Post-surgical Stability for Class III Patients with Asymmetry: A Comparison of Mandibular Setback, Maxillary Advancement, and Bimaxillary Surgeries.

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ABSTRACT

Gustav Darnell Horsey: Post-surgical Stability for Class III Patients with Asymmetry: A Comparison of Mandibular Setback, Maxillary Advancement, and Bimaxillary Surgeries. (Under the direction of Sylvia A. Frazier-Bowers)

Previous studies evaluated the stability of Class III corrective surgeries: mandibular setback, maxillary advancement, and bimaxillary surgery. According to one study, 40% of Class III patients seeking orthognathic surgery presented with a clinically detectable asymmetry. In our retrospective study, the purpose was to determine whether differences existed in the one year post-surgical stability of asymmetric Class III correction for three surgical procedures. We utilized cephalometric and panoramic radiographic analyses to compare the stability of asymmetric Class III patients including 43 bimaxillary surgery, 24 maxillary advancement, and 15 mandibular setback patients. Our analysis revealed that stability in the horizontal direction was greatest for bimaxillary surgery group and least for the mandibular setback group, while stability in the vertical direction was the exact opposite. Overall, our study suggests the anterior-posterior one year surgical stability tendency of asymmetric Class III patients is similar to that of other Class III samples, but differs in the vertical direction.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>vi</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>x</td>
</tr>
</tbody>
</table>

Chapter

## I. LITERATURE REVIEW ...........................................1

- INCIDENCE OF PATIENTS SEEKING CLASS III SURGICAL CORRECTION .............................................1
- ASYMMETRY IN THE CLASS III POPULATION ......................2
- IDENTIFICATION OF CLASS III SKELETAL PROBLEMS .............3
- ETIOLOGY OF CLASS III SKELETAL PROBLEMS ..................3

## MAXILLARY VERSUS MANDIBULAR SURGERY IN CLASS III

- CORRECTION ..................................................................4
  - Mandibular Surgery ..................................................7
  - Maxillary Advancement .............................................9
  - Bimaxillary Surgery ...............................................12

## SURGICAL FIXATION ...........................................12

- Wire Fixation ........................................................13
- Rigid Internal Fixation .............................................14
- Rigid Versus Wire Fixation .......................................16
ANALYSIS OF PANORAMIC RADIOGRAPHS……………………………………19
In Vitro Studies Utilizing Panoramic Radiography Measurements………………19
Clinical Studies Using Panoramic Measurements………………………………23
Asymmetry Analysis Using Panoramic Radiographs…………………………...…25

II. MASTER THESIS……………………………………………………………………28
   A. ABSTRACT……………………………………………………………………..29
   B. INTRODUCTION………………………………………………………………30
   C. METHODS………………………………………………………………………33
   D. RESULTS………………………………………………………………………..37
   E. DISCUSSION……………………………………………………………………..46
   F. ACKNOWLEDGEMENTS……………………………………………………….52
   G. TABLES…………………………………………………………………………53
   H. FIGURES…………………………………………………………………………60
   I. APPENDICES………………………………………………………………………92
   J. REFERENCES ……………………………………………………………………93
LIST OF TABLES

Table

1. Pre-surgical and treatment characteristics of the sample........................................52

2. Type of asymmetry present within each surgery group........................................53

3. Surgical and One Year Post-surgical Changes for LeFort I
   Maxillary Advancement Patients.................................................................54

4. Surgical and One Year Post-surgical Changes for BSSO
   Mandibular Setback Patients.................................................................55

5. Surgical and One Year Post-surgical Changes for Bimaxillary
   Surgery Patients.......................................................................................56

6. Asymmetry Percentage for each Surgery Group at Pre-surgical,
   Immediate Post-surgical and One Year Post-surgery.................................57

7. Surgical and One Year Post-surgical Changes in Condylar
   and Posterior Face Height Symmetry Percentage
   for each Surgery Group............................................................................58
LIST OF FIGURES

1. Matilla Method for Panoramic Measurements...........................................59

2. Percentage of the LeFort I maxillary advancement patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.........................................................60

3. Percentage of the LeFort I maxillary advancement patients with horizontal changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.......................................................61

4. Percentage of the LeFort I maxillary advancement patients with vertical changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.................................................................62

5. Percentage of the LeFort I maxillary advancement patients with vertical changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.......................................................63

6. Percentage of the LeFort I maxillary advancement patients with dimensional changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.................................................................64

7. Percentage of the LeFort I maxillary advancement patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.......................................................65

8. Percentage of the BSSO mandibular setback patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.................................................................66

9. Percentage of the BSSO mandibular setback patients with horizontal changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.......................................................67

10. Percentage of the BSSO mandibular setback patients with vertical changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.................................................................68

11. Percentage of the BSSO mandibular setback patients with vertical changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.......................................................69
12. Percentage of the BSSO mandibular setback patients with dimensional changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery…………………………………………………………………………….70

13. Percentage of the BSSO mandibular setback patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery…………………………………………………………………………….71

14. Percentage of the bimaxillary surgery patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery………………………………………………………………………………………………….72

15. Percentage of the bimaxillary surgery patients with horizontal changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery………………………………………………………………………………………………….73

16. Percentage of the bimaxillary surgery patients with vertical changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery……………………………………………………………………………………………………………..74

17. Percentage of the bimaxillary surgery patients with vertical changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery……………………………………………………………………………………………………………..75

18. Percentage of the bimaxillary surgery patients with dimensional changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery……………………………………………………………………………………………………………..76

19. Percentage of the bimaxillary surgery patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery……………………………………………………………………………………………………………..77

20. Statistically significant difference in mean one year post-surgical vertical relapse of B point for mandibular setback vs. bimaxillary surgery……………………………………………………………………………………………………………..78

21. Statistically significant difference in mean one year post-surgical dimensional relapse of mandibular plane angle for mandibular setback vs. maxillary advancement and maxillary advancement vs. bimaxillary surgery……………………………………………………………………………………………………………..79

22. Statistically significant difference in mean one year post-surgical dimensional relapse of gonial angle for maxillary advancement vs. bimaxillary surgery……………………………………………………………………………………………………………..80
23. Statistically significant difference in mean one year post-surgical vertical relapse of gonion for bimaxillary surgery vs. maxillary advancement..............................................................81

24. Condylar (COND) and posterior face height (PFH) Asymmetry Percentage for each Surgery Group at Pre-surgical (-pre), Immediate Post-surgical (-sx), and One Year Post-surgery (-post) time points. Calculated from the equation: \(|(R-L)/(R+L)| \times 100\).................................82

25. Statistically significant difference in mean one year post-surgical horizontal relapse of gonion for maxillary advancement vs Bimaxillary surgery patients with >6% of condylar asymmetry pre-surgically..........................................................83

26. Composite cephalometric changes from pre-surgery to immediate post-surgery time points for maxillary advancement patients.................................84

27. Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for maxillary advancement patients..........................................................85

28. Composite cephalometric changes from pre-surgery to immediate post-surgery time points for mandibular setback patients.................................86

29. Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for mandibular setback patients.............87

30. Composite cephalometric changes from pre-surgery to immediate post-surgery time points for bimaxillary surgery patients.................................88

31. Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for bimaxillary surgery patients..........89
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANB</td>
<td>angle measurement: point A to nasion to point B</td>
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<tr>
<td>AP</td>
<td>anterior posterior</td>
</tr>
<tr>
<td>Co</td>
<td>condylion</td>
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<tr>
<td>DFD</td>
<td>dentofacial deformity</td>
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<td>PNS</td>
<td>posterior nasal spine</td>
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<tr>
<td>UNC</td>
<td>University of North Carolina</td>
</tr>
</tbody>
</table>
CHAPTER 1
EXTENDED LITERATURE REVIEW

Incidence of Patients Seeking Skeletal Class III Correction

One percent of individuals in the U.S. (~2,700,000) are skeletal Class III, and about 33% of that population (~580,000) are severe enough to justify orthognathic surgery (Bailey et al., 1999). The Class III population in the United States continues to grow by roughly 12,000 people each year. Combined orthodontic and surgical correction of a dentofacial deformity is recommended if the problem falls outside the orthodontic “envelope of discrepancy” characterized by Proffit and White (1990). The “envelope of discrepancy” describes the limits of dental and skeletal movement with functional appliances and orthodontic treatment alone, and illustrates that movement necessary outside these limits can only be obtained with surgical correction.

Proffit and White (1990) reviewed data for malocclusion in the U.S. and reported that there were 1.2 million people with dentofacial problems severe enough to require combined orthodontic and surgical correction to attain a reasonably stable and esthetic result. Approximately 300,000 of these individuals were skeletal Class III. Moreover, about 45% (~130,000) of these skeletal Class III individuals needed mandibular setback alone, while 35% (~101,000) required maxillary advancement alone, and 20% (~58,000 cases) needed a combination of maxillary advancement and mandibular setback (Proffit and White, 1990).
Proffit et al. (1990) summarized the dentofacial characteristics of patients seen in the Dentofacial Program at UNC citing that one-third of the patients seeking orthodontic-surgical treatment were Class III, despite the fact that the incidence of Class III in the general public was less than 2%. It is likely that the socially unacceptable esthetics of a severe Class III malocclusion contributes to a higher percentage of these patients seeking surgical evaluations for correction of their deformity. Skeletal Class III patients and long face individuals sought treatment more often than patients with a skeletal Class II relationship or patients with short or normal face heights (Proffit et al., 1990). In this same study that reviewed 2000 patients for the necessity of orthodontic-surgical correction, Proffit reported that in the Class III population there was no correlation between severity, jaw affected, or amount of reverse overjet with one’s acceptance of surgical treatment plan. Since a strong chin is considered more acceptable in males than females, it was not surprising to discover that females were more likely to agree to Class III surgical treatment plans than males. Even though asymmetries were more prevalent in males, a higher percentage of females sought surgery to correct asymmetries.

**Asymmetry in the Class III Population**

Within the past ten years the occurrence of asymmetry was assessed in the patient population of the Dentofacial Deformity Clinic at UNC. As mentioned earlier, it was determined that 40% of the skeletal Class III patients were found to have a skeletal asymmetry and when the chin was off to one side there was an 80% chance that it would be off to the left (Severt et. al., 1997). Class III patients may present not only with an anteroposterior discrepancy, but often have transverse and vertical problems as well. Facial asymmetries including orbital dystopia, nasal tip deviation, chin deviation, maxillary occlusal
cant, and zygomatic arch discrepancy were found in 25% of these patients. Forty percent of Class III patients had a facial asymmetry, and this percentage is significantly higher than Class II patients who had a 28% chance of being asymmetric (Severt and Proffit, 1997). Since the Class III group represented the largest asymmetric subset, it has stimulated many new questions, specifically regarding the stability of the asymmetric Class III patient.

**Identification of Class III Skeletal Problems**

The Class III skeletal problem can present in many forms including mandibular prognathism, maxillary deficiency, or a combination of both. A true mandibular prognathic patient can be identified in profile by evaluating their neck form in conjunction with their throat length. These patients frequently present with a decreased mentolabial fold and a thin lower lip (Sinclair and Proffit, 1991). They often have flared incisors, moderate generalized dental spacing, and an open bite. A large anterior-positioned tongue is often present with scalloped indentations on the lateral margin from the mandibular teeth.

Maxillary deficiency patients often have an increased neck-chin angle and submental area with a sunken in facial appearance and thin upper lip (Sinclair and Proffit, 1991). Complete maxillary deficiency is further expressed with infraorbital, malar and paranasal deficiencies. Maxillary incisor display at rest is often decreased in these patients and their upper lip length is usually reduced. Maxillary deficient patients frequently possess an obtuse nasolabial angle, a narrowed alar base, and a more horizontally oriented columella (Sinclair and Proffit, 1991). An area of sclera is occasionally visible beneath the pupils as a consequence of infraorbital deficiency. Due to the small dimension of the maxilla in all three planes of space, maxillary deficient patients can present with severe maxillary crowding and
underdeveloped or missing maxillary lateral incisors. They often have a strong cross bite tendency because of the transverse deficiency of their maxilla, and this may cause buccal tipping of the maxillary molars to compensate (Sinclair and Proffit, 1991).

