A Retrospective Analysis of Pre-surgical Incisor Decompensation Attained in an Orthognathic Surgery Population

Gary Steven Mayne, Jr.

APPROVED:

Curtis M. Marsh, D.D.S., M.S., Supervising Professor

Brent J. Callegari, D.D.S., M.S.D., Program Director

David P. Lee, D.M.D., M.S., Chairman

1-Jul-2016
Date

APPROVED:

Drew W. Fallis, D.D.S., M.S., Dean, Air Force Post-Graduate Dental School

The author hereby certifies that the use of any copyrighted material in the thesis/dissertation manuscript entitled:

"A Retrospective Analysis of Pre-surgical Incisor Decompensation Attained in an Orthognathic Surgery Population"

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

GARY S. MAYNE, Maj, USAF, DC
Tri-Service Orthodontic Residency Program
Air Force Post Graduate Dental School
Uniformed Services University
25 May 2016

A Retrospective Analysis of Pre-surgical Incisor Decompensation Attained in an Orthognathic Surgery Population

A THESIS

Presented to the Faculty of

Uniform Services University of the Health Sciences

In Partial Fulfillment

Of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Gary Steven Mayne, Jr., D.D.S.

San Antonio, TX

July 1, 2016

A Retrospective Analysis of Pre-surgical Incisor Decompensation Attained in an Orthognathic Surgery Population

Gary Steven Mayne, Jr.

APPROVED:

____
Curtis M. Marsh, D.D.S., M.S., Supervising Professor

____
Brent J. Callegari, D.D.S., M.S.D., Program Director

____
David P. Lee, D.M.D., M.S., Chairman

____
Date

APPROVED:

____
Drew W. Fallis, D.D.S., M.S., Dean, Air Force Post-Graduate Dental School

DEDICATION

Foremost I thank my Father in Heaven for the opportunity to pursue an education in this field and for His constant support throughout the process, without which I could not have been successful. I dedicate this work to my beautiful wife, Kristen, and my amazing children, Aaron, Tacey, Nathan and Maddie. None of this would have been possible without their love, patience and understanding. For that I will be eternally grateful.

ACKNOWLEDGEMENTS

I am sincerely thankful to all of the TORP staff and faculty who have imparted of their wisdom and knowledge over the past two years. Specifically, I owe a debt of gratitude to Dr. Curtis Marsh for his mentorship and guidance throughout the process of this research project. I would also like to thank Dr. Anneke Bush for providing statistical support for this project.

ABSTRACT

Purpose: To evaluate pre-orthognathic surgery incisor decompensation attained in Class II and Class III patients treated in the Tri-Service Orthodontic Residency Program. **Methods**: Pre-treatment (T-1) and pre-surgical (T-2) lateral cephalometric radiographs reconstructed from 3D cone beam computed tomograms were obtained for 13 Class II Division 1 subjects and 13 Class III subjects. The lateral cephalograms were digitized and analyzed using Dolphin Imaging software (Dolphin Imaging and Management Solutions, Monrovia, California, USA). **Results**: Incisor decompensation to race-specific norms was achieved in 50% (U1-SN) and 60% (U1-PP) of upper and 33% (IMPA) of lower Class II incisors, and 40% (U1-SN) and 22% (U1-PP) of upper and 42% (IMPA) of lower Class III incisors. The greatest absolute changes were found in the lower incisors of Class II (4.8°) and Class III (6.8°) subjects. **Conclusion**: Complete incisor decompensation to race-specific norms was seldom achieved during orthodontic treatment prior to orthognathic surgery.

TABLE OF CONTENTS

I. INTRODUCTION

Early orthognathic surgery procedures date back to the mid-19th century. Simon P. Hullihen has been credited with performing the first orthognathic surgical procedure in 1849 in the treatment of a young woman with distortion of the lower jaw, lip, and neck, secondary to scar contracture from a severe burn received as a child (Aziz, 2004). In 1936 he was recognized as the "Father of Oral Surgery" in recognition of his contributions to the specialty of oral and maxillofacial surgery.

