

**Effect of timing on treatment outcomes and surgical complications of
orthognathic surgery in Class II patients**

Anna Morrow

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Committee:

Anne-Marie Bollen

Don Joondeph

Dale Bloomquist

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Anna Morrow

University of Washington

Abstract

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Anna Morrow

Chair of the Supervisory Committee:
Anne-Marie Bollen
Department of Orthodontics

Introduction

Class II malocclusions can be treated with a combination of orthodontics and orthognathic surgery. The severity of the malocclusion and growth potential play an important role in the treatment decision. Treatment involving orthognathic surgery is usually recommended after active growth is over to minimize relapse. On the other hand, improvement of a severe skeletal deformity and associated esthetic imbalance during adolescence can increase the patient's quality of life and, in some cases, early treatment may decrease the financial burden due to changes in insurance coverage. Also, surgery and recovery from surgery may be easier and with less complications in younger individuals. The purpose of this study is to evaluate the effect of timing on treatment outcomes and the surgical complications of orthognathic surgery between younger and older Class II malocclusion patients.

Methods

Records of local orthodontists and oral surgeons were screened for inclusion in the study: Class II malocclusion treated with a combination of orthodontics and orthognathic surgery of the

mandible (with or without maxillary surgery). Syndromic patients were excluded. Lateral cephalograms (initial, pre-surgical, post-surgical and final) as well as surgical notes were obtained. Patients were divided in 3 groups based on chronological age: 13-19, 20-25, 33-40. Dolphin imaging software was used and landmarks identified for cephalometric analysis. Cephalometric measurements were used to analyze the dental and skeletal changes associated with surgical and orthodontic treatment. Immediate and post-surgical complications were evaluated.

Results

A total of 112 patients were identified who fit the inclusion criteria. Only 35 patients had available cephalometric data (T1 pre-orthodontics; T2 pre-surgical; T3 postsurgical and T4 post treatment) which were used to compare anteroposterior (A-P) changes between the adolescent and adult patients. Less changes in cephalometric measurements were observed between T1-T2 and T3-T4 in the younger patients. Surgical data for 104 patients were included in the study, 8 patients were excluded due to missing data. For 1-jaw surgery, blood loss in the older group was greater than in the younger group. Limited TMJ opening (24-31 mm) at 6 weeks and more post-surgical complications after 1 jaw surgery were observed in the older group. More post-surgical complications after 2 jaw surgery (condylar resorption, infection, residual sensory loss and TMJ pain) were observed in the younger patient group.

Conclusions

Younger patients who underwent orthognathic surgery to correct a Class II malocclusion had similar orthodontic treatment outcomes and similar immediate surgical complications compared

to older patients. Possible continued mandibular growth contributed to improved skeletal relationships after the orthognathic surgery in the younger patients. Overall, there was no statistical or clinical difference in A-P changes of mandibular advancement surgery, nor differences in surgical complications between young and older patients.

Introduction and literature review

Global distribution of Class II malocclusion in the permanent dentition is 19.56% according to a recent systematic review (Alhammadi et al., 2018). There is a wide range from 1.6% (Nigeria) to 63% (Belgium) (Alhammadi et al., 2018). The etiology of most CI II malocclusions is a skeletal imbalance due to a retrognathic mandible, followed by maxillary prognathism and combination of both (Sinha et al., 2018).

Usually, class II malocclusions become apparent in the mixed dentition. Possibility of growth modification and the optimal timing are both important considerations for treatment planning (Tulloch et al., 1997). In some patients, the severity of the skeletal imbalance is such that orthognathic surgery may be chosen as the means of correcting the malocclusion. In still growing adolescent with a severe Class II, the clinician has to decide when to provide orthodontics. Most of the time, surgeons and orthodontists are reluctant to recommend a surgical treatment option for younger patients as they may still be growing. The option of postponing orthognathic surgery until after growth has mostly subsided. The rationale for waiting is that the total extent of the skeletal imbalance will be known at the time of treatment, and growing patients have more long-term changes in the antero-posterior and vertical position of the chin than those who had surgery later (Proffit et al., 2010). On the other hand, early surgical correction for esthetic improvement

may be an attractive option for some patients. There is limited evidence to support the need to postpone surgical treatment until late adolescence or early adulthood (Proffit et al., 2010). It provides patients with the benefit of improved esthetics during adolescence, especially in those for whom the skeletal discrepancy is severe. Another advantage may be a financial one, for those patients who may be without insurance coverage at a later age (Marangoni et al., 2016). There is a significant change in quality of life which occurs following orthognathic surgery (Lee et al., 2008)

There are only few studies that compare young and older patients to evaluate treatment success and the long-term stability after orthognathic surgery (Proffit et al., 2010). Some studies of patients who had mandibular advancement prior to the adolescent growth spurt show little or no forward growth of the mandible after surgery, although vertical growth of the mandible does occur so that downward-backward rotation of the mandible is avoided (Snow et al., 1991). Late forward mandibular growth almost never occurs in mandibular deficient patients, as often is the case in patients with mandibular prognathism (Proffit et al., 1992). Based on this, it does not seem necessary to wait for a surgical correction until after the adolescent growth spurt, especially not for severe situations in patients who want treatment as soon as possible before the growth spurt is completed or nearly completed (Proffit et al., 2010). For example, severe deficiency leading to possible sleep apnea or extreme social problems.

On the other hand, Proffit's study of long-term stability of adolescent versus adult surgery for treatment of mandibular deficiency shows some retention difference between growing and non-growing patients. Beyond 1 year post-surgery, the younger patients showed significantly greater change in the horizontal and vertical position of points B and pogonion, the horizontal (but not vertical) position of gonion, and mandibular plane angle. Older groups showed a decrease in the

mandibular angle, while younger patients had an increase. Satisfaction with treatment and perception of problems were similar for both groups (Proffit et al., 2010).