When evaluating the Class III patient it must be determined whether the anteroposterior discrepancy is a result of the maxilla, the mandible, or both jaws. In addition, there is often a significant vertical component to Class III malocclusions. A connection between the vertical growth of the maxilla and the anteroposterior position of the mandible has been discussed in the literature. The use of cephalometric analysis provides many of the necessary skeletal and dental comparisons and hence facilitates a more precise diagnosis. Specifically, the anteroposterior and vertical relationships of the maxilla and mandible to cranial base is very important when evaluating cephalometric radiographs. For instance, a decreased cranial base (S-N) is present in many Class III patients (Hopkins, 1968). Moreover, the Class III population often has a more acute cranial base angle (N-S-Ba), often resulting in a more forwardly positioned glenoid fossa that positions the mandible more anteriorly. Thus a comparison of direct measurements of the maxilla and mandible to established norms is also important. By compiling the above data, it can be determined if the skeletal Class III malocclusion is primarily caused by maxillary deficiency, mandibular prognathism, or a combination of both. This will help finalize the orthognathic surgical plan for correction of the skeletal problem.

**Etiology of Skeletal Class III Problems**

Throughout history, a significant genetic component to mandibular prognathism and Class III malocclusion has been recognized. In one sample of severe Class III children, it was reported that one-third had a parent with the same skeletal pattern and one-sixth had a
Class III sibling (Litton et al, 1970). We can also point to the historically prominent Hapsburg family, a frequently cited example of a Class III pattern with an obvious genetic component. Finally, the presence of the class III problem (especially maxillary deficiency) in medical syndromes such as Crouzon, Pfeifer and achondroplastic dwarfism obviates the genetic etiology. Nonetheless, both contemporary and historical perspectives have debated the relative contribution of genetics versus the environment in the development of Class III malocclusion.

Local environmental factors have also been implicated in altering the development of both the maxilla and mandible and ultimately leading to a Class III malocclusion. For example, if the mandible is continuously postured forward, growth at the condylar process may occur to maintain articulation with the skull. Harvold’s experiments on monkeys illustrated that positioning the mandible forward to assist mouth breathing caused a propensity to mandibular prognathism (Harvold, 1979). Some have concluded from this research that a growing child with a large tongue or reduced pharyngeal dimensions, and who positions their mandible forward to breathe, could cause excessive mandibular growth.

Moss’ functional matrix theory (which was first proposed in the 1960’s), suggests that the function of the respiratory passages affects maxillary growth. Since that time, research has shown little relationship between mouth breathing and vertical maxillary growth (Proffit, 1991). It was thought by some that long face individuals developed this pattern because of an increase in nasal obstruction with the resultant dependency on mouth breathing. The most conclusive research illustrating that nasal obstruction does not significantly affect maxillary vertical growth was by Turvey (1984). He calculated nasal resistance in long-face patients both before and after LeFort I maxillary impaction surgery.
In this study, two-thirds of the pre-surgical long-faced patients did not have any nasal obstruction before surgery, and one-third had elevated nasal resistance, which would have made them partial mouth breathers. There were no patients with normal nasal resistance before surgery that displayed any significant increase in nasal resistance after surgery. Eighty percent of the moderately high nasal resistance group, and 87% of the severely high nasal resistance group, had normal nasal resistance post-surgically. Proffit and Phillips explained that the decrease in nasal resistance after surgery is caused by the opening of the nostrils as the maxilla is moved up and the alar bases are broadened (1988). Cleft palate patients also experience growth alterations of the maxilla, however these are probably due to scarring after early surgery and not conventional environmental influences. In summary, a skeletal Class III discrepancy conceivably develops when a person having a genetic predisposition towards a Class III tendency is exposed to an environmental factor that affects growth enough to create a skeletal Class III malocclusion.

**Maxillary versus Mandibular Surgery in Class III Correction**

Edward Angle first described the need for orthognathic surgery to correct a prognathic mandible in 1907. Before the 1970’s surgery in Class III patients was limited to mandibular setback alone because many thought that the mandible was the primary cause of the problem and maxillary surgery was not yet a well-developed option. It is now known that isolated mandibular prognathism contributes to only 20% of Class III cases, isolated maxillary deficiency contributes to approximately 20% of cases, and combined maxillary deficiency and mandibular prognathism accounts for 50-60% of Class III cases (Proffit et al., 1990). In the 1970s, maxillary surgery began to be performed more often since a deficiency of the maxilla could be corrected surgically as easily as a prognathic mandible. Since 1980 there
has been a tendency to perform less isolated mandibular surgery to correct Class III skeletal patterns and more maxillary advancement or 2-jaw surgery procedures (Bailey et al., 1995). Advancements in surgery and fixation have made it possible to perform different types of surgeries for the treatment of Class III skeletal discrepancies.

An examination of the treatment records for 1,222 Class III patients seen by the UNC Dentofacial Program from 1978-1992, found that 333 of the patients were treated with mandibular setback, maxillary advancement or bimaxillary surgery. The authors recorded the prevalence of these surgical procedures during certain time periods. Before 1985, nearly half of the patients had mandibular setback surgery, just 15% had isolated maxillary advancement surgery, and about one-third had bimaxillary surgery performed. Between 1985 and 1989, the incidence of mandibular setback dropped to 22%, while the percentage of maxillary advancement surgeries almost doubled and the incidence of bimaxillary surgery rose to fifty percent. During the period from 1990-1992, just 9% of Class III surgeries were mandibular setback, compared with maxillary advancement at 40% and bimaxillary surgery at 50%. The investigators determined that since most patients have a combination of maxillary deficiency and mandibular prognathism, it is reasonable to expect that bimaxillary surgery would be the most prevalent surgical approach. Patients needing their maxilla moved down at surgery can achieve better stability post-surgically by performing a ramus osteotomy simultaneously. This also has led to a rise in bimaxillary surgery. If one jaw surgery is recommended, all other things being equal, the authors endorsed maxillary advancement or two-jaw surgery for increased stability and in most cases improved esthetic outcome over isolated mandibular setback (Bailey et al., 1995).
The Evolution of Orthognathic Surgery

Mandibular Surgery

The first orthognathic surgical procedures to manage skeletal discrepancies were mandibular body osteotomies performed to setback prognathic mandibles during the early 20th century. In 1954 Caldwell and Letterman reported predictable results using extraoral vertical oblique ramus osteotomies and horizontal ramus procedures as alternatives to previously used ramus body osteotomies. Currently, the most common mandibular surgical procedures to setback the mandible is the transoral sagittal split osteotomy and the inverted L osteotomy. These were described by Trauner and Obwegesser in 1957. In 1975, Hall, Chase and Payor performed vertical subcondylar osteotomies to correct 42 cases of mandibular prognathism. These authors reported comparable stability results to sagittal split osteotomies and extra-oral vertical subcondylar osteotomy. The authors thought one advantage of the vertical subcondylar osteotomy was the lower incidence of mandibular nerve damage (Hall, Chase and Payor, 1975). Since 1980, surgery to setback the mandible has been performed by utilizing intraoral ramus osteotomies (bilateral sagittal split osteotomy (BSSO), or transoral vertical oblique osteotomy (TOVRO).

Extensive stability studies for soft or hard tissue landmarks following mandibular setback surgery are relatively few in number in the literature considering how long these procedures have been performed. The following studies illustrate the surgical relapse tendencies in the mandibular setback population. In the 1970s, Astrand and Ridell described a relapse tendency in a patient population who had vertical ramus osteotomy, yet in the absence of a persistent growth pattern, the results remained relatively stable (Astrand and Ridell, 1973). This tendency was also reported by Reitzik (1974), who reviewed 50
prognathic patients post-surgically and illustrated substantial skeletal relapse with relatively stable occlusion. Likewise, Hall studied 40 prognathic patients after vertical ramus osteotomies and reported a 14% prevalence of anterior open bite post-surgically (Hall et al., 1975). In one study of patients 5 year post-surgery, it was found that 18% of patients had anterior dental relapse of more than 1.5 mm (Pepersack and Chausse, 1978). MacIntosh (1981) reviewed 49 BSSO patients and discovered vertical and anteroposterior relapse greater than 1 mm in 32% of the population. Anterior open bite was present in 13.5% of these relapse patients. Phillips et al. studied the stability of mandibular set backs between a TOVRO and a group and reported a greater relapse tendency in the BSSO group (Phillips et al., 1986).

Proffit et al. (1992) studied the stability of 48 patients after BSSO surgery to correct mandibular prognathism with or without a genioplasty. The mean post-surgical forward relapse at B point was 2.7 mm. Thirty-five percent of the patients had from 2-4 mm of relapse while 25% experienced more than 4 mm of forward movement at B point. All patients experienced forward post-surgical relapse of gonion with an average of 4 mm for the group. Forty percent of the patients had between 2–4 mm forward relapse, while 42% had more than 4 mm forward movement post-surgically. There was a correlation between anterior movement of gonion at the time of surgery and the amount of relapse post-surgically. Turvey believed that returning the proximal segment to its original pre-surgical position was important to reduce relapse following mandibular setback surgery.

Maxillary Advancement
While tumor resection was the first use for maxillary osteotomies in 1867, the LeFort I downfracture to reposition the maxilla in all three planes of space wasn’t widely adopted until the 1970’s (Obwegesser, 1969; Wilmar, 1974; and Bell, 1975). Since nearly half the patients with skeletal Class III malocclusion have maxillary deficiency as the major component of their problem it was fortunate to see maxillary advancement gain popularity (Proffit et al., 1990). From the beginning, it was evident that there was a tendency for the maxilla to relapse posteriorly following LeFort I maxillary advancement, and bone grafts were recommended as a way to reduce this relapse (Araujo et al., 1978). Post-surgical superior relapse of the maxilla following downward repositioning was also identified early as a problem, and a number of recommendations to improve stability were presented (Wessberg and Epker, 1981). Some researchers advised the use of rigid internal fixation (RIF) using bone plates to increase stability when the maxilla is moved downward (Luyk and Ward-Booth, 1985; Bennett and Wolford, 1985; and Bays, 1986). In 1995, Chow et al., reported that despite RIF, 28% of segmented LeFort I impactions tended to relapse downward by one year post-operatively. They also discovered no significant correlation between the severity of relapse and the amount of surgical movement.

Proffit et al. (1991) concluded that anterior movement of the maxilla to correct maxillary deficiency is a stable and predictable technique. On the other hand, inferior movement of the maxilla causing the mandible to rotate down and back had a strong relapse tendency that must be accounted for in surgical planning. It was suggested that inferior maxillary movements at the time of surgery should be combined with mandibular ramus osteotomies and/or bone grafts should be used to improve post-surgical stability (Proffit et al., 1991).
Proffit et al. (1987) evaluated cephalometric data for LeFort I maxillary superior repositioning patients to determine the stability of skeletal and dental landmarks. Twenty percent of the patients had 2 mm or more of post-surgical movement of skeletal and dental landmarks. At six weeks post-surgery, the maxilla had a strong superior relapse tendency. The anterior maxilla had a tendency to move posteriorly after it had been advanced in 20% of patients. The same study was extended to include a 5 year follow-up by Bailey et al. (1994). It was concluded that between the one year and five year follow-up, minimal changes occurred in both skeletal and dental landmarks in most of the patients. At 5 year follow-up, downward movement of the maxilla and/or eruption of maxillary teeth of 2 mm or greater occurred in approximately 25% of patients, thus causing a downward and backward rotation of the mandible. The change in these particular patients could not be explained by growth, however the study included patients with an initial diagnosis of increased vertical dimension.

In another study by Bailey et al. (1998), Class III patients were examined postsurgically and a minimal mean change in skeletal landmarks from 1 year post-surgery to the longest follow-up in the maxillary advancement group was reported. At the time of maxillary advancement, the posterior maxilla is often moved downward to facilitate its anterior movement. In these particular patients, the posterior maxilla relapses superiorly within the first year, but no significant superior movement is observed between one year and the longest follow-up. It was further reported that a simultaneous ramus osteotomy may improve the stability of a maxillary advancement when the maxilla is moved downward at the time of surgery. Unlike the previous study, no patients in this group had increased vertical face height that required maxilla impaction as well as advancement (Bailey et al., 1998).
Stability of maxillary transverse expansion has also been a great concern. Phillips et al. (1992) studied the stability after transverse expansion of the maxilla via LeFort I osteotomy with segments. They showed the greatest post-surgical relapse at the second molars. They found no correlation between transverse relapse and the type of pre-surgical orthodontic movement, the use of rigid fixation, or the use of an auxiliary stabilizing archwire. The amount of post-surgical relapse was significantly greater in those who had concurrent mandibular surgery. It has been well documented that the least stable orthognathic procedure is transverse expansion of the maxilla (Proffit et al., 1996).

