Profile Changes in Orthodontic Patients Following Mandibular Advancement Surgery

Susan Tsang, BSc(Dent), DMD

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (ORTHODONTICS)

May 11, 2006

Department of Preventive Dental Science
Division of Orthodontics
University of Manitoba, Faculty of Dentistry
Winnipeg, Manitoba, Canada

© Copyright 2006 by Susan Tsang
ABSTRACT

PROFILE CHANGES IN ORTHODONTIC PATIENTS FOLLOWING
MANDIBULAR ADVANCEMENT SURGERY

Purpose: To define the amount of initial hard and soft tissue convexity necessary for profiles
to consistently improve after mandibular advancement and to assess if extraction of lower
teeth and the pre-surgical lower incisor inclination (IMPA) affects profile change. Methods:
20 general public, 20 orthodontists, and 20 oral surgeons used a 5-point scale to rate
attractiveness of before and after treatment profiles of 20 mandibular advancement patients
(9 extraction, 11 non-extraction). Spearman’s correlation tested for relationships between
amount of profile change and varying pre-treatment ANB angles, profile angles and pre-
surgical IMPA. Plots of the distribution of profile changes with varying ANB and profile
angles were examined. Wilcoxon rank sum test compared extraction and non-extraction
profile changes. Results: There was a tendency for inverse correlations between profile
change and profile angle, but these were not statistically significant any of the 3 groups
(p>.05). There was a tendency for positive correlations between profile change and ANB
angle, but was considered significant (p<.05) only for orthodontists. Orthodontists, oral
surgeons and the general public found profiles to consistently improve when profile angles
were $\leq 159^\circ$, $\leq 158^\circ$ and $\leq 157^\circ$, respectively. Orthodontists and oral surgeons found profiles
consistently improved when ANB angles were $\geq 5.5^\circ$ and $\geq 6.5^\circ$, respectively, but the general
public did not show any trends between ANB angle and profile change. The incidence of
profile worsening increased 2.6 to 5.0 times when profile angles exceeded the thresholds, and
increased 4.5 to 7.9 times when ANB angles were less than thresholds. There was no
difference in pre-surgical IMPA or profile change between extraction and non-extraction
groups (p>0.05), and there was no significant correlation between profile change and IMPA. 

**Conclusion:** Extraction of mandibular teeth is not predictive of a greater surgical profile change. Pre-treatment profile angles <160° and ANB angles >6° are necessary for consistent improvements after surgery. Profiles may worsen after treatment when these thresholds are not met.
ACKNOWLEDGEMENTS

I have been fortunate to have had many great teachers throughout my life and it is through the contributions of several of these people that the completion of this thesis and adventure was possible.

Firstly, thank you to Dr. Lee McFadden for taking on the task of supervising this thesis and for always being a source of insight, encouragement and perspective.

Many thanks to Dr. William Wiltshire for his many hours of hard work, constructive feedback, and humour in all aspects during my time in the program.

I would like to recognize Dr. Neeraj Pershad, who believed in this project and went beyond what was asked of him. Thank you for the enthusiasm and input into developing this idea and for making the trip back to Winnipeg to see it to the end.

Sincere thanks to Dr. Allan Baker for participating in the examining committee. His unwavering support in so many aspects has made these past 3 years truly enjoyable and I am grateful to have experienced his patience, trust and friendship.

I would also like to acknowledge Dr. Ken Mount for his statistical input and patience in answering all my questions to help bring these results together.

I am indebted to Dr. Robert Baker for his undefeatable integrity and dedication to the progress of the Graduate program and our profession. His commitment to education has allowed so many residents to become orthodontists and we have all been moved by his
sense of humanity and encouragement for us to search for answers and seek out all sides of a story.

To my classmates, Drs. Sonia Lapointe and Amani Morra, with whom over 3 years we have shared tears, laughter and camaraderie. I was fortunate to have traveled this path with these individuals and to have developed friendships that I will always remember. I wish them both lots of success and happiness as we move forward from here.

Lastly, but certainly not least, thanks goes to my parents, Mark and Andrey Tsang, for their support of my education and constant belief that anything can be possible.

Acknowledgement of financial support from the University of Manitoba Faculty of Dentistry Partners in Excellence Endowment Fund, the Division of Graduate Orthodontics, and the Faculty of Graduate Studies Student Travel Award, the Canadian Foundation for the Advancement of Orthodontics and the American Association of Orthodontists.
# TABLE OF CONTENTS

Abstract ........................................................................................................................................................................... ii

Acknowledgements .................................................................................................................................................................. iv

Table of Contents ............................................................................................................................................................... vi

List of Tables .......................................................................................................................................................................... ix

List of Figures ........................................................................................................................................................................ xi

1.0 INTRODUCTION ........................................................................................................................................................... 1

2.0 LITERATURE REVIEW ................................................................................................................................................... 3

2.1 Class II Malocclusions .................................................................................................................................................. 3

2.2 Decision Making in Borderline Cases ......................................................................................................................... 8

2.3 Esthetics and Soft Tissue Treatment Planning ............................................................................................................ 11

2.4 The Perception of Esthetics ........................................................................................................................................ 15

2.5 Incisor Positioning in Pre-Surgical Orthodontics ......................................................................................................... 20

3.0 OBJECTIVES AND NULL HYPOTHESIS ........................................................................................................................... 24

4.0 METHODOLOGY ............................................................................................................................................................ 26

4.1 Surgical Sample ............................................................................................................................................................ 26

4.1.1 Sample Selection ...................................................................................................................................................... 26

4.1.2 Cephalometric Landmarks and Angles ..................................................................................................................... 28

4.1.3 Profile Silhouettes .................................................................................................................................................... 30
4.2 Survey Procedure ........................................................................................................ 31
4.3 Evaluators ................................................................................................................. 32
4.4 Statistical Analysis ..................................................................................................... 32

5.0 RESULTS .................................................................................................................... 35

5.1 Sample Description and Treatment Changes ..................................................... 35
5.2 Change in Esthetic Score and Initial Profile Angle ........................................ 41
5.3 Change in Esthetic Scores and Initial ANB Angle ............................................. 46
5.4 Change in Esthetic Scores, Lower Arch Extractions & Incisor Inclination .. 51
5.5 Comparison of the Perception of Esthetics by Orthodontists, Oral Surgeons and the General Public ................................................................. 53
5.6 Intra-Evaluator Reliability ..................................................................................... 54

6.0 DISCUSSION ............................................................................................................. 55

6.1 Study Findings .......................................................................................................... 55
  6.1.1 Sample Characteristics and Treatment Effects ............................................. 55
  6.1.2 Changes in Profile Esthetics ........................................................................... 61
  6.1.3 Inter-Evaluator Differences ............................................................................ 64
  6.1.4 Reliability .......................................................................................................... 65

6.2 Study Limitations ................................................................................................... 66
  6.2.1 Statistical Limitations ....................................................................................... 66
  6.2.2 Surgical Sample Selection ................................................................................ 67
    6.2.2.1 Changes in the Vertical Dimension ................................................................. 67
    6.2.2.2 Isolated Mandibular Advancements ................................................................. 68
    6.2.2.3 Surgical Technique ....................................................................................... 69
LIST OF TABLES

Table 1: Inclusion and exclusion criteria for the surgical sample............................... 26

Table 2: Definition of cephalometric landmarks .......................................................... 29

Table 3: Definition of angles ........................................................................................ 29

Table 4: Cephalometric description of the surgical sample and treatment changes ...... 36

Table 5: Cephalometric means at T1, T3, and IMPA at T2, in patients with and without lower arch extractions................................................................. 38

Table 6: Mean treatment changes in patients treated with and without extractions ...... 40

Table 7: Spearman’s correlational coefficients between initial profile angle and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons. ............................................................. 42

Table 8: Incidence of negative profile changes when profile angles are less than or equal to the threshold profile angle or above the threshold profile angle. ............... 45

Table 9: Spearman’s correlational coefficients between initial ANB angle and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons. ............................................................. 47

Table 10: Incidence of negative profile changes when ANB angles are greater than or equal to the threshold profile angle or less than the threshold profile angle. ... 50
Table 11: Spearman’s correlational coefficients between initial IMPA and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons. ........................................................................................................... 52
LIST OF FIGURES

Figure 1: Landmarks, planes and angles................................................................. 28

Figure 2: Pre-treatment and post-treatment profile silhouettes of a subject treated with orthodontics and orthognathic surgery................................................................. 30

Figure 3: Distribution of profile angles ................................................................ 37

Figure 4: Distribution of ANB angles................................................................. 37

Figure 5: Orthodontist evaluations of profiles with varying initial profile angles .... 43

Figure 6: Oral surgeon evaluations of profiles with varying initial profile angles .... 44

Figure 7: General public evaluations of profiles with varying initial profile angles .. 44

Figure 8: Orthodontist evaluations of profiles with varying initial ANB angles ....... 49

Figure 9: Oral surgeon evaluations of profiles with varying initial ANB angles ....... 49

Figure 10: General public evaluations of profiles with varying initial ANB angles .... 50

Figure 11: Spearman’s correlation between the first and second ratings of the repeated profiles by the 3 groups of evaluators................................................................. 54
1.0 INTRODUCTION

In planning orthodontic treatment with skeletal discrepancies, orthodontists must evaluate whether there is a need to include orthognathic surgery into the treatment plan. Frequently, such a decision is motivated by a desire to improve or maintain a patient’s facial esthetics while optimizing occlusion and function. In cases where the esthetic improvement from surgery is anticipated to be minimal, however, greater consideration should be given to alternatives, such as orthodontic camouflage or even no treatment. While these decisions can be obvious in some cases, many other cases are borderline and have both surgery and dental camouflage as possible alternatives, making it difficult to decide which patients should receive a surgical referral in conjunction with their orthodontic treatment.

Class II patients with compromised pre-treatment esthetics, a greater Class II skeletal dentofacial deformity and a larger surgical mandibular advancement have been shown to have greater esthetic improvements after surgery than those with smaller surgical movements (Dunlevy et al., 1987; Shelly et al., 2000). However, with the large variation present in soft tissues that potentially mask the skeletal relationships, guidelines determined from hard tissue positions, such as the ANB angle, may not necessarily correlate to what is perceived in the soft tissue.

Since incisor positioning established by the orthodontist determines the degree and direction of surgical movement during orthognathic surgery, inadequate incisor decompensation during pre-surgical orthodontics may be a limiting factor of the esthetic outcome from surgery. In patients treatment planned for mandibular advancement surgery, failing to remove dental compensations and leaving increased lower incisor
proclination can limit the amount of surgical advancement of the mandible and thus the esthetic change.

Therefore, this study will survey the opinions of oral and maxillofacial surgeons, orthodontists and the general public to investigate the influence of mandibular arch non-extraction and extraction treatment on profile changes associated with mandibular advancement surgery. This study will also seek to establish guidelines based on a patient’s pre-treatment soft tissue profile angle and skeletal ANB angle that would aid in determining the severity of Class II anteroposterior disharmony necessary before patients derive significant esthetic benefit from mandibular advancement surgery.
2.0.  LITERATURE REVIEW

2.1 Class II Malocclusions

Longitudinal data from the Iowa Facial Growth Study reported a Class II molar relationship in 34.4% of the population studied (Bishara et al., 1988). The University of North Carolina has estimated that over 50% of individuals presenting for orthodontic treatment at their clinic have a skeletal Class II relationship, with 75% judged clinically to have a mandibular deficiency and 31.7% of these individuals being more dysplastic and having overjet in excess of 6 mm (Bailey et al., 2001). In addition, data from the 3rd National Health and Nutrition Examination Survey (NHANES III) of over 7000 individuals in the United States indicates more than half the population has increased overjet, with overjet being mild (3-4 mm) and moderate (5-6 mm) in 39% and 11% of the population, respectively (Proffit et al., 1998). Four percent of the United States population had overjet in excess of 7 mm, which could likely require orthognathic surgery in conjunction with orthodontics to correct.

A differential diagnosis of a Class II malocclusion must take into account the various permutations of several possible horizontal and vertical facial types (Moyers et al., 1980). The horizontal components may include combinations of maxillary dental protrusion, mandibular dental procumbancy, midface prognathism and mandibular retrognathism, while the vertical component can be manifestations of altered relationships of the palatal, occlusal and mandibular planes (Moyers et al., 1980). Wolford et al. (1978) coined the term “mandibular deficiency syndrome” to encompass the wide spectrum of esthetic, neuromuscular, cephalometric and occlusal features exhibited by those with mandibular deficiency. The three subcategories in this
classification take into consideration differences in growth and development, orthodontic
mechanics needed during treatment, different surgical procedures necessary for optimal
results, and the potential stability of the final result among each of the groups.

In Wolford’s classification (1978), mandibular deficiency syndrome Type I is
typified by those with a low mandibular plane angle, deficient lower anterior facial
height, prominent soft-tissue pogonion, deep overbite and excessive curve of Spee.
Those with mandibular deficiency syndrome Type II generally have a median mandibular
plane angle and are characterized by good facial proportions and balance of facial thirds
that makes the mandibular deficiency less obvious from the frontal view, though
noticeable in profile. Mandibular deficiency syndrome Type III, on the other hand, is
often associated with vertical maxillary excess or long face syndrome and has
characteristics including a steep mandibular plane angle, increased gonial angle, long
lower facial third, excessive gingival display, lip incompetence, deficient chin contour
and anterior open bite tendency.

According to Ackerman and Proffit (1997), malocclusions are ideally treated non-
extraction, provided goals can be accomplished within the limits of the dental and facial
soft tissues. Dental extractions can provide relief of crowding and/or permit retraction of
incisors without excessive arch expansion, but should only be done provided facial
esthetics is not compromised by doing so. Orthognathic surgery in conjunction with
orthodontics may be necessary to meet all treatment goals, but is reserved for individuals
who cannot otherwise be treated by the more conservative means.
Ackerman and Proffit (1997) introduced the concept of the “envelope of discrepancy” to graphically illustrate the limits of changes possible with various treatment methodologies (Proffit and White, 1990), while Arnett and McLaughlin (2004) suggested a classification of orthodontic patients into 3 categories to facilitate treatment planning:

Group 1: Routine orthodontic cases which treat out uneventfully.

Group 2: More difficult cases with mild or moderate skeletal discrepancies, but which can still be well treated by dental compensation and growth management.

Group 3: Cases with moderate to severe facial imbalance and malocclusion which should be treated with combined orthognathic surgery and orthodontics.

Class II treatment can involve either orthognathic surgery to reposition the jaws, orthodontic camouflage to compensate for jaw discrepancies, growth modification, or combinations of these (Proffit and White, 1990; Shell and Woods, 2003). Pre-adolescent and adolescent children with mild to moderate Class II skeletal malocclusions are often treated with some form of growth modification in efforts to avoid the future need for extractions or orthognathic surgery. In non-growing patients or patients with skeletal discrepancies requiring more change than can be produced by growth modification, treatment options are limited to either surgical correction of the skeletal relationship, dental camouflage of the underlying skeletal problem, or no treatment if the patient/parents reject both the surgery and camouflage options (Weaver et al., 1996).
Results from growth modification have significant individual variability, but have been reported to include a reduction in soft tissue convexity, increase in facial height, advancement of mandibular skeletal, dental and soft tissues, and uncurling of the lower lip with reduction of the labiomental fold (Shell and Woods, 2003). Favorable skeletal and dental improvements have been reported in over 70% of subjects treated with headgears or functional appliances in randomized clinical trials (Tulloch et al., 1997; Wheeler et al., 2002), but recent questions have been raised about the long-term effectiveness of early Class II treatment (Aelbers and Dermaut, 1996; Wheeler et al., 2002; Tulloch et al., 2004).

Orthodontic camouflage addresses the obvious aspect of a condition without correcting the underlying deformity itself (Proffit and Sarver, 2003). Camouflage of a Class II malocclusion produces normal overjet by retracting protruding upper incisors and moving lower teeth forward, with or without the extraction of teeth. Ideal cases for Class II camouflage are patients in whom the most obvious facial feature is upper incisor protrusion rather than chin deficiency (Proffit and Sarver, 2003). Although a functional occlusion is an important objective of orthodontic treatment, achieving this is not necessarily a mark of a successful treatment outcome (Proffit and White, 1990).

The limits of orthodontic camouflage are determined by the severity of the malocclusion, extent of the jaw discrepancy, soft tissue pressures of the lips, cheeks and tongue, periodontium, temporomandibular joints (TMJ), and overlying soft tissue integument (Ackerman and Proffit, 1997). Camouflage treatment carries with it an “esthetic risk” of producing an acceptable occlusion but compromised esthetics and/or a potentially unstable result (Ackerman and Proffit, 1995). The possible adverse sequelae
of inappropriate case selection can include (Proffit and Sarver, 2003; Arnett and McLaughlin, 2004):

- Upper lip retrusion that accentuates prominence of the nose and/or gives the patient an aged appearance;

- Extrusion of upper incisors increasing gingival display;

- Mesial movement of the lower arch placing the lower incisors in an unstable position prone to post-treatment relapse, bony dehiscence and gingival recession;

- Extrusion of lower posterior teeth rotating the mandible down and back, which may increase in facial height and/or accentuate chin retrusion.