Another consideration for early surgical approach is the ability for full recovery and minimizing surgical complications. It seems reasonable to expect that surgical healing will be faster with minimal complications for younger patients. However, the possibility of continued growth after surgical correction and need for second surgery may be a contra-indication for early surgical intervention. To evaluate patient growth potential most of the practitioners base their decision on chronological age and gender. Usually, females stop active growth earlier than males. But because of the wide individual variation in the timing of the pubertal growth spurt, chronologic age cannot be used in the evaluation of pubertal growth (Hägg et al., 1982). Based on a study published in 1999 by Tulloch: age, skeletal severity, and gender (which may be a proxy measure for skeletal maturity or even for patient compliance), used separately or together, provide no more useful predictors of treatment success than the toss of a coin (Tulloch et al., 1999).

Early intervention is supported by some studies that showed that patients who had mandibular advancement prior to the adolescent growth spurt show little or no forward growth of the mandible after surgery, although vertical growth of the mandible does occur. The second is that late forward mandibular growth almost never occurs in mandibular deficient patients, as often is the case in patients with mandibular prognathism (Proffit et al., 2010, Snow et al., 1991).

There is limited information available on the differences in occlusal stability and surgical complications of early versus late orthognathic surgery to correct skeletal Class II malocclusions. The purpose of this study is to evaluate the effect of timing on treatment outcomes and surgical complications of orthognathic surgery between growing and non-growing patients with Class II malocclusion who were treated with a combination of orthodontics and orthognathic surgery.

Material and Methods

This study was approved by the University of Washington Human Subjects Division IRB.

Cephalometric radiographs, as well as surgical records were collected from oral surgeons in the Seattle area. The following inclusion criteria were used: patient had orthodontic treatment with orthognathic surgery of the mandible (with or without maxillary surgery) to correct a Class II malocclusion. Exclusion criteria: patients with clefts or craniofacial syndromes; poor quality radiographs. For each patient the following was obtained: age at the time of surgery, sex diagnosis, type of surgical treatment, pre- and post- surgical cephalometric radiographs, and surgical notes. Patients were divided in 3 groups based on chronological age: 13-19, 20-25, 33-40 for cephalometric analysis and 13-19, 20-28, 31-41 for surgical complications. The purpose of the division in three age groups was to allow comparison of growing to non-growing patients. It is hypothesized that the younger age group would mostly consist of growing adolescents and the older age group of non-growing adults; with the middle group consisting of both growing and non-growing patients.

Orthodontists, who treated the patients were also contacted to collect initial and final cephalometric radiographs. Time points of the lateral cephalograms were defined as T1 (the initial or pre-treatment lateral cephalogram), T2 (the lateral cephalogram taken on average within a month prior to the surgery), T3 (the lateral cephalogram taken after the orthognathic surgery), and T4 (the lateral cephalogram taken at the end of the orthodontic treatment).

All cephalometric radiographs were imported into Dolphin Imaging software (version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, California). The following landmarks were identified by one examiner: A point, anatomical gnathion, articulare, B point, condylion, gonion, nasion, ruler point 1, ruler point 2, sella, L6 mesial, distal and occlusal; U6 mesial, distal,

and occlusal; L1 root, tip, labial and lingual gingival borders; U1 root, tip, labial and lingual gingival borders. Lateral cephalograms were de-identified, and the examiner was blinded to the identity or timing of the cephalogram. The cephalometric measurements listed in Table 1 were automatically calculated with the Dolphin Imaging software based on a custom analysis designed for this study.

<i>Cephalometric measurements</i>
OJ (mm)
ANB (o)
Go-Gn (mm)
Go-B (mm)
Ar-B (mm)
Go-Pg (mm)
Co-Pg (mm)

Table 1: Cephalometric measurements collected on all available lateral cephalograms

Reliability of cephalometric measurements.

Intra-rater reliability of cephalometric measurements was calculated based on duplicate measurements on 10 random patients at 4 different time points by one investigator (AM).

Comparison of the first and second measurements of the quantitative measures over the 4 time points, and changes for T1 to T2, T2 to T3 and T3 to T4.

To compare the two measurements the mean and standard deviation (SD) was computed for each set of measurements, the mean (SD) of the differences and 95% confidence interval (CI) for the mean difference, the intraclass correlation coefficient (ICC) and 95% CI for the ICC (Cicchetti, DV, 1994), Dahlberg's error (Kim, H-Y, 2013), and the minimum and maximum for the absolute value of the difference between the two measurements.

The following were collected from the surgical notes for each patient: initial skeletal diagnosis, type and time of the orthognathic surgery, immediate and post-surgical complications (blood

loss, TMJ opening at 6 weeks in mm, pain, limited soft tissue movement, muscle spasm, headaches, residual sensory loss, infection, hardware removal, relapse, condylar resorption, other).

Results

Three oral surgeons participated in the study. Of the 62 orthodontists who were contacted, 15 agreed to participate in the study. A total of 112 patients fulfilled the inclusion criteria. Of these, 35 patients had cephalometric data for inclusion in the cephalometric analyses. The mean age was 21y (range 13-40 at the time of surgery). The female to male ratio was 3:1. There were no missing data for age and gender.

The 35 patients were divided in 3 age group: 13-19 (younger), 20-25 (middle), 33-40 (older) and analyzed by age and gender to evaluate differences between each group (Table 2). The younger group had the majority of the patients with median age of 16 years old and all groups had more female than male patients.