**Bimaxillary Surgery**

Previous studies on the stability of bimaxillary surgery have mainly dealt with skeletal open bite patients. The authors in these studies concluded that bimaxillary surgery is the treatment of choice for patients with severe Class III problems, and they also determined that combined maxillary and mandibular procedures did not present a greater risk of complications or relapse (Moser and Freihofer, 1980; LaBanc et al, 1982; Hennes et al, 1988; Satrom et al, 1991; and Turvey et al, 1988). Proffit et al. concluded that long-face Class III patients experience excellent post-surgical stability when upward and forward movement of the maxilla is combined with lower border ramus osteotomies, thus preventing excessive forward rotation of the mandible (1991). When the maxillary advancement surgeries were combined with mandible setbacks, as long as minimal vertical change occurred, moderate post-surgical relapse was reported in both jaws with most of the correction being sustained at one year. When the maxillary advancement and down grafting surgeries were combined with mandibular setbacks,
moderate post-surgical vertical relapse of the maxilla and anteroposterior relapse of the mandible was noted.

**Surgical Fixation**

Fixation is needed after orthognathic surgery to stabilize the segments of bone operated on and manipulated. Advancements in surgical techniques have made it possible to perform different types of surgeries in combination with robust fixation methods for the treatment of Class III skeletal discrepancies. These advancements, in particular rigid fixation of the maxilla and utilization of modified hypotension to decrease blood loss in anesthesia, have helped increase the utilization of maxillary surgeries as an option. Emerging stability research has substantiated the increased stability of maxillary advancement and bimaxillary surgery compared to mandibular setback. The concern that maxillary advancement could cause the potential for cleft palate speech development post-surgically, due to changes of the velopharyngeal mechanism, has been dispelled by research (Turvey, 1984). Maxillary advancement has a more esthetic result than mandibular setback, especially when the maxilla is deficient. Furthermore, maxillary versus mandibular surgery to correct a Class III problem avoids the undesirable effect of a mandibular set back where the tongue drops lower in the floor of the mouth causing a bulge in the neck area similar to that of an obese person. Advancements in surgical fixation techniques (discussed below) in combination with increased clinical experience of oral surgeons performing maxillary procedures, has produced a greater acceptance of maxillary advancement for treatment of Class III discrepancies.
**Wire Fixation**

Prior to the introduction of rigid fixation, wire fixation was the predominant surgical fixation technique. Wire fixation, includes transosseous wire fixation, skeletal wire fixation, and maxillomandibular fixation (MMF) for a period of six to eight weeks. A 24-26 gauge stainless steel wire is positioned across the osteotomy site and is used in combination with MMF to stabilize the bone segments. The twenty-four gauge wire is passed through the bur hole in the piriform rim area and passes through the maxillary mucobuccal fold and twisted. Following a LeFort I osteotomy, some surgeons recommend mobilization of the jaw in the third postoperative week. Because mandibular ramus surgery healing often takes longer, mobilization after 5-7 weeks of MMF is recommended. Following bimaxillary surgery, skeletal suspension wires are added to enhance stability in the areas of dense cortical bone (piriform rim) and a separate suspension wire loop is connected to the mandibular arch wire to prevent mandibular movements from altering the position of the maxilla.

A study by Astrand (1973) evaluated intraosseous wiring of prognathic patients who underwent an oblique osteotomy of the mandible, he reported there were few differences between the wired and unwired groups. Wiring was determined to be unnecessary, but was indicated if the surgeon wished to obtain optimal relationships between surgical segments during surgery. Another advantage of using wire fixation was the improved contact between segments and the possibility of reduced healing time. A disadvantage was that if the wiring was too tight there was a possibility of displacement the condyles (Astrand, 1983).

Bishara et. al. studied 31 patients who underwent a one-piece maxillary osteotomy with wire fixation, he noted a tendency toward superior and posterior relapse of the maxilla (1988). They related this relapse to resorption and remodeling at the osteotomy sites, or
perhaps periodic tightening of the suspension wire during fixation. More recently, Komori et al. (1989) identified factors influencing skeletal relapse of 15 patients who had modified BSSO setbacks with wire fixation. They reported that skeletal relapse took place due to incomplete proximal segment control. They emphasized the significance of preserving the proximal segment in its precise pre-surgical position and the use of a skeletal suspension wires to ensure a stable surgical outcome.

**Rigid Internal Fixation**

Pin systems to stabilize LeFort I maxillary osteotomies were the earliest rigid internal fixation technique reported by Bays (1985 and 1986) and Bennet and Wolford (1985). In spite of being an internal fixation method, a portion of the stabilization device was exposed intraorally and removal of the pins at a later date was required. Following correct positioning of the maxillary bony segment, the pin system was adapted to the maxilla, secured with screws to the lateral walls, and fixed to orthodontic appliances or splints. This technique allowed the surgeon to modify the position of the maxilla post-surgically by bending sections of the wire with three prong orthodontic pliers. Precise post-surgical adjustment of the maxilla was complicated and it was concluded that accurate placement of the segments at the time of surgery was preferred (Tucker and White, 1991).

Several authors have described using bone plates to stabilize the maxilla after LeFort I surgeries (Schilli et al., 1984, Van Sickles and Jeter, 1984, and Harsha et. al., 1986). Slight modifications in surgical cuts may be needed to place bone plates in areas of maximum bone thickness and protect against damaging teeth and nerves. Some techniques to accomplish this include positioning the cuts at a higher lever or using step osteotomies.
Horster described the utilization of bone plates in cleft patients who underwent single piece or segmental LeFort I and II osteotomies (1980). Follow-up reports on these patients from 6 months to one year revealed no significant relapse, no TMJ complaints, nor occlusal disturbances. Drommer and Luhr reported successful short-term results with the use of the Luhr mini-plate rigid fixation system in cleft patients after LeFort or LeFort II osteotomies involving substantial anterior and lateral movements (1981).

Steinhauser reported less relapse of mandibular prognathism in more than 100 patients following the use of bone screws instead of wire osteosynthesis in the fixation process (Steinhauser, 1982). Steinhauser recommended using miniplates of stainless steel or titanium following maxillary and mandibular surgery. After maxillary surgery, the bone plates and screws were inserted in the region of the zygomatico-alveolar crest or slightly lateral to the piriform aperture in the area of thicker cortical bone. After mandibular setback surgery or surgery to correct open bites, he suggested stabilization with bone plates and screws and recommended their removal 6-12 months post-surgery. Some advantages of the bone plates and screws include earlier healing time, less relapse, decrease in intermaxillary fixation time, and the prospect of immediate opening of the mouth which resulted in return to earlier functioning. Two disadvantages were the higher risk of nerve disruption and the need for post-surgical removal of the bone plates and screws.

**Rigid Versus Wire Fixation**

Kobayashi, Watanabe and Ueda (1986) stated that there was no evidence that RIF resulted in greater stability following mandibular setback. Reitzig and Schoorl (1983) illustrated that the histological pattern and mechanical properties of bone healing for RIF is different than that for wire fixation. Throughout wire fixation, bone healing is thought to
occur by secondary healing through the formation of a callus, followed by osteoblastic activity, bone deposition, and finally remodeling. During RIF, bone heals primarily without forming a callus, and this type of bone healing had been shown to be mechanically stronger than that from wire fixation (Reitzig, 1983; Reitzig and Schoorl, 1983). Buckley et al. (1989) observed 150 patients treated with RIF and 120 patients treated with wire fixation for maxillary surgery, mandibular surgery or combined maxillary and mandibular surgery. They reported increased weight loss for the wire fixation group, and attributed the lack of weight loss in the RIF group to their ability to function in a shorter period of time post-surgery. This allowed the RIF group the opportunity to eat a variety of foods sooner than their wire fixation counterparts. In 1986, Hashara and Terry reported RIF stabilization of LeFort I surgeries using bone plates and screws decreased or eliminated the postoperative period of intermaxillary fixation, provided stable long-term results, and improved nutrition and comfort for patients. Two disadvantages noted were longer operative time and operative difficulty.

The mode of surgical fixation plays a key role in post-surgical stability of mandibular setback procedures. Franco et al. (1989) found that relapse was proportional to the amount of mandibular setback even when bone screws were utilized. A study by Proffit et al. (1991) compared post-surgical stability of three surgical procedures: TOVRO, BSSO with wire osteosynthesis and maxillomandibular fixation, and BSSO with rigid internal fixation (RIF) using bone screws. Each surgery group had less than expected stability results regardless of fixation technique used. All procedures illustrated a tendency of post-surgical repositioning of the chin. In the BSSO groups with RIF, the chin moved forward 4 mm on average post-surgically suggesting that perhaps the condyles were forcefully seated and the ramus
segments were displaced posteriorly resulting in a gradual relapse forward. Schatz and Tsimas (1995) found a similar relapse tendency in a one year post-surgical BSSO RIF group. They noted greater horizontal than vertical relapse in their sample of 18 patients. Bailey et al. (1998) studied mandibular setback patients 2 years or longer post-surgically and reported a mean horizontal change at B point of 3.6 mm during the first year, taking into account splint removal, but minimal mean changes after the first year.

Studies by Rodriguez and Gonzalez (1996) of BSSO patients with circum-mandibular wiring and elastic intermaxillary fixation found that the relapse at 6 months was proportional to the extent of mandibular setback. They estimated that the degree of relapse to be 25% of the original surgical correction. Komori demonstrated a higher relapse tendency in patients when the proximal ramus segment posteriorly rotates at the time of surgery (Komori, 1989).

In a study of 49 patients who underwent maxillary advancement, Proffit et al. (1990) found no significant difference in the anteroposterior stability between wire fixation and rigid fixation. They found that RIF by itself could not prevent superior relapse following LeFort I maxillary downgrafting. These authors suggested simultaneous mandibular ramus osteotomy and/or progressively incorporated grafts in the maxillary osteotomy site to enhance stability. Following mandibular setback surgery to resolve a skeletal Class III discrepancy, RIF does not provide better stability than conventional fixation procedures. Some authors have even reported greater relapse tendency when using rigid internal fixation (Komori et. al., 1987; Kobayashi et al., 1986).

Proffit et al. (1992) also reported that the patients with wire fixation had better stability than those with rigid fixation using screws. As stated earlier, if the proximal segment was pushed posteriorly at the time of surgery the muscles adjust to reposition the
mandible forward. The wire fixation technique allowed more movement of the bone borders to occur during intermaxillary fixation, while the screw fixation technique was less forgiving and inhibited this movement during fixation. The authors suggested that removal of the medial pterygoid muscle from both the proximal and distal segments would permit these segments to be positioned passively at the time of surgery. They also recommend the stylomandibular ligament be freed from the posterior border of the proximal segment.

Silvestri et al. (1994) reported on patients receiving maxillary and mandibular surgery for a skeletal Class III discrepancy. In one group wire fixation was used in both the maxilla and mandible, and in the other group bicortical screws used in the mandible and plates with screws in the maxilla. In the short-term (20-40 days post-surgery), they reported comparable stability in the maxilla for the wire and rigid fixation groups. In the short-term (20-40 days post-surgery), they reported more mandible relapse in the wire fixation group in the form of downward and backward rotation of the mandibular body with upward and forward rotation of the ramus.

Analysis of Panoramic Radiographs

In Vitro Studies Utilizing Panoramic Radiography Measurements

In our study, we took advantage of panoramic radiographic analysis methods described below. Specifically, in vitro studies have utilized dry skulls or mandibular models to assess the accuracy of panoramic radiography at making different linear measurements (Table 1). The effect of patient positioning on the accuracy of linear measurements was examined in six of these studies (Tronje et al., 1981; Habets et. al., 1987; Kjellberg et al., 1994; McKee et al., 2001; Xie et al., 1994; Stramotas et al., 2002;). Condylar measurements and ratios were reported in three studies (Kjellberg et al., 1994; Turp et al., 1996; Catic et al.,
Two studies took into account variations in human skull sizes and incorporated multiple skulls (more than 5) in their experiment (Turp et al., 1996; Catic et al., 1997). More recently, Lassiter et al. (2005), utilized multiple orientations (ideal, rotated, and shifted) of skulls to assess the errors in linear measurements and symmetry ratios. In addition, they compared panoramic data and cone beam (CT) technology from the same skulls.