- Patient dissatisfaction with treatment outcome.

Advances in surgical techniques have made surgery a well-accepted approach for the management of dentofacial deformities. Indications for orthognathic surgery include impaired mastication or function, temporomandibular dysfunction (TMD), esthetics, and psychosocial issues (Bailey et al., 1999). A systematic review by Hunt et al. (2001) found that after orthognathic surgery, most patients report positive opinions of the outcome and psychological improvements, including improved self-esteem/self-confidence, body image, facial attractiveness, personality, social functioning, emotional stability, and overall mood and ability to socially interact, as well as life changes such as better personal relationships and employment prospects (Hunt et al., 2001).

Studies on the psychosocial aspects of orthognathic surgery often cite patient motivation for surgery as being primarily esthetic, primarily functional or a combination of both (Hunt et al., 2001). The desire to improve esthetics is frequently the most
common reason patients seek treatment and a common reason why clinicians recommend surgery to patients (Phillips et al., 1997). Other motivators can include the relief of TMD symptoms, prevention of future problems, social well-being, or to satisfy the wishes of others (Bell et al., 1985; Phillips et al., 1997; Rivera et al., 2000).

The surgical management of mandibular deficiency involves procedures to advance the mandible and/or adjunctive procedures to increase chin prominence (genioplasty). At the Dentofacial Clinic at the University of North Carolina, 59% of patients electing to have orthognathic surgery had a Class II malocclusion (Bailey et al., 2001). Surgical complications associated with mandibular advancements include permanent neurosensory deficit of the lower lip/chin, complications associated with the general anaesthetic, mandibular fractures, malpositioning of segments, development of infection, prolonged fixation, devitalization of teeth, periodontal problems, development or worsening of TMD, relapse and development of malocclusions requiring a second surgery (Proffit and Sarver, 2003).

2.2. Decision Making in Borderline Cases

A professional’s opinion may differ from that of the patient/parent when matters are subjective, such as those surrounding esthetics and psychosocial issues. Effective communication is critical to achieving a mutual understanding and consensus between clinicians and patients (Ackerman and Proffit, 1995; Arpino et al., 1998). If orthodontic treatment is necessary, an agreement must usually be made before active treatment can begin as to whether treatment will involve orthodontics only or orthodontics plus
orthognathic surgery. In the presence of skeletal disharmonies, camouflage treatment with orthodontics only attempts to accentuate dental compensations to mask the skeletal relationship, while the objectives of pre-surgical orthodontics removes dental compensations so that the dentition is aligned within the basal bone for skeletal imbalances to be surgically corrected.

Up to 10% of patients, however, have both surgery and dental camouflage as alternatives that can be considered, thus complicating the decision making process for clinicians and patients (Weaver et al., 1996). Many errors in treatment planning are made in the management of borderline camouflage–surgery patients when camouflage treatment is attempted in patients that should have received orthognathic surgery and vice versa by inappropriately treating a patient surgically when an acceptable result could have been reached with orthodontics and dental compensation alone (Arnett and McLaughlin, 2004).

In borderline cases, Arnett and McLaughlin (2004) feel that the decision between camouflage or surgery should be guided by the best probability of successfully achieving 7 objectives: (1) healthy musculature and TMJ; (2) facial balance; (3) correct static and functional occlusion; (4) periodontal health; (5) resolving the chief complaint; (6) stability of dental, skeletal and growth changes; and (7) maintaining or increasing the airway. One goal should not be met at the expense of an unacceptable change in another.

Individuals with severe problems generally more easily accept extractions or surgery as necessary elements of the correction, but borderline cases may have treatment alternatives that vary greatly, ranging from minimal treatment to treatment requiring
extractions and/or surgery (Ackerman and Proffit, 1995). Significant amounts of discussion are necessary about the possible risks/benefits of each option and parents/patients must have the wisdom to choose what they feel is most appropriate for their personal circumstances (Ackerman and Proffit, 1995). Variables to consider include cultural differences, patient personal preferences, orthodontist training and personal views, expertise and training of the surgeons in the region, and financial considerations (Arnett and McLaughlin, 2004).

A survey by Weaver et al. (1996) found that treatment recommendations for borderline surgical patients are influenced by the patient’s physical, psychological, attitude or support system traits. Orthodontists were most likely to recommend a surgical procedure for a borderline case if the patient displayed a developmental defect, traumatic defect, or self-consciousness about the prominence of one jaw. Camouflage was most likely to be recommended to borderline cases with good facial esthetics but poor dental esthetics, introverts, extroverts, those fearing surgical risks and those with a resemblance to other family members. No treatment was often recommended for those that were uncooperative or do not want the discomfort, inconvenience, duration or expense of braces and surgery.

In addition to the increased morbidity and risks of orthognathic surgery, the financial costs of a surgical treatment plan are greater than treatment with orthodontics alone. A survey of Canadian orthodontists found that the financial costs of orthognathic surgery were perceived to be more justified when the severity of functional or esthetic compromise was significant (Weaver et al., 1998). Approximately 80% of respondents felt the costs of orthognathic surgery are justified for severe dentofacial deformities, but
less than 12% of respondents felt the additional costs are warranted for mild esthetic and/or mild functional compromises. Orthodontists were generally split as to whether the costs of a surgical correction are justified when there is a moderate functional or esthetic compromise.

If improvement in facial appearance is a basis for a clinician to recommend a surgical treatment plan, then there is considerable usefulness in having guidelines available to help predict cases that will have a clinically significant esthetic improvement following orthognathic surgery, particularly when both surgical and a dental camouflage treatments are valid options. If a significant esthetics improvement is unlikely to occur with surgery, more consideration should be given to more conservative means of treatments with dental camouflage. Therefore, a greater understanding of the characteristics of Class II malocclusions that gain the most esthetic benefit from mandibular advancement will be a valuable tool in treatment planning.

2.3 Esthetics and Soft Tissue Treatment Planning

The evolution of orthodontics has seen the pendulum swing from an emphasis on hard tissue relationships towards philosophies with greater emphasis on facial soft tissue balance. For example, Ricketts in the 1950’s suggested that a lower incisor within 1mm ± 2.5mm to the subspinale to pogonion line (A-Pog) was associated with the dentition of individuals with good facial balance (Ricketts, 1981). However, Park and Burstone (1986) have shown that patients treated to a lower incisor position of 1.5 mm relative to the A-Pog line can have significant variations in soft tissue measurements, differences
which they attributed to variations in soft tissue thickness. For example, upper lip protrusion varied by over 10 mm from standards, despite having an “ideally” positioned dentition. They also reported cases that had similar hard tissue convexity angles but soft tissue profile angles that differed by as much as 22°. These inconsistencies support the concept that treatment based only on hard tissue cephalometric standards does not always lead to the expected or desired soft tissue results.

Advancements in the fields of esthetic dentistry and orthognathic surgery have fuelled a growing momentum for assessment of occlusal as well as esthetic treatment objectives. Arnett and Bergman (1993a) described 19 facial profile and frontal measurements to aid orthodontists and surgeons in the quantifying and describing facial soft tissue relationships. In their article they state: “Facial analysis should be used to identify positive and negative facial traits and therefore how the bite should be corrected to optimize facial change.” Insufficient information is gleaned about overlying soft tissue by evaluating only dentoskeletal patterns on a lateral cephalometric radiograph because of individual variations in soft tissue thickness, length and postural tone: i.e., treatment based solely on a hard tissue lateral cephalometric analysis does not imply ideal facial esthetics after treatment. Orthodontic treatment planning should therefore start with an examination of facial and dental relationships statically and dynamically in 3-dimensions, and treatment plan decisions then made based on the dental and skeletal changes needed to achieve the esthetic and occlusal goals (Sarver and Ackerman, 2000).

Several cephalometric analyses include a measure of soft-tissue relationships. Commonly mentioned profile lines include Rickett’s esthetic plane (E-line), Gonzales-Ulloa’s profile line, Steiner’s S-line, Merrifield’s Z-line, Holdaway’s profile line, and
Burstone’s facial contour angle, lip protrusion evaluation line, nasolabial angle and chin-throat angle (Mejia-Maidl and Evans, 2000). The literature is also replete with studies on facial and dental esthetics and the soft-tissue and esthetic changes that occur with growth, non-extraction vs extraction orthodontic treatment, growth modification and orthognathic surgery (Mejia-Maidl and Evans, 2000).

In 1985, Burstone defined the facial contour or convexity angle as the acute angle formed by tangents to tissue glabella and pogonion intersecting at subnasale, with a mean value of $-11^\circ \pm 4^\circ$. Legan and Burstone (1980) reported a mean value of $-12^\circ \pm 4^\circ$, and McCollum (2001) found males had an “ideal” facial contour angle between $-10^\circ$ to $-14^\circ$ and females had a slightly larger angle ranging from $-14^\circ$ to $-16^\circ$.

Similar lines connecting soft tissue glabella, subnasale and pogonion form an obtuse angle known as the profile angle to describe the general harmony of the upper, middle and lower face (Arnett and Bergman, 1993b). According to Arnett and Bergman (1993b) a Class I skeletal relationship should have a profile angle between $165^\circ$-$175^\circ$, while profile angles below or above this range represent Class II or Class III skeletal relationships, respectively. Fernandez-Riveiro et al. (2003) reported the average profile angle to be $168^\circ \pm 5^\circ$ in males and $167^\circ \pm 5^\circ$ in females from a young adult Caucasian population in northwest Spain, while Yeun and Hiranka (1989) found profile angles of $162^\circ \pm 5^\circ$ in males and $161^\circ \pm 6^\circ$ in females of an adolescent Asian population. Arnett and Bergman (1993b) suggested that the profile angle is useful as the primary classification of a patient’s soft tissue profile and the most critical determinant of the need for anterior-posterior surgical correction, since variations in soft-tissue thicknesses are usually not
responsible for large deviations beyond the normal range and significant departures from the norm therefore indicate an underlying skeletal disharmony.

When orthognathic surgery is planned with a goal of improving esthetics, the ability to predict soft and hard tissue changes with orthognathic surgery is important for the clinician and patient in deciding appropriate treatment. Soft-tissue response to orthognathic surgery procedures have been studied extensively. With mandibular advancement surgery, the soft-tissue chin has often been reported to advance in harmony with the underlying bony chin in a 1:1 ratio (Vetkamp, 2002), while soft tissue B-point advances similarly or slightly less than bony B-point (Hernandez-Orsini et al., 1989; McCollum, 2001; Dolce et al., 2003). The lower lip often advances approximately 75% of the amount of advancement of the lower incisor tip, but this can vary significantly depending on the thickness and the pre-surgical position of the lip (Hernandez-Orsini et al., 1989; McCollum, 2001; Vetkamp 2002). Thicker lips are likely to absorb hard tissue movements to a greater extent and thus advance less, while thinner lips respond more to hard tissue movements (McCollum, 2001).

Previous published studies evaluating the relationship between the severity of skeletal discrepancy and profile attractiveness have used skeletal measures of the anteroposterior jaw discrepancy, such as the ANB angle (Shelly et al., 2000; Johnston et al., 2005). ANB angle readings, however, have limitations because they are dependent on the geometric relationship to other variables, such as the anteroposterior position of nasion relative to the jaws and the clockwise/counterclockwise rotation of the jaws relative to cranial landmarks (Jacobson, 1975; Hussels and Nanda, 1984). Hussels and Nanda (1984) described variations in ANB angle as the vertical distances between A
point and B point and between nasion and B point are altered. Jacobson (1975) devised
the Wits appraisal as a means to relate the jaws to each other without the use of cranial or
extracranial landmarks. By using the occlusal plane as the reference plane, the effect of
jaw rotation on the assessment of skeletal disharmony is eliminated, but this measure has
the drawback of relying on a dental parameter (the occlusal plane) that can easily be
affected by dental development and orthodontic treatment, independent of skeletal
changes (Hussels and Nanda, 1984). Thus, despite its limitations, the ANB angle
measure remains a widely accepted and often cited means to describe the anteroposterior
relationship of the maxilla and mandible and to distinguish dentoskeletal problems from
purely dental problems (Hussels and Nanda, 1984). However, its interpretation must be
done with an understanding of the possible factors that can mask the true skeletal
relationship.

Orthodontists evaluating photographs of surgical patients have been found to
demonstrate significant inter-observer reliability in the assessment of mandibular position
and facial form, implying that the evaluation of mandibular position can be used as a tool
in recommending orthognathic surgery (Bell et al., 1985; Vargo et al., 2003). However,
given the limitations of the ANB angle and the variation that is possible between hard
tissues and the soft tissue drape, guidelines based on facial soft-tissue measurements are
needed.

2.4 The Perception of Esthetics

The perception of facial esthetics can be influenced by the frequency a particular
facial pattern is observed and perceived as being “correct” (Peck and Peck, 1970).
Selective conditioning may manifest as the acceptance of certain concepts of what is considered by society as being beautiful or as presumptive judgements being associated with particular facial patterns (Peck and Peck, 1970). Physical attractiveness is not only an important influence on an individual’s social and personality development, but it has also been suggested that others view physically attractive people as possessing more desirable social and psychological capabilities than less attractive counterparts (Tulloch et al., 1993).

The subjective perception of facial and body image and oral function do not necessarily correspond to objective factors, such as cephalometric values, but they may be significant determinants of post-treatment satisfaction and predictors of the individual’s willingness to undergo a particular treatment (Maxwell and Kiyak, 1991; Vargo et al., 2003). Patients anticipating to be less self-conscious about their appearance after orthognathic surgery have been reported to be 4.7 times more motivated for surgery than those not expecting a significant change in self-consciousness, while individuals with low profile attractiveness were found to be 3.74 times more likely to pursue surgery (Vargo et al., 2003). Arpino et al. (1998) found that patients with a dentofacial deformity themselves had a smaller zone of tolerance for deviations in upper or lower lip position, bimaxillary protrusion, chin position or lower face height than their significant other or professionals including orthodontists or oral surgeons, suggesting that patients undergoing orthognathic surgery usually have a definite idea of their esthetic goals.

Perceptions of esthetics and treatment need, however, may differ between the various groups. Orthodontists and oral surgeons, by nature of their training and work, may be sensitive to disharmonies in esthetics and may perceive a greater need for surgical
intervention than patients themselves (Juggins et al., 2005). Some studies report no differences between orthodontists and oral surgeons in how esthetics are rated (Bell et al., 1985; Proffit et al., 1990), but Dunlevy et al. (1987) found that oral surgeons were more likely to favour large anterior-posterior changes in the position of pogonion and more likely to see an improvement after treatment than orthodontists and laypersons.

Some authors have reported lay persons as having similar or more critical perceptions of profile esthetics than professionals (Dunlevy et al., 1987; Arpino et al., 1998; Shelly et al., 2000), but others have reported lay persons as being less discriminating than those with dental training (Bell et al., 1985; Kerr and O’Donnell, 1990; Johnston et al., 2005). Johnston et al. (2005) found that two-thirds of laypersons would not seek treatment for profiles with SNB values that ranged from 73° to 83°, suggesting that the general public accepts a wider range of skeletal relationships than professionals. Dunlevy et al. (1987) found that laypersons judged 25% of all mandibular advancement subjects to be unimproved after surgery, while orthodontists and oral surgeons only judged subjects with the smallest amounts of surgical movements to be unimproved following surgery, suggesting that laypersons are more difficult to impress despite the amount of surgical change. Maple et al. (2005) found that the esthetic scores of a Class I profile by the orthodontists and surgeons were significantly higher than ratings from laypersons, stressing the preference that professionals place on profile and good facial balance.

Orthognathic profiles are generally considered the most attractive profile type (Dongieux and Sassouni, 1980; De Smit and Dermaut, 1984; Kerr and O’Donnell, 1990; Michiels and Sather, 1994; Phillips et al., 1995; Johnston et al., 2005; Maples et al.,
2005). Class III profile types have been reported in some studies to be more attractive than Class II profiles (Michiels and Sather, 1994; Johnston et al., 2005), but others have reported the contrary (Dongieux and Sassouni, 1980). Johnston et al. (2005) found that lay persons preferred profiles with an SNB close to the norm of 78° and were more likely to desire treatment as mandibular prognathism became increasingly Class II or Class III. As the severity of both mandibular retrusion and protrusion increased, attractiveness ratings decreased at an increasing rate, suggesting that surgical correction of severe discrepancies should produce larger improvements in attractiveness than correction of modest skeletal discrepancies, even if the surgical correction of the SNB discrepancy is relatively small in severe Class II and Class III cases.