Panula (2003) described an intermittent, step-wise development of orthognathic surgery consisting of three stages, the first of which was initiated by Hullihen with the procedure described above. Much of the early development of orthognathic surgery in this period was concentrated in the U.S. with Vilray Blair performing the first mandibular osteotomy for the correction of prognathism in 1897. The second stage defined by Panula spanned the time period between World War I and World War II during which time surgeons were focused on treating war-related traumatic injuries. Little advancement occurred during this time, but surgeons gained valuable experience that would later benefit the development of orthognathic surgery. The third stage began in the early 1950's and, where European progress tended to lag that of the U.S. in the first two stages, it now became the focal point for significant advances in the field (Panula 2003). Obwegeser (2005) notes the significant contributions of European surgeons Gillies, Schuchard and Trauner, but credits Hugo Obwegeser with leading the field in the refinement of maxillary and mandibular surgical techniques through the 1950's and 1960's and with performing the first bimaxillary surgery in 1970.

Orthodontic treatment philosophies and techniques were also evolving during this time period. Edward Angle published his landmark treatise "Classification of Malocclusion" in 1899, bringing order and simplicity to what had previously been a chaotic and complex diagnostic process (Peck 2009). At that time treatment was focused on obtaining an Angle Class I molar relationship. Alignment of teeth was achieved primarily via non-extraction therapy and expansion. Treatment was directed at achieving a Class I molar relationship and aligning the teeth along a smooth curve; little attention was paid to facial proportions and esthetics. The realization that a strict non-extraction philosophy did not lend itself to optimal outcomes in all cases led Charles Tweed, Raymond Begg and others to incorporate extraction of teeth into their practices once more (Proffit et al, 2013).

During this period, attention in treatment planning shifted from the molars to the lower incisors. An ideal mandibular incisor position could be chosen and the maxillary incisors could be moved into proper relationship with the mandibular incisors. With the aforementioned advancements in orthognathic surgery to change the position of the maxilla, the focus shifted once more from the lower incisors to the upper incisors (McLaughlin et al, 2014). Now it was possible to plan a maxillary incisor position that would provide optimal soft tissue esthetics and then build the occlusion around that incisor position using orthodontic, orthopedic and orthognathic surgical treatment modalities.

The vast majority of malocclusions are mild enough to be treated with orthodontics alone. However, approximately 4% of the population has a skeletal malocclusion that requires surgical-orthodontic treatment to fully correct (Johnston et al. 2006). The most common indications for surgical correction are severe skeletal Class II, Class III and vertical discrepancies (Proffit 2013). These patients often present with dentoalveolar compensations. Goldsman (1959) theorized that there was a balancing property in the dentofacial complex that existed to maintain the overall harmony and proportions of the facial complex; when one component of the dentofacial complex was out of balance, other components would adjust to minimize (or compensate for) the anticipated effects of the discrepancy. In one study comparing Class II and Class III skeletal open bite cases to Class I controls, it was found that the Class III group demonstrated greater compensatory tendencies including increased maxillary incisor proclination and greater mandibular incisor retroclination (Arriola-Guillen et al. 2014). Results from a study by Ishikawa et al (2000) appeared to "indicate that for sagittal jaw discrepancies, normal incisor relationships can be attained by a combination of compensatory effects of the incisor inclination and occlusal plane angulation." Casko and Shepherd (1984) published research that illustrated this principle as well. They noted a pattern in which if the cephalometric A point-Nasion-B point (ANB) angle were high, as is often the case in skeletal Class II malocclusions, the mandibular plane was steeper, the cant of the occlusal plane was high, the maxillary incisors were more upright, and the mandibular incisors were more proclined.

One of the goals of pre-surgical orthodontic treatment is decompensation of the occlusion and movement of teeth into their ideal positions relative to the jaw in which they sit, without regard to the relationship between the maxilla and mandible (Proffit 2013). Adequate decompensation of the dentition, the incisors in particular, is important for a number of reasons. McNeil et al (2014) explained that proper incisor decompensation and positioning in relation to the maxillary and mandibular bases allows for maximization of surgical movements and an increased likelihood that pre-treatment orthodontic and esthetic goals will be met. They also reported that adequate decompensation can reduce the time needed for post-surgical orthodontics and also has implications for long-term stability of the surgical result.

Several studies were found in the literature that looked at incisor decompensation in presurgical orthodontic treatment. In their study of incisor decompensation, McNeil et al (2014) found that adequate decompensation was achieved in the mandible 80% of the time versus 63% of the time in the maxilla. They also found that the amount of mandibular tooth movement was statistically significantly greater in Class III malocclusions than in Class II malocclusions. They found no statistical difference in maxillary tooth movement between the Class II and Class III malocclusion groups (McNeil et al. 2014).