Variable	Overall, N = 35 ¹	13-19, N = 23	20-25, N = 6	33-40, N = 6	p-value ²
Age, years					<0.001
Mean (SD)	20.8 (8.0)	16.2 (1.3)	22.2 (1.8)	37.2 (2.3)	
Median (IQR)	17.0 (16.0, 22.0)	16.0 (15.5, 17.0)	22.0 (21.0, 23.0)	37.5 (37.0, 38.0)	
Range	13.0, 40.0	13.0, 19.0	20.0, 25.0	33.0, 40.0	
Gender					0.88
F	25 (71.4%)	16 (69.6%)	4 (66.7%)	5 (83.3%)	
M	10 (28.6%)	7 (30.4%)	2 (33.3%)	1 (16.7%)	

¹c("Mean (SD)", "Median (IQR)", "Range"); n (%)

²Kruskal-Wallis rank sum test; Fisher's exact test

Table 2. Age and gender by age categories

Treatment time in each group was evaluated based on the dates when the lateral cephalometric radiographs were taken. The presurgical orthodontic treatment time was longer for the older patient group compared to the other age groups. Post-surgical treatment time was shorter in the middle age group (Appendix 1). Only a few patients had missing cephalometric data at particular time points as demonstrated in Appendix 2. Mainly pre-surgical and post-surgical data were absent.

All cephalometric measurements were compared between the 4 time points. Comparison between the following cephalometric measurements were used to evaluate anterior-posterior changes between all four time points: OJ, ANB, Go-Gn, Go-B, Ar-B, Go-Pg, Co-Pg. We focused on the OJ, ANB, Go-B, Ar-B measurements due to the similarity between Go-Gn, Go-B, Ar-B, Go-Pg, Co-Pg, and the possible effect of a genioplasty on the Gn and Pg cephalometric landmarks.

An increase in overjet was noted between T1-T2 in all three groups. But less in the younger age group (13-19). A significant decrease in OJ was observed between the T2-T3 time points and minimal changes were noted between T3-T4 (Figure 1). A similar pattern is seen for the ANB angle between the four time points in the 3 age groups (Figure 2). A slight increase in ANB between T3-T4 was noted in the younger group (13-19).

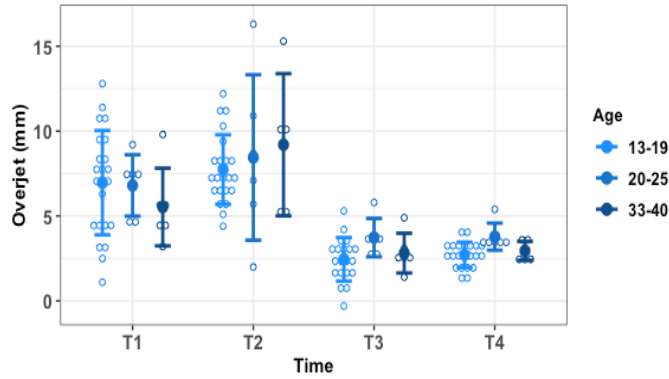


Figure 1. Overjet by time and age.

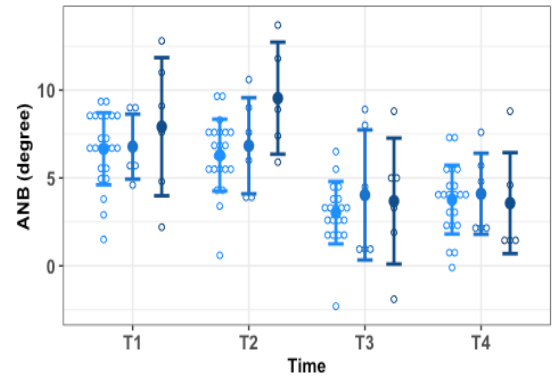


Figure 2. ANB by time and age

The Go-B measurements at T1 and T2, and the changes from T1-T2 are similar in all groups (Figure 3). There are increases for all three groups between T2-T3, more so for the older age groups than the younger age group (Figure 3). From T3 to T4 there was a decrease for the older age groups (Figure 3). Similar changes were observed for Ar-B (Figure 4) and Go-Pg (Appendix 3). For the Go-Gn measurements, there was a significant increase from T2 to T3 with greater changes in the older age groups. A noticeable decrease in Go-Gn between T3-T4 in the patient group aged 20-25 was noted (Appendix 4).

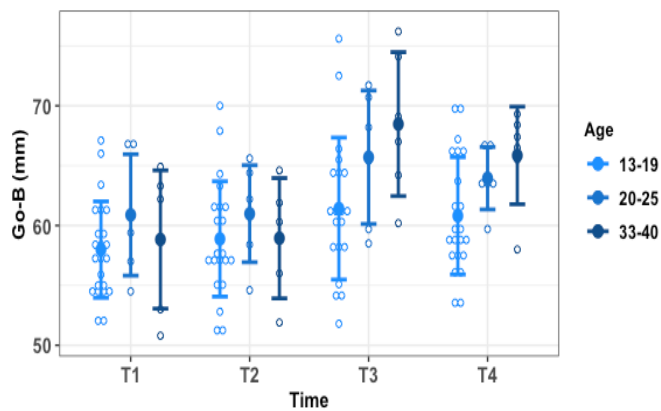


Figure 3. Go-B by time and age.

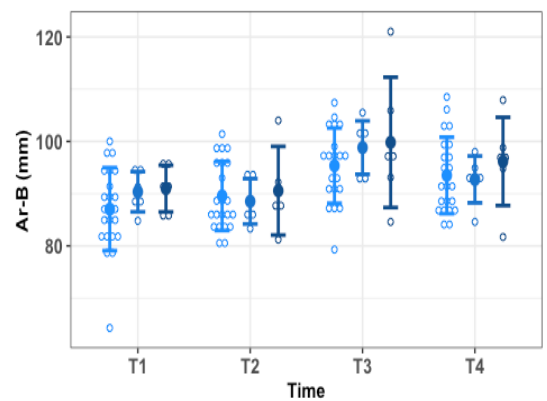


Figure 4. Ar-B by time and age

For the Co-Pg measurements, there were minimal changes between T2-T1 with an increase between T3-T2 for all three groups, and a noticeable decrease in the middle and older groups between T4-T3 (Appendix 5).

