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Are orthognathic surgical procedures for the correction of Class III malocclusion less stable in younger patients?

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Are orthognathic surgical procedures for the correction of Class III malocclusion less stable in younger patients?

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Abstract

Introduction: In patients with Class III malocclusion, continued disproportionate growth after orthognathic surgery has the potential to reverse the surgical correction.

Purpose: To determine if evaluation of patients' growth status allows for successful early surgical correction of Class III dentofacial deformity.

Materials and Methods: Patients having undergone combined orthodontic and orthognathic surgical treatment for the correction of Class III malocclusion were grouped into early and late surgery groups. Lateral cephalometric radiographs of 31 subjects were traced and measured, and the magnitude and direction of post-surgical change was evaluated. Differences in growth related to type of surgery and patient gender were determined for both groups.

Results: Differences in post-surgical change between the early and late treatment groups did not reach statistical significance. Patients undergoing combined maxillary and mandibular surgery exhibited greater post-treatment change than those having maxillary surgery alone. The magnitude of post-surgical change was small in most patients. All of the patients exhibited positive overbite and overjet at final records.

Conclusions: Results from this study indicate that in early-maturing individuals, surgical correction of Class III dentofacial deformity can be performed successfully in late adolescence. Some post-treatment change can be expected for all Class III surgical patients.

Key words: orthognathic surgery, early surgery, Class III malocclusion, post-surgical growth

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Introduction

Class III skeletal relationships are characterized by a prognathic mandible and/or retrognathic maxilla.[1] When the discrepancy between the mandible and maxilla is severe, orthognathic surgery may be required to achieve an ideal occlusal relationship and acceptable esthetics.

Surgical correction of the Class III skeletal pattern is routinely delayed into adulthood; clinicians fear that treatment in adolescence will be followed by disproportionate growth and skeletal or dental relapse.[2-4] Alternatively, the etiology of the Class III skeletal pattern may influence the timing of surgical intervention.[1] If maxillary retrusion alone produces the Class III malocclusion, orthognathic surgery could be performed soon after the adolescent growth spurt, with little risk of subsequent growth causing skeletal relapse.[3,5] However, when the Class III skeletal pattern has a component of excessive mandibular growth, orthognathic surgery is usually delayed until growth has ceased, as this growth pattern makes skeletal relapse a possibility.[2-4] "Early surgery *may* be justified when deformities are severe enough to negatively affect patients' self-perception, socialization, and interpersonal relationships", but clinicians are advised "to inform parents of the likelihood of growth restriction and additional surgical procedures in the future."[4]

Dentofacial deformity can lead to decreased self-esteem and negative body image in affected individuals, and the social attractiveness of children and adolescents with malocclusions is less than those with a harmonious facial appearance.[6-8] Individuals with a Class III skeletal pattern are judged to be more aggressive, while females with Class III faces are rated least attractive.[8]

Teenage orthodontic patients, especially females, are very aware of their appearance and eager to undergo corrective treatment. [7] Male and female patients undergoing orthognathic surgical procedures for Class III correction demonstrate improvements in physical well-being, social confidence and emotional status.[9] The motivation for early surgical correction of severe skeletal Class III problems thus stems from the improvements in psychological well-being seen in Class III patients after treatment.

Knowledge of late adolescent growth, Class III growth patterns, and effects of orthognathic surgery on jaw growth are helpful in deciding when to correct the skeletal discrepancy.

Wolford et al contends that 98% of facial growth is complete in girls by age 15 and in boys by age 17 or 18, but numerous investigations have demonstrated significant jaw growth many years beyond the adolescent growth spurt.[2,10-17]

Bjork studied mandibular growth in 45 boys between 5 and 22 years of age.[10] Growth ceased as early as 17 years 5 months, while growth continued in other patients into their early twenties. Woodside used longitudinal and cross-sectional data to demonstrate continued mandibular growth in females until age 16 and males until age 20.[11]

Hunter studied males and females from childhood into adulthood.[14] Facial growth ceased late in the second decade for females but continued into the third decade in males; facial growth was complete before body growth in the majority of females but only half of males. Van der Beek et al showed growth in stature to be strongly correlated with increases in anterior and posterior lower face heights.[18]

A longitudinal study of male and female subjects from the Child Research Council in Denver showed no further growth of the maxilla after age 18 in females; growth of both the mandible and maxilla continued to age 20 in males.[15]

Behrents' studies of facial growth in adulthood demonstrated changes in the mandible and maxilla beyond 30 years of age for both men and women.[12,13]

Edwards et al's analysis of individuals with normal dental and skeletal relationships showed that although considerable overlap of growth curves occurred, the overall pattern was for transverse growth to be completed first, followed by anteroposterior, then vertical growth measures.[19]

Studies of late adolescent facial growth in males by Love et al, and females by Foley et al, demonstrated continued increases in mandibular and maxillary length to age 20 in both genders; overall mandibular growth was found to be twice that of maxillary growth.[20,21]

Silveira et al determined dimensional changes in both jaws during late adolescence for early, average, and late maturers.[22] Maxillary changes were less than mandibular changes in late puberty; growth increments for both the maxilla and mandible were larger for the late maturers than for the other two groups.

The Bolton-Brush Longitudinal Growth Study demonstrated that midface length did not change significantly in females after age 14, while males showed continued increases to age18.[23] Rates of mandibular growth slowed considerably in females after age 14, while male growth rates remained unchanged.

Facial growth thus continues for most individuals into adulthood, although the magnitude of change is generally small. Does growth in individuals with a Class III skeletal pattern differ from those with normal jaw relationships?

Bacetti et al and Mitani compared those with normal and Class III skeletal relationships. They found maxillary growth increments between the two groups to be similar, but the position of the maxilla in Class III individuals was retrusive from an early age.[24,25] Bacetti et al found cranial base flexure in the male Class III subjects was significantly lower than normal, producing a more anterior position of the glenoid fossa.[26, 27] The pubertal peak occurred at the normal time in both males and female Class III subjects, but the duration of the pubertal peak was approximately six months longer in both sexes. Increases in mandibular length were significantly greater in Class III male and females both during both peak pubertal growth and in the postpubertal period.

Mitani et al compared cephalometric measurements of Class III and normal male and female subjects in the postpubertal period.[28] No significant difference in growth increments was evident in either gender, supporting his contention that the Class III phenotype is established early in childhood and maintained throughout the growth period. Sugawara and Mitani determined that Class III individuals showed neither excessive mandibular growth nor deficient maxillary growth from the prepubertal to the postpubertal periods.[29]

Battagel and Guyer et al found differences in the position and length of both jaws in Class III subjects relative to normals, with mandibular differences significantly greater than those found in the maxilla.[30,31] Growth patterns were similar in both Class III and normal males, while growth of female Class III individuals continued long after growth of their control peers had ceased.[30]

Conflicting evidence on Class III growth patterns thus complicates the decision to proceed with early surgery. If normal growth occurs in Class III individuals, with the retrusive maxillary position and protrusive mandibular position established early in development, surgery before completion of facial growth would be successful.[25-31] In these individuals, any remaining growth would be proportional and thus maintain the skeletal correction.[28,29] Conversely, if decreased maxillary growth, increased mandibular growth, and a worsening skeletal discrepancy characterize Class III individuals, early surgical correction may be inappropriate. Continued disproportionate growth in these patients would make early surgical correction unstable.[2,24,30,31]

