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CEPHALOMETRIC ANALYSIS OF ADOLESCENTS WITH SEVERE CLASS II DIVISION 1 MALOCCLUSIONS TREATED SURGICALLY AND NON-SURGICALLY

by

Patrick Brady

A thesis submitted in partial fulfillment
of the requirements for the Master of
Science degree in Orthodontics in
the Graduate College of
The University of Iowa

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Graduate College
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Iowa City, Iowa

CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

Patrick Brady

has been approved by the Examining Committee for the
thesis requirement for the Master of Science degree in
Orthodontics at the May 2016 graduation.

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ABSTRACT

Introduction: Class II Division 1 malocclusions are characterized by a retrusive mandible and prominent upper incisors. Despite Class II malocclusions being one of the most frequently treated cases in orthodontists' office, there is no uniform consensus in the orthodontic community on the best treatment modality and biomechanical approach to use in treating patients with Class II malocclusions.

Purpose: This paper examines the end-of-treatment outcomes of severe Class II Division I malocclusion patients treated with surgical versus non-surgical approaches.

Study Design: This is a retrospective study of consecutively treated severe Class II Division I patients at the University of Iowa. Initial and deband lateral cephalometric radiographs were compared between 45 non-surgical and 21 surgical patients. All patients that were debanded between the ages of 13 to 19 years were included. Multivariable regression analyses were used to examine differences in outcomes between treatment groups.

Results: Following adjustment for patient level confounders (age, gender, and race), those treated surgically had better end of treatment cephalometric outcomes. Those treated surgically had a more balanced skeletal profile, greater reduction in overjet, and improvement in ANB angle ($p<0.05$). Those treated non-surgically had proclined mandibular incisors ($p<0.01$).

Conclusion: Orthodontic treatment in conjunction with orthognathic surgery is a more ideal treatment for patients with severe Class II Division I malocclusion. When treated surgically, a greater amount of overjet can be reduced while keeping lower incisors in a more stable position in bone.

PUBLIC ABSTRACT

Class II Division 1 malocclusions are characterized by a retrusive lower jaw and prominent upper incisors. Despite Class II malocclusions being one of the most frequently treated cases in orthodontists' office, there is no uniform consensus in the orthodontic community on the best treatment modality and biomechanical approach to use in treating patients with Class II malocclusions. This paper examines the end-of-treatment outcomes of severe Class II Division I malocclusion patients treated with surgical versus non-surgical approaches. This is a retrospective study of consecutively treated severe Class II Division I patients at the University of Iowa. Initial and deband lateral head films were compared between 45 non-surgical and 21 surgical patients. All patients that were debanded between the ages of 15 to 19 years were included. Following adjustment for patient level confounders (age, gender, and race), those treated surgically had better end of treatment outcomes. Those treated surgically had a more balanced skeletal profile, greater reduction in incisor prominence, and improvement in ANB angle ($p < 0.05$). Those treated non-surgically had proclined lower incisors ($p < 0.01$). Orthodontic treatment in conjunction with orthognathic surgery is a more ideal treatment for patients with severe Class II Division I malocclusion. When treated surgically, a greater amount of upper incisor prominence can be reduced while keeping lower incisors in a more stable position in bone.

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INTRODUCTION

National epidemiologic studies show that 23% of children, 15% of youths, and 13% of adults have overjet of five millimeters or more, suggesting a class II malocclusion (Proffit, Fields & Sarver, 2007). The most common Class II malocclusions is a Class II Division I malocclusion. This malocclusion is characterized by increased overjet and a retrognathic mandible. If not treated Class II malocclusions can lead to a number of functional and psycho-social problems. Patients with severe Class II Division I malocclusions are at increased risk for maxillary incisor injuries (Borzabadi-Farahani, Borzabadi-Farahani, & Eslamipour, 2010). A study by Martins-Junior, Marques, and Ramos-Jorge (2012) showed severe malocclusions can have an increased negative effect on children's quality of life. Another study by Seehara, Fleming, Newton and DiBiase (2011) showed Class II Division 1 patients are more likely to be bullied and have self-esteem issues. Orthodontic treatment can be a tremendous help for these patients and improve their quality of life.

There are three main treatment categories for severe Class II Division 1 malocclusions. All of which have been shown to be effective (Proffit, Fields & Sarver 2007). These main categories are: 1) Orthopedic growth modification 2) Masking - during which teeth are moved to compensate for the underlying skeletal discrepancy 3) Orthognathic Surgery. The complexity of Class II Division I malocclusions ranges from mild to severe, and its manifestation is dependent on a multitude of growth, dental, and skeletal related factors (Janson, Sathler, Fernandes, Zanda & Pinzan, 2010). Often with Severe Class II Division 1 malocclusions there is a significant skeletal component. Mandibular advancement surgery is often the ideal treatment, because it addresses the underlying skeletal discrepancy, but patients do not always accept this procedure. When this occurs, non-surgical alternatives may be proposed, but this results in treatment that camouflages the skeletal imbalance. Camouflage treatment can result in acceptable occlusal correction, but there may be compromises in the skeletal and facial esthetic outcomes (Berger, Pangrazio-Kulbersh, George & Kaczynski, 2005; Chaiyongsirisern, Rabie & Wong, 2009; de Lir Ade, de Moura, Oliveira-Ruellas, Gomes-Souza & Nojima, 2013;

Kinzinger, Frye & Diedrich, 2009; Mihalik, Proffit & Phillips, 2003; Millett, Cunningham, O'Brien, Benson & de Oliveira, 2012; Proffit, Phillips & Douvartzidis, 1992; Tucker, 1995; Wigal et al., 2011).