Below are tables for the changes between T2-T1 and T4-T3 for OJ, ANB, Go-B, Ar-B. The changes for Go-Gn, Go-Pg, and Co-Pg can be found in Appendix 6 and 7. It includes the change in mm and in degree per year to adjust for differences in elapsed time between the various lateral cephalometric radiographs. Comparison was done between age groups based on the median and using the Kruskal-Wallis test (nonparametric test), see Table 3 and 4.

There was a significant difference between the younger and older groups when comparing the T2-T1 Ar-B measurements, with the younger group having increase in Ar-B compared to a decrease in the older group. Similar changes were observed for the T4-T3 Go-Gn measurements.

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Overjet (mm)					0.46
Mean (SD)	1.49 (3.63)	0.94 (3.53)	1.65 (3.36)	3.70 (4.25)	
Median (IQR)	1.10 (-1.10, 4.10)	1.45 (-1.60, 3.93)	1.00 (0.02, 3.03)	1.20 (0.50, 6.70)	
Range	-4.80, 9.70	-4.80, 6.60	-2.60, 7.10	0.40, 9.70	
Overjet (mm/yr)					0.69
Mean (SD)	0.07 (0.24)	0.02 (0.19)	0.21 (0.38)	0.06 (0.08)	
Median (IQR)	0.07 (-0.08, 0.15)	0.07 (-0.12, 0.15)	0.09 (0.00, 0.44)	0.01 (0.01, 0.08)	
Range	-0.31, 0.79	-0.31, 0.36	-0.23, 0.79	0.01, 0.15	
ANB (degree)					0.36
Mean (SD)	-0.02 (1.64)	-0.27 (1.71)	0.05 (1.21)	1.00 (1.60)	
Median (IQR)	-0.10 (-0.90, 0.90)	-0.20 (-1.05, 0.53)	-0.05 (-0.50, 0.70)	0.80 (-0.20, 0.90)	
Range	-3.20, 3.70	-3.20, 2.90	-1.70, 1.80	-0.20, 3.70	
ANB (degree/yr)					0.29
Mean (SD)	0.03 (0.13)	0.00 (0.10)	0.09 (0.22)	0.08 (0.05)	
Median (IQR)	0.00 (-0.03, 0.11)	-0.01 (-0.06, 0.04)	-0.01 (-0.03, 0.15)	0.11 (0.06, 0.11)	
Range	-0.16, 0.49	-0.16, 0.18	-0.12, 0.49	0.02, 0.12	
Go-B (mm)					0.94
Mean (SD)	0.78 (3.38)	0.91 (3.32)	0.10 (3.98)	1.00 (3.59)	
Median (IQR)	1.10 (-1.20, 3.00)	1.00 (-1.12, 3.28)	0.75 (-1.47, 2.45)	1.10 (-1.90, 3.00)	
Range	-6.50, 8.60	-5.60, 8.60	-6.50, 4.80	-3.00, 5.80	
Go-B (mm/yr)					0.80
Mean (SD)	0.04 (0.38)	0.01 (0.23)	0.19 (0.74)	-0.09 (0.24)	
Median (IQR)	0.03 (-0.06, 0.12)	0.04 (-0.04, 0.11)	0.06 (-0.07, 0.28)	0.03 (-0.16, 0.05)	
Range	-0.72, 1.53	-0.54, 0.35	-0.72, 1.53	-0.36, 0.07	
Ar-B (mm)					0.038
Mean (SD)	1.50 (5.63)	2.84 (5.67)	-1.83 (4.59)	-0.42 (5.18)	
Median (IQR)	1.40 (-0.60, 4.00)	1.70 (0.85, 4.15)	-0.05 (-1.62, 0.48)	-3.40 (-3.60, 0.70)	

Range	-10.90, 21.30	-6.20, 21.30	-10.90, 1.50	-4.00, 8.20	
Ar-B (mm/yr)					0.020
Mean (SD)	-0.04 (0.45)	0.09 (0.37)	-0.37 (0.61)	-0.18 (0.23)	
Median (IQR)	0.05 (-0.03, 0.11)	0.08 (0.03, 0.16)	-0.01 (-0.83, 0.04)	-0.13 (-0.28, -0.06)	
Range	-1.21, 1.34	-0.60, 1.34	-1.21, 0.07	-0.44, 0.02	

¹c("Mean (SD)", "Median (IQR)", "Range")

²Kruskal-Wallis rank sum test

Table 3. Changes between T1 and T2 by age using Kruskal-Wallis test

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Overjet (mm)					0.97
Mean (SD)	0.14 (1.25)	0.17 (1.19)	0.05 (1.37)	0.13 (1.54)	
Median (IQR)	0.10 (-0.55, 0.75)	0.10 (-0.70, 0.70)	0.30 (-0.40, 0.85)	0.05 (-0.55, 1.18)	
Range	-2.30, 3.30	-1.70, 3.30	-2.30, 1.60	-2.20, 2.10	
Overjet (mm/yr)					0.86
Mean (SD)	0.20 (0.49)	0.17 (0.41)	0.38 (0.84)	0.11 (0.04)	
Median (IQR)	0.13 (-0.15, 0.47)	0.02 (-0.19, 0.47)	0.13 (-0.10, 1.21)	0.13 (0.10, 0.14)	
Range	-0.62, 1.28	-0.30, 0.98	-0.62, 1.28	0.06, 0.14	
ANB (degree)					0.63
Mean (SD)	0.12 (2.10)	0.21 (2.19)	0.07 (2.46)	-0.12 (1.74)	
Median (IQR)	0.65 (-1.12, 1.35)	0.75 (-0.18, 1.17)	0.05 (-2.05, 1.48)	-0.45 (-1.12, -0.07)	
Range	-6.60, 3.60	-6.60, 3.50	-2.50, 3.60	-1.70, 3.20	
ANB (degree/yr)					0.052
Mean (SD)	-0.04 (0.26)	-0.09 (0.21)	-0.07 (0.32)	0.30 (0.25)	