Surgical intervention has definite, but highly variable effects on jaw growth.[32,33] Wolford et al states that mandibular surgery does not alter the preoperative growth rate or pattern; surgical correction of excessive growth must therefore be delayed until growth has ceased.[2,3] Bushang found altered mandibular growth patterns and growth restriction after mandibular surgery; isolated maxillary surgery also inhibited forward growth of the lower jaw.[33]

With regards to the maxilla, transverse growth is moderately restricted by early surgical intervention, anterior growth consistently shows severe restriction, and future vertical growth can be expected to continue unchanged.[5,33]

Serial cephalometric radiographs, taken at annual intervals, are considered the gold standard for assessment of facial growth.[34] Due to the propensity for Class III patients to have a longer adolescent growth spurt and increased increments of mandibular growth, many clinicians do not correct Class III skeletal patterns until early adulthood; surgical correction is undertaken when superimposition of annual cephalometric radiographs confirms no further mandibular growth.[34] Unfortunately, this method of growth evaluation is retrospective, resulting in considerable delay of definitive treatment. If, for example, radiographs are taken at yearly intervals, and completion of facial growth occurs soon after a cephalogram is taken, superimposition could not confirm growth completion until almost two years hence.

Changes in height are well correlated with jaw growth and stages of sexual maturation.[18,35-37] These relationships provides an alternative to serial cephalometric radiographs for evaluation of skeletal maturity. In the present study, growth in stature and sexual development were used to evaluate patients' readiness for orthognathic surgery.

The adolescent spurt in stature begins in females at approximately age 10.5 and ends 3 years later; in males the spurt begins on average at age 12.5 and lasts 5 years.[35,37] Peak height velocity occurs at age ages 11.9 for females and 13.9 for males.[35] Considerable variation is present in the timing of the adolescent growth spurt, with many early-maturing boys experiencing their peak height velocity before late-maturing girls.[35]

Menarche occurs on average 1.3 years after peak height velocity, with a range of 0 to 2.5 years.[35] Cessation of growth after sexual maturation is especially prominent in girls; at the onset of menstruation about 80% of the adolescent growth spurt is complete.[35,36,38] Voice changes begin at an average age of 13.9 years in boys, the same time as attainment of peak height velocity.[35]

Growth of the face, including the maxilla and mandible, accelerates to a maximum velocity a few months after peak growth in stature.[18,35,36] The lower jaw grows more during the adolescent growth spurt than the upper jaw.[37] Females showed higher peak velocities of maxillary growth, while mandibular peak growth rates were highest in males. Rapid deceleration of jaw growth velocity occurs after the peak in both genders.

Using sexual development as an alternative to cephalometric radiograph superimposition permits an immediate determination of patients' skeletal maturity. In our study, once Class III individuals were determined to be skeletally mature, their skeletal discrepancy was surgically corrected *regardless of their age.*

The purpose of this study was to determine if there is a difference in stability after Class III surgical correction in patients treated at different ages, and whether evaluation of adolescent patients' growth status allowed successful early correction of Class III dentofacial deformity.

Materials and methods

The cephalometric records of patients having undergone orthognathic surgical treatment by one oral and maxillofacial surgeon (MSS) were reviewed; all patients treated with orthognathic surgery for correction of Class III skeletal relationships were evaluated for inclusion in the study. Cephalometric analysis was performed on patients to determine positional changes in the maxilla and mandible occurring after surgery, as well as changes in face height, jaw orientation and incisor relationships.

The original sample of 44 patients included all Class III surgical patients treated by MSS. The final sample consisted of 18 females and 13 males and was selected by the following inclusion criteria:

1. pretreatment lateral cephalograms demonstrating Class III skeletal relationship (ANB < 1.0^{o}).
2. correction of occlusal relationships with orthognathic surgical procedures performed by MSS. (OJ $\geq$ 0mm at T1)
3. postreatment lateral cephalograms available, taken immediately after orthognathic surgery (T1) and a minimum of 12 months later (T2).
4. lateral cephalograms taken in habitual (maximum intercuspation) occlusal position.
5. no craniofacial syndromes or history of oral and/or facial clefts.

Charts of all subjects included in the sample were reviewed by the author (NBJ) and the following information recorded:

a. gender
b. date of birth
c. age at time of surgery
d. surgery dates
e. dates of all lateral cephalograms taken during patient treatment
f. time (in months) between T1 and T2 lateral cephalograms
g. type(s) of surgery performed
h. age at menarche in females of early treatment group
i. age at voice change in males of early treatment group
j. overjet, overbite, canine and occlusal relationships at T1 and T2

Patients were grouped into early or late treatment groups depending on their age at the time of surgery. The early treatment group consisted of sixteen male and female patients. The females were younger than 17 years of age and the males were younger than 19 years of age at the time of orthognathic surgery. The late treatment group of fifteen patients was composed of females 17 or older and males 19 or older. Individuals in the early treatment group were judged to be early-maturing individuals with little remaining craniofacial growth at the time of surgery. Maximum ages for the male and female groups were based on the expectation that some difference in post-surgical growth might be expected for males treated before age 19 and females treated before age 17. Similar ages were chosen in Bailey et al's study of long-term post-surgical growth in Class III patients treated at different ages.[32]

Suitability for early orthognathic surgical treatment was determined via patient interview and examination. Specifically, females with minimal change in stature in the previous year were questioned regarding timing of menarche, and males with little or no change in height were asked about the beginning of breaking of the voice. Orthognathic surgery was delayed until a minimum of one year after menarche in non-growing females, with an average time between onset of menstruation and surgery of 41 months. Surgical correction was delayed until a minimum of 2.5 years after voice change in non-growing males, with an average delay of 54 months. The minimum intervals were based on an average adolescent growth spurt of three years for females and five years for males; rapid deceleration in jaw growth occurs after attainment of peak statural growth in both genders.[36,37]

Of the 31 patients in the study sample, only two had mandibular setback alone. This reflects the trend towards combined maxillary and mandibular surgery in Class III patients with a component of mandibular prognathism.[39] Forward growth of the lower jaw may be more likely in patients with mandibular prognathism.[32] Subjects were therefore categorized into two surgical groups: those undergoing maxillary surgery alone and those who had mandibular setback with or without maxillary advancement.

Both normal and Class III male patients show greater mandibular growth increments in late adolescence than their female counterparts.[24] Post-surgical changes with respect to patient gender were therefore determined for each surgical group.

Maxillary and mandibular measurements were obtained from the lateral cephalograms taken immediately post-surgery (T1) and those taken at least 12 months later (T2). Mean differences between T1 and T2 measurements were used to determine the extent and direction of growth of the maxilla and mandible in the post-surgical period. Mean differences were then compared between the early and late treatment groups. Any effects on treatment outcome related to type of surgery and patient gender were determined. Changes in incisor relationships and face heights were also evaluated.