Despite Class II malocclusions being one of the most frequently treated cases in orthodontists' office, there is no consensus in the orthodontic community on the best treatment modality and biomechanical approach to use in treating these patients. Furthermore, the quality of studies examining outcomes in this cohort appears to be questionable with a large proportion of published trials suffering from high risks for bias (Jambi, Thiruvenkatachari, O'Brien, & Walsh, 2013; Koletsi, Pandis, & Fleming, 2014; Lembesi, Koletsi, Fleming, & Pandis, 2014; Millett et al., 2006; Millett et al., 2012; Thiruvenkatachari, Harrison, Worthington & O'Brien, 2013). Consequently, there is a need for well designed studies that are generalizable in this area.

To help address the lack of well-designed and generalizable studies the American Association of Orthodontist recently created the Practice Based Research Network Committee (PBRN) in 2013. The PBRN is a collection of private practice orthodontists all over the country who have volunteered to participate in research projects. The AAO surveyed their members for research topics to be performed in the PBRN. One of the top three responses that orthodontist wanted to research was severe Class II correction. One of The University of Iowa Orthodontic faculty members, Dr. Allareddy was chosen to be the lead researcher on this project which should start in a year or two. This research project will serve as a pilot study for that NIH funded project.

This research will focus on cephalometric outcomes of severe Class II Division 1 malocclusions in adolescents treated surgically and non-surgically. This is an important area of research, because there has only been one previous research project comparing outcomes of surgical vs. non-surgical treatment of patients in mid- to late adolescents (Proffit, Phillips, Tulloch, & Medland, 1992). Assessing treatment outcomes in adolescents is important, because it is one of the most common ages for orthodontic treatment. These patients often have moderate to little growth remaining, which can limit an orthodontists treatment options.

REVIEW OF THE LITERATURE

Cochrane Collaboration performs systematic reviews of randomized controlled trials and seeks to identify the best evidence based practices. These reviews are often considered the gold standard for making evidence based decisions. During recent years three Cochrane Collaboration reviews have examined outcomes in patients with Class II malocclusions (Thiruvenkatachari et al., 2013; Jambi et al., 2013; Millett at al., 2006).

Thiruvenkatachari et al. (2013) sought to answer whether early two phase treatment initiated between the ages of 7-11 years old, is better than one phase treatment initiated between 11-16 years old in Class II Division 1 patients. The review included 17 studies that examined the effects of removable, fixed orthodontic, and functional appliances on outcomes. The review found that early treatment lead to better outcomes immediately following the first phase of treatment. These patients had less incisor trauma and better alignment of teeth, however, there was no difference between the two groups at the end of comprehensive treatment. A major issue identified in this review was that 11 of the included 17 studies were considered to be at a high risk of bias. Consequently, the quality of evidence was deemed to be low. Based on the evidence available the authors suggested that two phase treatment is not better than one phase treatment when the additional cost of two phase treatment is considered.

Another Cochrane collaboration review by Jambi et al. (2013) examined the efficacy of orthodontic treatment for distalizing maxillary first molars for Class II correction. The appliances used for Class II correction included head gear, Forsus springs, Jasper Jumpers, and several appliances similar to a pendulum appliance. This review included 10 studies published between the years 2005 and 2011. The study concluded that intraoral appliances are more effective at distalizing molars than headgear, however they cause anterior anchorage lose. This review also concluded that the quality of trials examining orthodontic treatment for maxillary molar distalization is low to very low and any conclusions made from these results should be done cautiously.

The third Cochrane Review by Millett et al. (2006) examined the effectiveness of extraction and non-extraction treatment on Class II Division II malocclusions in adolescents less than 16 years old. No studies with surgical treatment were included. The study was not able to identify a single randomized controlled trial or clinical controlled trial to examine outcomes in this cohort, thus the authors could not provide any evidence based guidance.

These three reviews offer the best clinical evidence for basing treatment decision in Class II patients, however, they found the quality of evidence in this area to be low to very low. None of the reviews addressed the same exact question of this study. Thiruvenkatachari et al. (2013) examined best time for treatment. Jambi at al. (2013) examined the most effective way to distalize maxillary molars and did not include a surgical treatment group. Millett et al. (2006) had the chance to offer some solid guidelines for best treatment approach for Class II patients, albeit Division 2, and they found such poor research in the area that they could not make any treatment recommendations. Millett et al. (2006) also failed to include a surgical group.

Even though no systematic review has been performed to determine the best treatment approach for Class II Division 1 malocclusion there is some helpful research in this area. There is only one research project that has compared outcomes of adolescents treated surgically and non-surgically. Most of the research comparing surgical to non-surgical treatment has been performed in non-growing adults.

Proffit et al. (1992) is the most similar research to our study. Both papers compare cephalometric outcomes for surgical and non-surgical treatment in adolescents. Proffit et al. identified three groups: 40 successfully treated surgical patients, 40 successfully treated non-surgical patients, and 21 unsuccessfully treated non-surgical patients. They identified four big factors that lead to unsuccessful non-surgical treatment: 1) Initial overjet ≥ 10 mm 2) Distance from pogonion to nasion perpendicular is ≥ 18 mm 3) Mandibular body length is ≤ 70 mm 4) Facial height is ≥ 125 mm. Although treatment can never be based on numbers alone, these four factors can help push borderline patients into a surgical treatment.

There is one other study that compares adolescents to a surgical group. Berger et al. (2005) compared cephalometric outcomes for 15 Herbst and 15 Frankel cases treated at an average age of 10

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years old to 30 BSSO advancement cases treated at an average age of 27 years old. At the end of treatment the functional appliance group had more proclined lower incisors, a larger naso-labial angle, a shallower occlusal plane, and a longer lower lip length. The proclined lower incisors and larger naso-labial angle would be expected from the dental movement seen with functional appliances of retracting upper incisors and proclining lower incisors to fix class II malocclusions. This is valuable information when treating class II children, but many patients do not present until they are older.