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Median (IQR)	-0.01 (-0.13, 0.10)	-0.03 (-0.13, 0.04)	-0.05 (-0.08, 0.03)	0.21 (0.16, 0.39)	
Range	-0.58, 0.58	-0.58, 0.19	-0.57, 0.32	0.11, 0.58	
Go-B (mm)					0.82
Mean (SD)	-1.36 (6.20)	-0.84 (6.62)	-1.75 (7.00)	-2.62 (4.61)	
Median (IQR)	-2.20 (-4.00, 1.40)	-2.40 (-2.90, 1.30)	-1.50 (-5.63, 3.23)	-2.90 (-4.50, 0.50)	
Range	-17.70, 12.20	-17.70, 12.20	-12.00, 6.70	-9.70, 3.20	
Go-B (mm/yr)					0.36
Mean (SD)	-0.31 (1.04)	-0.09 (0.79)	-0.66 (1.60)	-0.79 (1.19)	
Median (IQR)	-0.25 (-0.54, 0.13)	-0.21 (-0.40, 0.14)	-0.60 (-1.25, -0.15)	-0.38 (-0.95, -0.22)	
Range	-2.86, 1.68	-1.79, 1.68	-2.86, 1.54	-2.53, 0.15	
Ar-B (mm)					0.73
Mean (SD)	-3.15 (7.34)	-2.05 (7.38)	-6.10 (8.22)	-3.65 (6.68)	
Median (IQR)	-2.90 (-6.85, 0.30)	-1.30 (-6.15, 0.55)	-3.25 (-8.48, -0.88)	-2.85 (-7.55, -0.48)	
Range	-20.90, 18.00	-13.80, 18.00	-20.90, 1.10	-13.10, 5.70	
Ar-B (mm/yr)					0.16
Mean (SD)	0.03 (0.60)	0.20 (0.46)	-0.34 (0.92)	-0.29 (0.42)	
Median (IQR)	0.13 (-0.17, 0.29)	0.23 (0.05, 0.35)	0.12 (-0.17, 0.13)	-0.43 (-0.53, -0.12)	
Range	-1.97, 1.31	-0.71, 1.31	-1.97, 0.19	-0.63, 0.18	

¹c("Mean (SD)", "Median (IQR)", "Range")

²Kruskal-Wallis rank sum test

Table 4. Changes between T3 and T4 by age using the Kruskal-Wallis test

Intra-rater reliability of the cephalometric measurements (ICC) was greater or equal to 0.96. The reliability was less for the Go-Gn measurements.

Surgical data results.

Of the 112 patients who fulfilled the inclusion criteria, 8 patients were excluded from the analysis of the surgical complications data analysis due to insufficient records. The 104 patients were divided in three groups based on age: 13-19, 20-28, 31-41. The majority of the patients were in the younger age group (69 vs 22 vs 13). Similar female to male ratios were observed between the younger and middle age groups (1:1); the older group had a higher female prevalence (3:1). The patient distribution among surgeons was statistically insignificant. When comparing patient characteristics by surgeon, age and gender were similar among the different surgeons.

Surgical complications are presented in Table 5. ¹Krusal-Wallis test was used for surgery time, one-way ANOVA for opening at 6 weeks, and Fisher's exact test for blood loss and other complications. The surgery time for 1&2 jaw was similar between groups with slight increase of 2 jaw surgery for patient group 31-41. When evaluating TMJ opening at 6 weeks, the older group showed significant limited jaw opening 24.5 mm – 30.5 mm, especially after 2 jaw surgery. Missing data for TMJ opening was reported in 28 subjects out of 104. More post-surgical complications after 1 jaw surgery were observed in older group, but after 2 jaw surgery were more in younger groups.

		Age Category			
	Overall	13-19	20-28	31-41	P-value ¹
Surgery time, median (IQR)					
1 jaw surgery	1.5 (1.5, 1.5)	1.5 (1.5, 1.5)	1.5 (1.5, 1.5)	1.5 (1.5, 1.5)	0.78
2 jaw surgery	2.5 (2.5, 3.0)	2.5 (2.5, 3.0)	2.5 (2.5, 2.5)	3.0 (3.0, 3.5)	0.085
Blood loss (ml), n (%)					
1 jaw surgery					0.20
<100 ml	8 (13.6%)	6 (16.2%)	2 (13.3%)	0 (0.0%)	

100 ml to 200 ml	36 (61.0%)	25 (67.6%)	8 (53.3%)	3 (42.9%)	
>200 ml	15 (25.4%)	6 (16.2%)	5 (33.3%)	4 (57.1%)	
2 jaw surgery					0.46
<200 ml	6 (16.7%)	5 (20.0%)	0 (0.0%)	1 (20.0%)	
200 ml to 400 ml	23 (63.9%)	14 (56.0%)	6 (100.0%)	3 (60.0%)	
>400 ml	7 (19.4%)	6 (24.0%)	0 (0.0%)	1 (20.0%)	
Opening at 6 w (mm), mean (SD)					
1 jaw surgery	37.0 (8.1)	39.4 (7.4)	34.8 (7.7)	31.0 (8.2)	0.023
2 jaw surgery	33.5 (8.4)	34.3 (7.0)	37.8 (11.1)	24.0 (2.9)	0.029
Other complications, n (%)					
1 jaw surgery	20 (29.4%)	11 (25.0%)	6 (37.5%)	3 (37.5%)	0.53
2 jaw surgery	10 (27.8%)	7 (28.0%)	2 (33.3%)	1 (20.0%)	>0.99

Table 5. Age comparisons by 1 or 2 jaw surgery

The following postsurgical complications were recorded from the surgical notes: TMJ pain, limited lip movement, muscle spasm and headaches, residual sensory loss, infection that was treated by antibiotics, infected hardware, condylar resorption (Appendix 8). Overall post-surgical complications were observed more in younger group, especially TMJ pain, residual sensory loss, infection and condylar resorption.