Mean change in the position of six cephalometric points relative to derived horizontal and vertical axes was determined, as seen in previous studies of surgical patients (See Appendix I).[32,40,41] The horizontal axis was obtained by rotating 6 degrees clockwise from the Sella-Nasion plane, while the vertical axis was a line perpendicular to the horizontal plane, oriented through Sella. The distance of A point to the vertical axis defined horizontal change in maxillary position, while the distance from Menton to the horizontal axis defined change in anterior face height. Change in mandibular position was represented by Pogonion, as B point was difficult to locate for the five patients undergoing lower border osteotomy on the mandible. The difference between the lengths of the maxilla and mandible was determined (see Appendix II). Fifteen other cephalometric planes and landmarks were used, as seen previously in studies by Bacetti et al and Sugawara and Mitani; these measurements characterized the changes in incisor position, jaw orientation and face height (See Appendix II).[24,29] Clinical success was defined as maintenance of positive overjet and overbite, and good occlusion/ intercuspation at the end of the observation period (T2).

All cephalometric variables were measured using Dolphin Imaging Software 10.0 on tracings of digitized cephalometric radiographs. All lateral cephalometric radiographs were traced by the author (NBJ). Statistical analysis was performed using JMP 8.

The null hypothesis of no difference in post-surgery growth between the early and late treatment groups for the outcome variables was tested using analysis of covariance (ANCOVA). The primary outcome variables were the change in Menton (in mm) relative to the x-axis and the change in Point A and Pogonion (in mm) relative to the y-axis. The secondary outcome variable was the change in the maxillomandibular differential ie. the difference between the length of the mandible and the length of the maxilla. The type of surgery (maxillary or combined maxillary and mandibular) and gender (male or female) were used as explanatory variables. Statistical significance was set at $p \leq 0.05$ and a difference in the means of the outcome variables ≥ 2 mm was deemed to be clinically significant.

Measurement error was assessed using 18 digitized radiographs randomly selected from the patient sample. The radiographs were re-traced 1 month after the initial tracing by the author, and the reproducibility of 23 cephalometric measurements was determined. Differences between the original measurements and measurements of the retraced lateral cephalograms were calculated. Dalberg's method was then used to estimate the measurement error associated with the cephalometric measurements. The reproducibility of the cephalometric measurements was evaluated by means of an intra-class correlation coefficient (R).

Results

Of the 44 Class III malocclusion patients having undergone orthognathic surgical treatment, 31 met all of the inclusion criteria. Patients were excluded for the following reasons:

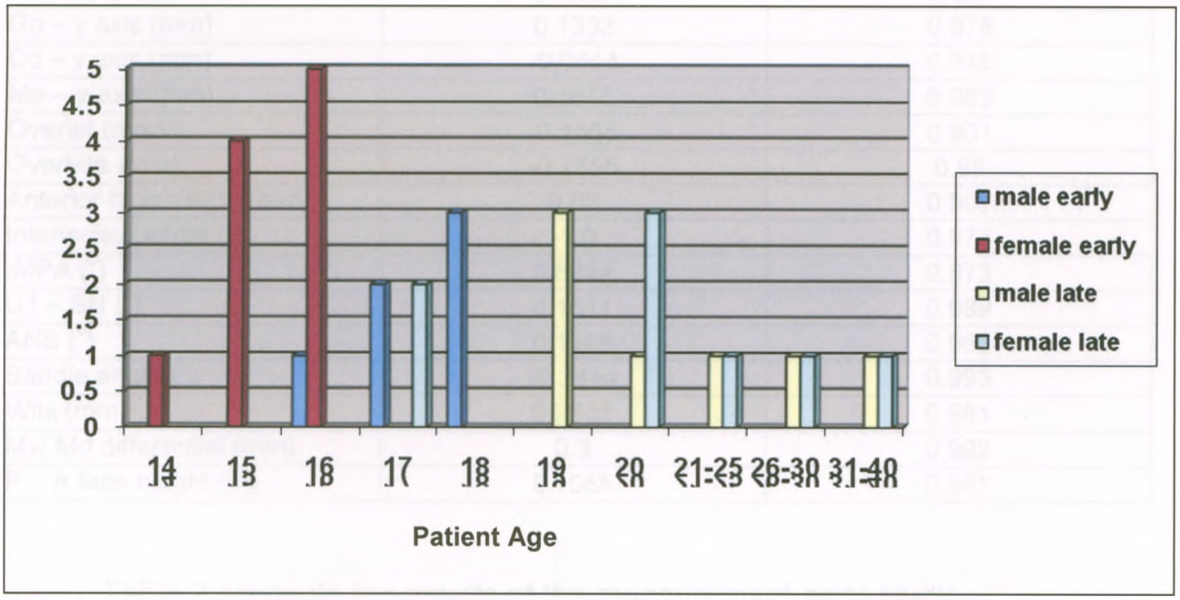
- no concomitant orthodontic treatment: 1 patient
- history of oral and/or facial clefts: 2 patients
- no T2 records available/ T2 records taken less than12 months after T1 records: 10 patients

Table 1. Characteristics of study sample

Group	*Early*	*Late*
N	16	15
Male subjects	6	7
Female subjects	10	8
T1 – T2(mts)	25	33
Mx surgery alone	6	7
Md surgery (alone/ in combination)	10 (1/ 9)	8 (1/ 7)
Initial ANB (T1)	1.99° (±2.69°)	2.14° (±3.08°)
Average age (years-months)	16-7	23-1

Table 1 presents the characteristics of the study sample. Thirteen male patients and eighteen female patients were included in the study. The age range for male patients was 16-8 to 32-10 years; the range for the female patients was 14-4 to 37-1 years. Sixteen patients were allocated to the early treatment group, which was composed of females less than 17 years of age and males less than 19 years of age. The remaining fifteen patients were allocated to the late treatment group. Maxillary surgery alone was performed on six patients (40%) in the early treatment group and seven patients (45%) in the late treatment group. Immediately after orthognathic surgery (T1), the ANB angle measured 1.99° in the early treatment group and 2.14 ° in the late treatment group. The age distribution of male and female patients in the early and late treatment groups is displayed in Figure 1.

Figure 1: Number of male and female patients at different ages for early and late treatment groups



The magnitude and direction of post-surgical changes was determined through analysis of the 27 cephalometric variables described in appendices I and II. The initial radiographs were taken immediately post-surgery (T1), and follow-up radiographs were taken a minimum of 12 months later (T2); 12 months was considered the minimum time necessary to demonstrate post-surgical changes. The average time between T1 and T2 was 25 months for the early treatment group and 33 months for the late treatment group.

Table 2. Results of measurement error study

Measurement	*Mean difference*	*R*
A point – x axis (mm)	0.1055	0.983
B point – x axis (mm)	-0.6111	0.98
Pog – x axis (mm)	-0.25	0.996
Go – x axis (mm)	0.2333	0.994
Co – x axis (mm)	0.0111	0.981
Me – x axis (mm)	0.0166	0.997
A point – y axis (mm)	0.4333	0.974
B point – y axis (mm)	0.4666	0.988
Pog – y axis (mm)	0.4944	0.99
Go – y axis (mm)	0.1333	0.978
Co – y axis (mm)	-0.0444	0.945
Me – y axis (mm)	0.1611	0.983
Overjet (mm)	-0.1555	0.901
Overbite (mm)	-0.2555	0.88
Anterior face height (mm)	0.05	0.997
Interincisal angle (°)	-1.0	0.975
IMPA (°)	0.8944	0.873
U1 – SN (°)	0.1611	0.989
ANB (°)	0.1388	0.963
Saddle angle (°)	-0.3444	0.993
Wits (mm)	0.2833	0.981
Mx/ Md differential (mm)	0.3	0.992
P – A face height (%)	0.1055	0.981

Table 2 presents the results of the measurement error study. Reproducibility (R) values ranged from 0.88 to 0.99, indicating that measurement error accounted for 1 to 12% of the variability in the measurements. For orthodontic studies, reproducibility (R) of 0.90 is desirable and 0.97 or greater is considered ideal.