Another study by Proffit, Phillips and Douvartzidis (1992) sought to answer a similar question to ours, but the participants were adults with no growth remaining. Cephalometric and cast measurements were compared between a BSSO advancement group and a premolar extraction group. The results for this study indicate the final occlusion was acceptable in both groups as seen in similar buccal interdigitation scores, but the surgical group fared better in most cephalometric measurements. The surgery group had a better ANB, maxillary incisor proclination, mandibular incisor position, soft tissue A and B difference and overjet. There was also a greater improvement in profile esthetics for the surgical group compared to the non-surgical group. Patients profiles were just as likely to be harmed as helped by masking treatment with premolar extraction. Despite the large improvement in surgically treated patients' profiles, because their initial esthetic ratings were low their final esthetic ratings were less than the masking group's initial esthetic rating.

Another study on adults by Kinzinger, Frye, & Diedrich (2009). compared the cephalometric measurements for adults treated with surgery, upper premolar extraction or a mandibular advancing appliance. The results were similar to what would be expected. All three treatments are viable options. All three reduced skeletal convexity, but only surgery significantly decreased facial convexity. Upper premolar extraction increased the naso-labial angle. Herbst treatment lead to proclination of the lower incisors and retraction of the upper incisors.

Two papers have compared herbst and surgical outcomes in adults. Ruf and Pancherz (2003) and Chayongsirisern, Rable and Wong (2009) compared cephalometric outcomes for herbst treatment on 22 year old patients to surgery patients between 24-26 years old. Both papers found similar results to each

other and to Kinzinger, Frye, & Diedrich (2009). Surgery had a greater influence on facial profile, but a herbst appliance is acceptable to use on borderline surgical patients who are not concerned about their profile. A herbst appliance will correct Class II malocclusions in adults by dental movements. As long as the gingiva can withstand lower incisor proclination, the herbst can correct the malocclusion.

There is a fair amount of research investigating surgical vs non-surgical treatment in adults, but relatively little research has been done comparing surgical and non-surgical treatment in adolescents. Most of the research is small single center retrospective studies. This research project will add to the scarce research on surgical vs non-surgical treatment in adolescents and it will set the groundwork for the NIH funded PBRN study to be performed by Dr. Allareddy at the University of Iowa. In this way the research will also help solve some of the problems that the Cochrane Collaboration Review articles identified in the literature.

MATERIALS AND METHODS

This is a retrospective study using records at the University of Iowa Orthodontic department. A patient database was searched for consecutively treated patients that met the following criteria: 1) Deband between the ages of 13 and 19 years old 2) ≥ 6mm of initial OJ 3) at least one half step class II molar. We initially sought 50 surgical and 50 non-surgical patients, but were unable to find enough patients. We identified 30 surgical patients and 56 non-surgical patients, but several had to be eliminated due to incomplete records. The final patient count was 21 surgical (8 female, 13 male) and 45 non-surgical (26 female, 19 male) patients. Group characteristics can be seen in Table 1. All patients except four were white. There were two hispanic and two mixed race patients in the non-surgical group. The mean age for surgical patients was 14.7 years old at the start of treatment, and 17.3 years old at deband. The mean age for non-surgical patients was 12.6 years old at the start of treatment, and 15.1 years old at deband. Mean treatment duration was 31.5 months for surgical and 29.1 months for non-surgical patients. There were five consent debands for the surgical group and 10 for the non-surgical group. A Pearson Chi-square and Fisher's Exact test were performed to compare surgical and non-surgical groups for gender, race, age at start, age at deband, duration of treatment, and consent deband. These results can be seen in Table 1. The Fisher's Exact test was performed, because it is a more conservative measure.

Table 1. Comparison of initial group characteristics

	Surgery		Non-Surgery		Pearson Chi-Square	Fisher's Exact Test	T-test
Gender	8 F	13 M	26 F	19 M	0.136 NS	0.188 NS	
Race	0 Non-white	21 white	4 Non-white	41 White	0.159 NS	0.298 NS	
Age at Start		176.7 months		151.8 months			.001 *
Age at Deband		208.2 months		181.6 months			.001 *
Treatment Duration		31.5 months		29.1 months			0.348 NS
Consent Debands		5		10	0.886 NS	1.00 NS	

Within the surgical group there were several treatment approaches. The 21 surgical procedures included 2 bi-maxillary surgeries, 3 single jaw maxillary impactions and 16 single jaw mandibular advancements. Nine patients had a genioplasty, eight with mandibular advancements alone and one with a maxillary impaction alone. Ten of the twenty-one surgeries included premolar extractions.

In the non-surgical group there were 14 patients treated with premolar extractions, 25 with HG, 4 with Herbst appliances, and 1 with a Forsus. In the extraction group 1 patient had upper and lower premolars extracted, while the remaining 13 had only upper premolars extracted. In patients treated with HG 23 of the 25 patients also used various amounts of class II elastics.