Discussion

In this study, we evaluated patients with Class II malocclusions, who underwent orthodontic treatment combined with orthognathic surgery. Our primary goals were to compare orthodontic treatment outcome and complications during and after the orthognathic surgery between younger patients and adults. Patients included in this study were divided in 3 age groups. Since the

middle age group may include both growing and non-growing patients, primarily the younger group (13-19) and older group (33-40) are compared in the following discussion to minimize variability of the skeletal maturity (and growth) likely found in the middle group.

Cephalometric measurements were used to evaluate the anteroposterior changes between all four time points.

Some changes suggestive of continued growth were noted for the younger age group. For all patients, overjet measurements (in mm and mm/ per year) increased from T1 to T2, which was mainly due to decompensation during the pre-surgical orthodontic treatment. However, there was less increase in overjet in the younger than the older age group, which may be the result of continued mandibular growth. Unfortunately, due to the small sample size it was not possible to evaluate differences between Class II div 1 or Class II div 2 patients, and/or extraction versus non-extraction treatment, which could also have impacted the OJ changes observed.

For the post-surgical changes in OJ (between T3 and T4) there was a slight increase in OJ in the older group compared to the younger group. This may similarly reflect possible continued mandibular growth in the younger patients offsetting possible relapse observed in the older age groups.

Similar changes were observed for the ANB measurements as for the OJ: in the younger group there was less increase in ANB measurements between T1 and T2. The decrease in the ANB angle post surgically (T3 to T4) in the younger group (but not in the older age group) is also suggestive of continued mandibular growth.

Mandibular length (Go-B and Ar-B) decreased from T3-T4, but more so for the middle and older age group than for the younger one. Again, this may have been the result from continued mandibular growth in the younger patients.

The changes in mandibular length using Go-B and Ar-B measurements are mirrored in similar measures of mandibular length: Go-Gn, Ar-B, Go-Pg and Co-Pg.

There were 104 patients with available surgical data. All patients had BSSO surgery with or without maxillary surgery. Patient age and gender were similar among the different surgeons, but one surgeon had no older patients (31-41). Two surgeons had 4 times as many 2 jaw as one jaw surgeries; the third surgeon had 1:1.20 times as many 2 jaw surgeries.

There was an insignificant difference in surgery time between 1 and 2 jaw surgery between the three patient age groups. There was increased blood loss for the older patients, and for 1 jaw surgery versus 2 jaw surgery. However, the amounts of blood loss were in the normal range and not of clinical concern. Average estimated blood loss has been reported to be 273.23 mL, where double-jaw procedures resulted in more blood loss than single-jaw procedures (Moenning JE et al, 1995). Usually, blood transfusions are received when blood loss is > 975 mL (Moenning JE et al, 1995).

When evaluating TMJ opening at 6 weeks, the older group showed significant limited jaw opening 24.5 mm – 30.5 mm, especially after 2 jaw surgery. Missing data for TMJ opening was reported in 28 subjects out of 104, which may have affected overall reliability. However, it may be concluded that younger patients are able to recover from surgery faster compared to older patients.

More post-surgical complications after 1 jaw surgery were observed in the older group, but younger patients had more post-surgical complications after 2 jaw surgery. Condylar resorption and infection were two of those complications.

One of the limitations of this study was the small number of patients with available lateral cephalometric radiographs. Among those patients, a few were also missing radiographs at some of the time points (mostly T2 and T3). Another limitation was the use of different cephalometric machines by oral surgeons and orthodontists, which may have affected the cephalometric measurements.

Of greatest clinical importance would be the long-term stability of orthognathic surgery performed in young (growing) patients versus older (non-growing) patients. Unfortunately, this study had no long-term records available to evaluate the long-term stability and/or relapse.

Conclusion

Young patients who had orthognathic surgery to correct a skeletal Class II malocclusion had similar orthodontic treatment outcomes and immediate surgical complications compared to older patients. Possible mandibular growth might have contributed to less A-P changes during orthodontic treatment in the younger group before and after the orthognathic surgery. Overall post-surgical complications were observed more in the younger group, especially TMJ pain, residual sensory loss, infection and condylar resorption. The older patients showed limited mouth opening at 6 weeks when compared to the younger group. Overall, there was no statistical or clinical difference in the “short term” A-P changes of mandibular advancement surgery between the growing and the nongrowing groups. Similar when comparing surgical complications between young and older patients.

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Appendix 1: Time between study points.