The subjects were divided into those with maxillary surgery alone, or mandibular surgery alone or in combination. Means and standard deviations of post-surgical growth experienced for patients undergoing early or late maxillary surgery is summarized in Table 3a. Means and standard deviations of post-surgical growth experienced for patients undergoing early or late mandibular surgery alone or in combination is summarized in Table 3b. Outcomes are also presented for male and female patients within each surgical category.

TABLE 3a. Maxillary surgery alone: Post-surgical change as function of Early or Late Treatment and Gender

	Change T1-T2		*Change T1-T2*	
Measurement	Late (N=7)	Early (N=6)	Male (N=3)	Female (N=10)
Menton – x axis (mm)	0.1 (±1.1)	-0.6 (±1.1)	0.1 (±0.5)	-0.3 (±1.2)
A point – y axis (mm)	-0.8 (±0.7)	-0.5 (±2.2)	-0.8 (±1.5)	-0.6 (±1.6)
Pogonion – y axis (mm)	0.4 (±2.4)	1.0 (±1.8)	1.6 (±1.9)	0.4 (±2.1)
Mx/Md difference (mm)	0.2 (±1.1)	0.9 (±2.5)	1.4 (±1.4)	0.3 (±1.3)

In the interval between T1 and T2, changes after maxillary surgery include: face height decreased 0.6mm in the early treatment group and increased 0.1mm in the late treatment group, while the maxilla moved back 0.5mm in younger individuals and 0.8mm in older individuals. The mandible moved anteriorly 0.4mm in older patients and 1mm in younger patients. The maxillo-mandibular differential increased in both groups, with a 0.2mm change in the late treatment group and a 0.9mm in the early treatment group. Male patients experienced little vertical change after maxillary surgery, while the maxilla moved back and the mandible came forward. Female patients exhibited vertical relapse after maxillary surgery, and the maxilla moved posteriorly while the mandible moved anteriorly. The maxillo-mandibular differential increased in both genders, with a greater change in male subjects.

Following maxillary surgery, the magnitude of post-surgical change was generally small, with none of the variables changing more than 1 mm in the early or late treatment groups. On average, the younger and older patients had posterior movement of the upper jaw and anterior movement of the lower jaw after surgery, increasing the maxillo-mandibular differential for both groups. Similar changes occurred in the male and female groups, although males tended to have greater anterior movement of the chin. The average difference between all groups was less than 2mm for all variables tested.

Changes after mandibular surgery alone or combined with maxillary surgery include the following: face height decreased 0.5mm in the early treatment group and 1.1mm in the late treatment group, while the horizontal position of the maxilla was stable in both younger and older subjects. The mandible moved anteriorly 2.7mm in the older patients and 3.0mm in the younger patients. The maxillo-mandibular differential was 2.2mm in the early treatment group and 0.8mm in the late treatment group, with absolute mandibular length increasing 1.3mm in younger patients and 0.8mm in older patients. Both male and female patients experienced a decrease in face height between T1 and T2, while the upper jaw came forward in males and changed little in females. The lower jaw moved anteriorly more than 2mm in both male and female groups. Absolute mandibular length increased 1.5mm in males and 0.7mm in females, contributing to an increased maxillo-mandibular differential for both genders.

TABLE 3b. Mandibular surgery with or without Maxillary surgery: Post-surgical change as function of Early or Late Treatment and Gender

	Change T1-T2		***Change T1-T2***	
Measurement	Late (N=8)	Early (N=10)	Male (N=10)	Female (N=8)
Menton – x axis (mm)	-1.1 (±1.7)	-0.5 (±1.6)	-0.7 (±1.7)	-0.9 (±1.6)
A point – y axis (mm)	0.1 (±1.8)	0.1 (±2.1)	0.4 (±2.0)	-0.1 (±1.9)
Pogonion – Y axis (mm)	2.7 (±2.7)	3.0 (±2.3)	3.1 (±2.6)	2.6 (±2.3)
Mx/Md difference (mm)	0.8 (±1.0)	2.2 (±2.6)	1.5 (±2.4)	1.8 (±2.0)

Following mandibular surgery, both younger and older patients had a decrease in face height and forward displacement of the maxilla and mandible. Vertical relapse was less, and forward mandibular movement was more, in the early treatment group. A combination of maxillary and mandibular changes increased the maxillo-mandibular differential for both younger and older individuals. Similar changes were seen in the male and female groups.

Collectively, maxillary surgery patients exhibited little change or a decrease in face height. The maxilla relapsed posteriorly while the mandible moved forward, likely contributing to the increased maxilla-mandibular differential seen across all groups.

Collectively, mandibular surgery patients exhibited a decrease in face height and little change in maxillary position. The mandible moved anteriorly greater than 2mm for all groups, likely contributing to the increased maxillo-mandibular differential seen across all patient groups.

The results of the test of the null hypothesis using ANCOVA are presented in Table 4 for isolated maxillary surgery and Table 5 for mandibular surgery alone or in combination. The difference in post-surgical change between early and late treatment did not reach statistical significance for any of the outcome variables tested. The effects of gender also did not reach statistical significance. There were no clinically significant (>2mm) differences between any of the groups following maxillary surgery alone or mandibular surgery with or without maxillary surgery.

Table 4. Maxillary surgery: Significance level (p<0.05) for all variables tested

	Menton – x axis (mm)	*A point – y axis (mm)*	*Pogonion – Y axis(mm)*	*Mx/Md difference(mm)*
Treatment Group (E)	.2	.67	.8	.5
Sex (F)	.39	.81	.46	.28

*significance ($p \leq 0.05$)

Table 5. Mandibular surgery: Significance level ($p<0.05$) for all variables tested

	Menton – x axis (mm)	*A point – y axis (mm)*	*Pogonion – Y axis(mm)*	*Mx/Md difference(mm)*
Treatment Group (E)	.35	.82	.63	.18
Sex (F)	.53	.55	.57	.83

*significance ($p \leq 0.05$)

Appendices III-VI present means for the 27 cephalometric measurements at T1 and T2, with subdivisions based on surgery type, age at surgery and gender. All patients achieved clinically successful long-term correction of their Class III malocclusion, with all 31 subjects exhibiting good intercuspation and positive overjet and overbite at the time of final records (T2). 30/32 (94%) patients maintained bilateral Class I canine relationships at T2 (Table 6).

Table 6: Occlusal relationships at T2 as a function of Surgery type and Early or Late Treatment

	Mx		*Md*	
	Early (N=6)	Late (N=7)	Early (N=10)	Late (N=8)
Overjet (mm)	2.2	2.4	2.2	2.1
Overbite (mm)	2.5	2.2	2.3	1.9
Bilateral Class I Canines	6/6	6/7	9/10	8/8
Satisfactory Interdigitation	6/6	7/7	10/10	8/8

Discussion

Clinicians treating patients with severe Class III skeletal relationships should consider the psychological benefits of early surgical correction, as malocclusion may adversely affect adolescent socialization and self-concept.[6,9] Unfortunately, premature surgical treatment may be followed by unfavorable growth and a reappearance of the original problem.[2,5,32] A method to determine the earliest that stable correction can be achieved would offer significant benefit to affected individuals.