Initial and final lateral cephalometric radiographs were transported into Dolphin Imaging. The following cephalometric landmarks were traced and can be found in Figure 1: Sella, Porion, Orbitale, Nasion, A Point, B Point, U1 Incisal Edge, U1 Root Tip, L1 Incisal Edge, L1 Root Tip, Menton, and Constructed Gonion. Angular and linear measurements can be seen in Figure 2. To determine if there was a normal distribution for the cephalometric landmarks a Kolmingorov-Smirnov test for normality of distribution was performed. These results can be seen in Table 2. Due to the non-normal distribution a Mann-Whitney Test was used to compare the initial, final and average change for the surgical versus the non-surgical group. To control for the possible confounding variables of gender, age, race, and consent debands multivariable linear regression was performed. To calculate inter- and intra-rater reliability one researcher traced 10 radiographs twice and a second researcher traced the same 10 radiographs once. The remaining radiographs were traced by the first researcher over several weeks.
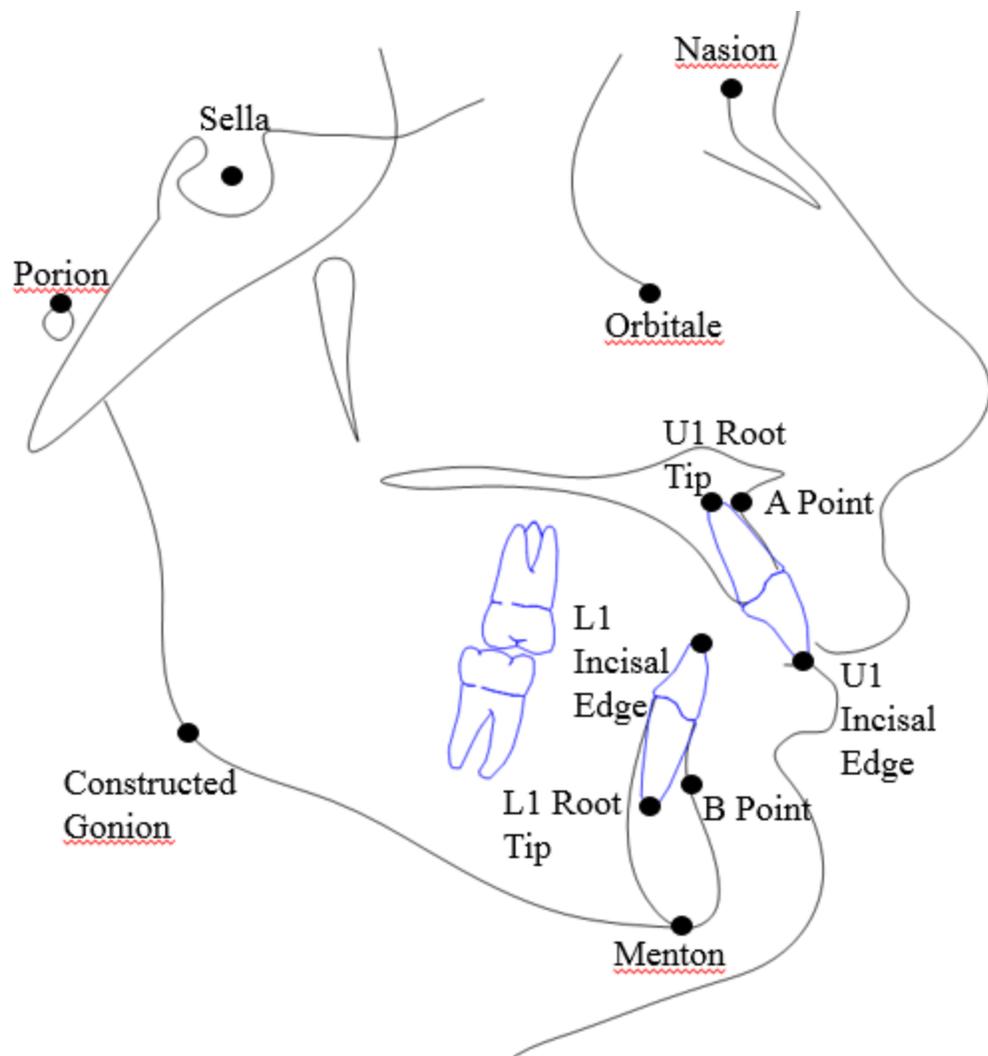
Figure 1. Cephalometric landmarks.
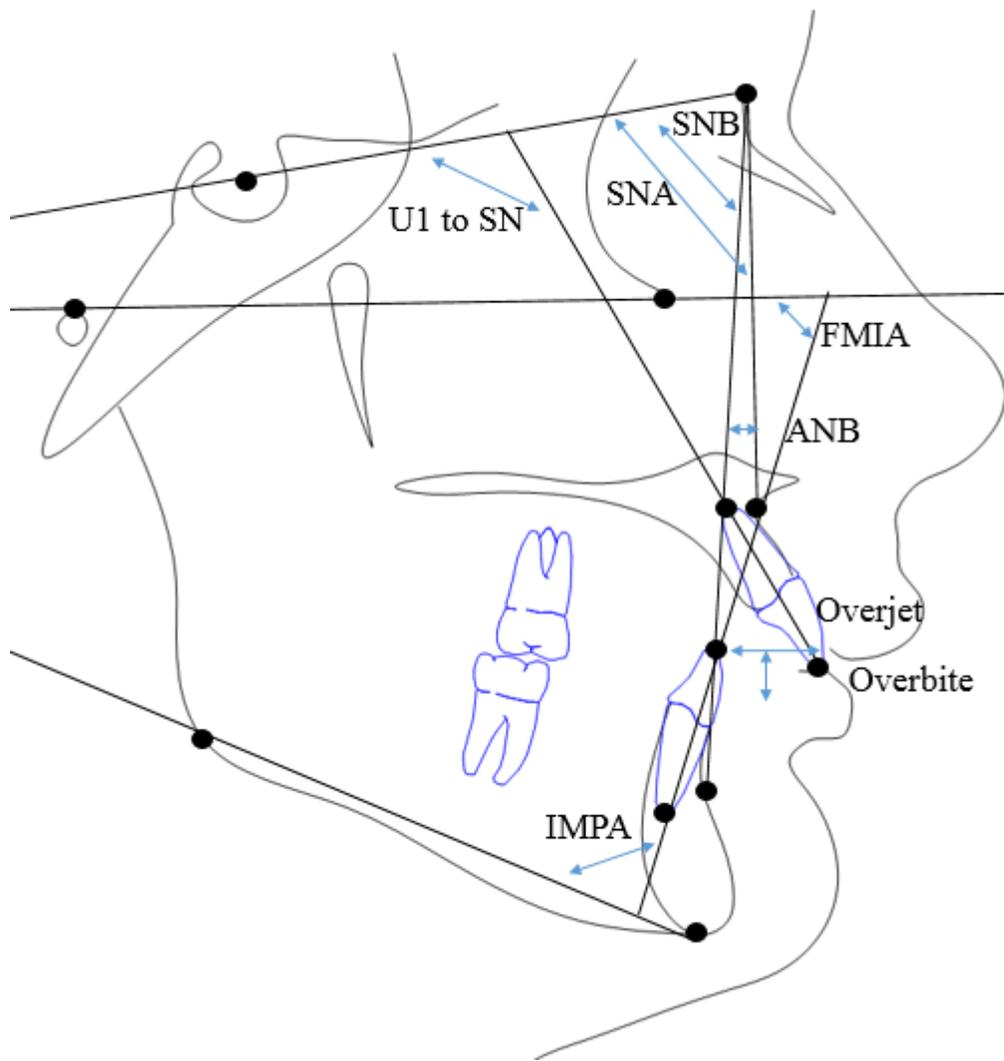
Figure 2. Angular and linear cephalometric measurements.