The literature has conflicting opinions on the validity of measurements taken on panoramic radiographs. Several studies maintain that examining linear measurements and/or symmetry ratios on panoramic radiographs is an accurate practice (Habets et al., 1987; Kjellberg et al., 1994; Xie et al., 1994; Catic et al., 1997; Stramotas et al., 2002). Some studies claim that patient positioning is the main obstacle to obtaining accurate measurements from panoramic radiography (Tronje et al., 1981; Turp et al., 1996; McKee et al., 2001). A study by Wyatt et al. (1992) concluded that lateral oblique radiographs may be more reliable for linear measurements and angles than panoramic radiograph measurements.
In-Vitro Panoramic Radiography Studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>N</th>
<th>Multiple positions</th>
<th>Panoramic Unit</th>
<th>Gold Standard</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tronje-Library</td>
<td>1981</td>
<td>1</td>
<td>Yes</td>
<td>Orthopantomograph-3 (Siemens)</td>
<td>Known distance</td>
<td>Cylinder</td>
</tr>
<tr>
<td>Habets</td>
<td>1987</td>
<td>1</td>
<td>Yes (9)</td>
<td>Orthopantomograph-5 (Siemens)</td>
<td>Known distance between points on a model</td>
<td>Model of mandible</td>
</tr>
<tr>
<td>Wyatt</td>
<td>1993</td>
<td>1</td>
<td>No (1)</td>
<td>Oralix Pan DC/1 (Dentsply) Panelipse (Gendex) Orthophos (Siemens)</td>
<td>Actual marker length (known distance)</td>
<td>Acrylic test models with wires as markers</td>
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<td>Kjellberg</td>
<td>1994</td>
<td>2</td>
<td>Yes (6)</td>
<td>Cranex (Soredex) OP 10 (Instrumentarium) PM 2002 C (Planmeca)</td>
<td>Caliper measured distance on skull</td>
<td>Skulls</td>
</tr>
<tr>
<td>Xie</td>
<td>1994</td>
<td>5</td>
<td>Yes (9)</td>
<td>PM 2002 CC (Planmeca)</td>
<td>Ideal pan</td>
<td>Dry skulls</td>
</tr>
<tr>
<td>Turp</td>
<td>1996</td>
<td>25</td>
<td>No (1)</td>
<td>Orthopantomograph-5 (Siemens)</td>
<td>Special angle iron</td>
<td>Macerated Skulls</td>
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<tr>
<td>Catic</td>
<td>1997</td>
<td>25</td>
<td>No (1)</td>
<td>Orthophos D3200 (Siemens)</td>
<td>Precise sliding ruler</td>
<td>Dry mandibles</td>
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<td>McKee</td>
<td>2001</td>
<td>1</td>
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<td>Ideal pan</td>
<td>Human Skull containing a typodont</td>
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<td>1</td>
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<td>Actual marker length</td>
<td>Model of the dentition and occlusal plane</td>
</tr>
<tr>
<td>Laster</td>
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<td>30</td>
<td>Yes (3)</td>
<td>Orthophos Plus (Siemens)</td>
<td>Known distance</td>
<td>Dry skulls</td>
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</tbody>
</table>


Habets et al. studied the accuracy of panoramic measurements to evaluate mandibular symmetry using a Throfydor bloc containing a sequence of bullet holes placed at fixed distances apart from each other (Habets, 1987). Panoramic radiographs were taken of the model which was situated in 9 different positions, within 10 mm of ideal position to simulate potential clinical errors. The data illustrated that the maximum error in vertical measurements between the bullets was 6% comparing right and left sides using the positions noted above (Habets et al. 1987). The conclusion was that differences in right and left measurements of more than 6% on panoramic radiographs were not due to positioning errors.
and therefore significant. Kjellberg et al. tested a new method for identifying vertical measurements (condylar height, ramal height, and posterior face height) by relating anatomical points to tangential lines (1994). The anatomical points were the most superior portion of the condyle (point A), the inferior sigmoid notch (point B), and the gonial angle (point C). The tangential lines used were the posterior border of the ramus (line 1) and the lower border of the mandible (line 2). Gonial angle point (point C) was defined as the point where the bisecting angle from the two tangential lines contact the mandible. Perpendicular lines are drawn from line 1 through point A (superior condyle), point B (inferior sigmoid notch), and point C. Point A’ was where the perpendicular line from line A crosses line 1, point B’ was where the perpendicular line passes through line B crosses line 1, and point C’ was where the perpendicular line passes through point C. The condylar height was the distance between A’ and B’. Ramal height was the distance between B’ and C’. Posterior face height was defined as the distance from A’ to C’. Kjellberg tested the accuracy of this method to measure linear distances on mandibles. The study used two dry skulls with metal markers to indicate anatomic points of interest which were situated in six different positions for panoramic radiography. The measurements taken from the radiographs using the technique described above were compared to measurements taken directly from the skulls using calipers. The ratios of the condylar height to the total face height were examined for each of the images. The authors reported that the head position did not affect these ratios. The study concluded that vertical measurements taken on panoramic radiographs and expressed as a ratio are not affected by patient head position.

Other studies have discounted linear measurements taken on panoramic radiographs. Turp et al. reported a low correlation between real values measured directly on macerated
skulls using a digital caliper and those same values measured on panoramic radiographs (Turp et al., 1996). They also found a low correlation between asymmetry values on the dry skull and on the panoramic images. However, this study used a different method than Kjellberg to determine the condylar and ramal heights. Turp did not test the effect of patient positioning on measurements taken, nor did they use markers at fixed distances to verify their measurement technique.

Catic et al. validate the hypothesis that linear measurements taken on panoramic images were close to the dimensions on the dry mandible, provided that the measurements did not cross the midline (1998). This in vitro study used the Kjellberg method to analyze condylar and ramal heights on 25 dry skulls. These investigators used metal markers to identify landmarks and related the measurements taken on the radiograph to those taken on the skulls using a precise sliding ruler. They did not evaluate the effect of patient positioning or look at symmetry ratios.

The Tronje study evaluated panoramic radiography by measuring fixed distances in a phantom cylinder (Tronje et al., 1981). They concluded that with proper positioning, panoramic radiography could be used to measure vertical distances in clinical practice, however they did acknowledge that distortion can occur when a patient is positioned improperly. Some in vitro studies have examined panoramic radiography to evaluate measurements made in tooth bearing areas. One study measured vertical distances in tooth bearing areas of mandibles and examined patient positioning effect on these measurements (Xie et al., 1994). The study examined 5 skulls in 9 positions and concluded that slight misalignment of the head did not significantly affect vertical measurements in the mandible. Stramotas et al. evaluated error in measuring simulated tooth length, and discovered that
these measurements were effected only by specific types of positioning errors (Stramotas et al., 2002). Another study concluded that more accurate linear measurements in the tooth borne areas are achieved with lateral films compared to panoramic films (Wyatt et al., 1993). When predicting the angulations of teeth off panoramic radiographs, one in vitro study discovered that even minor positioning errors can significantly affect measurement accuracy (McKee et al., 2001). These in vitro studies provided methods for analyzing panoramic radiographs that were applied to clinical situations.

**Clinical Studies Using Panoramic Measurements**

Panoramic radiographs are routinely taken at the start of orthodontic treatment as part of initial records, and some studies have evaluated the accuracy of measurements on these films. As of 1988, ten studies have evaluated the accuracy of linear measurements taken on panoramic films (Table 2). The reproducibility of measurements taken on panoramic images was examined in one study (Larheim et al., 1986), and other studies have compared the characteristics of two groups of patients using measurements from panoramic radiographs (Habets et al., 1988; Bezuur et al., 1988; Habets et al., 1989; Miller et al., 1994; Matilla et al., 1995; Miller et al., 1997; Luz et al., 2002; Kjellberg et al., 2002; Saglam et al., 2003). Most of the studies above used the method described by Habets (1988) to make comparisons of vertical mandibular symmetry (Habets et al., 1988; Bezuur et al.; 1988; Habets et al., 1989; Miller et al., 1994; Miller et al., 1997; Luz et al., 2002; Saglam et al., 2003). However, some studies used the method described by Kjellberg (Kjellberg et al., 1994, Matilla et al., 1995) and contended that his method allows more exact measurements.
Most of the clinical research papers that used linear measurements on panoramic radiographs have compared a symptomatic patient population with a control group (Habets et al., 1988; Bezuur et al., 1988; Habets et al., 1989; Miller et al., 1994; Kjellberg et al., 1994; Matilla et al., 1995; Luz et al., 2002). These studies have evaluated differences between psoriatic arthritis patients and controls (Matilla et al., 1995), myogenious cranio-mandibular dysfunction (CMD) and arthrogenous CMD (Miller et al., 1994), CMD patients and routine dental controls (Habets et al., 1988), CMD patients and normal values (Bezuur et al., 1988), and juvenile chronic arthritis patients and normal patients (Kjellberg et al., 1994).

**Clinical Studies Using linear measurements on panoramic films**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Subjects</th>
<th>Compared to</th>
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<td>6</td>
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<td>Habets</td>
<td>Orthopantomograph 5 (Siemens)</td>
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<td>Miller</td>
<td>1994</td>
<td>Panoramic films on myogenous CMD</td>
<td>Panoramic films on non-CMD patients</td>
<td>18 CMD 13 control</td>
<td>Habets</td>
<td>Orthopantomograph 10 (Siemens)</td>
</tr>
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<td>Kjellberg</td>
<td>1994</td>
<td>Panoramic films on Juvenile Chronic Arthritis patients</td>
<td>Panoramic films on an Angle Class I and Angle Class II group</td>
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<td>Kjellberg</td>
<td>Orthopantomograph 5 or Orthopantomograph 10 (Siemens)</td>
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<td>1995</td>
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<td>1997</td>
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<td>Luz</td>
<td>2002</td>
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<td>72</td>
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*Laster e. al., 2004*
Using Panoramic Radiographs for Analysis of Asymmetry

An area of interest concerning the use of linear measurements on panoramic films refers to its ability to assess mandibular symmetry. A study by Kjellberg evaluated a method to evaluate mandibular symmetry using linear measurements on panoramic films (1994). Since studies have shown that patient positioning has minimal effects on vertical linear measurements made from panoramic films, some authors believe that panoramic radiography can be an adequate screening tool for mandibular asymmetry (Habets, 1988; Kjellberg, 1994; Matilla, 1995). Some authors have criticized the inadequacies of using two-dimensional images to assess skeletal asymmetries (Tronje et al., 1981; Wyatt et al., 1994; Turp et al., 1996, Quintero et al., 1999); Stramotas et al., 2002). Panoramic radiographs are taken as a diagnostic tool on all patients contemplating orthodontic treatment, therefore it would be useful to understand more about the information they can provide on mandibular symmetry.

Condylar asymmetries are discussed in the literature as another diagnostic use for panoramic radiographs. Norholt et al. examined recall radiographs of patients with a history of a previous condylar fractures. This study concluded that an increased incidence of condylar asymmetry was seen in this patient population (Norholt et al., 1993). Proffit et al. reported that that 5-10% of mandibular asymmetries are probably caused by previous condylar fractures (1980).

The literature on quantifying asymmetry using radiographs illustrates some limitations to using radiography other than panoramic films. Severt et al. utilized PA cephalograms to quantify the surgical stability of patients following surgery to correct asymmetry (1997). However, out of the 202 asymmetry patients that underwent surgery to
correct facial asymmetry during the time period investigated, just 28 patients (>14%) of the sample, had all the required records to qualify for the study. There was a lack of PA cephalometric radiographs as they were not routinely taken on recall exam for this patient population, even though they were identified as asymmetric. Unlike PA cephalometric radiographs, panoramic radiographs are routinely taken on the Dentofacial deformity (DFD) patient pool at pre-surgery, post-surgery, and at recall intervals. Since serial panoramic radiographs are routinely available in the DFD population, modalities to assess asymmetry from these radiographs would be a valuable tool for assessing stability in the surgical patient population. Many believe that in the future three-dimensional images will be the standard of care in assessing asymmetry and many other dentofacial anomalies (Quintero et al., 1999; Danforth, 2002). Evaluation of information obtained from current imaging techniques (panoramic radiographs) would be beneficial to assess data collected from three-dimensional radiography.
CHAPTER 2

MASTER THESIS

Post-surgical Stability for Class III Patients with Asymmetry:
A Comparison of Mandibular Setback, Maxillary Advancement, and Bimaxillary Surgeries.