Patients' growth status was evaluated via interview and patient examination, focusing on recent changes in stature and sexual maturation. This method permitted immediate evaluation of growth status, thus avoiding the inevitable delay that occurs with the serial cephalometric method of growth assessment. In the early maturing patients, age at surgical correction was considerably younger (mean age: 16-7) than is conventional for Class III patients. The youngest female underwent orthognathic surgery at age 14 and the youngest male at age 16, yet all the younger patients were treated successfully as evidenced by maintenance of good intercuspation and positive overjet and overbite at T2 (see Table 6). Because dentofacial deformity can have such a negative impact on adolescents' self-image and social attractiveness, the psychological benefits of earlier treatment would be considerable.[7,8] Patients would also realize the benefits of good functional occlusion at an earlier age.

The results of the present study indicate that routinely delaying surgical correction of Class III patients until adulthood may not be appropriate. All patients in the early and late treatment groups exhibited stable occlusal correction at the time of final records. Changes in cephalometric measures were not significantly different between the early and late treatment group (Tables 4, 5). Both younger and older patients showed some change in the post-surgical period (Tables 3a, 3b). Although jaw growth has been shown to continue into adulthood, for early-maturing individuals the changes are small, and don't necessarily preclude treating Class III patients at a younger age.[22]

Maxillary surgery

Thirteen patients who underwent maxillary advancement surgery alone for the correction of Class III dentofacial deformity were evaluated for long-term ($\geq$ 1 year) changes in jaw position. Much of the data for long-term stability after orthognathic surgery comes from studies at the University of North Carolina (UNC).[32,40-42] The direction of changes in jaw position after maxillary surgery were generally consistent with previous studies of post-surgical stability in Class III patients, as was the high variability seen for all cephalometric measurements (Tables 3a, 3b). The post-treatment observation period averaged 29 months in the present investigation, and the magnitude of change in our subjects was generally less than that seen in previous investigations. For patients undergoing maxillary surgery alone, face height decreased in 6/13 (56%) of subjects, with only 1/13 (7%) decreasing more than 2mm. Because maxillary deficiency often has both vertical and horizontal components, the maxilla may be moved downward during surgical correction; this movement is particularly unstable.[32,41]

A study of Class III maxillary surgery patients showed that by one year after surgery, more than 40% had 2mm or more of upward movement of the maxilla.[41] After one year, 21% had further superior movement of the maxilla, while in 9% the maxilla moved inferiorly. Iannetti et al's study of stability after Class III open bite correction found a 2.2mm decrease in face height two years after LeFort 1 procedures alone.[43] In our sample of six early maxillary surgery patients, 5/6 (83%) subjects had little post-surgical change in vertical facial dimension, while one experienced a decrease of greater than 2mm. Bailey et al found vertical maxillary relapse in older patients, but no change in younger patients.[40] Because surgery has minimal effect on subsequent vertical jaw growth, one would expect a greater decrease in face height in older patients, as less vertical facial growth remains after surgery to compensate for vertical relapse.[2,5,19]

Maxillary advancement in the present sample was followed by a mean posterior movement in both younger and older subjects, with greater change in the older patients. Posterior relapse may be due to the pronounced effects on anterior growth which sometimes occur with maxillary surgery.[5] Potential causes of this relapse include scarring and wound contracture, surgical insults to the nasal septum, and soft tissue stretching.[33] Despite the average posterior movement of the maxilla, the upper jaw actually came forward in a majority (54%) of patients. Surgery may thus have had little inhibitory effect on subsequent growth; greater residual midface growth remaining in the younger patients may have accounted for the smaller posterior movement seen in this group.[12,15,20,21] Despite the difference in average change between the younger and older subjects, most individuals in the present study experienced little (<2mm) change. Bailey et al's study comparing maxillary advancement in younger and older patients showed posterior relapse regardless of patient age. Busby et al followed Class III patients one to five years after surgery; he found backward movement at A point in 10% of maxillary advancement patients, while in 10% forward movement occured.[41] This contrasts with candidates for orthognathic surgery who decided not to proceed with surgery.[42] In these subjects, only anterior movement of A point occurs. Thus, some aspect of the surgical procedure "creates the propensity for remodeling in the direction of relapse", although continued anterior movement in some individuals suggests that growth restriction is not universal.[34]

Pogonion moved forward in both early and late treatment groups, with greater change in the younger subjects. With the decrease in face height often seen in maxillary advancement patients, anterior movement of the chin could be expected.[41] Bailey et al's comparison of younger and older patients showed greater average anterior chin movement in the early treatment group.[32] Other studies of maxillary advancement patients show variable horizontal change in the mandible beyond one year post-surgery. Bailey et al showed the chin moving back in 9% of patients and forward in 6% of patients, while Busby et al found 2mm or more anterior movement at Pogonion in more than 80% of patients, and posterior movement in about 5%.[40,41] The maxillo-mandibular differential was almost unchanged in the late treatment group, while in younger patients it increased 0.9mm. Although more mandibular than maxillary growth is a consistent feature of facial growth in late adolescence, the increase differential observed in younger patients was not statistically or clinically significant.[15,20-21,23]

Differences in post-surgical growth were apparent for males and females. Male patients undergoing maxillary advancement alone had no vertical relapse, while female subjects showed a decrease in anterior face height. Both males and females had mean posterior movement of the maxilla and mean anterior movement of the mandible, with greater change seen in the male subjects. No comparative data on gender differences in post-surgical change is available; gender differences may be due to greater vertical and mandibular growth remaining after maxillary advancement in the male subjects.[23] Anterior displacement of the maxilla does occur in some maxillary advancement patients, with most change apparent from one to five years post-surgery.[40,41] This contrasts with Wolford et al's assertion than severe restriction of anterior growth occurs after LeFort 1 osteotomy.[4]

The magnitude of the changes observed after maxillary advancement surgery were small, and generally followed the pattern expected for facial growth in late adolescence: younger patients had greater forward mandibular movement than older patients, and males had greater forward movement of the lower jaw than females. None of the changes resulted in clinically significant relapse, with all maxillary advancement patients exhibiting satisfactory interdigitation and positive overbite and overjet at the time of final records (T2). All but one of the isolated maxillary surgery patients had maintained bilateral Class I canine relationships at T2.

<u>Mandibular and 2-jaw surgery:</u>

Eighteen patients who underwent mandibular setback with or without maxillary advancement surgery for the correction of Class III dentofacial deformity were evaluated for long-term ($\geq$1 year) changes in jaw position. The pattern of changes in mandibular surgery patients differed from that in patients who had maxillary surgery alone.