In a study of Class III patients with mandibular hypertrophy, Xu et al (1995) found that incisors could be decompensated to the same level as that of a group of similar non-surgical patients. Phonpraserth et al (1999) compared the mandibular incisor decompensation in subjects with Class II division 1, Class II division 2 and Class III skeletal malocclusions. They found significant changes in incisor position in both Class III and Class II Division 2. In Class II Division 1 subjects, they found that changes in the mandibular incisor inclination were the opposite of what was anticipated, that they proclined further instead of uprighting. Xu et al (1995) attributed this finding to possible non-extraction treatment in cases with mild crowding or to leveling of the curve of Spee. Pereira-Stabile et al (2012) studied a group of subjects with Class III malocclusions. They found that mandibular incisor decompensation tended to be greater than that of maxillary incisors, but in a majority of subjects, incisor compensations still remained immediately prior to surgery. Another study compared two groups of Class III patients in which one group was considered to be adequately decompensated while the other was not (Capelloza et al 1996). Similar to other studies, they found that in both groups, mandibular incisor decompensation was greater than that of the maxillary incisors. Even within the group considered to have adequate decompensation, while mandibular incisor compensation was eliminated (compared to race-appropriate norms), some degree of maxillary incisor compensation still remained. Capelloza et al (1996) postulated that this might be due to factors orthodontists encounter during the presurgical orthodontic phase.

In Class III skeletal discrepancies, decompensation of the maxillary incisors usually involves retraction and uprighting. If the posterior teeth are buccally inclined and there is no spacing or even crowding, then adequate decompensation of the upper incisors may not be possible without extraction of premolars or palatal expansion. Conversely, in the compensated mandibular arch, retroclined incisors and lingually inclined posterior teeth are often encountered. Decompensation of this arch tends to create space as posterior segments are uprighted and incisors are proclined. Thus, decompensation of mandibular incisors may often be accomplished with greater ease compared to maxillary incisors. Finally, Capelloza et al (1996) did note that at least in one case, incomplete decompensation of maxillary incisors was not a detriment to the final esthetic result and that final judgment as to whether or not adequate incisor decompensation has been obtained will often depend on the clinical presentation of the subject and the amount of anteroposterior surgical correction needed to achieve optimal functional and esthetic results. The hypothesis of this study is that complete incisor decompensation does not occur during pre-orthognathic surgery orthodontic treatment, when teeth are not extracted.

II. OBJECTIVES

A. Purpose of Study

The purpose of this study is to analyze pre-surgical orthodontic incisor decompensation attained in a group of orthognathic surgery patients treated in the Tri-Service Orthodontic Residency Program.

B. Specific Hypothesis

Pre-surgical orthodontic treatment does not achieve full decompensation of maxillary and mandibular incisors compared to ethnic-appropriate norms.

C. Null Hypothesis

There will be no difference in incisor angulation between decompensated subjects and their race-specific norms.

III. MATERIALS AND METHODS

A. Experimental Design

This retrospective study was conducted using cephalometric radiographs (derived from CBCT images) from patients treated in the Tri-Service Orthodontic Residency Program (Air Force Postgraduate Dental School, Joint Base San Antonio-Lackland, San Antonio, Texas, USA). Inclusion criteria for the study were 1) previous exam and pre-treatment diagnosis of skeletal Class II or III, 2) post-peak growth status, 3) pre-orthognathic surgery orthodontic treatment in the Tri-Service Orthodontic Residency Program (TORP), 4) pre-treatment (T1) and pre-surgical (T2) three-dimensional (3D) cone beam computed tomography (CBCT) images on file, and 5) non-extraction orthodontic therapy. Subjects with craniofacial anomalies or severe skeletal asymmetries were excluded from the study.

An initial search of the TORP patient database yielded 181 potential subjects. After applying inclusion and exclusion criteria, a total of 26 subjects remained. The study sample consisted of 13 skeletal Class II patients (8 females and 5 males) with a mean initial age of 23.51 ± 8.9 years and a mean pre-surgical age of 25.39 ± 8.85 years, and 13 skeletal Class III patients (6 females and 7 males) with an initial mean age of 26.29 ± 6.96 years and a pre-surgical mean age of 27.84 ± 7.16 years. All subjects were treated by residents and staff at TORP using a non-extraction protocol and an MBT™ prescription 0.022 inch slot stainless steel labial orthodontic appliance (3M Unitek, Monrovia, California).

