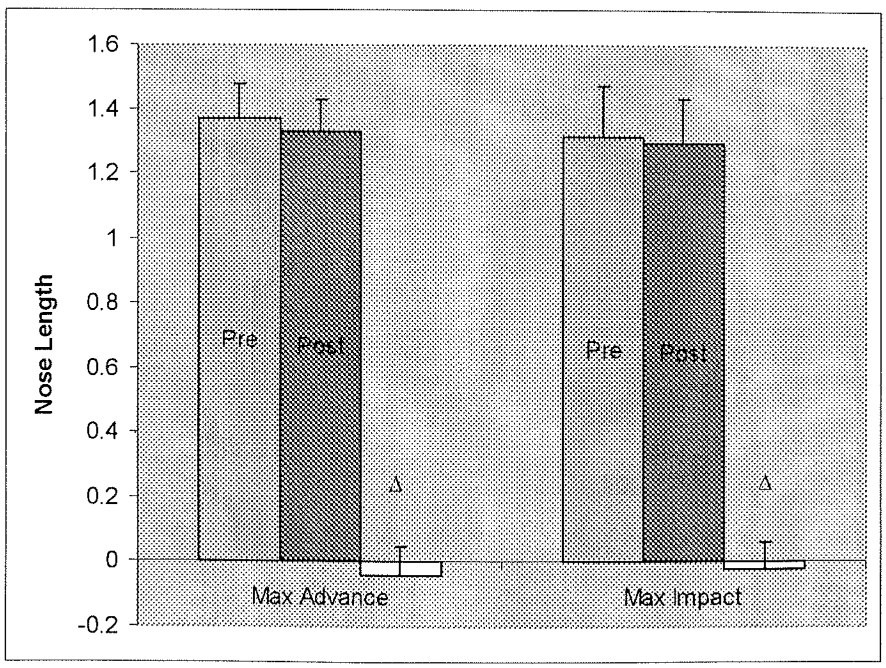

Figure 8. The mean positions and mean differences of Nose Length pre-surgery and post-treatment. Error bars represent the standard deviation.

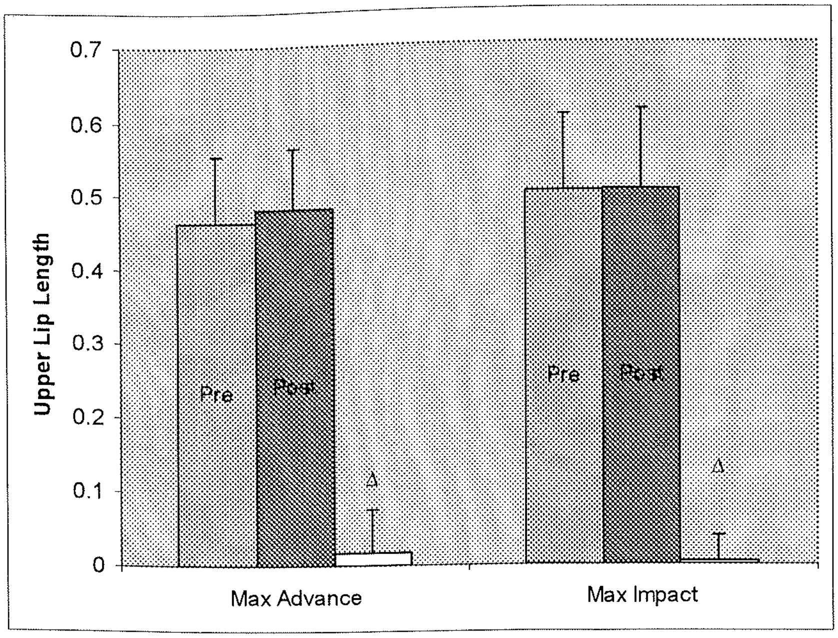

Figure 9. The mean positions and mean differences of Upper Lip Length pre-surgery and post-treatment. Error bars represent the standard deviation.

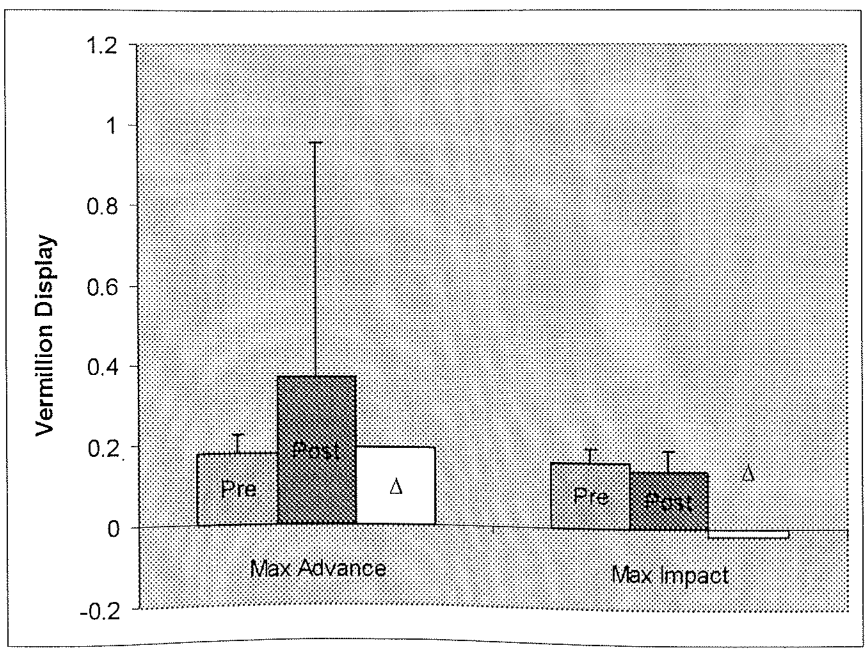

Figure 10. The mean positions and mean differences of Vermillion Display pre-surgery and post-treatment. Error bars represent the standard deviation.