Traditionally, all patients with Class III skeletal patterns were treated with mandibular setbacks.[34] Development of maxillary surgery in the 1970s, coupled with awareness that maxillary deficiency and mandibular excess contribute equally to Class III problems, has altered the approach to surgical correction for these patients.[39] In contemporary practice, fewer than 10% of Class III patients are treated with mandibular setback alone, and isolated maxillary surgery is used 40% of the time.[39] Maxillary advancement often improves the esthetic result in Class III surgery, and may enhance stability of mandibular surgery. Mandibular setback procedures (with or without maxillary advancement) are now generally reserved for those having a component of mandibular prognathism.[32]

Mandibular setback combined with maxillary advancement was performed on 16/18 (89%) of patients in the mandibular sample. Isolated mandibular setback was used in 2/18 (11%) patients, with one in each of the early and late treatment groups. As two subjects was deemed too small a sample to be evaluated independently, a decision was made to combine these two patients with the two-jaw group. This mirrors Bailey et al's most recent study on Class III stability as a function of age at surgery.[32] No statistically or clinically significant differences were found in outcomes with the inclusion of these patients.

Vertical relapse occurred in 13 of 18 (72%) of patients following mandibular surgery. Two patients in the early treatment group and one patient in the late treatment group experienced vertical relapse of greater than 2mm. Although vertical relapse is a common feature of the maxillary movements used in Class III orthognathic surgery, it is often reduced with concomitant mandibular surgery.[3,40,41] Kwon et al used three-dimensional cephalograms to evaluate stability after combined maxillary and mandibular surgery in Class III subjects.[45] No movement of A point occurred in any dimension during the six month observation period.

In the present study, the horizontal position of the maxilla was stable for most patients, while in 3/18 (17%) post-surgical change greater than 2mm occured. Anterior movement of A point was noted in both early and late treatment groups, occurring in 5 of the 18 (28%) patients having mandibular setback or 2-jaw surgery. Busby et al showed minimal change in maxillary position for a large majority of Class III maxillary advancements. [41] Bailey et al found mean posterior relapse in both younger and older subjects, although minimal change of A point occurred in 90% of younger and 75% of older patients after mandibular or 2-jaw surgery.[32,] The average age for the older patients in Bailey et al's study was 29.4 years, while the average age in the older group of the present study was 23.1 years; this difference may account for the increased maxillary stability in this sample. Alternatively, differences in surgical techniques may produce less growth restriction or posterior relapse after maxillary advancement.[34]

The mandible continued to be displaced anteriorly in both the early and late mandibular surgery groups, with 3mm horizontal change in the younger patients and 2.7mm in the older patients. Mandibular setback is now generally reserved for those patients with a component of mandibular prognathism, and prognathic mandibles tend to have increased growth increments and continued mandibular growth into early adulthood.[24] Bailey et al found 3mm of anterior movement at Pogonion in the older group and 3.2mm in the younger group.[32] Other studies of change after two-jaw surgery also show the chin moving forward 3.1-3.2 mm on average. [40,41] Greater than 4mm of anterior movement was found in 2/10(20%) of our younger mandibular setback patients and 3/8 (38%) of the older patients. Substantial post-treatment change was thus less frequent in our sample than in Bailey et al's sample, where more than 4mm of change was noted in 42% of the early treatment group and 28% of the late treatment group.[32] Findings of substantial late mandibular growth are consistent with previous studies on Class III individuals, as well as Wolford et al's assertion that anteroposterior growth of the mandible is unaffected by surgery. [2,5,24] Bushang's finding of diminished mandibular growth in some patients with both maxillary and mandibular surgery was not supported.[33]

An increased maxillo-mandibular differential was found for both the early and late treatment groups, with greater change in the younger subjects. More mandibular than maxillary growth is a consistent feature in late adolescence for both normal and Class III individuals.[20,21,24,30] Other studies consistently shows the maxilla displaced posteriorly after two-jaw surgery, coupled with increasing mandibular length.[41,42] Bailey et al showed posterior maxillary displacement for both early and late treatment groups, while mandibular length increased 2.4mm with early surgery and 2.0mm with later surgery.[32] Collectively, Bailey et al's findings suggest an increasing maxillo-mandibular differential for both groups. Although an increasing maxillo-mandibular differential was demonstrated in the present investigation, mandibular length increases were small, with change of only 1.3mm following early surgery and 0.8mm following later surgery.

Of the eighteen patients treated with bilateral sagittal split osteotomy, all but two (11%) had concomitant maxillary surgery; both male and female patients had the expected decrease in face height after LeFort I procedures. Female subjects exhibited little change in the horizontal position of the maxilla, while male patients grew forward at A point, perhaps due to greater midface growth in males in late adolescence.[23] Both male and female patients with setback of the lower jaw showed anterior movement at Pogonion and increasing maxillo-mandibular differential, although the changes were not considered clinically significant. Larger growth increments and a longer postpubertal growth period have been shown for both male and female Class III subjects.[24,25,30]

Anterior movement of the mandible after setback occurred in all patient groups, with the chin moving forward an average of 2.6mm to 3.1mm. Anterior movement at Pogonion exceeded increases in mandibular length for all patient groups, suggesting that both mandibular growth and positional change contributed to the increased chin projection. Similar changes have been shown in other long-term studies after Class III surgery.[32,39,40,41] For individuals undergoing surgical correction of mandibular prognathism, clinicians should expect some anterior movement of the mandible in both male and female adult patients. Adequate overbite and overjet and a well-interdigitated occlusion are essential in these patients to maintain the occlusal relationships with continued mandibular growth.

Changes in face height, maxillary position and mandibular position were observed in the post-surgical period across all patient groups. None of the differences *between* the groups with respect to timing of surgery, type of surgery, or gender reached statistical significance ($p \leq 0.05$). With a study power of 80, approximately 30 patients per group would be required to detect a clinically significant ($\geq$2mm) difference between groups. As such, the present study is useful as a pilot study to guide the planning of future research.

Bailey et al showed no significant difference in post-surgical growth or likelihood of loss of positive overjet in Class III patients treated at different ages.[32] Serial cephalograms were used for growth evaluation, however, so the authors still supported using this method for all Class III surgery patients. Determination of Class III surgical patients' growth status via assessment of sexual maturation and changes in stature is supported by our study, with all those in the early treatment group maintaining their correction at the time of final records. Continued lower-jaw growth after surgery was noted for individuals having mandibular setback, however, with all patient groups showing greater than 2mm of anterior movement at Pogonion.

Average follow-up in the present investigation was 29 months; this study may have benefited from a longer post-treatment observation period. Bailey et al monitored Class III patients at least five years after surgery, and noted overjet had decreased to zero in some subjects from both early and late treatment groups.[32]

Long-term evaluation of all subgroups in this study showed that change after orthognathic surgery is the norm and not the exception. Despite a mean decrease in ANB angle and a mean increase in maxillo-mandibular differential across all patient subgroups (see Appendices III-VI), overbite and overjet showed little change in the post-surgical period. A well-interdigitated occlusion was seen in all patients, and 29/31 (94%) of patients had maintained bilateral Class I canine relationships. When patients' growth status is evaluated accurately, early surgical correction of Class III malocclusion can be performed successfully.

Conclusion

When growth status is accurately evaluated in patients with Class III dentofacial deformity, the occlusal correction can be maintained successfully following early surgical treatment. Skeletal changes in the post-treatment period must be small enough that the dentition can adapt to maintain occlusal relationships. In the present study, the skeletal correction achieved in younger patients was as stable as that achieved in older patients. Changes in face height, maxillary and mandibular position, and maxillo-mandibular length differential were not statistically or clinically different in the early or late treatment groups. It appears that all patients were correctly evaluated with respect to their growth status, as all met our definition of clinical success at the time of final records (see Table 6). Increasing the sample size and continued reexamination of post-surgical changes in the present study sample would increase confidence in this method of growth evaluation.