Table 2. Kolmingorov-Smirnov test for normality of distribution.

| | N | Normal Parameters[a,b] | | Asymp. Sig. (2-tailed) |
		Mean	Std. Deviation	
Initial SNA	66	78.5965	3.20491	.200[c,d]
Initial SNB	66	74.232	3.5271	.200[c,d]
Initial ANB	66	4.358	2.2101	.200[c,d]
Initial FMIA	66	60.855	7.9139	.200[c,d]
Initial IMPA	66	94.224	7.2983	.200[c,d]
Initial U1 to SN	66	107.198	7.2058	.200[c,d]
Initial Ceph OB	66	4.552	2.5536	.000[d]
Initial Ceph OJ	66	8.6895	2.43391	.031[d]
Deband Ceph SNA	66	77.820	3.4250	.200[c,d]
Deband SNB	66	75.511	3.9179	.200[c,d]
Deband ANB	66	2.298	2.3351	.056[c]
Deband FMIA	66	57.295	6.6713	.200[c,d]
Deband IMPA	66	97.683	7.0954	.026[d]
Deband U1 to SN	66	102.511	8.4500	.061[c]
Deband OB	66	1.733	.8511	.200[c,d]
Deband OJ	66	2.967	1.0965	.018[d]
Change of SNA from Initial to Deband	66	.7768	1.67689	.200[c,d]
Change of SNB from Initial to Deband	66	-1.2788	2.11060	.080[c]
Change of ANB from Initial to Deband	66	2.0591	1.92514	.058[c]
Change of FMIA from Initial to Deband	66	3.5591	6.62705	.200[c,d]
Change of IMPA from Initial to Deband	66	-3.4591	6.37278	.200[c,d]
Change of U1 to SN from Initial to Deband	66	4.6879	9.21278	.200[c,d]
Change of OJ from Initial to Deband	66	5.7229	2.61050	.200[c,d]
Change of OB from Initial to Deband	66	2.8182	2.47616	.033[d]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

RESULTS

Intra-examiner and inter-examiner **r**eliability measurements can be seen for all cephalometric points in Table 3. All cephalometric points had excellent reliability. The smallest intra-class correlation coefficient was 0.824 for inter-examiner A-point. The mean intraclass correlation coefficient for all the cephalometric landmarks was 0.949.

Table 3. Correlation coefficients for Inter- and Intra-examiner reliability.

Cephalometric Measurement	Inter-Examiner Reliability	Intra-Examiner Reliability
SNA	0.824	0.952
SNB	0.977	0.985
ANB	0.901	0.971
FMIA	0.953	0.98
IMPA	0.89	0.942
U1 to SN	0.921	0.966
Overbite	0.964	0.977
Overjet	0.955	0.991

A comparison of surgical and non-surgical groups for gender, race, age at start, age at deband, duration of treatment, and number of consent debands can be found in Table 1. There was no significant difference between the groups for gender, race, duration of treatment, or number of consent debands. The only significant difference between the groups was the age at start and deband. The non-surgical group was on average about two years younger than the surgical group at both start of treatment and deband.

To determine if non-parametric tests should be used for comparison of cephalometric points a Kolmingorov-Smirnov test for normality of distribution was completed. The results can be seen in Table 2. The test showed that initial overbite, initial overjet, deband IMPA, deband overjet, and percent change in overbite were not normally distributed. Due to these results we used the non-parametric Mann Whitney test to compare initial cephalometric, deband cephalometric and average change measurements between the groups.

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A comparison of the initial cephalometric measurements can be seen in Table 5. The surgical and non-surgical groups had a significantly different initial overjet, SNB, and ANB. All other measurements were not significantly different. The surgical group had a larger overjet, larger ANB angle and smaller SNB angle. The surgical groups overjet was about 2.2 mm greater, ANB angle was about 2.5 degrees greater, and SNB angle was about 2.5 degrees less.

Table 4. Comparison of initial cephalometric measurements.

Cephalometric Measurement	Treatment	Mean	SD	Mann-Whitney U	Sig.
SNA	Surgical	78.4	2.6	455	NS
	Non-Surgical	78.6	3.5		
SNB	Surgical	72.4	3.4	298.5	*
	Non-Surgical	75.1	3.3		
ANB	Surgical	5.9	2.0	196.5	*
	Non-Surgical	3.6	1.9		
FMIA	Surgical	60.7	9.1	452.5	NS
	Non-Surgical	60.9	7.4		
IMPA	Surgical	92.0	8.3	359.5	NS
	Non-Surgical	95.3	6.6		
U1 to SN	Surgical	106.2	9.3	459	NS
	Non-Surgical	107.7	6.1		
Overbite	Surgical	4.3	3.8	457	NS
	Non-Surgical	4.7	1.7		
Overjet	Surgical	10.2	2.6	232.5	*
	Non-Surgical	8.0	2.0		

A comparison of final cephalometric measurements can be seen in Table 6. The surgical and non-surgical groups had a significantly different IMPA. All other measurements were not significantly different. The non-surgical groups IMPA was about 7.0 degrees greater.