T1 and T2 3D CBCT images for each subject were de-identified, exported from Dolphin Imaging® software (Chatsworth, California), and assigned an alphanumeric identifier. Each set of de-identified CBCT images was subsequently imported back into Dolphin Imaging into separate research study files. T1 and T2 lateral cephalometric images were reconstructed from the 3D CBCT images and digitized by the PI (G.M.) using Dolphin Imaging© software. Cephalometric landmarks and planes pertinent to this study are shown in Figure 1. Specific cephalometric measures from the traced radiographs were selected to demonstrate changes in the labiolingual inclination and bodily position of maxillary and mandibular incisors at T1 and T2. The angular cephalometric measurements chosen were Upper Incisor to Sella-Nasion (U1-SN), Upper Incisor to Palatal Plane (U1-PP), and Incisor Mandibular Plane Angle (IMPA). The linear measures used were Upper Incisor to Nasion-A Point (U1-NA) and Lower Incisor to Nasion-B Point (L1-NB). These measurements are highlighted in yellow in Figure 1 below. Race-specific normative standards for these measurements are shown in Table 2. Study data were recorded and analyzed using Microsoft Excel® (Redmond, Washington).

Figure 1. Cephalometric Landmarks, Planes and Measures Used In Study

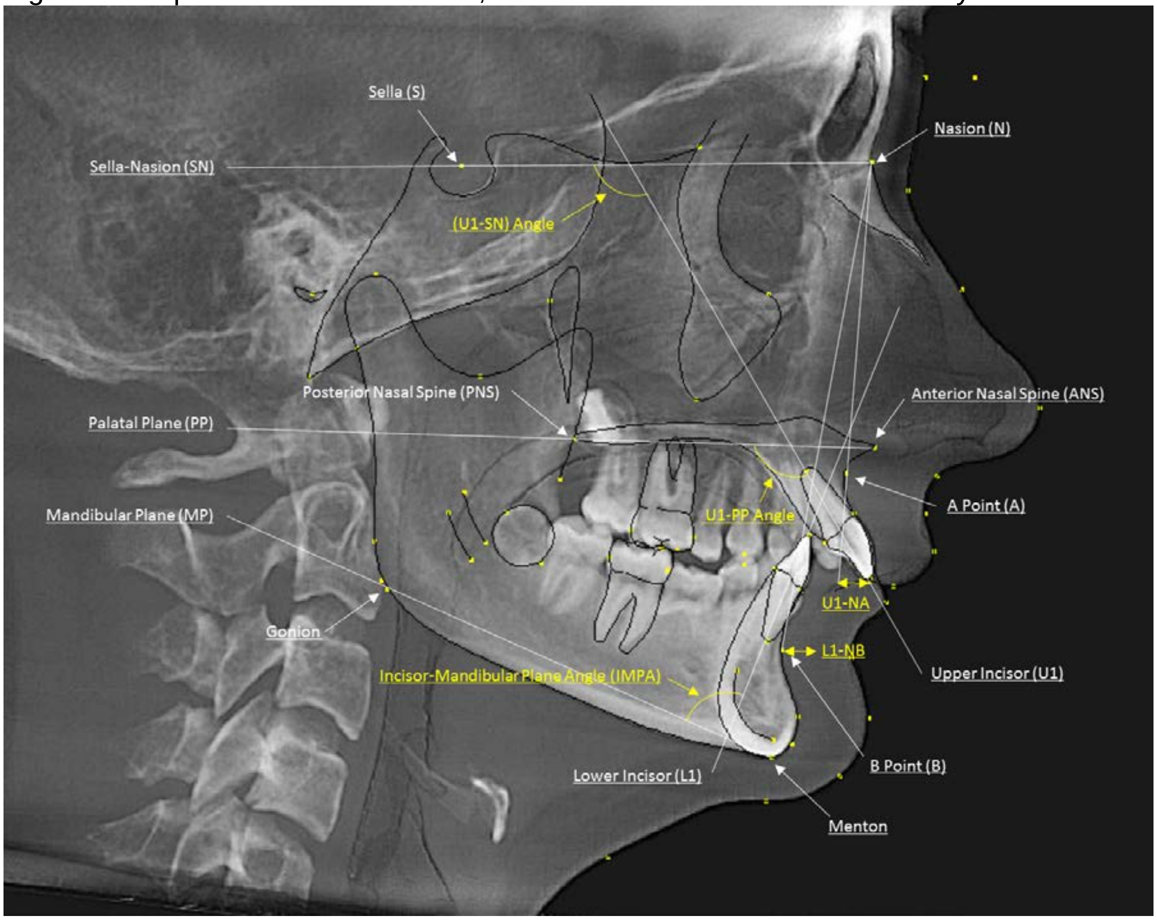


Table 1. Cephalometric measurements with race-specific normal values

	Caucasian (TORP Ceph Analysis)	**African-American** (Drummond)	**Hispanic** (Swlerenga et al)	**Korean** (Kim; Park et al)
U1-SN (º)	103 ± 6	109 ± 7	105 ± 8	
U1-PP (º)	110 ± 6			
U1-NA (mm)	4	7 ± 2		6.8
IMPA (º)	91 ± 5	100 ± 5	96 ± 5	97 ± 5
L1-NB (mm)	4	11 ± 3		6.9

To test intra-rater reliability, twenty-five radiographs were randomly selected, re-digitized and re-measured two weeks after initial measurements were made. Intraclass correlation coefficients and their upper and lower 95 percent confidence intervals were calculated for each of the five cephalometric measures shown in Table 2 and are displayed in Table 3. The intraclass correlation coefficients, and their upper and lower 95 percent confidence intervals, ranged from a high of 0.978 (range 0.950 to 0.990) to a low of 0.783 (range 0.567 to 0.898) for L1-NB and U1-PP, respectively.