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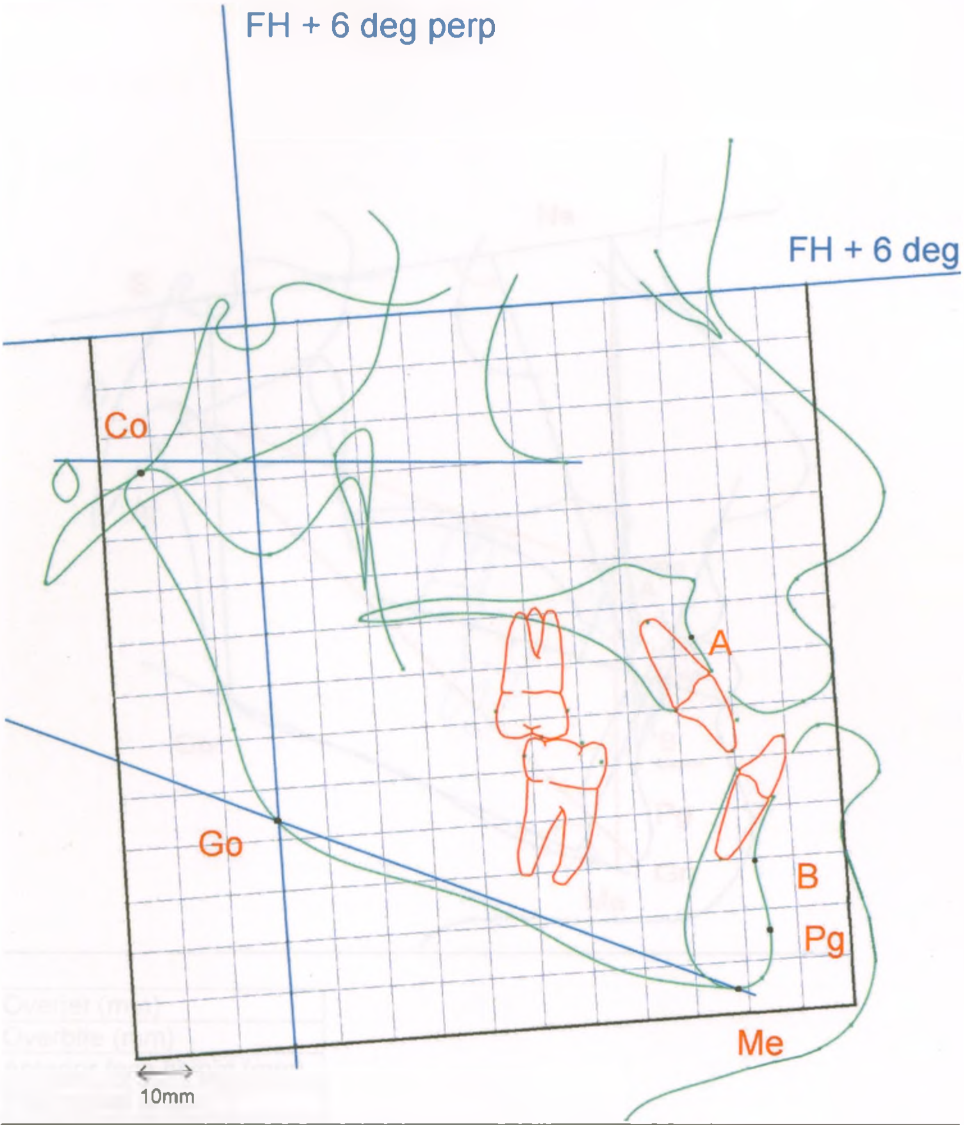
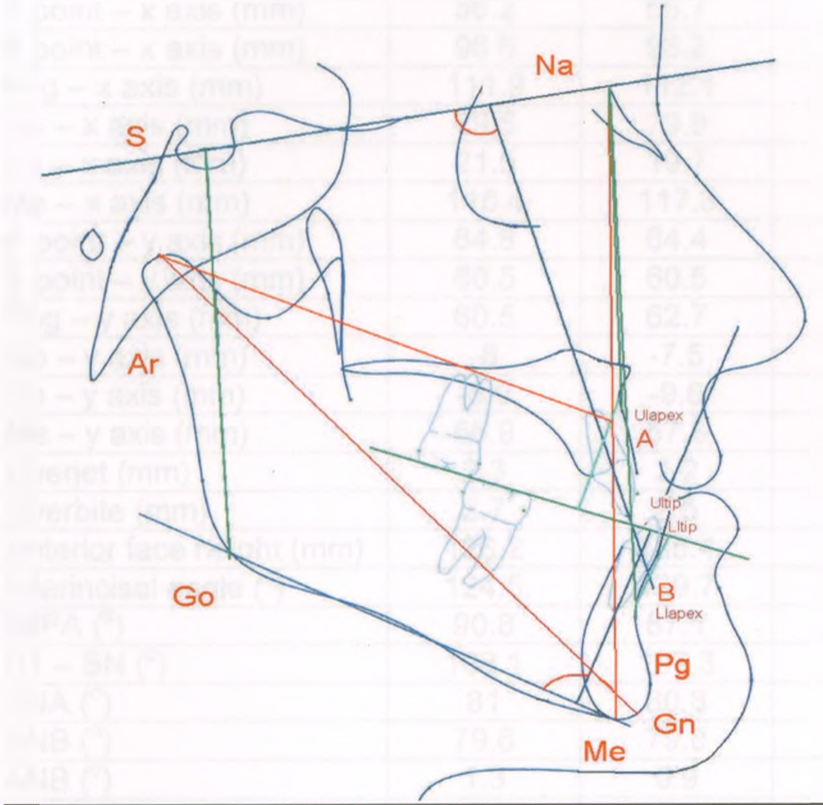
Appendices:

Appendix I: Skeletal Linear Cephalometric Landmarks and Measurements



A point – x axis (mm)
B point – x axis (mm)
Pog – x axis (mm)
Go – x axis (mm)
Co – x axis (mm)
Me – x axis (mm)
A point – y axis (mm)
B point – y axis (mm)
Pog – y axis (mm)
Go – y axis (mm)
Co – y axis (mm)
Me – y axis (mm)

Appendix II: Skeletal and Dental Linear and Angular Cephalometric Landmarks and Measurements



Overjet (mm)
Overbite (mm)
Anterior face height (mm)
Interincisal angle (°)
IMPA (°)
U1 – SN (°)
SNA (°)
SNB (°)
ANB (°)
Saddle angle (°)
Wits (mm)
Mx length (mm)
Md length (mm)
Mx/ Md differential (mm)
P – A face height (%)

Appendix III.