Table 5. Comparison of deband cephalometric measurements.

Cephalometric Measurement	Treatment	Mean	SD	Mann-Whitney U	Sig.
SNA	Surgical	77.8	2.6	440	NS
	Non-Surgical	77.8	3.8		
SNB	Surgical	75.2	3.5	461.5	NS
	Non-Surgical	75.7	4.1		
ANB	Surgical	2.6	2.8	460	NS
	Non-Surgical	2.2	2.1		
FMIA	Surgical	58.3	5.2	403	NS
	Non-Surgical	56.8	7.3		
IMPA	Surgical	92.9	8.0	223	*
	Non-Surgical	100.0	5.4		
U1 to SN	Surgical	103.1	10	454	NS
	Non-Surgical	102.2	7.6		
Overbite	Surgical	1.5	1.0	354.5	NS
	Non-Surgical	1.8	0.8		
Overjet	Surgical	3.0	0.9	420	NS
	Non-Surgical	2.9	1.2		

A comparison of the average change from initial to deband measurements can be seen in Table 7. The surgical and non-surgical groups had a significantly different average change in SNB, ANB, IMPA, and OJ. All other measurements were not significantly different. There was an average of 2.2 degree greater increase in SNB, a 1.8 degree greater reduction in ANB, 3.8 less degrees of proclination in IMPA, and 2.2 mm of greater overjet reduction.

Table 6. Comparison of change from initial to deband in cephalometric measurements.

Cephalometric Measurement	Treatment	Mean	SD	Mann-Whitney U	Sig.
Change of SNA Initial to Deband	Surgical	0.6	1.6	449	NS
	Non-Surgical	0.9	1.7		
Change of SNB Initial to Deband	Surgical	-2.8	2.0	179.5	*
	Non-Surgical	-0.6	1.8		
Change of ANB Initial to Deband	Surgical	3.3	2.0	223	*
	Non-Surgical	1.5	1.6		
Change FMIA Initial to Deband	Surgical	2.4	7.8	365.5	NS
	Non-Surgical	4.1	6.0		
Change IMPA Initial to Deband	Surgical	-0.9	7.1	314.5	*
	Non-Surgical	-4.7	5.7		
Change U1 to SN Initial to Deband	Surgical	3.1	10	423.5	NS
	Non-Surgical	5.4	8.8		
Change Overbite Initial to Deband	Surgical	2.8	3.6	237	*
	Non-Surgical	2.8	1.8		
Change Overjet Initial to Deband	Surgical	7.2	2.4	462	NS
	Non-Surgical	5.0	2.4		

The results for our multivariable linear regression analysis can be seen in Tables 8-15. These results show that when controlling for gender, age, race, and number of consent deband patients in each group the average change in ANB, SNB, and overjet were still significantly different between the groups. There appears to be a confounding variable that is affecting IMPA, because it was not significantly different according to the linear regression analysis.

Table 7. Multivariable linear regression analysis for change in SNA.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	.709	1.803		.393	.696	-2.898	4.316
	Male Gender	.210	.425	.063	.495	.622	-.639	1.059
	AgeinYears_Start	-.068	.126	-.078	-.540	.591	-.320	.184
	White Race	1.208	.891	.173	1.356	.180	-.574	2.990
	Patient elected to deband by giving consent	-.743	.502	-.187	-1.481	.144	-1.747	.261
	Treatment Group	-.299	.525	-.084	-.570	.571	-1.350	.751

Table 8. Multivariable linear regression analysis for change in SNB.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	-1.987	2.024		-.982	.330	-6.035	2.061
	Male Gender	-.172	.476	-.041	-.361	.720	-1.125	.781
	AgeinYears_Start	.018	.141	.016	.124	.902	-.265	.300
	White Race	1.435	1.000	.163	1.435	.156	-.565	3.435
	Patient elected to deband by giving consent	-.264	.563	-.053	-.469	.641	-1.390	.863
	Treatment Group	-2.294	.589	-.510	-3.892	.000	-3.473	-1.115

Table 9. Multivariable linear regression analysis for change in ANB.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	2.522	1.882		1.340	.185	-1.243	6.287
	Male Gender	.419	.443	.110	.945	.349	-.468	1.305
	AgeinYears_Start	-.071	.132	-.072	-.542	.590	-.334	.192
	White Race	-.231	.930	-.029	-.249	.805	-2.091	1.629
	Patient elected to deband by giving consent	-.516	.524	-.113	-.986	.328	-1.564	.531
	Treatment Group	1.942	.548	.474	3.543	.001	.846	3.039

Table 10. Multivariable linear regression analysis for change in FMIA.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	7.845	6.926		1.133	.262	-6.010	21.699
	Male Gender	-.938	1.631	-.071	-.575	.567	-4.200	2.323
	AgeinYears_Start	-.708	.484	-.207	-1.463	.149	-1.676	.260
	White Race	6.604	3.422	.240	1.930	.058	-.240	13.448
	Patient elected to deband by giving consent	-1.813	1.927	-.116	-.941	.351	-5.668	2.042
	Treatment Group	-.611	2.017	-.043	-.303	.763	-4.647	3.424