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A. ABSTRACT

Previous studies evaluated the stability of Class III corrective surgeries: mandibular setback, maxillary advancement, and bimaxillary surgery. According to one study, 40% of Class III patients seeking orthognathic surgery presented with a clinically detectable asymmetry. In our retrospective study, the purpose was to determine whether differences existed in the one year post-surgical stability of asymmetric Class III correction for the three surgical procedures. We utilized cephalometric and panoramic radiographic analyses to compare the stability of asymmetric Class III patients including 43 bimaxillary surgery, 24 maxillary advancement, and 15 mandibular setback patients. Our analysis revealed that stability in the horizontal direction was greatest for bimaxillary surgery group and least for the mandibular setback group, while stability in the vertical direction was the exact opposite. Overall, our study suggests the anterior-posterior one year surgical stability tendency of asymmetric Class III patients is similar to that of other Class III samples, but differs in the vertical direction.
B. INTRODUCTION

Edward Angle first described the need for orthognathic surgery to correct a prognathic mandible in 1907. Prior to the 1970’s, surgical correction of Class III malocclusions was mainly achieved with mandibular setback surgery. This was due to the lack of surgical proficiency in the field of LeFort I maxillary advancement and the fact that skeletal Class III malocclusions were often diagnosed as primarily caused by mandibular excess. It is now estimated that isolated mandibular prognathism contributes to about 20% of skeletal Class III cases, isolated maxillary deficiency contributes to approximately 20% of cases, and combined maxillary deficiency and mandibular prognathism accounts for approximately 50-60% of Class III cases (Proffit et al., 1990). Enhancements in surgical methods and fixation techniques have made it viable to perform maxillary LeFort I advancements alone or in combination with mandibular ramus osteotomies for treatment of Class III skeletal discrepancies. Accordingly, since 1980 there has been a tendency to perform less isolated mandibular surgeries to correct Class III skeletal patterns and more LeFort I maxillary advancements or two-jaw surgical procedures (Bailey et al., 1995).

One study found that 40% of Class III patients seen in the dentofacial deformities clinic (DFD) at UNC presented with a clinically detectable facial asymmetry (Severt et al., 1997). Seventy percent of these asymmetries were deviation of the chin due to asymmetric growth of the mandible. The asymmetry may be the chief concern of the patient or a routine finding during the clinical exam. Several authors have utilized radiographs (PA cephalometric, panoramic, and cone-beam CT) to examine linear measurements and quantify the degree of asymmetry present in patients (Habets et al., 1987; Kjellberg et al., 1994; Xie et al., 1996; Stramotas et al., 2002).
Our study proposes to examine the stability of asymmetric Class III patients that received orthognathic surgery at the UNC School of Dentistry through cephalometric and panoramic radiographic analysis. This study is significant because there are no previous studies that have utilized panoramic and cephalometric radiographic measurements to report surgical change or post-surgical relapse of condylar and posterior face height asymmetries. Furthermore, there is a lack of data concerning surgical stability of Class III asymmetric patients using lateral cephalometric measurements and no studies to date have used panoramic radiographs to examine asymmetry in the surgical Class III population. Data concerning the stability of different surgical treatment options for Class III correction (maxillary advancement, mandibular setback, and bimaxillary surgery) would prove beneficial, in terms of patient management, treatment planning, and prognosis for both surgeons and orthodontists.

In this study we test the fundamental hypothesis that Class III asymmetric patients will have similar one year surgical stability among three surgery groups similar to that previously reported for Class III surgical stability. The following specific aims are proposed to test the above hypothesis: 1) To identify asymmetries in Class III patients who underwent orthognathic surgery at UNC School of Dentistry; and collect pre-surgical, immediate post-surgical (72 hours), and one year post-surgical lateral cephalometric radiographs, panoramic radiographs, and treatment notes. 2) To analyze panoramic and lateral cephalometric radiographs from three time points collected for Class III asymmetric patients. 3) To compare stability results between each surgical group utilizing paired t-tests of cephalometric and panoramic measurements obtained in aim 2. Post-surgical relapse will be assessed at one
year using radiographic measurements for each asymmetric Class III surgical group: mandibular setback, maxillary advancement, and a combination of the two procedures.
C. METHODS

Patient Inclusion

This is a retrospective study of patients receiving orthognathic surgery at the University of North Carolina (UNC) School of Dentistry. All participants have previously consented to participation in this study through a larger study (DE-05215). Institutional Review Board (IRB) approval was obtained for this study (05-ORTHO-630) through the UNC Biomedical Institutional Review Board. Patients were identified as Class III by an orthodontist or an oral and maxillofacial surgeon and treated with bilateral sagittal split osteotomy (BSSO) setback, LeFort I maxillary advancement, or a combination of the two procedures. A query was run of the Dentofacial Deformities Clinic database for Class III patients with one of the following documented asymmetries: deviation of chin greater than 2 mm to the right or left, canted maxillary occlusal plane down on right or left, orbital dystopia, zygomatic arch height discrepancy, or nasal tip deviation. If asymmetry information was incomplete in the database, then the patients' chart was examined for clinical notes from the examining oral maxillofacial surgeon or orthodontist diagnosing one or more of the above mentioned asymmetries. Patients were excluded if the Class III malocclusion was due to a diagnosed cleft palate, syndrome, or trauma. The skeletal Class III discrepancy had to be treated by mandibular ramus osteotomy with the mandible set back at least 2 mm at point B, maxillary advancement with at least 2 mm advancement at point A, or a combination of these procedures and displacements. In this study only patients with an initial age of 14 for females and 16 for males were included. These minimum ages are consistent with the recommended earliest age to initiate orthognathic surgery from a study of more than 300 orthodontists (Weaver et al., 1992). Only 4 female patients under the age of 16 were used in the final analysis. No other
maxillofacial surgery was performed except genioplasty. In order to be included in this study, all patients were required to have diagnostic cephalometric and panoramic radiographs that were available at the following time points: pre-surgery, immediately post-surgery, and one-year post-surgery.

Of the Class III patients in the database, 208 presented with a qualifying asymmetry and 82 had all the required radiographs. The final data set included 43 patients with bimaxillary surgery, 24 patients with maxillary advancement, and 15 patients with mandibular setback who met all the criteria. Demographic and treatment characteristics of the sample of 82 patients are shown in Table 1. The types of pre-surgical asymmetries present within each surgery group are shown in Table 2.

Radiographic Interpretation

Cephalometric radiographs were taken in natural head position and digitized by one examiner using the UNC 139-point model for each time point (pre-surgery, immediate post-surgery, and one year post-surgery). An x-y coordinate axis was determined for analysis, utilizing a horizontal line through sella rotated down 6° anteriorly as the x-axis, and a vertical line through sella perpendicular to it as the y-axis. Paired t-tests were used to compare the mean cephalometric changes from pre-surgery to immediate post-surgery and from immediate post-surgery to one-year post-surgery for each surgery group. For the above data analysis the level of significance was set at p= 0.01 due to the number of variables and analyses performed. A 2 mm or 2 degree change was viewed as outside the inherent error in cephalometric method or change due to surgical splint removal and thus deemed clinically significant. Measurements of greater than 4 mm or degrees were determined to be highly clinically significant (Habets et al., 1987). The percentage of patients with surgical and one-
year post-surgical changes between 2-4 mm (or degrees) and greater than 4 mm (or degrees) was calculated. Data was also analyzed controlling for the effect of fixation technique on cephalometric change within each of the three surgical types.

Panoramic radiographs were collected at similar time points from the records of patients who qualified for the study. The panoramic radiographs were traced by one examiner using the Matilla method (described below) to determine condylar height, ramus height, and posterior face height for each time point. Condylar and ramus heights were based on two anatomical points and two tangential lines (Figure 1). Anatomical point A was defined as the most superior point on each condyle and point B was defined as the lowest point of the sigmoid notch. Tangential line L1 was drawn parallel to the outline at of the ramus using the most distal aspects of the condylar head and border of the ramus. Tangential line L2 was drawn parallel to the outline of the corpus using the most inferior bony chin point and border of the ramus. Point C was plotted at the bisecting line of tangential lines L1 and L2. Lines were constructed from points A, B and C perpendicular to tangential line L1. Line A (condylar height) was measured from the line through point A to the line through point B. Line B (ramus height) was measured from the line through point B to the line through point C. Line A (condylar height) plus Line B (ramus height) equaled posterior face height.

Repeated measurement error was calculated from measuring 10 randomly selected panoramic radiographs on 3 different occasions. The symmetry of the right vs. left sides was calculated using the formula: \(|(R-L)/(R+L)| \times 100\); taken from the study by Habets et al. A measurement of 0% indicated complete symmetry and a measurement of 100% indicated complete asymmetry. Habets et al. concluded that measurements greater than 6% were outside patient positioning error and thus valid asymmetries. Symmetry measurements at
each time point was compared and assessed between surgery groups. Stability of cephalometric landmarks and measurements was evaluated for patients presenting with greater than 6% asymmetry of condylar or posterior face height and compared to those with <6% asymmetry for these measurements. This would test to see if patients with condylar or posterior face height asymmetries experienced different stability results. A paired t-test result of $P < 0.05$ was used to calculate statistically significant values between panoramic time points among surgery groups.
D. RESULTS

Stability Assessed from Cephalometric Analysis

Eighty-two patients were evaluated using the following time points: pre-surgery, immediate post-surgery (72 hours post-surgery), and one year post-surgery. Data summarizing mean surgical and one year post-surgical changes of cephalometric landmarks, measurements, and angles in the horizontal and vertical dimensions for each surgery group are listed in Tables 3-5. Mean surgical and one year post-surgical changes of 2-4 mm (clinically significant) and >4 mm (highly clinically significant) in the positive or negative direction for the above dimensions in each surgery group are reported in Figures 2-19. The results are reported by surgical procedure groups (maxillary advancement, mandibular setback, and a combination of two jaw surgery) for both surgical changes and one year post-surgical changes.

LeFort I Maxillary Advancement Group- Surgical Changes

Mean changes

The surgical stability results for the LeFort I maxillary advancement group included 24 patients. Mean surgical movements for horizontal, vertical, and dimensional measurements are listed in Table 3. At the time of surgery, the maxilla was repositioned anteriorly an average of 4.65 mm at ANS and 4.82 mm at A point. In the vertical dimension, the maxilla was moved downward 2.75 mm at ANS and 2.25 mm at A point, but just 0.25 mm at PNS, thus causing the palatal plane angle to increase 2.69°. These movements caused the mandible to rotate down and back with B point displaced downward 2.26 mm and posterior 2.99 mm, thereby causing the mandibular plane angle to increase 1.44°. Gonion was displaced posteriorly 2.11 mm and
downward 0.29 mm. The combined anterior-posterior and vertical movements of the maxilla and mandible resulted in an overjet increase of 5.04 mm and an overbite increase of 0.9 mm. The composite lateral cephalometric tracings of pre-surgery and immediate post-surgery time points for maxillary advancement patients are shown in Figure 26.

_Clinically Significant Changes_

The percentage of patients with clinically significant (2-4 mm or degrees) and highly clinically significant (>4 mm or degrees) surgical changes for various horizontal, vertical, and dimensional measurements is listed in Figures 2, 4, and 6. Highly clinically significant horizontal changes included: 60% of patients had an anterior surgical change in A point, ANS, and PNS. Twenty percent of patients experienced posterior movement of B point. Thirty percent of the patient had posterior movement at pogonion. Highly clinically significant vertical changes included: 30% of patients had an inferior surgical change in A point and 20% of patients experienced inferior movement of B point and pogonion. Highly clinically significant dimensional changes included: 70% of patients had increase in OJ and 30% with an increase in palatal plane angle.