Studies have also addressed the effect of vertical proportions on facial esthetics and concluded that vertical facial proportions have a definitive impact on facial esthetics. Dongieux and Sassouni (1980) found that not only do deviations in mandibular anteroposterior positions decrease attractiveness, but lower facial height increases of 5-10 mm also create more unpleasing facial appearances in comparison to normal vertical proportions. Maple et al. (2005) digitally altered facial profile photographs in 4mm increments sagittally and vertically and found that profiles with horizontal discrepancies accentuated by vertical disharmonies (e.g. long face Class II or short face Class III) were the least attractive. Michiels and Sather (1994) found increased vertical features to be a greater impediment to facial attractiveness than decreased facial features, such as short facial height and deep mentolabial sulcus. Among the least attractive females, 8% had decreased vertical facial features but 42% had increased vertical facial features.
Furthermore, ideal vertical facial proportions were found in 88% of those who were considered the most attractive, but only in 27% of those who were the least attractive.

In studies rating facial esthetics before and after mandibular surgery for class II malocclusions, it has been found that those with the poorest pre-treatment esthetics had the greatest esthetic improvement (Proffit et al., 1992; Shelly et al., 2000). Dunlevy et al. (1987) found that patients with smaller amounts of surgical movements (≤5 mm of pogonion change) were more likely to be ranked as unimproved after treatment in comparison to those treated with larger mandibular advancements. Shelly et al. (2000) evaluated the perception of lay people and orthodontic residents and found that an initial ANB of 6° was a threshold for judging the potential for significant profile improvement after mandibular advancement. Those with an initial ANB of 6° or greater, had esthetic ratings improve by approximately 45%, while those with an initial ANB of less than 6° experienced an overall post-treatment change that was statistically insignificant.

While average facial esthetics following Class II treatment generally improves after growth modification, camouflage or surgical treatment (Proffit et al., 1992; Shelly et al., 2000; Shell and Woods, 2003), a lack of improvement or even a worsening of esthetics is also a reality with all 3 treatment methods. A randomized trial by O’Neill et al. (2000) found that after 18 months of functional appliance treatment, there was no significant difference in the profile attractiveness in comparison to untreated controls. Improvements in profile occurred in 65% of the untreated controls and 67-77% of the treated subjects, but less attractive profiles also occurred in some subjects in all the groups, leading the authors to suggest it is unwise for clinicians to promise that functional appliance treatment will significantly improve attractiveness of a growing patient’s
profile. The study by Shelly et al. (2000) found that approximately half of the study profiles were judged by lay persons and orthodontic residents to have worse esthetics after orthognathic surgery, a result similar to Shell and Woods (2003), in which the changes in esthetics judged by lay people and professional evaluators were extremely variable and a worsening or no change in esthetics following orthognathic surgery or growth modification treatment occurred in over 40% of patients.

2.5 Incisor Positioning in Pre-Surgical Orthodontics

Although Edward Angle’s classification of malocclusion based on the relationship of the upper and lower first molars remains popular in modern dentistry and orthodontics, Larry Andrews (1972) recognized that other occlusal discrepancies often existed in orthodontically treated cases despite Angle’s cusp-groove relationship. Andrews consequently defined six characteristics that he deemed as requirements for a naturally optimal occlusion. These characteristics were referred to as the “six keys to normal occlusion” and included proper molar relationship, correct crown angulation, correct crown inclination, absence of rotations, presence of tight contacts and a flat curve of Spee (Andrews, 1972). Andrews concluded that the lack of even one of these characteristics would be predictive of an incomplete orthodontically treated result.

According to Andrews’ principles (1989), upper incisors with a moderately positive inclination and lower incisors with a slightly negative inclination are essential for optimal occlusion. A mandibular arch with excessively proclined lower incisors has increased perimeter, core and midsaggital lines. Proper occlusion of such an arch with
the maxillary teeth can only occur if the maxillary teeth also have increased inclination.

Occlusion between a properly aligned maxillary arch and a lower arch with an increased perimeter line results in a normal anterior occlusion, but a Class II tendency of the posterior teeth (Andrews, 1989).

Pre-surgical positioning of incisors by orthodontists is an important determinant of the position of the jaws at the time of surgery. Skeletal disharmonies are often masked by dental compensations, which can include upper incisor retrusion or lower incisor protrusion in patients with Class II skeletal relationships (Arnett and Bergman, 1993b). Inadequate decompensation that leaves maxillary incisors too upright or lower incisors too proclined result in a maxillary perimeter line that is short relative to the mandibular perimeter line (Andrews, 1989). Following subsequent surgical advancement of the mandible to ideal overjet and overbite there is a normal anterior dental relationship but Class II posterior occlusion and residual chin deficiency because the mandible could not be advanced sufficiently (Sarver and Sample, 1999). Thus, the goal of pre-surgical orthodontics is to remove dental compensations and properly align the teeth within their respective basal bones before surgery (Arnett and Bergman, 1993b; Epker et al., 1994).

The curve of Spee (COS) is an important factor to consider in the overall space analysis, particularly in Class II malocclusions in which overeruption of anterior teeth has occurred until tooth contact is made with the opposing anterior teeth, palate or tongue (McLaughlin et al., 2001). Removing these dental compensations from the mandibular arch using reverse COS in a continuous archwire or intrusion arch often results in incisor proclination, especially in non-extraction cases without excess space (Epker et al., 1995; Proffit, 2001; Proffit et al., 2003a). Bite opening mechanics generate biomechanical
moments that tend to distally tip lower molars and accentuate the Class II relationship of the posterior teeth (Proffit, 2001), while proclining the lower incisors and reducing the overjet, making it counterproductive for proper Class II correction.

Baldridge (1969) found that levelling of an excessive curve of Spee without lateral expansion, labial tipping of incisors or distalization of molars requires additional arch length that can be approximated by averaging the greatest depth of the curve on both sides and subtracting 0.51mm. Braun et al. (1996) found less arch length to be required than had been reported in earlier studies and suggested that incisor flaring during levelling may be related to inappropriate biomechanics.

Proper decompensation involves creating overjet pre-surgically that matches the degree of chin retrusion to allow for total skeletal correction with surgical advancement (Arnett and Bergman, 1993b). Sarver and Sample (1999) believe that it is vital for the orthodontist to recognize the presence of dental compensations during treatment planning and decide whether treatment is justified to rectify the situation. The failure to recognize the presence of compensations or deciding to leave dental compensations to avoid extraction of teeth may result in compromised functional, esthetic and/or occlusal outcomes following mandibular advancement. According to Sarver and Sample (1999), the consequences of inadequate maxillary incisor torque or excessive mandibular incisor proclination prior to mandibular advancement can include:

1. Compromised buccal interdigitation.
2. Compromised esthetic outcome because there is insufficient overjet for the oral surgeon to advance the mandible to bring about a significant facial change.
3. Limiting the functional improvement that can occur and possibly compromising the overall health of the patient. There are some circumstances, such as mandibular advancement suggested as a treatment for obstructive sleep apnea, where alleviating certain functional problems is the primary objective.

In surgical Class II patients, proper decompensation of upper and lower incisors may require pre-operative Class III elastics, extraction of lower teeth, or coil springs to open space distal to the upper lateral incisors to flare the upper incisors and/or compensate for tooth-size discrepancies (Sarver and Sample, 1999). Mandibular advancement in conjunction with non-extraction treatment is best reserved for those with little or no crowding and mild or moderate dental compensations, in whom non-extraction treatment would also have been attempted had their malocclusion been associated with a Class I skeletal relationship (Epker et al., 1995).

If excessive incisor flaring cannot be avoided by use of Class III elastics and/or air-rotor stripping, it is often necessary to extract teeth to remove dental compensations (Epker et al., 1995). Non-extraction treatment precludes removal of dental compensations and often leaves lower incisors more protrusive than ideal, making an advancement genioplasty necessary to improve stability of the protrusive lower incisors and further increase chin projection to compensate for the reduced anteroposterior change (Epker et al., 1995). It may be preferable to add the genioplasty rather than remove healthy teeth when no crowding is present in the lower arch, but if crowding is present, extraction treatment may be appropriate (Epker et al., 1995).
3.0 OBJECTIVES AND NULL HYPOTHESIS

**Objective #1:** To determine if orthodontic treatment involving mandibular arch extraction(s) affects the amount of post-treatment profile change that occurs following mandibular advancement surgery.

**Null Hypothesis #1:** There is no relationship between lower arch extractions and the post-treatment profile change as perceived by orthodontists.

**Null Hypothesis #2:** There is no relationship between lower arch extractions and the post-treatment profile change as perceived by oral surgeons.

**Null Hypothesis #3:** There is no relationship between lower arch extractions and the post-treatment profile change as perceived by the general public.

**Objective #2:** To determine the thresholds of maxillo-mandibular sagittal skeletal discrepancy and soft tissue convexity necessary for a significant post-treatment improvement in profile after mandibular advancement surgery.

**Null Hypothesis #4:** There is no relationship between the pre-treatment hard tissue sagittal disharmony (ANB angle) and the post-treatment profile change as perceived by orthodontists.

**Null Hypothesis #5:** There is no relationship between the pre-treatment hard tissue sagittal disharmony (ANB angle) and the post-treatment profile change as perceived by oral surgeons.
Null Hypothesis #6: There is no relationship between the pre-treatment hard tissue sagittal disharmony (ANB angle) and post-treatment profile change as perceived by the general public.

Null Hypothesis #7: There is no relationship between the pre-treatment soft tissue convexity (profile angle) and post-treatment profile change as perceived by orthodontists.

Null Hypothesis #8: There is no relationship between the pre-treatment soft tissue convexity (profile angle) and post-treatment profile change as perceived by oral surgeons.

Null Hypothesis #9: There is no relationship between the pre-treatment soft tissue convexity (profile angle) and post-treatment profile change as perceived by the general public.

Objective #3: To examine whether there is a difference in the perception of facial profiles of surgically treated patients when judged by orthodontists, oral surgeons and dentally-untrained general public.

Null Hypothesis #10: There is no difference in the perception of orthodontist, oral surgeons and dentally-untrained individuals on the profiles of individuals with mandibular deficiency treated with orthognathic surgery.
4.0 METHODOLOGY

4.1 Surgical Sample

4.1.1 Sample Selection

Records of 61 individuals treated with orthodontics and mandibular advancement between 1980 and 2003 were located from the University of Manitoba Graduate Orthodontic Clinic archives. Patients undergoing orthognathic surgery had diagnostic records taken pre-treatment (T1), pre-surgical (T2) and at time of removal of the braces (T3). No preference was given to the degree or location of the skeletal anteroposterior discrepancy, patient gender or ethnicity, or the surgeon who performed the operation. After applying inclusion and exclusion criteria, there were 20 usable records/charts.

Table 1: Inclusion and exclusion criteria for the surgical sample

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Pre-treatment MP-SN angle of 33° ± 6° (Björk, 1960);</td>
<td>(1) Craniofacial anomalies (e.g. cleft lip, cleft palate);</td>
</tr>
<tr>
<td>(2) Treatment with orthodontics and mandibular advancement surgery with rigid or intermaxillary wire fixation and with or without use of a surgical splint;</td>
<td>(2) Maxillary surgery or genioplasty;</td>
</tr>
<tr>
<td>(3) May or may not have had extractions for correction of crowding, dental compensations and/or asymmetries;</td>
<td>(3) Missing or poor quality lateral cephalometric radiographs at T1, T2 and T3.</td>
</tr>
<tr>
<td>(4) T1, T2, and T3 lateral cephalometric radiographs with distinguishable soft tissue contours extending past soft-tissue glabella and neck throat point.</td>
<td></td>
</tr>
</tbody>
</table>
The use of records of human subjects was approved by the University of Manitoba Health Research Ethics Board (HREB) (Appendix 8.1). The 20 subjects were contacted in writing to explain the nature of the study and further written consent was obtained for the use of their records. The 3 groups of study participants (orthodontists, oral surgeons and general public) that agreed to review and rate the profiles were also explained the nature of the study and provided their written consent to participate prior to taking part in the study, as per HREB requirements.

Information on patient age and treatment time was collected from treatment notes from the charts. Due to the nature of the Graduate program, it was not uncommon for pre-treatment records to be taken several months prior to appliance placement. As such, treatment length was calculated as the number of months elapsed between the date of appliance placement to the time of appliance removal, rather than the time between pre- and post-treatment records.
4.1.2 Cephalometric Landmarks and Angles

**Figure 1:** Landmarks, planes and angles. *A*, Sella (S); Nasion (N); Soft-tissue glabella (G’); A-point (A); B-point (B); Subnasale (Sn); Soft-tissue pogonion (Pog’); Menton (M); Neck-throat point (NTP). *B*, Sella-nasion plane (SN); ANB angle (ANB); Profile angle (PA); Incisor mandibular plane angle (IMPA); Mandibular plane (MP).
Table 2: Definition of cephalometric landmarks (Jacobson and Vlachos, 1995; Caufield, 1995)

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Abbr.</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft-tissue Glabella</td>
<td>G’</td>
<td>Most prominent anterior soft-tissue point in the midsagittal plane of the forehead</td>
</tr>
<tr>
<td>Subnasale</td>
<td>Sn</td>
<td>Point where the columella merges with the upper lip.</td>
</tr>
<tr>
<td>Soft-Tissue Pogonion</td>
<td>Pog’</td>
<td>Most prominent or anterior soft-tissue point in the midsagittal plane of the chin.</td>
</tr>
<tr>
<td>A Point</td>
<td>A</td>
<td>Most posterior midline point in the concavity between the anterior nasal spine and prosthion</td>
</tr>
<tr>
<td>B Point</td>
<td>B</td>
<td>Most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lower incisors and pogonion.</td>
</tr>
<tr>
<td>Nasion</td>
<td>N</td>
<td>Most anterior point of the frontonasal suture in the midsagittal plane.</td>
</tr>
<tr>
<td>Sella</td>
<td>S</td>
<td>Centre of pituitary fossa, located by visual inspection.</td>
</tr>
<tr>
<td>Menton</td>
<td>M</td>
<td>Lowest point on the symphyseal shadow of the mandible</td>
</tr>
</tbody>
</table>

Table 3: Definition of angles

<table>
<thead>
<tr>
<th>Angle</th>
<th>Abbr.</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular plane angle</td>
<td>MPA</td>
<td>Angle between the sella-nasion line and a line tangent to the inferior border of the mandible and most inferior point of the symphysis (Jacobson, 1995)</td>
</tr>
<tr>
<td>Profile angle</td>
<td>PA</td>
<td>Obtuse angle formed by tangents to glabella and soft tissue pogonion that intersect at subnasale (Arnett, 1993b)</td>
</tr>
<tr>
<td>ANB angle</td>
<td>ANB</td>
<td>Angle formed by lines joining N to A-point and N to B-point (Steiner, 1953)</td>
</tr>
<tr>
<td>Incisor-mandibular plane angle</td>
<td>IMPA</td>
<td>Angle formed by the intersection of the long axis of the lower incisors from the incisal edge to root apex with the plane formed by the lower border of the mandible (Tweed, 1946)</td>
</tr>
</tbody>
</table>
4.1.3 Profile Silhouettes

Pre-treatment, pre-surgical and post-treatment lateral cephalometric radiographs were hand traced on acetate paper for hard and soft tissue analysis. The soft tissue profile was traced from a point above glabella to a point past throat point. To orientate a subject’s pre- and post-treatment tracings to the same head position, the two tracings were superimposed on anterior cranial base to confirm whether Frankfort horizontal (FH) planes were coincident (Shelly et al., 2000). If the FH planes at T1 and T3 were not coincident, the FH plane at T1 was transferred to the T3 tracing and used for orientation of the tracings. The profiles were scanned at 200 dpi on a flatbed scanner (CanoScan Lide 30, Canon, Mississauga, ON) and imported into Jasc Paint Shop Pro (Jasc Software Inc, version 8.1, Ottawa, ON). Images were oriented with FH parallel to the top edge of the screen and the profiles filled in black to produce silhouettes.