Table 11. Multivariable linear regression analysis for change in IMPA.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	-12.180	6.407		-1.901	.062	-24.996	.635
	Male Gender	-.085	1.508	-.007	-.057	.955	-3.102	2.932
	AgeinYears_Start	.905	.448	.275	2.021	.048	.009	1.800
	White Race	-4.817	3.165	-.182	-1.522	.133	-11.148	1.514
	Patient elected to deband by giving consent	2.183	1.783	.145	1.225	.225	-1.383	5.749
	Treatment Group	2.350	1.866	.173	1.259	.213	-1.383	6.082

Table 12. Multivariable linear regression analysis for change in U1 to SN.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	-5.751	9.914		-.580	.564	-25.583	14.081
	Male Gender	-3.318	2.334	-.181	-1.422	.160	-7.987	1.351
	AgeinYears_Start	.939	.693	.197	1.356	.180	-.447	2.325
	White Race	.895	4.898	.023	.183	.856	-8.903	10.692
	Patient elected to deband by giving consent	-.564	2.759	-.026	-.204	.839	-6.082	4.955
	Treatment Group	-3.667	2.888	-.187	-1.270	.209	-9.443	2.110

Table 13. Linear regression analysis for change in overjet.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	5.645	2.537		2.225	.030	.571	10.719
	Male Gender	-.291	.597	-.056	-.487	.628	-1.486	.903
	AgeinYears_Start	-.037	.177	-.028	-.211	.834	-.392	.317
	White Race	.410	1.253	.038	.327	.745	-2.097	2.916
	Patient elected to deband by giving consent	-1.773	.706	-.287	-2.512	.015	-3.185	-.361
	Treatment Group	2.307	.739	.415	3.122	.003	.829	3.785

Table 14. Linear regression Analysis for change in overbite.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	1.517	2.638		.575	.568	-3.760	6.794
	Male Gender	1.356	.621	.276	2.183	.033	.114	2.598
	AgeinYears_Start	.040	.184	.031	.216	.830	-.329	.409
	White Race	.451	1.303	.044	.346	.731	-2.156	3.058
	Patient elected to deband by giving consent	-.764	.734	-.130	-1.041	.302	-2.233	.704
	Treatment Group	-.425	.768	-.081	-.553	.582	-1.962	1.112

DISCUSSION

The surgical and non-surgical groups were significantly different in two demographic characteristics. The surgical group was significantly older at the start and end of treatment, by about two years. Ideally we would like to see both treatment groups be similar on all measures, but this age difference is similar to the only other paper that compared a teenage surgical group to a teenage non-surgical group (Proffit et al., 1992). On average our patient population was about two years older compared to Proffit et al. (1992). This age difference is not surprising as most orthodontists and surgeons want to wait for a majority of growth to be completed before starting surgical treatment. The groups were similar in all other characteristics: race, gender, consent debands and duration of treatment.

There were also several differences in initial cephalometric measurements. The surgical group had greater overjet, a smaller SNB angle and a greater ANB angle. The magnitude of the difference is similar to other studies in this area. (Camilla Tulloch, Lenz & Phillips, 1999; Mihalik, Proffit & Phillips, 2003; Proffit, Phillips & Douvartzidis, 1992; Proffit et al., 1992). Ideally, we would like to see both groups similar on all measures, but this is difficult to do, as can be seen from similar results in multiple studies. This difference can be expected for several reasons. Surgery has inherent risks including death that many patients and orthodontists want to avoid unless there is no alternative. Therefore, surgery is often reserved for the most severe cases. In their paper Mihalik, Proffit, and Phillips (2003) state that surgery and masking are not alternative treatments for comparable problems. Ideally that is what we are trying to find from studies like this. When there is a true border line case that could be treated surgically or non-surgically we want to know which treatment approach is better. This is difficult to do because patient desires greatly influence treatment approach, especially with surgery. Surgical patients often differ from non-surgical patients in a few ways. Surgical patients often see themselves as more abnormal than non-surgical patients (Bell, Kiyak, Joondeph, McNeill, & Wallen, 1985) and they often suffer from body dysmorphic disorders at a higher rate than the general population (Collins, Gonzalez, Gaudillierre, Shrestha, and Girod, 2014). To create the ideal study patients would need to be randomly assigned to

treatment groups, but it would be difficult to get patients to consent, because many want to avoid surgery at all costs.

The only significant difference for deband cephalometric measurements was IMPA. The non-surgical group had more proclined lower incisors (92.9º vs 99.9º). This is not surprising as many non-surgical treatments lead to proclination of lower incisors to reduce overjet. In the surgical group lower premolars were extracted in 9 of 21 patients. The purpose for this was most likely two fold. First, Class II dental compensations often appear as proclined lower incisors. Whenever this occurs lower premolars can be extracted to decompensate the incisors and place them within the alveolus. Second, lower premolar extractions in a deficient mandible help maximize the mandibular advancement. The lower premolar extractions in the surgical group along with the proclination of lower incisors in the non-surgical group most likely explains the difference in IMPA.

There were several differences between the groups in terms of average change. The surgical group had significantly greater reduction in overjet, increase in SNB, decrease in ANB and less proclination of lower incisors. However, when multivariable linear regression analysis was performed it showed the difference in IMPA was influenced by gender, age, race or consent debands. This result suggests that if a patient has a larger amount of overjet or skeletal convexity surgery will improve these cephalometric measurements to a greater extent. The difference in average change may reflect the greater initial discrepancy in the surgical group. Both treatment approaches led to acceptable outcomes in most cases, but the surgical group did so by addressing this greater initial discrepancy.