**LeFort I Maxillary Advancement Group- One year Post-surgical Changes**

_Mean changes_

Mean one year post-surgical movements for horizontal, vertical, and dimensional measurements are listed in Table 3. At one year follow-up, the maxilla relapsed posteriorly an average of 1.34 mm at ANS and 1.17 mm at A point. In the vertical dimension, the maxilla relapsed superiorly 1.76 mm at ANS and 1.91 mm at A point, while the palatal plane angle decreased 1.83°. These movements caused the mandible to rotate counterclockwise with B point relapsing superiorly 2.90 mm and anteriorly 3.06 mm, thus causing the mandibular plane
angle to decrease 2.29°. Gonion also relapsed counterclockwise with anterior movement of 2.60 mm and superior movement of 0.25 mm observed post-surgery. The combined anterior-posterior and vertical relapse of the maxilla and mandible post-surgery caused overjet to decrease by 0.93 mm and overbite to decrease by 1.36 mm. The composite lateral cephalometric tracings of immediate post-surgery and one year post-surgery time points for maxillary advancement patients are shown in Figure 27.

**Clinically Significant Changes**

The percentage of patients with clinically significant and highly clinically significant one year post-surgical changes for various horizontal, vertical, and dimensional measurements are listed in Figures 3, 5, and 7. Highly clinically significant horizontal changes included: 20% of patients with posterior post-surgical change in ANS (only 5% with such change in A point), and 25% of patients experienced anterior relapse of B point. Sixty percent had similar movements at pogonion. Highly clinically significant vertical relapse included: 20% of patients with superior post-surgical change in A point and 25% of patients experienced superior movement of B point and pogonion. Highly clinically significant dimensional changes included: 20% of patients with decreased palatal plane and mandibular plane angle. However, no patients experienced >4 mm decrease in overjet or overbite.

**BSSO Mandibular Setback Group- Surgical Changes**

**Mean Changes**

The surgical stability results for the BSSO mandibular setback surgery group included 15 patients. Mean surgical movements for horizontal, vertical, and dimensional measurements are listed in Table 4. At the time of surgery, the mandible was repositioned posteriorly an average of 4.9 mm at B point, 3.43 mm at pogonion, and 3.38 at gonion. In the vertical dimension, the
mandibular surgical group experienced minimal surgical movement with B point moved superiorly 0.65 mm and gonion moving superiorly just 1.01 mm, thereby causing the mandibular plane angle to decrease 0.62° and the gonial angle to decrease 3.77°. Mandibular length measurements of condylion to gonion increased 0.81 mm while the measurement of condylion to pogonion decreased 2.59 mm. The combined anterior-posterior and vertical movements of the mandible at the time of surgery caused the overjet to increase by 4.02 mm and the overbite to increase by 0.74 mm. The composite lateral cephalometric tracings of pre-surgery and immediate post-surgery time points for mandibular setback patients are shown in Figure 28.

**Clinically Significant Changes**

The percentage of patients with clinically significant and highly clinically significant surgical changes for various horizontal, vertical, and dimensional measurements is listed in Figures 8, 10, and 12. Highly clinically significant horizontal changes included: 60% of patients had a posterior surgical change in B point (30% of patients had a change at pogonion) and 40% of patients experienced posterior movement of gonion. Highly clinically significant vertical changes included: 15% of patients with superior surgical movement in B point and pogonion and five percent of patients experienced inferior movement of gonion. Highly clinically significant dimensional changes included: 50% of patients had an increase in overjet and 60% had a decrease in gonial angle.

**BSSO Mandibular Setback Group- One year Post-surgical Changes**

*Mean Change*
Mean one year post-surgical movements for horizontal, vertical, and dimensional measurements are listed in Table 4. At one year follow-up, the mandible relapsed anteriorly an average of 2.72 mm at B point and 2.91 at pogonion while the condylion to pogonion length measurement increased 0.91 mm. In the vertical dimension, the mandible and pogonion continued to move superiorly 0.34 mm and 1.01 mm respectively. Gonion relapsed 1.37 mm superiorly and the condylion to gonion measurement decreased 0.98 mm. With the above movements, the mandibular plane angle increased 0.53° and gonial angle increased 4.39°. The combined anterior-posterior and vertical movements of the mandible post-surgically resulting in overjet decreasing by 1.38 mm and overbite increasing by 0.66 mm. The composite lateral cephalometric tracings of immediate post-surgery and one year post-surgery time points for mandibular setback patients are shown in Figure 29.

**Clinically Significant Changes**

The percentage of patients with clinically significant and highly clinically significant one year post-surgical changes for various horizontal, vertical, and dimensional measurements are listed in Figures 9, 11, and 13. Highly clinically significant horizontal changes included: 20% of patients with anterior post-surgical relapse of B point, 35% at pogonion, and 30% of patients experiencing such anterior relapse of gonion. Highly clinically significant dimensional changes included: 60% of patients with an increase in gonial angle and only 5% of patients had a decrease in overjet or overbite.

**Bimaxillary Surgery Group- Surgical Changes**

**Mean Changes**

The surgical stability results for the bimaxillary surgery group included 43 patients. Mean surgical movements for horizontal, vertical, and dimensional measurements are listed in Table
5. At the time of surgery, the mandible was positioned posteriorly an average of 4.73 mm at B point and 3.22 mm at pogonion while the measurement of condylion to pogonion decreased 2.58 mm. The maxilla was positioned anteriorly 4.56 mm at A point and 4.33 mm at ANS. In the vertical dimension, both the mandible and the maxilla experienced inferior surgical movements with B point having moved downward 1.17 mm (0.25 mm at pogonion) mm and A point having moved downward 1.67 mm (2.04 at ANS); PNS was displaced 0.48 mm superiorly, resulting in a palatal plane to increase of 2.63°. A 1.32 mm inferior movement at gonion was also noted and gonial angle decreased 2.19° as the mandibular length measurements of condylion to gonion increased 0.66 mm. Mandibular plane angle maintained with only a 0.21° decrease noted at the time of surgery. The combined anterior-posterior and vertical movements of the mandible and maxilla caused the overjet to increase by 6.77 mm and overbite to increase by 0.89 mm. The composite lateral cephalometric tracings of pre-surgery and immediate post-surgery time points for bimaxillary surgery patients are shown in Figure 30.

**Clinically Significant Changes**

The percentage of patients with clinically significant and highly clinically significant surgical changes for various horizontal, vertical, and dimensional measurements is listed in Figures 14, 16, and 18. Highly clinically significant horizontal changes included: 45% of patients with posterior surgical change of B point and 55% with anterior movement of A point. Twenty-percent of patients experienced highly clinically significant inferior surgical movement of gonion. Highly clinically significant dimensional changes included: 70% of patients with an increase in OJ, 40% with an increase in gonial angle, and 30% with an increase in palatal plane angle.
Bimaxillary Surgery Group- One year Post-surgical Changes

Mean one year post-surgical movements for horizontal, vertical, and dimensional measurements are listed in Table 5. At one year follow-up, the mandible relapsed anteriorly an average of 2.36 mm at B point and 2.99 at gonion, while the maxilla relapsed posteriorly 1.18 mm at A point. In the vertical dimension, the mandible moved superiorly 3.00 mm at B point and 2.45 mm at gonion. The maxilla also relapsed superiorly 1.39 mm at A point. As a result of these movements, the gonial angle increased 3.67º. The combined anterior-posterior and vertical movements of the mandible post-surgically caused overjet to decrease by 0.61 mm and overbite to increase 1.63 mm. The composite lateral cephalometric tracings of immediate post-surgery and one year post-surgery time points for bimaxillary surgery patients are shown in Figure 31.

Clinically Significant Changes

The percentage of patients with clinically significant and highly clinically significant one year post-surgical changes for various horizontal, vertical, and dimensional measurements are listed in Figures 15, 17, 19. Highly clinically significant horizontal changes included: 30% of patients had an anterior change in B point and gonion. Greater stability in A point was noted with only 5% of patients experiencing change at one year. Highly clinically significant vertical changes included: 30% of patients with superior movement of B point and gonion. Highly clinically significant dimensional and linear changes included: 40% of patients with an increase in gonial angle and 25% with a decrease in the measurement condylion to gonion.

Stability Assessed from Panoramic Analysis
Panoramic radiographs from pre-surgical, immediate post-surgical, and one year post-surgical time points were collected from patient records for the same group of patients. The condylar and posterior face heights were measured using the Matilla method and the asymmetry percentage calculated by the equation: $\left| \frac{R-L}{R+L} \right| \times 100$. The repeated measures analysis revealed an ICC of 0.877 for posterior face height measurements and an ICC of 0.763 for condylar height measurements.

**Pre-surgical Asymmetry**

The types of pre-surgical asymmetries patients presented with are listed in Table 2 by surgery group. A maxillary cant and/or chin deviation was diagnosed in 93% of the bimaxillary surgery, 100% of the mandibular setback, and 85% of the maxillary advancement group. A chin deviation was present in 84% of all patients, with 76% of these deviations being to the left. This is consistent with published results on chin asymmetries by Severt et al. Maxillary cants and chin deviations are asymmetries that are correctable at the time of orthognathic surgery and may be manifestations of condylar and/or posterior face height asymmetries which were specifically examined for this study.

Table 6 and Figure 24 illustrate the asymmetry percentage (comparing right vs. left side) within each surgery group for condylar height and posterior face height measurements at pre-surgical, immediate post-surgical, and one year post-surgical time points. Pre-surgical condylar asymmetry percentages were slightly below the threshold of 6% (considered asymmetric) for bimaxillary surgery and maxillary advancement patients, but right at 6% for mandibular setback patients. Pre-surgical posterior face height measurements were well below this threshold, ranging from 2.21-2.81% for the surgery groups. The mean difference among surgery groups for pre-surgical condylar height and posterior face height were not significant.

**Post-surgical Asymmetry Stability Assessed from Panoramic Analysis**
Immediate post-surgical and one year post-surgical mean percent asymmetries for condylar height (COND) and posterior face height (PFH) are reported in Table 6, Table 7, and Figure 24. Posterior face height asymmetry percentages remained constant from pre-surgery to immediate post-surgery for the mandibular setback and bimaxillary surgery groups. The maxillary advancement group, which did not have mandibular surgery to aid in correction of posterior face height, presented with the highest percentage of PFH asymmetry change from pre-surgery to immediate post-surgery (0.65%). The maxillary advancement groups also showed the lowest amount of one year post-surgical relapse in PFH asymmetry percentage. The mandibular setback group started with a mean condylar asymmetry percentage of 6%, which was just at the threshold for being classified as asymmetric, and these patients had the highest increase in one year post-surgery condylar asymmetry (2.64%).

For patients with greater than 6% pre-surgical condylar asymmetry (Figure 25), the difference in the mean one year post-surgical horizontal relapse of pogonion between maxillary advancement and bimaxillary surgery patients was statistically significant (P= 0.009). Maxillary advancement patients with a pre-surgical condylar asymmetry of >6% also had more horizontal one year relapse at pogonion (5.08 mm) than the mean for the bimaxillary surgery group (3.92 mm).
E. DISCUSSION

In this retrospective study, we examined radiographs and records of patients receiving orthognathic surgery at UNC School of Dentistry. The focal point of this paper is the one year post-surgical stability of Class III patients who presented with facial asymmetries. Posterioanterior (PA) cephalometric radiographs were not used because upon initial review there was limited availability of these radiographs at the needed time points of pre-surgery, immediate post-surgery, and one year post-surgery. Nevertheless, the panoramic radiographs provided valuable information regarding condylar and posterior face height asymmetry and the clinical notes detailed clinically significant asymmetries.

Pre-surgical Data and Changes at the Time of Surgery

Pre-surgical and surgical change data was similar among the three surgery groups. Mean patient age at one year follow-up (21.13 to 22.56 y.o.) and length of follow-up (1.17-1.51 years) were comparable among the surgery groups. There were no statistically significant changes in horizontal, vertical, and dimensional measurements among the bimaxillary surgery, maxillary advancement, and mandibular setback groups (P<0.01) at the time of surgery. Fixation technique (wire vs. rigid) was also evaluated for each jaw within each surgery group to determine statistically significant differences in movements at the time of surgery. The only measurement to show statistically significant surgical change (P<0.01) due to fixation type within the three surgery groups was the horizontal change of condylion in the maxillary advancement group. The wire fixation groups had significantly more posterior movement of condylion at the time of surgery compared to the rigid fixation group. However, only 4 patients received wire fixation in the maxillary advancement group and this small sample likely affected the results.
The pre-surgical asymmetry present was similar among the surgery groups. Ninety-three percent of bimaxillary surgery, 100% of mandibular setback, and 88% of maxillary advancement patients presented with a diagnosed maxillary cant and/or chin deviation. The mean pre-surgical condylar asymmetry among the surgery groups ranged from 5.00% to 6.02% and the mean pre-surgical posterior face height ranged from 2.56% to 2.86%. These differences were not statistically different between the surgery groups (P<0.05).