Figure 2: Pre-treatment (T1) and post-treatment (T3) profile silhouettes of a subject treated with orthodontics and orthognathic surgery.
4.2 Survey Procedure

The 20 pre-treatment and 20 post-treatment profiles silhouettes were randomized and inserted into a PowerPoint® presentation (Microsoft Office Profession Edition 2003, Microsoft Corporation, Mississauga, ON). Three additional unrelated silhouettes were added in the beginning of the slide show to familiarize participants with the procedure only and were not used in any subsequent analysis. Seven of the 40 silhouettes were randomly selected and inserted within the presentation a second time to test for intra-observer reliability. Participants were not told that there were duplicate images. Responses from the first time the profiles were rated were used to calculate change in profile after surgery. The initial 3 introductory slides were shown for 20, 15 and 10 seconds each and the remaining 47 slides were shown for 10 seconds each. In total, participants evaluated 50 profile silhouettes and rated each profile on a 5-point Likert scale from “Very Unattractive” to “Very Attractive”, similar to scales used in earlier studies (Dongieux and Sassouni, 1980, Shelly et al., 2000) The Powerpoint presentation was viewed on a computer monitor and participants were given the following instructions to read:

*You will be shown 50 “before” and “after” profile silhouettes, in no particular order, of individuals who have had braces and jaw surgery. Each picture is identified in the upper right corner by a number. The pictures will advance automatically and a bell will sound to indicate the change to the next picture. The first 3 pictures will be shown for 20 seconds, 15 seconds and 10 seconds each. The next 47 pictures will then be shown for 10 seconds each. As you proceed, locate the corresponding answer on the score sheet and circle a rating from 1 to 5, according to how you would best describe the overall profile:*

1. Very unattractive
2. Unattractive
3. Fair
4. Attractive
5. Very attractive
4.3 Evaluators

Sample size of subjects participating in the questionnaire was determined after discussion with a statistician from the University of Manitoba Biostatistical Consulting Unit. The study surveyed 20 orthodontists, 20 oral surgeons and 20 lay persons without dental training (general public). For those who could not be reached in person, the material was distributed via electronic mail or compact disc to be viewed on a computer. Response sheets were sent back via fax or mail. The questionnaire was distributed to 17 Manitoba orthodontists, 3 Graduate Orthodontic residents within 6 months of completing their final year of study at the University of Manitoba and 25 oral and maxillofacial surgeons across Canada who perform orthognathic surgery as a component of their practice. The first 20 responses received from the oral and maxillofacial surgeons were included in the study. The 20 members of the general public were individuals with a variety of backgrounds but all with no prior training in any dental-related field.

4.4 Statistical Analysis

Angles on the lateral cephalometric radiographs (MPA, IMPA, SNA, SNB, ANB, and PA) were manually measured by the researcher to the nearest 0.5° using a protractor with 1° increments. Statistical analyses were performed with SAS statistical software (version 9.1.3, SAS Institute, Inc, Cary, NC) in consultation with the Statistical Consulting Unit of the University of Manitoba. The surgical sample was divided into those treated with lower arch extractions (extraction group) and those treated without extractions (non-extraction group). Multiple univariate student t-tests were used to compare the extraction group to the non-extraction groups at T1 and again at T3. IMPA
was also compared between the extraction and non-extraction groups at T2. With 13 independent t-tests, inflation of experimental error was controlled by reducing the desired significance level of 0.05 by a factor of 13, resulting in the two-tailed tests being considered statistically significant at the $p < 0.05/13$ or 0.0038 level. Multiple univariate student t-tests were used to compare treatment changes in the six measured cephalometric angles from T1 to T3, in addition to the change in IMPA from T1 to T2, in the overall sample as well as in the extraction and non-extraction groups. With 7 independent t-tests, statistical significance was taken at the $p < 0.05/7$ or 0.0071 level.

Based on the 6º threshold suggested by Shelly et al. (2000), student’s t-tests were used to compare the mean pre-surgical IMPA of subjects with an initial ANB angle of 6º or less and those with an ANB angle greater than 6º, with significance level set at $p < 0.05$. Pearson’s correlation was also carried out between initial ANB angle and initial profile angles, also at a significance level of $p<0.05$.

Changes in patient profiles were calculated as the difference between the post-treatment esthetic score and the pre-treatment esthetic score. Differences greater zero indicated a profile improvement following treatment, scores less than zero indicated a worsening of the profile, while difference equal to zero indicated no change with treatment. With 20 evaluators in each panel evaluating 20 profiles, there were a total of 400 judgements made by each panel. Each group of 400 judgements was plotted as a three-dimensional scatterplot that graphically depicted the frequency profile changes after treatment at varying pre-treatment ANB angle. Similar scatterplots were generated to depict the frequency of the relationship between profile changes with treatment and varying pre-treatment profile angle. Similar to Shelly et al. (2000), the plots were
examined for values of ANB and profile angles at which the difference in esthetic score from T1 to T3 were consistently greater than or equal to zero. A threshold requirement of fewer than 3 evaluations (<1% of the 400 evaluations) below zero was accepted.

Given the non-parametric nature of this data, Spearman’s rank correlation (r) was used to calculate intra-observer reliability and the relationship between the change in esthetic scores and pre-treatment ANB angle, pre-treatment soft tissue profile angle, and pre-surgical lower incisor-to-mandibular plane angle. Wilcoxon rank sums test compared the esthetic difference following surgery between patients treated with extractions to those treated non-extraction. Friedman’s tests (two-way non-parametric ANOVA) were used to examine for differences between how esthetics was evaluated by the 3 groups of evaluators. Statistical testing of the above tests were two-tailed and considered significant at p < 0.05.
5.0 RESULTS

5.1 Sample Description and Treatment Changes

The sample of 20 patients treated with mandibular advancement consisted of 3 (15%) males and 17 (85%) females. The average time lapsed between pre-treatment and post-treatment records was just over 3 years, but actual average treatment time from date of appliance placement to date of appliance removal was 2 years and 7.6 months (SD ± 7.5 months), with a range of 1 year and 9 months to 3 years and 10 months.

Table 4 describes the cephalometric characteristics of the 20 patients in the surgical sample. All treatment changes were considered statistically significant at the p < 0.0071. The mean initial MPA of 32.7º increased by 3.6º with treatment. Mean IMPA increased pre-surgically (T1 to T2) by 3.6º, though the final change in IMPA (T1 to T3) was slightly less (2.7º). None of the IMPA changes, however, were statistically significantly. Treatment had no effect on the maxillary position (SNA), but did increase mandibular prominence, evidenced by a significant increase in SNB angle by 2.5º. Concurrently, there was a significant decrease in ANB by 2.6º and an increase in the profile angle by 4.3 º.
### Table 4: Cephalometric description of the surgical sample and treatment changes (n = 20).

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th></th>
<th></th>
<th>Final</th>
<th></th>
<th></th>
<th>Treatment Change</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Min</td>
<td>Max</td>
<td>Mean (SD)</td>
<td>Min</td>
<td>Max</td>
<td>Mean (SD)</td>
<td>Min</td>
<td>Max</td>
<td>p</td>
<td></td>
</tr>
<tr>
<td>MPA (°)</td>
<td>32.7 (3.1)</td>
<td>28.0</td>
<td>38.0</td>
<td>36.3 (3.6)</td>
<td>29.0</td>
<td>43.0</td>
<td>3.6 (2.7)</td>
<td>-1.0</td>
<td>9.0</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>IMPA (°)</td>
<td>94.9 (8.0)</td>
<td>79.0</td>
<td>109.0</td>
<td>98.5 (6.7)†</td>
<td>84.0†</td>
<td>110.0†</td>
<td>3.6 (8.1)†</td>
<td>-9.0†</td>
<td>20.0†</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>SNA (°)</td>
<td>80.3 (4.1)</td>
<td>74.0</td>
<td>92.0</td>
<td>80.3 (3.6)</td>
<td>75.0</td>
<td>91.0</td>
<td>-0.1 (2.1)</td>
<td>-5.0</td>
<td>4.5</td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>SNB (°)</td>
<td>74.0 (3.6)</td>
<td>69.0</td>
<td>83.0</td>
<td>76.6 (3.0)</td>
<td>72.0</td>
<td>84.0</td>
<td>2.5 (1.8)</td>
<td>-2.0</td>
<td>6.5</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>ANB (°)</td>
<td>6.3 (1.7)</td>
<td>3.5</td>
<td>10.0</td>
<td>3.7 (1.6)</td>
<td>1.0</td>
<td>7.0</td>
<td>-2.6 (1.2)</td>
<td>-0.5</td>
<td>-5.0</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td>PA (°)</td>
<td>161.0 (4.6)</td>
<td>152.0</td>
<td>170.0</td>
<td>165.3 (4.3)</td>
<td>156.0</td>
<td>172.0</td>
<td>4.3 (3.2)</td>
<td>-2.0</td>
<td>12.0</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at p < 0.0071 level

† IMPA measured at T2 and treatment change in IMPA calculated as T2 minus T1. All other final values in the table are measured from T3 records and treatment change is calculated as T3 minus T1.

Mean treatment changes may vary slightly from the difference of final and initial values due to rounding of values.
Figures 3 and 4 show the distribution of the initial profile angles and ANB angles of the patients in the surgical sample, respectively. The distribution of profile angles is slightly negatively skewed, while the distribution of ANB angles is positively skewed.

**Figure 3:** Distribution of profile angles (n = 20)

**Figure 4:** Distribution of ANB angles (n = 20)
Of the 20 subjects used in the study, 11 were treated non-extraction and 9 were treated with mandibular arch extractions of either premolars (7 subjects) or lower incisors (2 subjects). From the extraction group, 5 subjects also had extractions of either first or second premolars in the maxilla. A comparison of the characteristics of the extraction and non-extraction groups is presented in Table 5, with results considered statistically significant if the p value was < 0.0038. There were no statistically significant differences between the two groups at T1, T3, or in IMPA at T2.

Table 5: Cephalometric means (standard deviation) at T1, T3, and IMPA at T2, in patients with (n = 9) and without (n = 11) lower arch extractions.

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th></th>
<th>Final</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extraction</td>
<td>Non-Extraction</td>
<td>p</td>
<td>Extraction</td>
</tr>
<tr>
<td>MPA (º)</td>
<td>34.0 (3.0)</td>
<td>31.6 (2.8)</td>
<td>0.086</td>
<td>38.0 (2.9)</td>
</tr>
<tr>
<td>IMPA (º)</td>
<td>94.0 (7.4)</td>
<td>95.5 (8.7)</td>
<td>0.68</td>
<td>95.5 (6.1)†</td>
</tr>
<tr>
<td>SNA (º)</td>
<td>80.1 (3.5)</td>
<td>80.5 (4.7)</td>
<td>0.84</td>
<td>79.7 (2.6)</td>
</tr>
<tr>
<td>SNB (º)</td>
<td>73.6 (3.1)</td>
<td>74.4 (4.1)</td>
<td>0.61</td>
<td>75.6 (2.1)</td>
</tr>
<tr>
<td>ANB (º)</td>
<td>6.6 (1.5)</td>
<td>6.1 (2.0)</td>
<td>0.57</td>
<td>4.1 (1.3)</td>
</tr>
<tr>
<td>PA (º)</td>
<td>158.6 (4.0)</td>
<td>163.0 (4.3)</td>
<td>0.029</td>
<td>164.8 (5.2)</td>
</tr>
</tbody>
</table>

* Significant at p < 0.0038 level.

† All final values were measured at T3, except IMPA values noted with “†” to indicate T2 measurements.
Table 6 describes treatment changes that occurred in the extraction and non-extraction groups, with the significance level set at \( p < 0.0071 \). Pre-surgical orthodontics (T1 to T2) with extractions proclined the lower incisors 1.5° (from 94° to 95.5°), while non-extraction treatment proclined the lower incisors 5.4° (from 95.5° to 100.9°). Between T2 and T3, mean IMPA further increased by 1.2° in the extraction group to finish at 96.7°, and decreased in the non-extraction group by 2.7° to finish at 98.2° (Table 5). IMPA changes from T1 to T2 and from T1 to T3, however, were not statistically significant between the extraction and non-extraction groups (\( p > 0.0071 \)).

Both non-extraction and extraction groups had significant decreases in ANB angle of approximately 2.5° with treatment, but at a significance level of 0.0071, the SNB change was statistically significant only for the non-extraction group (Table 6). The difference in the treatment change in SNB between the 2 groups was only 0.8° and is likely not of clinical significance.

Patients in the extraction group had more acute initial profile angles (158.6°) than the non-extraction group (163°), but the difference was not statistically different (\( p > 0.0038 \)) (Table 5). There was a statistically greater increase in this angle with treatment in the extraction group than the non-extraction group (Table 6), resulting in a post-treatment difference between the two groups of only 0.9°.
Table 6: Mean treatment changes (standard deviation) in patients treated with (n = 9) and without extractions (n = 11).

<table>
<thead>
<tr>
<th>Treatment Change</th>
<th>Extraction</th>
<th>p</th>
<th>Non-Extraction</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPA (°)</td>
<td>4.0 (3.2)</td>
<td>0.005*</td>
<td>3.2 (2.3)</td>
<td>0.001*</td>
</tr>
<tr>
<td>IMPA (°)</td>
<td>1.5 (8.9) †</td>
<td>0.63</td>
<td>5.4 (7.3) †</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>2.7 (7.4)b</td>
<td>0.31</td>
<td>2.6 (8.2)b</td>
<td>0.31</td>
</tr>
<tr>
<td>SNA (°)</td>
<td>-0.4 (2.4)</td>
<td>0.59</td>
<td>0.2 (2.0)</td>
<td>0.71</td>
</tr>
<tr>
<td>SNB (°)</td>
<td>2.1 (1.8)</td>
<td>0.010</td>
<td>2.9 (1.7)</td>
<td>0.0002*</td>
</tr>
<tr>
<td>ANB (°)</td>
<td>-2.5 (1.2)</td>
<td>0.0003*</td>
<td>-2.6 (1.2)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>PA (°)</td>
<td>6.2 (2.7)</td>
<td>0.0001*</td>
<td>2.7 (2.8)</td>
<td>0.0096</td>
</tr>
</tbody>
</table>

* Significant at p < 0.0071 level
† IMPA change calculated as T2 minus T1.

All other values represent treatment change calculated as T3 minus T1.
5.2 Change in Esthetic Score and Initial Profile Angle

Ninety percent of the general public evaluators and 85% of the orthodontist and oral surgeon evaluators found negative correlations between the patients’ changes in profile and initial profile angles (Table 7). A negative correlation implies that as the initial profile angle decreases (i.e. profiles become more convex), there is an increasing improvement in the profile after surgery. Correlation values ranged from -0.64 to 0.08 among general public evaluators, from -0.39 to 0.23 among orthodontists, and from -0.38 to 0.13 among oral surgeons. The correlations between profile angle and changes in the profile were statistically significant (p<.05) for 2 evaluators in the general public group.
Table 7: Spearman’s correlational coefficients (r) between the initial profile angle and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.07</td>
<td>-.31</td>
<td>-.15</td>
<td>-.37</td>
<td>-.19</td>
<td>.07</td>
<td>-.12</td>
<td>-.64</td>
<td>-.44</td>
<td>-.31</td>
<td>-.34</td>
<td>-.34</td>
<td>-.31</td>
<td>.08</td>
<td>-.22</td>
<td>-.43</td>
<td>-.27</td>
<td>-.28</td>
<td>-.20</td>
<td>-.36</td>
</tr>
<tr>
<td>p</td>
<td>.77</td>
<td>.17</td>
<td>.54</td>
<td>.11</td>
<td>.42</td>
<td>.78</td>
<td>.63</td>
<td>.00*</td>
<td>.05</td>
<td>.19</td>
<td>.14</td>
<td>.18</td>
<td>.71</td>
<td>.35</td>
<td>.06</td>
<td>.24</td>
<td>.23</td>
<td>.40</td>
<td>.88</td>
<td>.01*</td>
</tr>
<tr>
<td>Orthodontists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.15</td>
<td>-.34</td>
<td>-.29</td>
<td>-.23</td>
<td>-.14</td>
<td>-.20</td>
<td>-.16</td>
<td>-.33</td>
<td>-.10</td>
<td>-.39</td>
<td>-.08</td>
<td>-.16</td>
<td>-.19</td>
<td>-.39</td>
<td>.15</td>
<td>-.33</td>
<td>.14</td>
<td>.29</td>
<td>.21</td>
<td>.23</td>
</tr>
<tr>
<td>p</td>
<td>.51</td>
<td>.10</td>
<td>.21</td>
<td>.32</td>
<td>.54</td>
<td>.41</td>
<td>.51</td>
<td>.68</td>
<td>.09</td>
<td>.72</td>
<td>.49</td>
<td>.43</td>
<td>.09</td>
<td>.54</td>
<td>.16</td>
<td>.55</td>
<td>.22</td>
<td>.36</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.22</td>
<td>-.20</td>
<td>-.21</td>
<td>-.30</td>
<td>-.31</td>
<td>-.01</td>
<td>-.14</td>
<td>-.21</td>
<td>-.35</td>
<td>-.17</td>
<td>-.07</td>
<td>-.38</td>
<td>-.32</td>
<td>.04</td>
<td>-.05</td>
<td>-.28</td>
<td>-.31</td>
<td>-.28</td>
<td>-.31</td>
<td>-.20</td>
</tr>
<tr>
<td>p</td>
<td>.36</td>
<td>.39</td>
<td>.37</td>
<td>.20</td>
<td>.19</td>
<td>.97</td>
<td>.55</td>
<td>.37</td>
<td>.13</td>
<td>.47</td>
<td>.75</td>
<td>.78</td>
<td>.10</td>
<td>.87</td>
<td>.83</td>
<td>.23</td>
<td>.18</td>
<td>.40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*statistically significant at p < 0.05
The 3-dimensional scatterplots show that patients can have a worsening of esthetics after surgery (difference in esthetic score < 0), particularly as initial profile angle increases. Fourteen of the 400 orthodontist evaluations had profile changes < 0, but 86% of the negative changes occurred in patients with profile angles of 160º or greater (Figure 5). When initial profile angle was 159º or less, profiles tended to consistently improve with treatment, as shown by the shaded area of the graph. Similarly, oral surgeons found 32 of the 400 evaluations had negative profile changes, but the majority (93.8%) occurred when the profile angle was 159º or greater (Figure 6). The general public found 55 of the 400 evaluations to be < 0, but 94.5% occurred in individuals with initial profile angle of 158º or greater (Figures 7).