Variable	Overall, N = 35 ¹	13-19, N = 23	20-25, N = 6	33-40, N = 6	p-value ²
T1 to T2, months					0.21
Mean (SD)	21.2 (10.5)	22.3 (9.3)	14.2 (8.9)	27.6 (17.7)	
Median (IQR)	18.4 (14.5, 28.9)	21.5 (15.3, 29.2)	13.0 (9.6, 19.7)	31.6 (19.9, 37.3)	
Range	1.8, 43.0	8.7, 40.0	1.8, 26.7	8.2, 43.0	
T2 to T3, months					0.11
Mean (SD)	1.3 (1.0)	1.2 (0.8)	1.9 (1.4)	0.6 (0.3)	
Median (IQR)	0.9 (0.7, 1.4)	0.9 (0.7, 1.4)	1.4 (0.8, 2.9)	0.7 (0.5, 0.7)	
Range	0.2, 4.1	0.5, 3.5	0.7, 4.1	0.2, 0.9	
T3 to T4, months					0.019
Mean (SD)	10.4 (9.2)	12.8 (10.5)	4.7 (2.0)	7.0 (2.4)	
Median (IQR)	7.5 (5.7, 11.4)	8.8 (6.8, 13.8)	4.2 (3.0, 5.5)	7.4 (5.8, 8.6)	
Range	3.0, 45.2	4.6, 45.2	3.0, 7.8	3.8, 9.1	

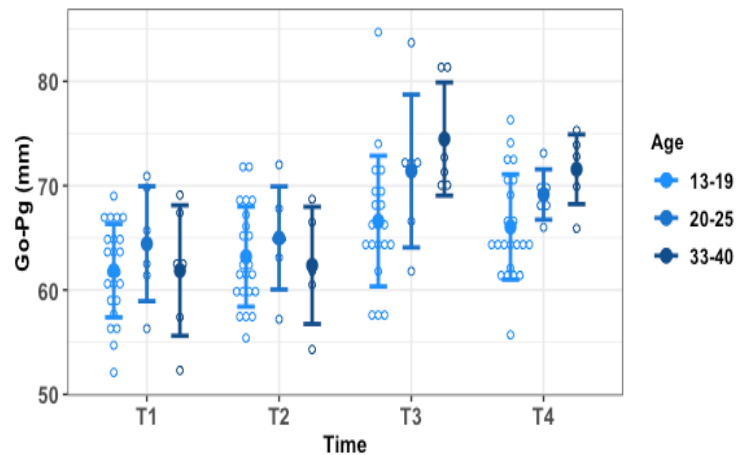
¹c("Mean (SD)", "Median (IQR)", "Range")

²Kruskal-Wallis rank sum test

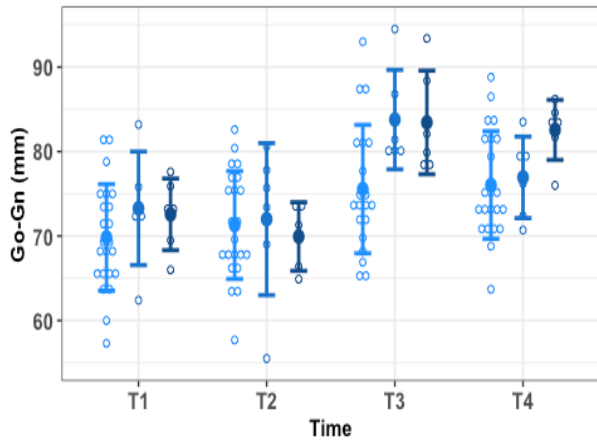
Appendix 2: Missing cephalometric data.

Missing Ceph Data	N = 35
T1	0
T2	2
T3	3
T4	1
T1 or T2	2
T2 or T3	4
T3 or T4	4

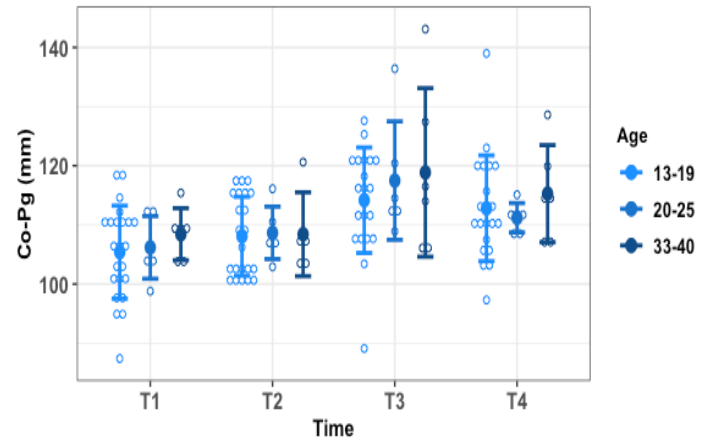
Appendix 3: Go-Pg by time and age.



Appendix 4: Go-Gn by time and age.



Appendix 5: Co-Pg by time and age



Appendix 6: Changes between T1 and T2 by age using Kruskal-Wallis test

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Go-Gn (mm)					0.12
Mean (SD)	0.43 (4.10)	1.45 (3.80)	-1.28 (4.38)	-1.96 (4.21)	
Median (IQR)	0.40 (-1.70, 3.80)	1.20 (-1.05, 3.87)	-1.40 (-3.58, -0.12)	-1.70 (-4.30, -1.10)	
Range	-7.30, 9.40	-7.30, 9.40	-6.90, 6.00	-7.00, 4.30	
Go-Gn (mm/yr)					0.44
Mean (SD)	0.09 (0.66)	0.02 (0.24)	0.40 (1.41)	-0.14 (0.34)	
Median (IQR)	0.01 (-0.12, 0.11)	0.05 (-0.06, 0.11)	-0.07 (-0.22, -0.01)	-0.03 (-0.27, 0.06)	
Range	-0.71, 3.27	-0.71, 0.51	-0.43, 3.27	-0.52, 0.14	
Go-Pg (mm)					0.87
Mean (SD)	1.39 (3.58)	1.57 (3.55)	0.55 (4.21)	1.60 (3.56)	
Median (IQR)	1.40 (-0.60, 3.60)	1.40 (0.00, 4.12)	1.30 (-2.10, 2.60)	2.00 (-1.00, 3.10)	
Range	-6.20, 8.50	-6.20, 8.50	-5.40, 6.30	-2.60, 6.50	
Go-Pg (mm/yr)					0.79
Mean (SD)	0.07 (0.40)	0.04 (0.26)	0.24 (0.74)	-0.06 (0.23)	