The long term implications of these results is a little unclear. Some studies have found that proclination of lower incisors is unstable (Litowitz, 1948) and (Mills, 1966). Another study by Artun, Krogstad, and Little (1990) found that proclination of incisors was stable, but this was in class III patients with dental compensations in the opposite direction of our sample. Possibly the most relevant to our study is Artun, Garol, and Little's (1996) research on long term stability of class II Div 1 malocclusions. They only had two groups: 1) non extraction and 2) four premolar extraction. There was no surgical group. The only predictors of incisor relapse were narrow pretreatment intercanine width and increased

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incisor irregularity. They did not find an association between lower incisor proclination and subsequent

crowding. One could assume that the more crowded the lower incisor region the more proclination of the

lower incisors in non-extraction treatment. The authors state that incisor crowding is likely multifactorial

which makes it difficult to establish simple correlations of clinical significance. The one thing that

remains constant in all of Little's articles on retention is that intercanine width decreases with time and

arch length decreases with time. If retainers are not worn for life some degree of crowding is certain.

This may suggest that a fixed retainer on non-surgical cases is a good idea.

Another concern for long term stability is gingival health. There is also some debate over the

effect of lower incisors proclination on gingival recession. Some papers have found an increased risk of

gingival recession due to lower incisor proclination (Artun & Krogstad, 1987; Dorfman, 1978; Fuhrmann,

1996; Hollender, Ronnerman & Thilander, 1980), while others have not (Artun & Groberty, 2001; Djeu,

Hayes & Zawaideh, 2002; Melsen & Allais, 2005; Ruf, Hansen & Pancherz, 1998). A systematic review

by Aziz and Flores Mir (2011) found no effect of lower incisor proclination on gingival recession. They

concluded that gingival recession is more likely related to oral hygiene, periodontal health and

periodontal characteristics. The authors did acknowledge that there are some shortcomings in the

included studies. All were retrospective and some relied on cast measurements. All the measurements

were performed on initial and final records. It's possible that some patients experienced gingival

recession mid-treatment and then had their lower incisors retracted with inter-proximal reduction. Such

treatment could make finding correlations between incisor proclination and gingival recession difficult.

Another concern for long term retention is surgical stability. Two articles have addressed

stability of surgical versus non-surgical treatment in severe Class II Division 1 malocclusions. Cassidy,

Herbosa, Rotskoff and Johnston (1993) recalled a group of surgery patients 4.7 years after treatment and a

non-surgical group 7.1 years after treatment. They found that both groups had similar amounts of relapse,

but the surgical group had 3 of 26 patients that underwent extensive relapse. They assumed the relapse

was due to condylar resorption. Another paper by Mihalik, Proffit and Phillips (2003) recalled 31 ortho

only masking patients 14 years post deband and compared them to a similar surgery group from a

previous study. They found surgery patients were twice as likely to have an increase in overjet. The surgery group was also more likely to have TMJ issues. Both groups were positive about their outcomes, but the surgical group had a more positive dentofacial self-image. Another interesting paper on surgical stability by Proffit, Phillips and Turvey (2010) compared surgical stability for adult versus adolescent surgery. The adolescent group had greater relapse than the adult group. Both groups had similar levels of satisfaction with treatment and outcomes. Taking all of these studies into consideration, surgery appears to be stable, but it does seem to have a higher risk of relapse in overjet especially in younger patients. Despite this relapse patients are still satisfied with treatment. The improved dentofacial self-image is important if a patient has profile concerns at the beginning of treatment, and is worth the increased risk of overjet relapse.

Taking everything into consideration patient preference is most likely the biggest factor in deciding between surgical and non-surgical treatment. Both treatment approaches can result in satisfactory occlusion, but if a patient has profile concerns surgery will be able to improve profile to a greater extent than non-surgical treatment. Depending on amount of growth remaining non-surgical treatment is a viable option, but it will likely result in more proclined lower incisors. There is debate on the influence of incisor proclination on stability and gingival recession. If a non-surgical treatment is chosen the orthodontist should use a fixed retainer to relieve stability concerns. Discussing the possibility of gingival recession with patients would also be wise. Striving for good oral hygiene practices should lessen some fear about gingival recession.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

There are several limitations to this study. It is a single center study so the results may not be generalizable to other locations. It is a retrospective design so patients cannot be randomly assigned to treatment groups. There is limited diversity in the patient pool so the results may not be generalizable to a more diverse population. The researcher who performed the cephalometric analysis was not blinded to the hypothesis, and thus may have introduced bias into the results. Based on variances and correlations from prior Class II studies we sought to obtain 50 surgical and 50 non-surgical patients, but were only able to find 21 surgical and 45 non-surgical patients, thus our analysis may not be adequately powered. We also initially planned to include only surgical patients with a normally positioned maxilla and BSSO advancements. By doing this we tried to limit our population to patients with mandibular hyploplasia. Both of these criteria had to be disregarded to find more surgical patients.

Future studies should seek to address these shortcomings. Additionally, future studies should focus on retention records. Will proclination of lower incisors lead to more relapse or an increase in overjet for non-surgically treated patients? The patients from the present study could be recalled for a set of retention records to determine stability of treatment. A measure of facial convexity would also be helpful in determining the soft tissue result of surgical and non-surgical treatment. Finally, casts measurements would be helpful in the future. To determine quality of AP dental correction buccal interdigitation determined on casts may reveal different results compared to cephalometric overjet.

CONCLUSION

Surgical versus non-surgical treatment of severe Class II Division 1 malocclusions in adolescents leads to several different cephalometric outcomes.   Our non-surgical group finished with more proclined lower incisors. Our results also showed that surgical treatment has a bigger average change in SNB, ANB, IMPA and overjet. These results suggest surgery is a better treatment option for patients with more severe malocclusions. One has to also consider the stability of each treatment option. Proclination of lower incisors with non-surgical treatment may lead to a higher rate of relapse, but these patients will have no surgical relapse. In the end patient desires is most likely the biggest influence in deciding between surgical and non-surgical treatment.

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