**Figure 5:** Orthodontist evaluations of profiles with varying initial profile angles (n = 400). Profile angles ≤ 159º consistently had a positive change in profile after treatment (shaded area).
Figure 6: Oral surgeon evaluations of profiles with varying initial profile angles (n = 400). Profile angles $\leq 158^\circ$ consistently had a positive change in profile after treatment (shaded area).

Figure 7: General public evaluations of profiles with varying initial profile angles (n = 400). Profile angles $\leq 157^\circ$ consistently had a positive change in profile after treatment (shaded area).
When initial profile angles are above the threshold profile angle, orthodontists found the incidence of negative profile changes after treatment to be 2.6 times greater than when the initial profile angle where less than or equal to the thresholds (Table 8). Oral surgeons found a 5 fold increase in incidence of negative changes, while the general public found a 4.3 times greater increase when initial profile angles were above their threshold profile angles.

**Table 8:** Incidence of negative profile changes when pre-treatment profile angles are less than or equal to the threshold profile angle or above the threshold profile angle.

<table>
<thead>
<tr>
<th></th>
<th>Threshold Profile Angle</th>
<th>Incidence of Negative Profile Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Less than or Equal to the Threshold</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greater Than the Threshold</td>
</tr>
<tr>
<td>Orthodontists</td>
<td>159°</td>
<td>1.67%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.29%</td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td>158°</td>
<td>2.00%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.00%</td>
</tr>
<tr>
<td>General Public</td>
<td>157°</td>
<td>3.75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.25%</td>
</tr>
</tbody>
</table>
5.3 Change in Esthetic Scores and Initial ANB Angle

Seventy five percent of the general public evaluators and 90% of the orthodontist and oral surgeon evaluators found positive correlations between the patients’ changes in profile and their initial ANB angles (Table 9). A positive correlation between these 2 variables implies that as initial ANB angle increases (i.e. increasing severity of Class II skeletal relationship), there is an increasing improvement in profile after surgery. Correlation values ranged from -0.21 to 0.50 among the general public evaluators, from -0.26 to 0.6 among orthodontists, and from -0.05 to 0.65 among oral surgeons. These correlations between changes in profile scores and initial ANB were statistically significant (p < 0.05) for 1 oral surgeon, 3 general public and 8 orthodontists.

Calculation of Pearson’s correlation found a non-statistically significant inverse correlation between pre-treatment ANB angle and the profile angle (r = -.40, p = .08).

Student t-test also found no statistical difference (p = 0.53) between pre-surgical IMPA in subjects with ANB angles greater than 6º (IMPA = 97.4º ± 4.7º) and those with ANB angles less than or equal to 6º (IMPA = 99.4º ± 8.1º).
Table 9: Spearman’s correlational coefficients (r) between the initial ANB angle and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons.

| Evaluator          | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| General Public     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| r                  | .50 | -.02| .33 | .05 | -.02| .22 | .16 | .05 | .35 | .25 | .15 | -.21| .28 | .35 | .23 | .40 | .16 | -.09| -.04| .14 |
| p                  | .02*| .95 | .16 | .95 | .34 | .48 | .84 | .13 | .29 | .52 | .37 | .23 | .12 | .34 | .08 | .49 | .07 | .72 | .85 | .57 |
| Orthodontists      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| r                  | -.26| .21 | .48 | .28 | .13 | .28 | .55 | .19 | .48 | .59 | .60 | .16 | .44 | .48 | .23 | .05 | .56 | .55 | -.02| .93 |
| p                  | -.26| .37 | .03*| .23 | .58 | .24 | .32 | .01*| .43 | .03*| .00*| .49 | .05 | .03*| .32 | .01*| .91 | .01*| .93 |
| Oral Surgeons      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| r                  | .49 | .18 | .65 | .33 | -.01| -.05| .14 | .06 | .30 | .26 | .30 | .29 | .52 | .28 | .27 | .30 | .50 | .32 | .17 | .25 |
| p                  | .03 | .44 | .00*| .16 | .98 | .83 | .57 | .44 | .79 | .27 | .19 | .22 | .02*| .23 | .25 | .20 | .03*| .17 | .28 |

*statistically significant at p < 0.05 level
Similar to the profile angle plots, patients can have a deterioration of esthetics after treatment (difference in esthetic score < 0), particularly as ANB angle becomes less severe and the Class II skeletal relationship becomes milder. When orthodontists evaluated the profiles, 14 of the 400 evaluations had profile changes that were negative, but 11 of them (78.5%) occurred in patients with ANB angles of 5º or less (Figure 8). When oral surgeons evaluated profiles, 32 of the 400 evaluations had negative profile changes, with 90.6% of these occurring in individuals with initial ANB angle of 6º or less (Figure 9). Thus, orthodontists and oral surgeons found profiles consistently improved when ANB angles were greater than or equal to 5.5º and 6.5º, respectively. The general public found 53 of the 400 evaluations to be negative, but these scores occurred across a wide range of ANB angles and only at high ANB angles of 9º or higher was the occurrence of negative changes fewer than 3 evaluations. There was no break in the distribution to indicate what degree of ANB angle consistently improves after treatment and which angles can potentially worsen with treatment.
Figure 8: Orthodontist evaluations of profiles with varying initial ANB angles (n = 400). ANB angles ≥ 5.5° consistently had a positive change in profile after treatment (shaded area).

Figure 9: Oral surgeon evaluations of profiles with varying initial ANB angles (n = 400). ANB angles ≥ 6.5° consistently had a positive change in profile after treatment (shaded area).
Figure 10: General public evaluations of profiles with varying initial ANB angles (n = 400). Negative profile changes occur over a wide rage of ANB angles.

When initial ANB angles were less than the threshold ANB angle, orthodontists and oral surgeons found the incidence of negative profile changes after treatment to be 4.5 times and 7.9 times greater, respectively, than when the initial ANB angle was greater than or equal to the thresholds (Table 10).

Table 10: Incidence of negative profile changes when pre-treatment ANB angles are greater than or equal to the threshold ANB angle or less than the threshold ANB angle.

<table>
<thead>
<tr>
<th></th>
<th>Threshold ANB Angle</th>
<th>Incidence of Negative Profile Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthodontists</td>
<td>5.5°</td>
<td>Less Than Threshold: 6.11%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greater Than or Equal to Threshold: 1.36%</td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td>6.5°</td>
<td>Less Than Threshold: 13.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greater Than or Equal to Threshold: 1.67%</td>
</tr>
</tbody>
</table>
5.4 Change in Esthetic Scores, Lower Arch Extractions & Incisor Inclination

Wilcoxon rank sums test showed the 3 panels of evaluators did not detect a significant difference (p > 0.05) in the esthetic change after surgery between patients treated with extractions and those treated non-extraction.

Eighty percent of the general public, 90% of orthodontists and 70% of oral surgeons found positive correlations between the patients’ changes in profile and pre-surgical IMPA (Table 9). A positive correlation implies that as pre-surgical IMPA increases (i.e. lower incisors are proclined by pre-surgical orthodontics), there is an increasing profile improvement after treatment. Correlation values ranged from -0.16 to 0.42 among the general public, from -0.23 to 0.41 among orthodontists, and from -0.26 to 0.55 among oral surgeons. The correlations between IMPA and changes in profile were statistically significant (p < 0.05) for only 2 oral surgeon evaluators.
Table 11: Spearman’s correlational coefficients (r) between the initial IMPA and the difference in esthetic scores evaluated by panels of general public, orthodontists and oral surgeons.

<table>
<thead>
<tr>
<th>Judge</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.09</td>
<td>.08</td>
<td>.08</td>
<td>-.16</td>
<td>.23</td>
<td>.17</td>
<td>.19</td>
<td>.01</td>
<td>.17</td>
<td>-.04</td>
<td>.14</td>
<td>.01</td>
<td>-.03</td>
<td>.42</td>
<td>.39</td>
<td>.24</td>
<td>.30</td>
<td>.40</td>
<td>.30</td>
<td>.14</td>
</tr>
<tr>
<td>p</td>
<td>.69</td>
<td>.73</td>
<td>.72</td>
<td>.51</td>
<td>.33</td>
<td>.46</td>
<td>.42</td>
<td>.96</td>
<td>.46</td>
<td>.11</td>
<td>.54</td>
<td>.98</td>
<td>.27</td>
<td>.07</td>
<td>.09</td>
<td>.31</td>
<td>.20</td>
<td>.08</td>
<td>.19</td>
<td>.56</td>
</tr>
<tr>
<td>Orthodontists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>.15</td>
<td>-.12</td>
<td>.36</td>
<td>-.08</td>
<td>.29</td>
<td>.41</td>
<td>.18</td>
<td>.17</td>
<td>.15</td>
<td>.11</td>
<td>.28</td>
<td>.00</td>
<td>.11</td>
<td>.22</td>
<td>.21</td>
<td>.23</td>
<td>.21</td>
<td>.30</td>
<td>.30</td>
<td>.04</td>
</tr>
<tr>
<td>p</td>
<td>.52</td>
<td>.61</td>
<td>.12</td>
<td>.74</td>
<td>.21</td>
<td>.07</td>
<td>.45</td>
<td>.47</td>
<td>.52</td>
<td>.64</td>
<td>.24</td>
<td>.99</td>
<td>.64</td>
<td>.36</td>
<td>.39</td>
<td>.33</td>
<td>.38</td>
<td>.20</td>
<td>.80</td>
<td>.88</td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-.05</td>
<td>.44</td>
<td>-.26</td>
<td>.23</td>
<td>.55</td>
<td>.37</td>
<td>.17</td>
<td>.39</td>
<td>.33</td>
<td>.21</td>
<td>.06</td>
<td>.08</td>
<td>-.06</td>
<td>-.16</td>
<td>-.22</td>
<td>-.18</td>
<td>.03</td>
<td>.31</td>
<td>.18</td>
<td>.08</td>
</tr>
<tr>
<td>p</td>
<td>.83</td>
<td>.05*</td>
<td>.28</td>
<td>.32</td>
<td>.01*</td>
<td>.11</td>
<td>.47</td>
<td>.09</td>
<td>.16</td>
<td>.37</td>
<td>.80</td>
<td>.74</td>
<td>.81</td>
<td>.51</td>
<td>.34</td>
<td>.44</td>
<td>.91</td>
<td>.18</td>
<td>.45</td>
<td>.73</td>
</tr>
</tbody>
</table>

* Statistically significant at p < 0.05 level
5.5 Comparison of the Perception of Esthetics by Orthodontists, Oral Surgeons and the General Public.

Friedman’s test was used to compare the ranks of the change in esthetic scores among each group of evaluators. Results showed no statistical difference (p = 0.066) in how individual oral surgeons rated the change in profiles relative to other oral surgeons, allowing this data to be pooled for further analysis. Similarly, there was no statistical difference in how individual evaluators among the general public group rated the change in profiles relative to the other members of the general public group, also allowing data to be pooled.

Orthodontists were different statistically in their distribution of rankings of the change in profiles (p <0.05). Comparison of box plots of the ranks for the profiles and box plots of the change in esthetic scores from each orthodontist showed that 3 orthodontists had data that tended to not be consistent with other orthodontists and were omitted from this portion of the statistical analysis only. Re-analysis with Friedman’s test showed no statistically significant difference among the remaining 17 orthodontists, allowing data to be pooled.

Friedman’s test of the pooled data found the median scores of the 3 groups were not statistically different from each other, though the results were close to statistical significance (p = 0.053).
5.6 Intra-Evaluator Reliability

A strong correlation between the first and second times an evaluator rates a profile implies good intra-evaluator reliability. For the general public, the Spearman’s correlation coefficients had a range of 0.65, with a minimum of 0.26 and a maximum of 0.91. The range of correlations among oral surgeons was 0.56, with minimum of 0.44 to a maximum of 1. Orthodontists had correlations that ranged from a 0 to 1.0, but if one orthodontist with no correlation is disregarded for this section of the analysis, the remaining 19 orthodontists had the smallest range of correlations of the 3 groups of evaluators with 0.31, ranging from 0.69 to 1.0.

![Correlation Co-efficient](image)

**Figure 11:** Spearman’s correlation between the first and second ratings of the repeated profiles by the 3 groups of evaluators (n = 20).
6.0 DISCUSSION

6.1 Study Findings

6.1.1 Sample Characteristics and Treatment Effects

Females comprised 85% of the surgical sample. The greater number of females is consistent with studies reporting that females are more likely than males to seek orthodontic treatment and to accept orthodontic/orthognathic surgery treatment plans (Bailey et al., 2001). At the University of North Carolina, 63% of the individuals seeking treatment in the Dentofacial Program were females and 69% of those that ultimately accepted and underwent orthognathic surgery were females (Bailey et al., 2001).

Males and females are distinctive in certain facial characteristics and a profile that is considered attractive in males may be perceived as less desirable in females, and vice versa. In comparison to females, the ideal male face has a more prominent forehead, deeper radix, greater projection of the nasal dorsum and lower nasal tip, flatter lips with less vermillion display, upper lip protrusion even with the lower lip and stronger chin prominence (Sarver et al., 2003). According to McCollum (2001), the “ideal” profile in females is slightly more convex (mean facial contour angle = -15º in females, -12º in males) and has a nasal tip that is often more elevated, making a more obtuse nasolabial acceptable (110º-120º in females, 100º-110º in males). Sergl et al. (1998) confirmed that lay persons found attractive females to have more convex soft-tissue profiles with smaller noses than males.

Orthodontists, oral surgeons and general public evaluators in the present study were unaware of the gender of the profiles they were evaluating, making the unequal
gender distribution in the surgical sample a source of bias because the evaluators’ opinions of the profiles may have been different had they been aware of the genders of the subjects they were evaluating. The results may also have been different had there been an equal gender distribution between males and females. DeSmit and Demaut (1984), however, found no significant differences in the evaluation of profiles by lay persons or individuals with some orthodontic training, regardless of whether the same profiles are considered during evaluation as males or females.

The mean MPA of the sample was 32.7º, which is consistent with norms cited by Steiner (1953) and Björk (1960). After treatment, there was a statistically significant increase of 3.6º in the MPA. An increase in MPA is often a result of mechanics that extrude posterior teeth in non-growing patients and/or clockwise rotation of the distal segment of the mandible during mandibular advancement surgery to facilitate deep overbite correction, increase lower anterior facial height and improve stability (Proffit and Phillips, 2003).

Subjects in this study had a MPA angle within the normal range suggested by Björk (1960). Mandibular plane angle was used as a criterion for sample selection based on its ease of measurement and its association as one of the factors to be considered when evaluating skeletal growth pattern (Skieller et al., 1984). The diagnostic and prognostic value of MPA alone as a predictor of facial growth pattern, however, should be used cautiously, since, for example, a large MPA can be associated with both forward and backwards facial growth patterns due to remodelling of the lower border of the mandible that masks the actual rotation of the mandibular corpus (Björk and Skieller, 1985; Nanda, 1990; Grubb et al., 1996). While there are limitations to the use of the mandibular plane
angle as a method to classify facial pattern, it has also been demonstrated that orthodontists with access to many cephalometric measurements are no more successful at the prediction of forward and backwards rotators with orthodontic treatment than would have occurred by chance (50% success rate) (Baumrind et al., 1984). By limiting the study sample to those with a MPA within a median range, however, it is most likely that extreme forward and backward rotators were excluded from the sample.

Pre-surgical orthodontics proclined the lower incisor to a greater extent in the non-extraction group than the extraction group, but extraction treatment still resulted in lower incisor proclination of 1.5° at T2 pre-surgical records. Mean pre-surgical IMPA in the extraction group was 95.5°, which is more proclined than the ideal IMPA of 90° ± 5° recommended by Tweed (1946), but within normal ranges for IMPA from other cephalometric analyses, such as the Bell, Proffit and White analysis (95° ± 7°) and the Reidel analysis (93° ± 6.8°) (Bosch and Athanasiou, 1995). The non-extraction group showed even more proclination at 100.9°, but this was not statistically different from the extraction group and falls within normal ranges of the other analyses.

Since a mandibular arch with excessively retroclined lower incisors would result in a mild Class III occlusion post-surgery (Andrews, 1989), the absence of overly retroclined lower incisor in the extraction group may not be unusual, since the goal of pre-surgical orthodontics is to place the teeth in their normal relation in their respective basal bones prior to surgical correction of the skeletal discrepancy (Epker et al., 1994). An absence of incisor uprighting despite extractions may be a reflection of the multiple variables that can affect lower incisor inclination, such as the extraction pattern, anchorage control, orthodontic mechanics, bracket prescription, and/or severity of the
pre-treatment crowding. For example, if a severe tooth size-arch length discrepancy exists, lower incisors will procline if extraction spaces are used entirely for incisor alignment rather than incisor uprighting. Also, two of the nine extraction cases involved extraction of a single lower incisor, which minimizes the amount of retraction or retroclination possible in comparison to cases with extraction of two lower premolars. No investigations were done in this study to determine the reason as to why extractions were done in each individual case. Future studies incorporating occlusal indices, such as the PAR rating, may be helpful in defining the relationship between incisor inclination, extractions decisions and their effect on profile changes.