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Median (IQR)	0.05 (-0.04, 0.18)	0.04 (-0.02, 0.19)	0.09 (-0.10, 0.36)	0.05 (-0.13, 0.07)	
Range	-0.60, 1.58	-0.60, 0.45	-0.60, 1.58	-0.32, 0.10	
Co-Pg (mm)					0.21
Mean (SD)	2.66 (4.24)	3.32 (4.43)	2.47 (4.05)	0.02 (3.08)	
Median (IQR)	3.20 (-0.40, 5.40)	3.50 (1.88, 5.77)	3.15 (-0.35, 4.93)	-0.80 (-2.10, 0.20)	
Range	-8.40, 14.30	-8.40, 14.30	-3.10, 7.60	-2.40, 5.20	
Co-Pg (mm/yr)					0.25
Mean (SD)	0.22 (0.80)	0.10 (0.29)	0.76 (1.68)	-0.09 (0.14)	
Median (IQR)	0.13 (-0.02, 0.22)	0.15 (0.07, 0.21)	0.17 (-0.02, 0.41)	-0.02 (-0.14, -0.01)	
Range	-0.82, 4.14	-0.82, 0.62	-0.35, 4.14	-0.26, 0.01	

¹c("Mean (SD)", "Median (IQR)", "Range")

²Kruskal-Wallis rank sum test

Appendix 7: Changes between T3 and T4 by age using the Kruskal-Wallis test

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Go-Gn (mm)					0.058
Mean (SD)	-1.23 (6.23)	0.44 (5.84)	-6.83 (5.10)	-0.88 (5.99)	
Median (IQR)	-1.60 (-4.70, 1.80)	0.80 (-3.50, 2.55)	-5.80 (-8.62, -3.57)	-1.50 (-4.35, 2.70)	
Range	-15.60, 16.40	-8.60, 16.40	-15.60, -1.40	-8.80, 7.70	
Go-Gn (mm/yr)					0.019
Mean (SD)	-0.40 (1.16)	0.05 (0.66)	-1.78 (1.50)	-0.61 (1.20)	
Median (IQR)	-0.19 (-0.59, 0.15)	0.06 (-0.35, 0.23)	-1.30 (-2.98, -0.47)	-0.25 (-1.03, 0.17)	
Range	-3.72, 2.26	-0.67, 2.26	-3.72, -0.42	-2.29, 0.36	
Go-Pg (mm)					0.65
Mean (SD)	-1.48 (6.72)	-0.78 (7.00)	-2.25 (8.10)	-2.90 (4.88)	
Median (IQR)	-2.30 (-4.90, 2.65)	-2.10 (-4.60, 2.45)	-2.40 (-5.03, 3.90)	-3.45 (-5.68, 1.25)	

Variable	Overall ¹	13-19	20-25	33-40	p-value ²
Range	-17.60, 13.40	-17.60, 13.40	-15.30, 6.50	-9.60, 2.70	
Go-Pg (mm/yr)					0.33
Mean (SD)	-0.33 (1.17)	-0.10 (0.83)	-0.77 (2.00)	-0.80 (1.20)	
Median (IQR)	-0.31 (-0.72, 0.05)	-0.17 (-0.41, 0.07)	-0.80 (-1.06, -0.31)	-0.49 (-1.11, -0.18)	
Range	-3.65, 1.97	-1.78, 1.75	-3.65, 1.97	-2.50, 0.28	
Co-Pg (mm)					0.97
Mean (SD)	-3.12 (9.52)	-1.91 (9.62)	-6.28 (11.13)	-3.58 (8.32)	
Median (IQR)	-2.60 (-7.50, 0.05)	-2.60 (-7.30, 1.10)	-3.20 (-5.75, -0.43)	-3.90 (-8.25, 0.00)	
Range	-28.00, 21.90	-15.00, 21.90	-28.00, 2.80	-14.50, 9.20	
Co-Pg (mm/yr)					0.36
Mean (SD)	-0.64 (1.62)	-0.26 (1.08)	-1.94 (2.74)	-0.48 (1.28)	
Median (IQR)	-0.24 (-1.06, -0.01)	-0.21 (-0.82, 0.01)	-1.06 (-1.78, -0.14)	-0.49 (-1.24, 0.26)	
Range	-6.67, 3.02	-2.02, 3.02	-6.67, -0.07	-1.96, 1.01	

¹c("Mean (SD)", "Median (IQR)", "Range")

²Kruskal-Wallis rank sum test

Appendix 8: Other post-surgery complications.

Variable	Overall, N = 104 ¹	13-19, N = 69 ¹	20-28, N = 22 ¹	31-41, N = 13 ¹
TMJ pain	4 (3.8%)	3 (4.3%)	1 (4.5%)	0 (0.0%)
Limited lip movement	1 (1.0%)	0 (0.0%)	1 (4.5%)	0 (0.0%)
Muscle spasm headaches	2 (1.9%)	0 (0.0%)	1 (4.5%)	1 (7.7%)
Residual sensory loss	8 (7.7%)	6 (8.7%)	2 (9.1%)	0 (0.0%)
Infection Tx antibiotics	8 (7.7%)	6 (8.7%)	2 (9.1%)	0 (0.0%)
Infection screws	3 (2.9%)	1 (1.4%)	2 (9.1%)	0 (0.0%)
Condylar resorption	4 (3.8%)	3 (4.3%)	1 (4.5%)	0 (0.0%)

Variable	Overall, N = 104 ¹	13-19, N = 69 ¹	20-28, N = 22 ¹	31-41, N = 13 ¹
Additional surgery history complications	6 (5.8%)	2 (2.9%)	1 (4.5%)	3 (2.3%)

¹n (%)