**Mean Cephalometric Changes at One Year Post-surgery**

The statistically significant mean one year post-surgical changes between surgery groups are illustrated in Figures 20-23. Two vertical and two dimension measurements had statistically significant (P<0.01) changes between the surgery groups: vertical change in B point and gonion and dimensional change in gonial angle and mandibular plane angle.

Vertical superior relapse of B point was significantly greater in the bimaxillary surgery and maxillary advancement groups compared to the mandibular setback group. The fact that the bimaxillary surgery and maxillary advancement groups (both involving the maxilla) experienced a greater mean downward movement of the maxilla and mandible contributed to greater relapse at B point for these surgery groups and this could not occur in the mandibular setback group. As the maxilla relapsed superiorly in the bimaxillary and maxillary advancement groups, the mandible rotated counterclockwise and B point relapsed superiorly. The bimaxillary surgery groups experienced less of this relapse (2.36 mm) compared to the maxillary advancement group (3.06 mm). However, the change was not statistically significant (P>0.01) between bimaxillary surgery and maxillary advancement groups in superior relapse of B point. It has been previously reported by Busby et al. that stability of vertical mandibular landmarks could be enhanced with bimaxillary surgery, due
to the fact that combined maxillary and mandibular surgery reduces forced counterclockwise rotation of the mandible as experienced in maxillary-only surgery patients (Busby et al., 2002).

Vertical superior post-surgical movement of gonion was significantly greater in bimaxillary surgery patients compared to maxillary advancement patients. Previous studies have not reported vertical change at gonion comparing maxillary advancement and bimaxillary surgery patients. Bimaxillary surgery patients experience relapse in gonion due to a combination of both maxillary and mandibular changes, which was an expected result.

A statistically significant increase in gonial angle was found for bimaxillary surgery patients compared to that of maxillary advancement patients or mandibular setback patients ($P<0.01$). Mandibular setback and bimaxillary surgery patients experienced an increase of $4.39^\circ$ and $3.67^\circ$, respectively. Maxillary advancement patients had only a slight increase of $0.23^\circ$. However, mandibular setback patients had a greater mean decrease in gonial angle at the time of surgery compared to maxillary advancement patients ($P<0.01$) and this could explain the greater relapse. On the other hand, the mandibular post-surgery group mean increase of $4.39^\circ$ at gonial angle was the only one year post-surgical mean above our threshold for highly clinically significant ($>4^\circ$ change). The bimaxillary surgery group also had a greater surgical change in gonial angle compared to the maxillary advancement group ($2.19^\circ$ vs. $0.28^\circ$, respectively), but this was not significant ($P=0.05$) as was the mandibular surgery group. The larger surgical decrease in gonial angle at the time of surgery for bimaxillary and mandibular setback surgery patients could explain the significant post-surgical relapse compared to maxillary surgery patients.
A significant mean decrease in mandibular plane angle (MPA) was found for maxillary advancement patients when compared to bimaxillary and mandibular setback patients. As stated above, combining maxillary surgical procedures that incorporate downward movement of the maxilla with a mandibular procedure (as in bimaxillary surgery) has been shown to be beneficial in a reducing post-surgical counterclockwise relapse of the mandible (i.e. decrease in mandibular plane angle). The surgery groups involving the mandible (bimaxillary surgery and mandibular setback) experienced a slight increase in MPA (0.16° and 0.53°, respectively), while the maxillary advancement groups had a decrease of 2.29°. This is a finding comparable to the Class III studies by Busby et al.

**Clinically significant One year Post-surgical Cephalometric Changes**

The percentages of patients with highly clinically significant (>4 millimeters or degrees) horizontal and vertical changes one year post-surgery are illustrated in Figures 3, 5, 9, 11, 15, and 17. Bimaxillary surgery and maxillary advancement patients both had less of highly clinically significant horizontal relapse than mandibular setback patients. This is consistent with the Class III stability studies by Busby et al. comparing these three surgery groups in the horizontal direction (Busby et al., 2002). However, mandibular setback patients had the least amount of highly clinically significant vertical relapse post-surgically. Maxillary advancement patients were the second most stable, with bimaxillary surgery patients experiencing the most relapse. This is not consistent with previously reported one year stability results; however it is similar to stability results reported for Class III patients from one year post-surgery to five year post-surgery (Busby et al., 2002). One explanation could be that the asymmetry patients experience differential and sometime accelerated
growth that could manifest in vertical relapse at one year similar to that seen at 1-5 year post-
surgery in other Class III patients.

Mean Panoramic Asymmetry Changes

Figure 24 summarized the pre-surgical, immediate post-surgical, and one year post-
surgical condylar and posterior face height asymmetry for the three surgery groups. Table 7
shows the mean change in these asymmetry measurements from pre-surgery to immediate
post-surgery and from immediate post-surgery to one year follow-up.

Mean Panoramic Surgical change in Asymmetry

The average pre-surgical condylar and posterior face height asymmetry percentages
were at or slightly below the predetermined asymmetry threshold of 6%. There was a
tendency for a slight increase in asymmetry percentage immediately post-surgery in both
condylar and posterior face height measurements in all surgery groups. The condylar height
symmetry showed similar surgical increase among the surgery groups, while posterior face
height asymmetry increased 0.65% in the maxillary advancement groups and almost none
(0.01%-0.02%) in the other two surgery groups. Since these changes are not statistically
significant and within patient positioning error a more controlled study with a larger sample
size would be necessary to confirm that maxillary advancement patients experience an
increase in posterior face height asymmetry at the time of surgery compared to the other
surgery groups.

Mean Panoramic One Year Post-surgical Change in Asymmetry

The one year post-surgical changes in condylar height and posterior face height also
showed a tendency to increase. The greatest relapse was seen in condylar height asymmetry
for the mandibular setback group (2.64%). The one year post-surgical condylar height
asymmetry percentage of 9.04% is considered asymmetric and outside patient positioning error. The mandibular setback group was the only one to present with >6% asymmetry in condylar height pre-surgery. Every patient in the mandibular setback group also presented with a horizontal chin deviation of greater than 2 mm. These factors may have contributed to the greater one year relapse (2.64%) compared to the bimaxillary surgery (0.50%) and maxillary advancement (0.92%) groups. Interestingly, the maxillary advancement group, which experienced a greater increase in posterior face height asymmetry at the time of surgery, had the least relapse in posterior face height asymmetry at one year post-surgery (0.37%). Again, this could be due to the fact that maxillary advancement patients had no surgery performed on their mandible.

_Limitations and Future Research_

There are limitations to this retrospective research study of one year surgical stability of Class III asymmetric patients. In this study, we were only able to look at radiographs and treatment records to evaluate asymmetry and stability. Photographs, orthodontic models, and three dimensional images would have been more helpful in characterizing the stability of these asymmetric patients. Future research should focus on the long-term (5 year) stability of these patients to determine which surgical approach has the best long-term prognosis.
F. ACKNOWLEDGEMENT

I thank Debora Price for her assistance with the DFD Database and composite tracings.

This research was a component of the current study DE-05215.
Table 1 Pre-surgical and treatment characteristics of the sample.

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Table 2  Type of asymmetry present within each surgery group.

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<th>Zygo Arch</th>
<th>Nasal Tip</th>
<th>Canted Max OccPl</th>
<th>Chin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mand</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Max</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2-Jaw</td>
<td>3</td>
<td>4</td>
<td>8</td>
<td>10</td>
<td>4</td>
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<tr>
<td>Total</td>
<td>7</td>
<td>10</td>
<td>15</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

*Orb Dys = Orbital dystopia*

*Zygo Arch = Zygomatic Arch*

*Canted Max OccPl = Canted Maxillary Occlusal Plane*
Table 3  Surgical and One Year Post-surgical Changes for LeFort I Maxillary Advancement Patients.

<table>
<thead>
<tr>
<th>Variables Max</th>
<th>Pre-surgery to Immediate Post-surgery</th>
<th>Immediate Post-surgery to 1-yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean (se)</td>
<td>mean (se)</td>
</tr>
<tr>
<td>Horizontal (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANS</td>
<td>5.37 (.50)</td>
<td>-1.55 (.47)</td>
</tr>
<tr>
<td>Point A</td>
<td>5.37 (.44)</td>
<td>-1.22 (.39)</td>
</tr>
<tr>
<td>PNS</td>
<td>5.05 (.48)</td>
<td>-1.59 (.43)</td>
</tr>
<tr>
<td>Point B</td>
<td>-2.21 (.85)</td>
<td>2.73 (.56)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>-2.76 (1.2)</td>
<td>3.51 (.64)</td>
</tr>
<tr>
<td>Condylion</td>
<td>-0.10 (.37)</td>
<td>0.07 (.33)</td>
</tr>
<tr>
<td>Gonion</td>
<td>-1.54 (.70)</td>
<td>2.11 (.62)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vertical (mm)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ANS</td>
<td>2.33 (.67)</td>
<td>-1.76 (.45)</td>
</tr>
<tr>
<td>Point A</td>
<td>1.89 (.60)</td>
<td>-1.88 (.44)</td>
</tr>
<tr>
<td>PNS</td>
<td>0.05 (.41)</td>
<td>-0.05 (.31)</td>
</tr>
<tr>
<td>Point B</td>
<td>1.63 (.74)</td>
<td>-2.46 (.55)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>1.65 (1.00)</td>
<td>-2.51 (.66)</td>
</tr>
<tr>
<td>Condylion</td>
<td>-0.17 (0.31)</td>
<td>0.11 (.35)</td>
</tr>
<tr>
<td>Gonion</td>
<td>0.29 (.53)</td>
<td>-0.25 (.52)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimensions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overjet (mm)</td>
<td>5.05 (.72)</td>
<td>-0.94 (.27)</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>1.08 (.51)</td>
<td>1.31 (.32)</td>
</tr>
<tr>
<td>Palatal Plane (°)</td>
<td>2.42 (.76)</td>
<td>-1.89 (.52)</td>
</tr>
<tr>
<td>Mand. Plane (°)</td>
<td>1.03 (.82)</td>
<td>-1.99 (.51)</td>
</tr>
<tr>
<td>Gonial Angle (°)</td>
<td>-0.27 (.82)</td>
<td>0.05 (.63)</td>
</tr>
<tr>
<td>ANB (°)</td>
<td>3.03 (1.00)</td>
<td>-1.55 (.39)</td>
</tr>
</tbody>
</table>

ANS= Anterior Nasal Spine, PNS= Posterior Nasal Spine

Horizontal changes: - = posterior; + = anterior
Vertical changes: - = superior; + = inferior
Dimensional changes: - = decrease; + = increase
Table 4  Surgical and One Year Post-surgical Changes for BSSO Mandibular Setback Patients.