From T2 to T3, mean IMPA increased further in the extraction group but decreased in the non-extraction group. Lower incisor inclination often increases during the post-surgery period from use of post-surgical Class II elastics or post-surgical curve of Spee levelling after surgically establishing a “three-point landing” to increase lower facial height (Proffit et al., 2003a). While both groups had patients with 1-2º of decrease in IMPA from pre-surgical to final records, the non-extraction group had 3 patients with large IMPA decreases of 5º, 9º and 13º, thus contributing to the greater average IMPA decrease of this group. Review of the charts of these three patients did not show any particular orthodontic mechanics that would account for this decrease (e.g. Class III elastics or interproximal reduction of the lower incisors).

Other studies have also reported decreases in IMPA during the post-surgical period after mandibular advancement surgery, but do not offer any definite explanation for this change (Lim et al., 1998; Berger et al., 2000). Lim et al. (1998) noted a weak inverse correlation between a decreased lower incisor-mandibular plane angle and a
change in the mandibular plane due to mandibular advancement surgery, but also suggested that the effects of orthodontic finishing and compensatory tooth movements as skeletal equilibrium re-establishes may play a role in decreasing the IMPA.

Alternatively, some patients may have had post-surgical gonial angle remodelling that increased MPA and thus decreased IMPA. Watzke et al. (1990) reported at 1 year post-surgery that patients treated with screw fixation on average had significantly more superior remodelling of the gonial region in comparison to patients treated with intermaxillary fixation, thus increasing the mandibular plane. Greater amounts of post-surgical gonial angle remodelling may be a possible explanation for the changes observed in IMPA in the 3 subjects in the present study, but an investigation of gonial changes are beyond the scope of this current study and would require further analysis. Furthermore, since mandibular regional superimpositions were not included as a part of the present study, it is difficult to isolate whether the changes in IMPA are a function of changes in the mandibular plane or whether there were genuine changes in lower incisor inclination within the symphysis.

According to norms by Steiner (1953), the initial skeletal cephalometric measurements for SNA, SNB and ANB angles classify the sample as having a skeletal Class II relationship with a deficient mandible. The range of values for SNA and SNB in the sample, however, would suggest that there were some patients with maxillary protrusion rather than mandibular deficiency. A real maxillary excess may have existed in a few of the patients, but caution should be used in interpreting cephalometric values given the sensitivity of the SNA, SNB and ANB angles to the geometric relationship of A-point, B-point and nasion to each other (Hussels and Nanda, 1984). However,
regardless of the specific cephalometric diagnosis, the treatment plan for all patients included in this study involved correction of the anteroposterior jaw disharmony with mandibular advancement surgery.

As expected after mandibular advancement surgery, treatment had essentially no effect on the position of the maxilla but did increase mandibular prominence and decrease soft-tissue facial convexity. According to profile angle guidelines by Arnett and Bergman (1993b), the 161° mean initial profile angle is indicative of a Class II skeletal relationship that should be surgically treated. Post-treatment, the profile angle of the surgical sample is within Arnett and Bergman’s (1993b) recommended normal range of 165°-175° and the post-treatment mean ANB angle is consistent with a Class I skeletal relationship defined by Steiner (1953). The ANB angle change of -2.6° is consistent with the other studies, such as Shelly et al. (2000), who found that the ANB angle decreased -3.0°, Proffit et al. (1992), who reported a -2.8° ANB decrease, and Berger et al. (2000), who reported a -2.4° ANB decrease after surgical treatment.

Patients treated with extractions started with a smaller profile angle than those treated non-extraction, but this difference was not statistically significant because the p-value required for significance was 0.0038. Although the extraction and non-extraction groups had similar initial ANB angles and nearly identical ANB treatment changes, the profile angle improvement was larger in the extraction group, resulting in similar profile angles after treatment. The presence of a more acute profile angle and greater chin retrusion may have had a role in treatment planning decisions to support the extraction of teeth to ensure complete correction of dental compensations to maximize the surgical mandibular advancement and soft-tissue profile change.
The variability in profile angle change despite similar ANB changes, in conjunction with the finding that there was no statistically significant correlation between ANB angle and profile angle, supports the study by Park and Burstone (1986) which emphasized the variability that can exist between hard and soft tissues relationships. It also reinforces the need to develop treatment planning guidelines based on soft-tissue analyses rather than hard tissue cephalometric analyses, particularly when attempting to achieve esthetic improvements through orthognathic surgery.

6.1.2 Changes in Profile Esthetics

The trend for individuals with more acute profile angles to have greater improvements in esthetics after surgery was reflected in correlation coefficients having negative values, but for the most part, these correlations were not statistically significant for the 3 groups of evaluators. Profile change after mandibular advancement were significantly correlated to initial ANB angle for 40% of the orthodontists that participated, but generally not for oral surgeons or general public.

The 3 groups of evaluators in this study generally agreed with the guidelines of Arnett and Bergman (1993b), which suggested that cosmetic improvement comes with surgical correction of severe profile imbalances. Arnett and Bergman (1993b) recommended a profile angle of 165° as the threshold for requiring surgical treatment, but this study found that the threshold at which profiles consistently improve with surgery is lower than earlier indications. Only at profile angles < 160° did individuals with normal vertical proportions have a minimal chance that their profile would deteriorate with
treatment. When profiles angles were $\geq 160^\circ$, the incidence of profile deterioration increased 2.6 to 5 times. A worsening of the profile, however, remains an uncommon occurrence. Profiles more orthognathic than threshold profile angles improved 83-95% of the time.

Orthodontists and oral surgeons in this present study rated post-treatment profiles of some patients as worse than the initial profile when initial ANB was less than 5.5$^\circ$ and 6.5$^\circ$, respectively, similar to the findings reported by Shelly et al. (2000). Shelly et al. (2000) proposed a guideline of using an ANB angle of 6$^\circ$ as a threshold for gauging which patients may have a negative change in esthetics post-surgery. Although their study results utilized parametric statistics with ordinal data, which may give misleading results, the current study findings are supportive of using an ANB angle of 6$^\circ$ as a guideline in treatment planning of Class II patients.

Among orthodontists and oral surgeons, a worsening of profiles occurred 4.5 to 7.9 times more frequently when initial ANB angles were less than the threshold values. Similar to profile angle, however, the incidence of profile deterioration, even in those with mild Class II skeletal relationships, did not occur frequently and the majority of individuals (86-93%) still improve with surgery.

Nonetheless, clinicians need to be more aware that as profiles become more orthognathic, greater consideration should be directed towards non-surgical options, if feasible. In fact, Cassidy et al. (1993) used discriminant analysis to identify a homogenous group of borderline adult camouflage/surgery patients with Class II div 1 malocclusions and found that although camouflage treatment produced significantly more
upper incisor and lip retraction and mandibular advancement produced more significant treatment changes in mandibular projection, there were no significant differences in the patients’ satisfaction with their profile improvement, TMJ function or incisor stability. Given that 3 of the 26 patients in the study had relapse likely due to condylar resorption, Cassidy et al. (1993) argue that orthodontic treatment is the more appropriate treatment for an adult patient with a Class II malocclusion who can be treated with either dental camouflage or surgery, and surgery should be reserved for more serious cases where changes are needed that only surgery can provide.

Many authors have indicated that proclination of lower incisors will increase arch length and prevent complete Class II correction (Andrews, 1972; Epker et al., 1994; Sarver and Sample, 1999). Extractions are one method to level and align dental arches without excessive incisor proclination, but the extraction group in this study had slight lower incisor proclination and was not different from the non-extraction group pre-surgically. The lack of statistical difference in pre-surgical IMPA between the extraction and non-extraction groups may explain why there was also no difference in esthetic change following treatment between the non-extraction and extraction groups.

Due to a limitation in the number of suitable patient charts, the sample could not be matched for pre-surgical IMPA and severity of the anteroposterior discrepancy. A more ideal study design would have matched individuals according to the initial ANB angle or profile angle but with differing IMPA angles in order to isolate the effect of IMPA on profile changes. With the present study design, it is difficult to draw any conclusion on the relationship between the degree of the IMPA and esthetic change following surgery.
6.1.3 Inter-Evaluator Differences

The ANB scatterplots also reveal that in comparison to the general public, dental specialists are more critical and able to note changes in profiles of patients with mildly increased initial ANB values and moderate Class II skeletal relationship. The general public, on the other hand, is less discriminating in their assessment of profiles and rated some patients as being worse after surgical treatment despite large ANB values and severe Class II skeletal relationships. For both profile and ANB angles, oral surgeon had a larger proportion of individuals with negative profile changes (8%) than orthodontists (3.5%), while the general public had the largest proportion of worse profiles after treatment (13-14%). This may suggest that orthodontists most critically evaluate profiles to be able to detect subtle profile changes, followed by oral surgeons and then the general public.

Statistical analysis, however, found no statistical difference between the 3 groups in how esthetics is perceived, though it was close to achieving statistical significance. Due to the limitations of non-parametric statistical testing, performing the necessary statistical testing required data within each group to be pooled, but this could not be done without omitting 3 orthodontists from this portion of the analysis who appeared to have ratings not consistent with the rest of the orthodontists. While an argument can be made for excluding these evaluators who had considerably different results, individuals with outlying opinions are part of the dental and general population and doing so may have contributed bias to this portion of the study (Shelly et al., 2000). Thus, caution should be used in interpreting whether there are statistical differences in how profiles are evaluated by the 3 groups of evaluators.
Other studies have differed in their findings as to whether there is a difference among different groups of evaluators. Some have reported no difference between groups of laypersons, orthodontists and/or oral surgeons (Shelly et al., 2000), while others have found various professional groups evaluate profiles and esthetics differently than others as well as laypersons. Maple et al. (2005) found that orthodontists and surgeons rated photos of Class I profiles as statistically more attractive than the general public. The authors suggest that professionals are conditioned to focus on specific features in the lower third of the face, such as the lips and chin, while laypersons are generally less aware of profiles on a regular basis and their judgement of attractiveness is more influenced by other facial features on photos, such as the complexion, nose size and shape and hair style.

6.1.4 Reliability

As a correlation coefficient approaches either 0 or 1, it indicates either no correlation or a perfect correlation, respectively, between how profiles were rated the first and second times they were evaluated. All three groups demonstrated acceptable reliability in the evaluation of profiles, with orthodontists tending to be the most consistent in their ratings, with higher correlations and the narrowest range. The general public showed a tendency to be less consistent than the other 2 groups in how they rated profiles, with lower correlations and the widest range.

Correlation coefficients from this study are similar to findings of other profile evaluation studies, whose average correlations ranged from 0.46 to 0.78 (Johnston et al.,
2005; Maple et al., 2005). Maple et al. (2005) reported that lay persons had the highest mean correlation coefficients (0.78), followed by orthodontists (0.62) and then oral surgeons (0.46). They found that laypersons, on average, required the least time to complete the task of evaluating the profiles, while oral surgeons required the longest average time, a possible indication that laypersons may have had higher reliability scores than dental professionals because professionals tended to “overevaluate” each profile and concentrate on specific areas rather than giving their initial reaction to an overall profile.

6.2 Study Limitations

6.2.1 Statistical Limitations

Performing multiple t-tests for treatment changes and comparisons between the non-extraction and extraction groups required a Bonferroni correction to maintain the overall p-level at 0.05. While this minimized the likelihood of a type I error (ie the risk of obtaining an apparently significant difference purely by accident), using the much more stringent critical values of $p < 0.0071$ and $p < 0.0038$ for statistical significance made it more difficult to identify statistical differences (Hassard, 1991a). For example, mean profile angle was 4.4° smaller in the groups treated with extractions ($p = 0.029$), but was not statistically significant at the $p < 0.0038$ level.

The ordinal nature of a Likert scale also required that non-parametric statistics be used for many of the calculations. With ordinal scales, it is not known whether the magnitude of difference between the intervals is consistent and therefore average scores cannot be calculated to allow parametric statistics to be performed. The use of non-
parametric statistics is less powerful and carries a greater risk of type II or β error (accept the null hypothesis that there is no difference when in fact the groups are genuinely different) and thus missing real treatment effects (Hassard, 1991b). This may have been a factor contributing to the lack of clinical significance in the data.

Rather than an ordinal scale, other studies on facial esthetics have used visual analogue scales (VAS) anchored at either ends by descriptors such as “Very Unattractive” and “Very Attractive,” (Phillips et al., 1992; Michiels and Sather, 1994; O’Neil et al., 2000; Maple et al., 2005). While a VAS allows more powerful parametric statistics to be used and may be more sensitive than a Likert scale, scores from a VAS are subjective and variable and have their own disadvantages. It cannot be assumed that anchor terms are interpreted similarly and convey the same feelings by different people. It also cannot be assumed that identical positions on the scales by different people express comparable intensity of feelings, that a multiple of a particular rating represents a multiple of the intensity of the feeling or that all portions of the scale were given equal consideration by the evaluators (Aitkens, 1969; Phillips et al., 1992; O’Neil et al., 2000; Maple et al., 2005). VAS also does not identify how many millimetres of difference are required for there to be clinical significance (Aitkens, 1969; Maple et al., 2005).

6.2.2. Surgical Sample Selection

6.2.2.1 Changes in the Vertical Dimension

De Smit and Dermaut (1984) have shown that vertical profile changes associated with open or deep bites more negatively affect the perception of a profile than
anteroposterior changes (Class II or Class III) and the effects were particularly pronounced in profiles with an increased lower facial height. Mandibular advancement with clockwise rotation of the distal segment to increase lower facial height improves surgical stability, but doing the reverse (counter-clockwise mandibular rotation) is traditionally considered unstable (Proffit et al., 2003b). Clockwise rotation normalizes face height and works in favour of improving esthetics in patients with a short lower face height, but does not improve, and possibly even worsens face height and esthetics in patients that already have a long lower face height prior to treatment. These vertical changes are potential confounding factors when surgical changes are evaluated.

The sample used in the present study was limited to those with an MPA of $33^\circ \pm 6^\circ$ to minimize the confounding effect that surgical increases or decreases in the vertical facial dimension may have on the evaluation of the post-treatment profile. Thus, findings from the study can be applied only to Class II patients with an average MPA.

6.2.2.2 Isolated Mandibular Advancements

The surgical sample used in this study consisted of patients treated with mandibular advancement surgery only. Other surgical procedures, such as genioplasties, are often used to augment chin projection in patients with considerable Class II malocclusions or proclined lower incisors (Epker et al., 1994; Shelly et al., 2000). Dolce et al. (2001) found that patients receiving mandibular advancements plus genioplasty tended to have larger ANB angles than those treated with advancements only. The profiles of patients in this present study who had a negative or only a small positive
profile change with the ramus osteotomy may have improved more if there was an additional genioplasty performed, particularly if there was a pre-existing flat mentolabial sulcus contour. For some patients with Wolford’s type II mandibular deficiency, however, genioplasty may not be indicated if there is already a sufficient symphyseal and mentolabial sulcus contour.

It should also be considered, however, that treatment for some patients is still considered successful if there was a considerable functional or vertical improvement, despite a lack of significant anteroposterior or soft-tissue change (Shelly et al., 2000). Some cases are also best treated surgically for biomechanical, stability and esthetics reasons despite anticipation of minimal anteroposterior mandibular changes. For example, treatment plans often call for Class II div 2 deepbite malocclusions with adequate chin projection to be treated surgically to maintain good upper lip position, improve torque of the upper incisors, increase vertical face height and improve stability of the overbite correction (Epker et al., 1994).

6.2.2.3 Surgical Technique

Surgical treatment of patients included in this study occurred over a 21 year period, during which time, the surgical procedures were performed by several oral and maxillofacial surgeons using either rigid or intermaxillary fixation techniques, with or without a surgical splint. Due to an insufficient number of suitable patients treated by only one surgeon, all cases that satisfied the inclusion criteria were included. A prospective randomized clinical trial of short and long-term profile changes in patients having BSSO with either wire or rigid fixation have shown that at 5 years post-surgery,
that there were no statistically significant differences in the soft-tissue profiles of the lower lip and chin between the 2 fixation methods despite approximately 30% relapse in the intermaxillary fixation group (Dolce et al., 2003).