Maxillary Surgery: Means of Cephalometric Measurements at T1 and T2 for Early and Late Treatment Groups

Measurement	**Early (N=6)**		**Late (N=7)**	
	T1	T2	T1	T2
A point – x axis (mm)	56.2	55.7	56.2	56.3
B point – x axis (mm)	96.6	96.2	93.8	94.1
Pog – x axis (mm)	111.9	112.1	109	109
Go – x axis (mm)	79.6	79.9	78.5	78.1
Co – x axis (mm)	21.5	19.7	17.1	18.5
Me – x axis (mm)	118.4	117.8	115.8	115.9
A point – y axis (mm)	64.8	64.4	66.2	65.3
B point – y axis (mm)	60.5	60.5	58.4	58.3
Pog – y axis (mm)	60.5	62.7	60.5	60.9
Go – y axis (mm)	-8	-7.5	-7.1	-9
Co – y axis (mm)	-8.9	-9.6	-9.9	-10
Me – y axis (mm)	56.9	57.8	54.5	55.1
Overjet (mm)	2.3	2.2	2.4	2.4
Overbite (mm)	2.7	2.5	2.1	2.2
Anterior face height (mm)	126.2	125.4	123.9	124
Interincisal angle (°)	124.5	129.7	139.2	135.4
IMPA (°)	90.8	87.1	87	87.7
U1 – SN (°)	108.1	107.3	96.8	100.2
SNA (°)	81	80.8	81.8	80.5
SNB (°)	79.6	79.8	78.3	77.9
ANB (°)	1.3	0.9	3.5	2.7
Saddle angle (°)	119.1	121.7	122.8	123.4
Wits (mm)	-5.8	-4.3	-2	-1.9
Mx length (mm)	81.5	82.4	85.6	84.4
Md length (mm)	118.4	120.2	118.9	118
Mx/ Md differential (mm)	36.9	37.8	33.4	33.6
P – A face height (%)	62.3	63.6	63.9	63.1

Appendix IV.

Maxillary Surgery: Means of Cephalometric Measurements at T1 and T2 for Males and Females

Measurement	Male (N=3)		Female (N=10)	
	T1	T2	T1	T2
A point – x axis (mm)	58.5	57.7	55.5	55.5
B point – x axis (mm)	101.8	101.5	93.1	93.2
Pog – x axis (mm)	116.1	117.8	108.6	108.2
Go – x axis (mm)	88.6	90.3	76.1	75.5
Co – x axis (mm)	23.9	25	17.7	17.2
Me – x axis (mm)	124,7	124.8	114.7	114.3
A point – y axis (mm)	70.9	70.1	63.9	63.3
B point – y axis (mm)	65	66	57.6	57.3
Pog – y axis (mm)	68.2	69.8	59.5	59.9
Go – y axis (mm)	-1.9	-2	-9.2	-10.2
Co – y axis (mm)	-9.2	-9.1	-9.5	-10.1
Me – y axis (mm)	61.5	62.8	53.8	54.4
Overjet (mm)	2.3	2.3	2.4	2.3
Overbite (mm)	2.3	2	2.4	2.5
Anterior face height (mm)	132.4	132.4	122.7	122.4
Interincisal angle (^{o})	130.6	132.7	132.9	132.8
IMPA (^{o})	90.2	88	88.3	87.3
U1 – SN (^{o})	103.9	105.5	101.4	102.9
SNA (^{o})	84.8	84.1	80.4	79.6
SNB (^{o})	81.4	81.9	78.1	77.8
ANB (^{o})	3.4	2.1	2.2	1.8
Saddle angle (^{o})	119.3	120.3	121.6	123.3
Wits (mm)	-3.9	-3.2	-3.7	-2.9
Mx length (mm)	87.3	85.7	82.6	82.8
Md length (mm)	124.4	124.2	117	117.4
Mx/ Md differential (mm)	37.1	38.5	34.4	34.6
P – A face height (%)	67.2	68	61.9	61.9

Appendix V.

Mandibular Surgery with or without Maxillary Surgery: Means of Cephalometric Measurements at T1 and T2 for Early and Late Treatment Groups

Measurement	Early (N=10)		Late (N=8)	
	T1	T2	T1	T2
A point – x axis (mm)	55.3	53.8	56.3	55.5
B point – x axis (mm)	94.4	93.6	101.3	99.8
Pog – x axis (mm)	108.1	107.8	117.2	116.4
Go – x axis (mm)	76.7	77.1	81.4	81.3
Co – x axis (mm)	19.9	20	20.7	20.5
Me – x axis (mm)	115.2	114.7	124	122.9
A point – y axis (mm)	69.1	69.2	69.9	70
B point – y axis (mm)	63.6	66	66.8	69
Pog – y axis (mm)	65.9	69	70.3	73
Go – y axis (mm)	-5	-2	-3.1	-2.2
Co – y axis (mm)	-9.6	-9.3	-11.2	-11.5
Me – y axis (mm)	59.8	62.8	62.5	65.6
Overjet (mm)	2.4	2.2	2.3	2.1
Overbite (mm)	2.5	2.3	2	1.9
Anterior face height (mm)	123.4	122.7	132.3	131.1
Interincisal angle (^{o})	130	127.9	131.7	131.2
IMPA (^{o})	87.5	88.3	81.5	80.6
U1 – SN (^{o})	105.5	107.5	107.7	110.7
SNA (^{o})	81.9	82.2	81.6	81.6
SNB (^{o})	79.7	81.1	80.9	81.9
ANB (^{o})	2.3	1.2	0.7	-0.3
Saddle angle (^{o})	121	120.4	123.1	122.4
Wits (mm)	-2.9	-4.8	-4.7	-5.1
Mx length (mm)	86.5	85.6	89.1	89
Md length (mm)	119.2	120.5	129.4	130.2
Mx/ Md differential (mm)	32.7	35	40.8	41.5
P – A face height (%)	62.7	63.7	61.6	61.9

Appendix VI.

Mandibular Surgery with or without Maxillary Surgery: Means of Cephalometric Measurements at T1 and T2 for Males and Females

Measurement	**Male (N=10)**		**Female (N=8)**	
	T1	T2	T1	T2
A point – x axis (mm)	57.1	56.1	54	52.6
B point – x axis (mm)	100.6	98.9	93.6	93.1
Pog – x axis (mm)	115.7	114.8	107.8	107.7
Go – x axis (mm)	82.9	83.4	73.6	73.5
Co – x axis (mm)	20.6	20.9	19.7	19.4
Me – x axis (mm)	122.7	122	114.7	113.8
A point – y axis (mm)	72	72.4	66.3	66.1
B point – y axis (mm)	67.8	70.3	61.5	63.6
Pog – y axis (mm)	71.5	74.6	63.4	66
Go – y axis (mm)	-3.6	-1.9	-4.8	-2.3
Co – y axis (mm)	-11.4	-11.7	-8.9	-8.5
Me – y axis (mm)	63.8	67.3	57.5	60
Overjet (mm)	2.4	2.2	2.3	2.1
Overbite (mm)	2.3	2	2.3	2.3
Anterior face height (mm)	131.2	130.3	122.6	121.6
Interincisal angle (°)	128	128.4	134.3	130.6
IMPA (°)	87	85.8	82.1	83.7
U1 – SN (°)	108.5	110.6	104	106.8
SNA (°)	81.5	82	82	81.9
SNB (°)	80.3	81.7	80	81.1
ANB (°)	1.2	0.3	2	0.8
Saddle angle (°)	123.2	122.9	120.4	119.3
Wits (mm)	-3.1	-3.9	-4.5	-6.2
Mx length (mm)	91.2	91.2	83.3	82
Md length (mm)	128.8	130.3	117.3	118
Mx/ Md differential (mm)	37.1	39.1	34.5	36.3
P – A face height (%)	63.2	63.8	61	61.8