<table>
<thead>
<tr>
<th>Variables Mand</th>
<th>Pre-surgery to Immediate Post-surgery mean (se)</th>
<th>Immediate Post-surgery to 1-yr mean (se)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point A</td>
<td>0.18 (.6)</td>
<td>-0.14 (.49)</td>
</tr>
<tr>
<td>Point B</td>
<td>-4.9 (1.12)</td>
<td>2.72 (.72)</td>
</tr>
<tr>
<td>Condylion</td>
<td>-0.09 (.46)</td>
<td>0.25 (.41)</td>
</tr>
<tr>
<td>Gonion</td>
<td>-3.48 (.91)</td>
<td>3.42 (.82)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>-3.43 (1.48)</td>
<td>2.91 (.82)</td>
</tr>
<tr>
<td>Vertical (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point A</td>
<td>0.32 (.8)</td>
<td>0.02 (.57)</td>
</tr>
<tr>
<td>Point B</td>
<td>-0.65 (.97)</td>
<td>-0.34 (.71)</td>
</tr>
<tr>
<td>Condylion</td>
<td>-0.29 (.40)</td>
<td>0.12 (.44)</td>
</tr>
<tr>
<td>Gonion</td>
<td>1.01 (.71)</td>
<td>-1.37 (.70)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>-0.84 (1.27)</td>
<td>-1.01 (.83)</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>4.02 (.93)</td>
<td>-1.38 (.35)</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>0.74 (.67)</td>
<td>0.66 (.42)</td>
</tr>
<tr>
<td>Mand Plane (°)</td>
<td>-0.62 (1.04)</td>
<td>0.53 (.65)</td>
</tr>
<tr>
<td>Co-Pogonion (mm)</td>
<td>-2.59 (.85)</td>
<td>0.91 (.59)</td>
</tr>
<tr>
<td>Co-Gonion (mm)</td>
<td>0.81 (.88)</td>
<td>-0.98 (.86)</td>
</tr>
<tr>
<td>Gonial Angle (°)</td>
<td>-3.77 (1.02)</td>
<td>4.39 (.79)</td>
</tr>
<tr>
<td>ANB(°)</td>
<td>-0.01 (1.27)</td>
<td>-0.03 (.49)</td>
</tr>
</tbody>
</table>

ANS= Anterior Nasal Spine, PNS= Posterior Nasal Spine

Horizontal changes: - = posterior; + = anterior
Vertical changes: - = superior; + =inferior
Dimensional changes: - = decrease; + = increase
Table 5 Surgical and One Year Post-surgical Changes for Bimaxillary Surgery Patients.

<table>
<thead>
<tr>
<th>Variables 2 jaw</th>
<th>Pre-surgery to Immediate Post-surgery mean (se)</th>
<th>Immediate Post-surgery to 1-yr mean (se)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Horizontal (mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point A</td>
<td>4.56 (.35)</td>
<td>-1.18 (.29)</td>
</tr>
<tr>
<td>Point B</td>
<td>-4.73 (.66)</td>
<td>2.36 (.42)</td>
</tr>
<tr>
<td>Condylion</td>
<td>0.25 (.27)</td>
<td>-0.48 (.24)</td>
</tr>
<tr>
<td>Gonion</td>
<td>-1.70 (.54)</td>
<td>2.99 (.48)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>-3.22 (.87)</td>
<td>2.29 (.48)</td>
</tr>
<tr>
<td>ANS</td>
<td>4.33 (.42)</td>
<td>-2.05 (.35)</td>
</tr>
<tr>
<td>PNS</td>
<td>5.00 (.38)</td>
<td>-1.62 (.32)</td>
</tr>
<tr>
<td><strong>Vertical (mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point A</td>
<td>1.67 (.47)</td>
<td>-1.39 (.33)</td>
</tr>
<tr>
<td>Point B</td>
<td>1.17 (.57)</td>
<td>-3.00 (.42)</td>
</tr>
<tr>
<td>Condylion</td>
<td>0.22 (.23)</td>
<td>-0.48 (.26)</td>
</tr>
<tr>
<td>Gonion</td>
<td>1.32 (.42)</td>
<td>-2.45 (.42)</td>
</tr>
<tr>
<td>Pogonion</td>
<td>0.25 (.75)</td>
<td>-2.53 (.49)</td>
</tr>
<tr>
<td>ANS</td>
<td>2.04 (.52)</td>
<td>-1.43 (.34)</td>
</tr>
<tr>
<td>PNS</td>
<td>-0.48 (.31)</td>
<td>-0.28 (.24)</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overjet (mm)</td>
<td>6.77 (.53)</td>
<td>-0.61 (.20)</td>
</tr>
<tr>
<td>Overbite (mm)</td>
<td>0.89 (.38)</td>
<td>1.63 (.24)</td>
</tr>
<tr>
<td>Mand Plane (°)</td>
<td>-0.21 (.62)</td>
<td>0.16 (.38)</td>
</tr>
<tr>
<td>Pal Plane (°)</td>
<td>2.63 (.75)</td>
<td>-1.15 (.40)</td>
</tr>
<tr>
<td>Co-Pogonion (mm)</td>
<td>-2.58 (.50)</td>
<td>0.38 (.35)</td>
</tr>
<tr>
<td>Co-Gonion (mm)</td>
<td>0.66 (.52)</td>
<td>-1.26 (.51)</td>
</tr>
<tr>
<td>Gonial Angle (°)</td>
<td>-2.19 (.60)</td>
<td>3.67 (.46)</td>
</tr>
<tr>
<td>ANB (°)</td>
<td>2.63 (.75)</td>
<td>-1.67 (.29)</td>
</tr>
</tbody>
</table>

ANS= Anterior Nasal Spine, PNS= Posterior Nasal Spine
Horizontal changes: - = posterior; + = anterior
Vertical changes: - = superior; + = inferior
Dimensional changes: - = decrease; + = increase
Table 6  Asymmetry Percentage for each Surgery Group at Pre-surgical, Immediate Post-surgical and One Year Post-surgery.

Condylar (COND) and Posterior Face Height (PFH) Asymmetry Percentage by Surgery Group

<table>
<thead>
<tr>
<th></th>
<th>COND-Pre mean (se)</th>
<th>COND-Sx mean (se)</th>
<th>COND- Post mean (se)</th>
<th>PFH-Pre mean (se)</th>
<th>PFH-Sx mean (se)</th>
<th>PFH- Post mean (se)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2J</td>
<td>5.60% (0.58)</td>
<td>5.86% (0.63)</td>
<td>6.35% (0.96)</td>
<td>2.54% (0.30)</td>
<td>2.56% (0.26)</td>
<td>3.50% (0.66)</td>
</tr>
<tr>
<td>MAND</td>
<td>6.02% (1.02)</td>
<td>6.39% (1.21)</td>
<td>9.04% (1.69)</td>
<td>2.84% (0.59)</td>
<td>2.85% (0.66)</td>
<td>3.73% (0.83)</td>
</tr>
<tr>
<td>MAX</td>
<td>5.00% (0.77)</td>
<td>5.47% (1.01)</td>
<td>4.55% (0.96)</td>
<td>2.21% (0.39)</td>
<td>2.86% (0.49)</td>
<td>3.24% (0.57)</td>
</tr>
</tbody>
</table>

2J= two-jaw surgery (bimaxillary), MAND= mandibular setback, MAX= maxillary advancement
COND= condylar height asymmetry percentage: \((R-L)/(R+L)\) \times 100
PFH= posterior face height asymmetry percentage: \((R-L)/(R+L)\) \times 100
Pre= pre-surgery, Sx= immediate post-surgery, Post= one year post-surgery
<table>
<thead>
<tr>
<th></th>
<th>Pre-surgery</th>
<th>Pre-surgery to Immediate Post-surgery</th>
<th>Immediate Post-surgery to 1-yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>mean (se)</td>
<td>mean (se)</td>
</tr>
<tr>
<td><strong>Bimaxillary Surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condylar Height Symmetry (%)</td>
<td>5.60</td>
<td>0.26 (0.84)</td>
<td>0.50 (1.15)</td>
</tr>
<tr>
<td>Posterior Face Height Symmetry (%)</td>
<td>2.54</td>
<td>0.02 (0.41)</td>
<td>0.94 (0.66)</td>
</tr>
<tr>
<td><strong>Mandibular Setback</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condylar Height Symmetry (%)</td>
<td>6.01</td>
<td>0.37 (1.66)</td>
<td>2.64 (2.01)</td>
</tr>
<tr>
<td>Posterior Face Height Symmetry (%)</td>
<td>2.84</td>
<td>0.01 (0.78)</td>
<td>0.88 (0.83)</td>
</tr>
<tr>
<td><strong>Maxillary Advancement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condylar Height Symmetry (%)</td>
<td>5.00</td>
<td>0.47 (1.04)</td>
<td>0.92 (1.47)</td>
</tr>
<tr>
<td>Posterior Face Height Symmetry (%)</td>
<td>2.21</td>
<td>0.65 (0.57)</td>
<td>0.37 (0.67)</td>
</tr>
</tbody>
</table>
**Figure 1** Panoramic radiograph with tangential lines L1, L2, and bony points a,b,c. Line A (condylar height) and line B (ramus height) are constructed with these bony points.
Figure 2. Percentage of the LeFort I maxillary advancement patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
**Horizontal One Year Post-surgical Change for Maxillary Advancement Patients**

**Figure 3** Percentage of the LeFort I maxillary advancement patients with horizontal changes of 2–4 mm and >4mm from immediate post-surgery to one year post-surgery.
**Figure 4** Percentage of the LeFort I maxillary advancement patients with vertical changes of 2-4 mm and >4 mm from pre-surgery to immediate post-surgery.
Vertical One Year Post-surgical Change for Maxillary Advancement Patients

**Figure 5** Percentage of the LeFort I maxillary advancement patients with vertical changes of 2-4 mm and >4mm from immediate post-surgery to one year post-surgery.
Dimensional Surgical Change for Maxillary Advancement Patients

**Figure 6** Percentage of the LeFort I maxillary advancement patients with dimensional changes of 2-4 mm and >4 mm from pre-surgery to immediate post-surgery.
Dimensional One Year Post-surgical Change for Maxillary Advancement Patients

**Figure 7** Percentage of the LeFort I maxillary advancement patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
Horizontal Surgical Change for Mandibular Setback Patients

Figure 8  Percentage of the BSSO mandibular setback patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Figure 9  Percentage of the BSSO mandibular setback patients with horizontal changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
**Figure 10** Percentage of the BSSO mandibular setback patients with vertical changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Vertical One Year Post-surgical Change for Mandibular Setback Patients

**Figure 11** Percentage of the BSSO mandibular setback patients with vertical changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
**Figure 12** Percentage of the BSSO mandibular setback patients with dimensional changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Figure 13  Percentage of the BSSO mandibular setback patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
Figure 14  Percentage of the bimaxillary surgery patients with horizontal changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Figure 15 Percentage of the bimaxillary surgery patients with horizontal changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
Figure 16  Percentage of the bimaxillary surgery patients with vertical changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Vertical One Year Post-surgical Change for Bimaxillary Surgery Patients

Figure 17  Percentage of the bimaxillary surgery patients with vertical changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
Figure 18 Percentage of the bimaxillary surgery patients with dimensional changes of 2-4 mm and > 4mm from pre-surgery to immediate post-surgery.
Figure 19  Percentage of the bimaxillary surgery patients with dimensional changes of 2-4 mm and > 4mm from immediate post-surgery to one year post-surgery.
**Figure 20** Statistically significant differences in mean one year post-surgical vertical relapse of B point for mandibular setback vs. bimaxillary surgery.
Figure 21 Statistically significant difference in mean one year post-surgical dimensional relapse of mandibular plane angle for mandibular setback vs. maxillary advancement and maxillary advancement vs. bimaxillary surgery.
**Figure 22** Statistically significant difference in mean one year post-surgical dimensional relapse of gonial angle for maxillary advancement vs. bimaxillary surgery.
**Figure 23** Statistically significant difference in mean one year post-surgical vertical relapse of gonion for bimaxillary surgery vs. maxillary advancement.
Figure 24  Condylar (COND) and posterior face height (PFH) Asymmetry Percentage for each Surgery Group at Pre-surgical (-pre), Immediate Post-surgical (-sx), and One Year Post-surgery (-post) time points. Calculated from the equation: \( \left| \frac{R-L}{R+L} \right| \times 100. \)
Figure 25 Statistically significant difference in mean one year post-surgical horizontal relapse of gonion for maxillary advancement vs. bimaxillary surgery patients with >6% of condylar asymmetry pre-surgically.
Figure 26  Composite cephalometric changes from pre-surgery to immediate post-surgery time points for maxillary advancement patients.
Maxilla Only

Figure 27 Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for maxillary advancement patients.
Figure 28 Composite cephalometric changes from pre-surgery to immediate post-surgery time points for mandibular setback patients.
Figure 29  Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for mandibular setback patients.
Two Jaw

Figure 30  Composite cephalometric changes from pre-surgery to immediate post-surgery time points for bimaxillary surgery patients.
Figure 31  Composite cephalometric changes from immediate post-surgery to one year post-surgery time points for bimaxillary surgery patients.
UNC computerized cephalometric model adopted from Walker and Kowalski. 139 skeletal, soft tissue, superimposition and registration points are identified.


Harvold EP. Neuromuscular and morphological adaptation in experimentally induced oral respiration. In McNamara JA (eds): Naso-respiratory function and craniofacial