6.2.3. **Evaluator Selection**

Specialty dental training occurs at numerous centres nationally and internationally and dental specialists in any one centre represent a concentration of clinicians with varied training and philosophies. Despite the diversity of training, regional biases within centres can exist, depending on factors such as the availability of resources and specialist expertise (Arnett and McLaughlin, 2004). The number of orthodontists/orthodontic residents in Manitoba available to participate in this study was sufficient for statistical purposes, but in order to have the participation of a sufficient number of oral and maxillofacial surgeons who routinely perform orthognathic surgery, it was necessary to extend the study to oral surgeons across Canada. Thus, the study results represent the opinions of orthodontists and general public from the Winnipeg region, but the opinions of oral and maxillofacial surgeons come from across Canada, thereby potentially introducing some biases into the results.

6.2.4. **Other Treatment Factors**

6.2.4.1 **Upper Incisor Inclination**

Andrews’ six keys emphasized the importance of correct inclination of both upper and lower incisors to establish ideal occlusion. Similar to a mandibular arch with
proclined lower incisors, an upper arch with retroclined upper incisors reduces the pre-
surgical overjet and contributes to the inability to achieve complete correction of the
skeletal discrepancy. In this scenario, a Class II posterior occlusion is the result when
proper anterior overjet and overbite are surgically established (Andrews, 1989). This
study attempted to evaluate the effect of lower incisor inclination on post-treatment
esthetics, but could not make a conclusive finding due to limitations in a sample size.
The effect of upper incisor inclination was not examined in this study to minimize the
number of variables examined at any one time. Further study with larger samples are
warranted to further examine the impact of upper and lower incisor inclination on the
amount of pre-surgical overjet and consequently the degree of change in the profile after
treatment.

### 6.2.4.2 Other Soft Tissue Changes

Facial photographs should be used in facial esthetics studies if overall
attractiveness is being evaluated, but profile silhouettes are advantageous when
evaluating treatment effect on facial profiles, as in this present study, because they
minimize the influence of confounding effects of factors, such as gender, skin
complexion, hair color/style, and facial expression (Maple et al., 2005). They do not,
however, prevent other variables such as changes in lip protrusion, lip competence and
nasolabial angle and nose shape from affecting the evaluator’s judgement of the profile.
Michiels and Sather (1994) found that the chin, upper lip and nose most often influenced
esthetic judgements, followed by the throat and lower lip.
The influence of treatment changes in other facial structures may have introduced bias into the results. Orthodontic treatment alone, regardless of changes induced by orthognathic surgery, can affect the position of features, such as the lips and nasolabial angle, as incisor position and occlusion is altered. Thus, the esthetic scores may reflect positive or negative changes in these other soft tissue rather than being a sole reflection of the changes from mandibular advancement surgery.

De Smit and Dermaut (1984) found that the shape of the nasal dorsum had no effect on the esthetic rating of profiles, except in Class II patients with normal vertical proportion, in whom a convex nasal dorsum was less appreciated than a straight nasal dorsum. Although these are the same type of patients that were used in the present study, factors such as nose shape are unchanged with orthodontic and orthognathic surgery of the mandibular alone, and thus are variables that remain constant in both the pre- and post-treatment profiles.

6.3 Evaluation of Null Hypotheses

1.) There is insufficient evidence to reject null hypotheses #1, 2 and 3.

Extraction of mandibular teeth did not result in significant differences in IMPA when compared to cases treated non-extraction. Orthodontists, oral surgeons and the general public did not find orthodontic treatment with mandibular advancement surgery to produce a greater profile change when done in conjunction with extractions of mandibular teeth, in comparison to non-extraction treatment.
2.) There is insufficient evidence to reject null hypotheses #4, 5, 6, 8 and 9, but there is sufficient evidence to reject null hypothesis #6.

Profile changes after mandibular advancement is not significantly correlated to decreasing initial profile angle or increasing initial ANB angle, except for 40% of orthodontists who correlated profile changes after mandibular advancement to increasing initial ANB angle. A profile angles less than 160º or an ANB angle of greater than 6º is necessary for consistently had profile improvements after treatment with orthodontics and mandibular advancement surgery.

3.) There is insufficient evidence to reject null hypotheses #10.

There was no statistical difference between orthodontists, oral surgeons and the general public in their perception of profile changes after mandibular advancement surgery.
7.0 CONCLUSIONS

1. Extraction of mandibular teeth does not result in less proclined lower incisors in comparison to those treated non-extraction because of the multi-factorial nature of the extraction decision.

2. Individuals with profile angles < 160° or an ANB angle of > 6° consistently have profile improvements after orthodontics and mandibular advancement surgery.

3. Although the majority of patients will have profile improvements after mandibular advancement surgery, there is a 2.6 to 5 times increase in incidence of profile worsening when profile angle thresholds are not met and a 4.5-7.9 times increase when the threshold of ANB angle is not met.
8.0 REFERENCES


Proffit WR. The first stages of comprehensive treatment: alignment and levelling. *In:*


Proffit WR, Phillips C. Physiologic responses to treatment and post-surgical stability. *In:*


Proffit WR, Sarver DM. Treatment planning: optimizing benefit to the patient. *In:*


9.0 APPENDICES

9.1 Participant Informed Consent Form
Participant Information & Consent

Evaluation of Facial Profiles Before & After Mandibular Advancement Surgery

Principal Investigator: Dr. Susan Tsang
Graduate Orthodontics
University of Manitoba
D-341, 780 Bannatyne Ave
Winnipeg, MB R3E 0W2

Co-Investigator: Dr. Leland McFadden
Department of Dental Diagnostics & Surgical Sciences
University of Manitoba
D-343, 780 Bannatyne Ave
Winnipeg, MB R3E 0W2

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study. Please ask the study staff to explain any information that you do not clearly understand.

Purpose of the Study
This research study is being conducted to examine factors that influence the esthetic outcome after treatment with braces and jaw surgery, as evaluated by orthodontists, oral surgeons, and the general public. The study will also examine whether there is a difference in how esthetics is perceived by these 3 groups.

A total of 60 participants will be included in this survey.

Study Procedures
If you choose to participate, you will be asked to complete the following:

You will evaluate 50 facial profile silhouettes on a computer monitor, shown in no particular order. Each silhouette will be identified in the upper right corner by a number. After evaluating the profile, please circle on the corresponding location on the score sheet a rating from 1 to 5 according to how you would best describes the profile:

1 = Very unattractive
2 = Unattractive
3 = Fair
4 = Attractive
5 = Very attractive

Participation in the study should take approximately 10 minutes of your time.
**Risks and Benefits**  
There will be no anticipated direct risks, benefits, or costs to you from participating in this study. We hope the information learned from this study will benefit the dental profession and affect how future treatment decisions are made.

**Confidentiality**  
You will be asked to identify the category to which you belong (orthodontist, oral surgeon or general public) but will not be asked to identify yourself on the score sheet.

Information gathered in this research study may be published or presented in public forums, however any identifying information will not be used or revealed. The University of Manitoba Health Research Ethics Board may review records related to the study for quality assurance purposes. All records will be kept in a locked secure area and only those persons identified will have access to these records. No information revealing any personal information, such as your name, address or telephone number will leave the University of Manitoba.

**Voluntary Participation/Withdrawal from the Study**  
Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study without any consequence to yourself. Any performance evaluation will not be affected by your participation or performance in this study.

**Questions**  
You are free to ask any questions that you may have about your rights as a research participant. If any questions come up during or after the study, contact Dr. Susan Tsang at (204) 789-3545.

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.
STATEMENT OF CONSENT

I have read this consent form. I have had the opportunity to discuss this research study with Susan Tsang. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor or family member) I may have with the study team has not affected my decision to participate. I understand that my participation in this study is voluntary and that I may choose to withdraw. I freely agree to participate in this research study. I understand that information regarding my personal identity will be kept confidential, but that confidentiality is not guaranteed.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

Participant signature: ______________________  Date: ____________________________  
(day/month/year)

Participant printed name: ______________________

Relationship (if any) to study team members: ______________________

For study staff:

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent

Printed Name: ______________________  Date: ____________________________  
(day/month/year)

Signature: ______________________

Role in the study: ______________________
9.2 Article for Publication
The Relationship Between Profile Angle and ANB Angle on Profile Changes in Orthodontic Patients Treated With Mandibular Advancement Surgery

ABSTRACT. **Background:** Borderline orthodontic cases can be treated with either orthognathic surgery or dental camouflage. The purpose of this study was to determine to the degree of skeletal and soft tissue Class II disharmony necessary before significant esthetic benefit is derived from mandibular advancement surgery. **Methods:** Twenty general public, 20 orthodontists, and 20 oral surgeons rated the attractiveness of pre- and post- treatment profiles of 20 mandibular advancement patients using a 5-point scale. Spearman’s correlation tested for relationships between amount of profile change and varying pre-treatment ANB and profile angles. Plots of the distribution of profile changes with varying ANB and profile angles were then examined. **Results:** There was a tendency for inverse correlations between profile change and profile angle, but these were not statistically significant any of the 3 groups (p>.05). There was a tendency for positive correlations between profile change and ANB angle, but was considered significant (p<.05) for only orthodontists. Orthodontists, oral surgeons and the general public found that profiles consistently improved when profile angles were ≤159º, ≤158º and ≤157º, respectively. Orthodontists and oral surgeons found profiles consistently improved when ANB angles were ≥5.5º and ≥6.5º, respectively, while the general public did not show any trends between ANB angle and profile change. The incidence of profile worsening increased 2.6 to 5.0 times when profile angle exceeded the thresholds, and increased 4.5 to 7.9 times when ANB angle is less than thresholds. **Conclusion:** Pre-treatment profile angles <160º and ANB angles >6º are necessary for consistent improvements after surgery and to minimize the incidence of profile worsening after treatment.
INTRODUCTION

It has been suggested that the orthodontic treatment of up to 10% of patients is borderline between being able to be accomplished with dental camouflage alone or alternatively requiring orthognathic surgery. Unacceptable results may occur when camouflage treatment is attempted in patients who should preferably have been treated with orthognathic surgery and it is considered an error to treat a patient surgically when an acceptable result could have been reached with orthodontics and dental compensations. The decision making process is further complicated by variables such as patient desires and values, cultural differences, orthodontist preferences, surgical expertise, and financial considerations. From the standpoint of facial esthetics, this dilemma raises the question of under what conditions would one treatment method be preferred over the other?

Non-growing, Class II patients with retrognathic profiles can be treated with either dental camouflage to retract protrusive incisors and/or move lower teeth forward, or orthognathic surgery to advance the deficient mandible and improve the convexity of the profile. Although treatment often improves facial esthetics, a lack of improvement or even a worsening of esthetics can also potentially occur with any treatment modality. Greater esthetic improvements after surgery have been reported in Class II patients with poorer pre-treatment esthetics and larger surgical movements. Shelley et al reported that lay people and orthodontic residents found that a pre-treatment ANB angle of 6° was the threshold for predicting whether significant esthetic change occurs after mandibular advancement surgery. Profiles improved by 45% in patients with an initial ANB angle ≥
6°, but when the initial ANB was <6°, there were not statistically significant overall post-treatment changes in patients and half the subjects had a worsening of their esthetics.

Given the large variation in soft tissues, however, measurements and guidelines based on hard tissue relationships may not necessarily correlate to the actual soft tissue outcome. Park and Burstone⁶ reported cases that had similar hard tissue convexity angles but soft tissue profile angles that differed by as much as 22°, lending credence to the concept that treatment based only on hard tissue cephalometric standards does not always lead to the expected or desired soft tissue results.

The general harmony of the upper, middle and lower soft tissue profile can be described by the measurement known as the profile angle, an obtuse angle formed by lines connecting soft tissue glabella, subnasale and soft tissue pogonion. A Class I skeletal relationship is represented by a profile angle of 165°-175°, while angles below or above this range represent Class II or Class III skeletal relationships, respectively.⁷ The profile angle has been suggested as the most critical determinant of the need for anterior-posterior surgical correction because variations in soft tissue thickness are not usually responsible for deviations beyond the normal range and departures from the norm are thus indicative of a significant underlying skeletal disharmony.⁷

When considering mandibular advancement to improve facial appearance in borderline cases, being able to identify the cases that will likely have a clinically noticeable esthetic improvement would be a valuable tool. Therefore, the purpose of this study is to establish guidelines for the severity hard and soft tissue anteroposterior disharmony necessary before patients derive noticeable profile improvement from mandibular advancement surgery.
MATERIALS AND METHODS

Charts of 20 patients treated with orthodontics and mandibular advancement from a university-based graduate orthodontic clinic were selected. Diagnostic records had been taken pre-treatment (T1) and at time of appliance removal (T2). No preference was given to the degree or location of the skeletal anteroposterior discrepancy, patient gender or ethnicity, use of dental extractions, type of skeletal fixation or use of a surgical splint with the surgery.

The sample was limited to patients with a pre-treatment mandibular plane to sella-nasion angle (MPA) of $33^\circ \pm 6^\circ$ to eliminate patients with excessive or deficient vertical facial growth patterns. Charts of patients with craniofacial anomalies, maxillary surgery or genioplasty were excluded. Charts with missing lateral cephalometric radiographs or those with soft tissue contours that could not be distinguishable extending past soft-tissue glabella and neck throat point were also excluded.

T1 and T2 lateral cephalometric radiographs were hand traced on acetate paper. Landmarks and angles used are shown in Figure 1. The soft tissue profile was traced from a point above glabella to a point the past neck-throat point. Profile angle and ANB angle were measured manually to the nearest 0.5º using a protractor with 1º increments by a single operator. To orientate a subject’s T1 and T2 tracings to the same head position, the two tracings were superimposed on anterior cranial base to confirm whether Frankfort horizontal (FH) planes were coincident. If the FH planes at T1 and T2 were not coincident, the FH plane at T1 was transferred to the T2 tracing. Profiles were scanned at 200 dpi on a flatbed scanner (CanoScan Lide 30, Canon, Mississauga, ON) and imported into Jasc Paint Shop Pro (Jasc Software Inc, version 8.1, Ottawa, ON).
Images were oriented with FH parallel to the top edge of the screen and filled in black to produce silhouettes (Figure 2).

The 20 pre-treatment and 20 post-treatment profiles silhouettes were randomized and inserted into a PowerPoint® presentation (Microsoft Corporation, Mississauga, ON). Three unrelated silhouettes were added in the beginning of the slide show to familiarize participants with the procedure but were not used for subsequent data analysis. Seven of the 40 silhouettes were randomly selected and randomly inserted within the presentation a second time to test for intra-observer reliability. Participants were unaware of the duplicate images. Responses from the first time the profiles were rated were used to calculate change in profile after surgery. The slideshow was viewed on a computer monitor, with the initial 3 introductory slides shown for 20, 15 and 10 seconds each and the remaining 47 slides shown for 10 seconds each.

Twenty orthodontists, 20 oral and maxillofacial surgeons who perform orthognathic surgery and 20 general public members without any dental-related training comprised the three panels. Participants evaluated the 50 profile silhouettes and gave each profile an esthetic score by rating each profile on a 5-point scale from “Very Unattractive” to “Very Attractive.”

Statistical analyses were performed with SAS statistical software (version 9.1.3, SAS Institute, Inc, Cary, NC). Multiple univariate student t-tests analyzed treatment changes in MPA, SNA, SNB, ANB and PA from T1 to T2. With 5 independent t-tests, statistical significance was taken at the p < .05/5 or .01 level. Pearson’s correlation was carried out between pre-treatment ANB angle and profile angles with a significance level of p < .05.
Changes in patient profiles were calculated as the difference between T2 esthetic score and T1 esthetic score. Differences > 0 indicate a profile improvement with treatment, scores < 0 indicate a worsening of the profile, and difference equal to zero indicate no change with treatment. With 20 evaluators in each panel evaluating 20 profiles, there were a total of 400 judgments from each panel. Each group of 400 judgments was plotted on three-dimensional scatterplots to graphically depict the frequency of profile changes at varying pre-treatment ANB and profile angles. Similar to Shelly et al, the plots were examined for thresholds ANB and profile angles where the difference in esthetic score from T1 to T2 were consistently (<1% of the 400 below zero) greater than or equal to zero. Based the number of evaluations that are either above or below the threshold, the incidence of profile worsening at ANB and profile angles above or below threshold was calculated as the proportion in each circumstance less than zero.

Given the non-parametric nature of this data, Spearman’s rank correlation was used to determine intra-observer reliability and the relationship between the change in esthetic scores and pre-treatment ANB angle and profile angle. A higher correlation between the first and second times an evaluator rates a profile implies better intra-evaluator reliability.

RESULTS

Sample Characteristics

The sample consisted of 3 (15%) males and 17 (85%) females. Nine were treated with extractions and 11 were treated non-extraction. Descriptive statistics for the
cephalometric measurements are presented in Table I. Distribution of pre-treatment ANB and profile angles are shown in Figures 3 and 4.

**Effect of Profile Angle on Profile Change**

Ninety percent of the general public evaluators and 85% of the orthodontist and oral surgeon evaluators found negative correlations between the patients’ changes in profile and initial profile angles. A negative correlation implies that as the initial profile angle decreases (i.e. profiles become more convex), there is an increasing improvement in the profile after surgery. Correlation values ranged from -0.64 to 0.08 among general public evaluators, from -0.39 to 0.23 among orthodontists, and from -0.38 to 0.13 among oral surgeons. The correlations between profile angle and changes in the profile were statistically significant (p < .05) for 2 evaluators in the general public group.

Three-dimensional scatterplots show that patients can have a worsening of esthetics after surgery at higher initial profile angles. Negative profile changes accounted for 14 of the 400 orthodontists evaluations, with 86% of these negative changes occurring when pre-treatment profile angles were ≥160º (Figure 5). When initial profile angles were ≤159º, profiles tended to consistently improve with treatment, shown by the shaded area of the graph. Similarly, oral surgeons found 32 of the 400 evaluations to be negative changes, but the most (93.8%) occurred when the profile angle was ≥159º (Figure 6). The general public found 55 of the 400 evaluations to be negative, with 94.5% occurring in individuals with pre-treatment profile angle of ≥158º (Figures 7).

When initial profile angles are above the threshold profile angle, orthodontists found the incidence of negative profile changes after treatment to be 2.6 times greater
than when the initial profile angle where less than or equal to the thresholds (Table II). Oral surgeons found a 5 fold increase in incidence of negative changes, while the general public found a 4.3 fold increase when initial profile angles were above their threshold profile angles.

**Effect of ANB Angle on Profile Change**

Seventy five percent of the general public evaluators and 90% of the orthodontist and oral surgeon evaluators found positive correlations between the patients’ changes in profile and their initial ANB angles. A positive correlation between these 2 variables implies that as initial ANB angle increases (i.e. increasing severity of Class II skeletal relationship), there is an increasing improvement in profile after surgery. Correlation values ranged from -0.21 to 0.50 among the general public, from -0.26 to 0.6 among orthodontists, and from -0.05 to 0.65 among oral surgeons. These correlations between changes in profile scores and initial ANB were statistically significant (p < .05) for 1 oral surgeon, 3 general public and 8 orthodontists.

Calculation of Pearson’s co-efficient found a non-statistically significant inverse correlation between pre-treatment ANB angle and the profile angle (r = -.40, p = .08).

Similar to profile angle plots, deterioration of esthetics after treatment occurred, particularly at less severe ANB angles and milder Class II skeletal relationships. When orthodontists evaluated profiles, 14 of the 400 profile changes were negative, but 11 of them (78.5%) occurred in patients with ANB angles of $\leq 5^\circ$ (Figure 8). When oral surgeons evaluated profiles, 32 of the 400 evaluations had negative profile changes, with 90.6% of these occurring in individuals with initial ANB angle $\leq 6^\circ$ (Figure 9). Thus,
orthodontists and oral surgeons found profiles consistently improved when ANB angles were $\geq 5.5^\circ$ and $6.5^\circ$, respectively. The general public found 53 of the 400 evaluations to be negative, but these scores occurred across a wide distribution of ANB angles and only at high ANB angles of $9^\circ$ or higher was the occurrence of negative changes fewer than 3 evaluations. There was no break in the distribution to indicate what degree of ANB angle consistently improves after treatment and which angles can potentially worsen with treatment.

When pre-treatment ANB angles were less than the threshold ANB angle, orthodontists and oral surgeons found the incidence of negative profile changes to be 4.5 times and 7.9 times greater, respectively, in comparison to when pre-treatment ANB angles were greater than or equal to the threshold value (Table III).

**Intra-Evaluator Reliability**

Correlation values are depicted in Figure 11. For the general public, Spearman’s correlation coefficients had the widest range, from a minimum of 0.26 to a maximum of 0.91. Correlations among oral surgeons ranged from a minimum of 0.44 to a maximum of 1. Orthodontists had correlations that ranged from a 0 to 1.0, but if one orthodontist with no correlation is disregarded for this section of the analysis, the remaining 19 orthodontists had the narrowest range of correlations of the 3 groups of evaluators, from 0.69 to 1.0.
DISCUSSION

Sample Characteristics

The surgical sample was predominantly (85%) comprised of females, consistent with studies reporting that females are more likely than males to seek orthodontic treatment and to accept orthognathic surgery treatment plans.\textsuperscript{10} Males and females, however, are distinctive in certain facial characteristics and a profile considered attractive in males may less desirable in females, and vice versa.\textsuperscript{11-13} Although evaluators in the study were unaware of the gender of the patients they were evaluating, DeSmit and Demaut\textsuperscript{14} found no significant differences in the esthetic evaluation of profiles regardless of whether profiles are evaluated as male or female.

As expected after mandibular advancement surgery, treatment had no effect on the position of the maxilla but did increase mandibular prominence and decrease facial convexity. According to profile angle guidelines by Arnett and Bergman,\textsuperscript{7} the 161° mean pre-treatment profile angle indicates a sample with Class II skeletal relationships that should be surgically treated. Post-treatment, the mean profile angle of the sample was within the normal range of 165°-175° and the mean ANB angle was consistent with a Class I skeletal relationship. The 2.6° decrease in mean ANB angle is similar to other studies that have reported decreases of between 2.4° to 3.0°.\textsuperscript{4,5,15}

Mandibular plane angle was a criterion for sample selection based on its ease of measurement and its frequent use as a factor in the evaluation of skeletal growth pattern. Surgically induced increases in facial height are favorable in patients with a pre-treatment short lower facial height, but detrimental in patients starting with an already long lower facial height, who often benefit from maxillary surgery to decrease facial height. These
types of vertical profile changes have been shown to more negatively affect the perception of a profile than anteroposterior changes, with negative effects particularly pronounced in profiles when lower facial height is increased.\textsuperscript{14} Although steep or flat mandibular planes can be associated with either forward and backwards facial patterns if remodeling of the lower border of the mandible masks the true rotation of the mandibular corpus,\textsuperscript{16,17} limiting the study sample to those with an average MPA most likely excluded the most extreme forward or backward rotators to minimize confounding effects that surgically induced changes in vertical facial dimension could potentially create.

**Profile Changes With Treatment**

Negative correlations between profile change and pre-treatment profile angle and positive correlations in relation to initial ANB angle reflect a trend for individuals with more acute profile angles or severe Class II skeletal relationships to have greater improvements in esthetics after surgery. Correlations, however, were statistically significant for only the orthodontist group and initial ANB angle, with 40\% of the correlations reaching statistical significance. The lack of clinical significance in the correlations maybe due to the ordinal scale that required non-parametric statistics to be used. Other studies on facial esthetics have used visual analogue scales (VAS) anchored at by descriptors such as “Very Unattractive” and “Very Attractive.”\textsuperscript{18-21} VAS allows parametric statistics to be used and may be more sensitive than a Likert scale, but can be subjective and has other disadvantages. It cannot be assumed that anchor terms convey the same feelings in different people, that identical positions on the scales by different
people express comparable intensity of feelings, or that a multiple of a particular rating represents a multiple of the intensity of the feeling.\textsuperscript{18,20-22} VAS also does not identify how many millimeters of difference are required for a significant clinical difference.\textsuperscript{21,22}

Arnett and Bergman\textsuperscript{7} recommended a profile angle of 165° as the threshold for requiring surgical treatment, but this present study found a profile angle of 160° to be the threshold at which profiles consistently improved with surgery and individuals had a minimal chance that their profile would worsen with treatment. The incidence of profile deterioration increased 2.6 to 5 times when profiles angles were $\geq 160^\circ$. Orthodontists and oral surgeons found worsening of profiles of some patients in patients with initial ANB angle less than 5.5° and 6.5°, respectively, similar to the findings reported by Shelly et al\textsuperscript{5} and supporting the use of a threshold ANB angle of 6° as a guideline in esthetic treatment planning of Class II patient. A worsening of profiles occurred 4.5 to 7.9 times more frequently when initial ANB angles were less than the threshold ANB values according to orthodontists and oral surgeons. Despite these increases, profile deterioration still remains a relatively uncommon occurrence and 83-95\% of profiles more orthognathic than the profile angle thresholds and 86-93\% of patients with less severe initial ANB values than the thresholds still esthetically benefit from treatment.

Nonetheless, clinicians need to be more aware that as profiles become more orthognathic, greater consideration should be directed towards non-surgical options, if feasible. Cassidy et al\textsuperscript{23} studied Class II div 1 borderline adult camouflage/surgery patients and found that although mandibular advancement surgery produced more significant treatment changes in mandibular projection in comparison to camouflage treatment that produced more upper incisor and lip retraction, there were no significant
differences in the patients’ satisfaction with their profile improvement, TMJ function or incisor stability with either treatment choice. Given that 3 of the 26 patients in that study had skeletal relapse likely due to condylar resorption, Cassidy et al\textsuperscript{23} argued that orthodontic treatment alone is the more appropriate treatment for adult Class II patients who can be treated with a choice of either dental camouflage or surgery, with surgery being reserved for more serious cases where changes are needed that only surgery can provide.

**Inter-Evaluator Differences**

ANB scatterplots reveal that in comparison to the general public, dental specialists are more critical and able to note changes in profiles of patients with mildly increased initial ANB values and moderate Class II skeletal relationship, whereas the general public seem less discriminating in their assessment and rated more patients as having poor esthetics post-treatment, despite severe Class II skeletal relationships. For both profile angle and ANB angle, oral surgeons had a larger proportion of individuals with negative profile changes (8%) than orthodontists (3.5%), while the general public had the largest proportion of worse profiles after treatment (13-14%). This may suggest that orthodontists most critically evaluate profiles and notice subtle profile changes, followed by oral surgeons and then the general public.

Studies have differed in their findings as to whether there is a difference among various groups of evaluators. Oral surgeons have also been reported to find large surgical changes in pogonion more esthetically desirable than orthodontists or laypersons and less likely to rank patients as unimproved after mandibular advancement.\textsuperscript{3} Laypersons have
been found to rank 25% of the patients as “unimproved” even when there were large surgical changes, while dental professionals only ranked 25% of the patients with the least amount of surgical change as “unimproved.”  

Other authors have found that dental professionals rate Class I profiles as statistically more attractive than the general public do, possibly because professionals are conditioned to focus on specific features in the lower third of the face while laypersons are less aware of profiles on a regular basis and other facial features, such as the complexion, nose size and shape and hair, are greater influences on their judgment of attractiveness.

**Intra-Evaluator Reliability**

Orthodontists tended to be the most consistent in their ratings, with higher correlations and the narrowest range. The general public showed a tendency to be less consistent than the other 2 groups in how they rated profiles, with lower correlations and the widest range.

Correlation coefficients from this study are similar to findings of other profile evaluation studies, whose average correlations ranged from 0.46 to 0.78. It is in contrast to Maple and coworkers, who reported that lay persons had the highest mean correlation coefficients, followed by orthodontists and oral surgeons, possibly because professionals “overevaluate” profiles and concentrate on specific areas rather than giving their initial reaction to the overall profile.
Study Limitations

The sample in this study consisted of patients treated with mandibular advancement surgery only. Other surgical procedures, such as genioplasty, are used to augment chin projection in patients needing more chin projection or having proclined lower incisors (Epker et al., 1994; Shelly et al., 2000; Dolce et al., 2001). Profiles of patients who had negative or small improvements in profile with ramus osteotomy only may have had greater improvement if an additional genioplasty was performed, particularly if there was a pre-existing flat mentolabial sulcus contour. Patients with average facial proportions, however, often have a good balance of the soft tissue chin and lower lip and a genioplasty would not be indicated.

Treatment, however, may still be considered successful if there was a considerable functional improvement or vertical change, despite a lack of significant anteroposterior change. Some cases are best treated surgically for biomechanical, stability and esthetics reasons despite anticipation of minimal anteroposterior mandibular changes. For example Class II div 2 deepbite malocclusions with adequate chin projection may be treated surgically to maintain good upper lip position, torque of the upper incisors, increase vertical face height and improve stability of the overbite correction, rather than to further chin projection.

Profile silhouettes are advantageous when evaluating treatment effect on facial profiles because they minimize the influence of confounding factors, such as gender, skin complexion, hair color/style, and facial expression. The use of silhouettes, however, does not prevent variables such as changes in lip protrusion, lip competence and nasolabial angle from affecting an evaluator’s judgment and thus treatment changes in
these other soft tissues may have introduced bias. Orthodontic treatment that alters incisor position, regardless of any changes from orthognathic surgery, can affect the position of features, such as the lips and nasolabial angle and esthetic scores may reflect positive or negative changes in other soft tissue rather than being a sole reflection of the changes from mandibular advancement surgery.

CONCLUSIONS

1. There is a trend for more acute profile angles and severe Class II skeletal relationships to have increasing esthetic improvements in profile after mandibular advancement, but this was statistically significant only between orthodontists and ANB angles.

2. Individuals with profile angles < 160° or an ANB angle of > 6° consistently have profile improvements after treatment with orthodontics and mandibular advancement surgery.

3. Although the majority of patients will have profile improvements after mandibular advancement surgery, there is a 2.6 to 5 times increase in incidence of profile worsening when profile angle thresholds are not met and a 4.5 to 7.9 times increase when the threshold of ANB angle is not met.

REFERENCES


**Figure 1:** Landmarks, angles and planes. Sella (S), Nasion (N), Subspinale (A), Suprarnentale (B), Menton (Me), Porion (P), Orbitale (O), Soft tissue glabella (G’), Subnasale (Sn), Soft tissue pogonion (Pg’), Neck-throat point (NTP), Frankfort horizontal plane (FH), Mandibular plane (MP), ANB angle (ANB), Profile angle (PA).
Figure 2: Example of pre-treatment (T1) and post-treatment (T2) profile silhouettes of a subject treated with orthodontics and orthognathic surgery.
Figure 3: Distribution of ANB angles in the surgical sample (n = 20)

Figure 4: Distribution of profiles angles in the surgical sample (n = 20)
Figure 5: Orthodontist evaluations of profiles with varying initial profile angles (n = 400). Profile angles ≤159° consistently had a positive change in profile after treatment (shaded area).

Figure 6: Oral surgeon evaluations of profiles with varying initial profile angles (n = 400). Profile angles ≤158° consistently had a positive change in profile after treatment (shaded area).
Figure 7: General public evaluations of profiles with varying initial profile angles (n = 400). Profile angles ≤157º consistently had a positive change in profile after treatment (shaded area).

Figure 8: Orthodontist evaluations of profiles with varying initial ANB angles (n = 400). ANB angles ≥ 5.5º consistently had a positive change in profile after treatment (shaded area).
Figure 9: Oral surgeon evaluations of profiles with varying initial ANB angles (n = 400). ANB angles $\geq 6.5^\circ$ consistently had a positive change in profile after treatment (shaded area).

Figure 10: General public evaluations of profiles with varying initial ANB angles (n = 400). Negative profile changes occur over a wide range of ANB angles.
Figure 11: Spearman’s correlation between the first and second ratings of the repeated profiles by the 3 groups of evaluators (n = 20).
Table I: Descriptive statistics (in degrees) of the surgical sample (n = 20).

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>Treatment Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>MPA</td>
<td>32.7 (3.1)</td>
<td>28.0</td>
<td>38.0</td>
</tr>
<tr>
<td>SNA</td>
<td>80.3 (4.1)</td>
<td>74.0</td>
<td>92.0</td>
</tr>
<tr>
<td>SNB</td>
<td>74.0 (3.6)</td>
<td>69.0</td>
<td>83.0</td>
</tr>
<tr>
<td>ANB</td>
<td>6.3 (1.7)</td>
<td>3.5</td>
<td>10.0</td>
</tr>
<tr>
<td>PA</td>
<td>161.0 (4.6)</td>
<td>152.0</td>
<td>170.0</td>
</tr>
</tbody>
</table>

*Significant at p<.01 level

Table II: Incidence of negative profile changes when pre-treatment profile angles are less than or equal to the threshold profile angle or less than the threshold profile angle.

<table>
<thead>
<tr>
<th>Threshold Profile Angle</th>
<th>Incidence of Negative Profile Changes</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less than Equal to the Threshold</td>
<td>Greater Than the Threshold</td>
<td></td>
</tr>
<tr>
<td>Orthodontists</td>
<td>159°</td>
<td>1.67%</td>
<td>4.29%</td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td>158°</td>
<td>2.00%</td>
<td>10.00%</td>
</tr>
<tr>
<td>General Public</td>
<td>157°</td>
<td>3.75%</td>
<td>16.25%</td>
</tr>
</tbody>
</table>

Table III: Incidence of negative profile changes when pre-treatment ANB angles are greater than or equal to the threshold ANB angle or less than the threshold ANB angle.

<table>
<thead>
<tr>
<th>Threshold ANB Angle</th>
<th>Incidence of Negative Profile Changes</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less Than Threshold</td>
<td>Greater Than or Equal to Threshold</td>
<td></td>
</tr>
<tr>
<td>Orthodontists</td>
<td>5.5°</td>
<td>6.11%</td>
<td>1.36%</td>
</tr>
<tr>
<td>Oral Surgeons</td>
<td>6.5°</td>
<td>13.2%</td>
<td>1.67%</td>
</tr>
</tbody>
</table>