Table 2. Intraclass correlation coefficients with upper and lower 95% confidence intervals

		Intraclass correlation	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
Cephalometric Measure	**U1-SN (º)**	0.859	0.705	0.935
	U1-PP (º)	0.783	0.567	0.898
	U1-NA (mm)	0.917	0.822	0.963
	IMPA (º)	0.926	0.839	0.967
	L1-NB (mm)	0.978	0.95	0.99

B. Statistical Analysis

Means and standard deviations were calculated for U1-SN, U1-PP, U1-NA, IMPA and L1-NB at T1, T2, the change between T1 and T2, and the normal cephalometric values for both the Class II and Class III groups and are shown in Tables 4 and 5, respectively.

Paired t-tests were performed to compare mean values at T1 and T2 to determine if the effected changes in incisor position were statistically significant. T1 and T2 means were also compared to the mean normative values for each of the cephalometric measures. The level of significance was set at 5%.

Table 3. Class II Group means and standard deviations (SD)

	T1		T2		T1-T2		Normal value	
	mean	SD	mean	SD	mean	SD	mean	SD
U1-SN (º)	105.5	6.99	109.14*****	5.29	3.64	7.49	104.54	2.6
U1-PP (º)	112.26	7.56	115.88*****	3.28	3.62	7.8	110	0
U1-NA (mm)	4.22	2.01	4.95	1.45	0.74	2.09	4.91	1.42
IMPA (º)	**93.39**	8.83	**98.15***	5.92	4.75	6.09	93.92	4.01
L1-NB (mm)	**4.91**	2.3	**5.82**	3.17	0.92	1.76	5.84	3.05

Bold = significant difference between T1-T2 means (p<0.05)
***** = significant difference between time point and normal mean (p<0.05)

Table 4. Class III Group means and standard deviations (SD)

	T1		T2			T1-T2		Normal value	
	mean	SD	mean	SD		mean	SD	mean	SD
U1-SN (º)	109.5*	7.8	113.02*	7.9		3.52	6.41	104.54	2.6
U1-PP (º)	117.75*	6.75	120.25*	6.2		2.5	5.34	110	0
U1-NA (mm)	**6.21**	2.88	**7.52***	2.56		1.32	2.18	4.91	1.42
IMPA (º)	**81.77***	8.71	**88.58**	6.51		6.81	4.52	93.92	4.01
L1-NB (mm)	**5.55**	3.78	**7.4***	3.33		1.85	1.25	5.84	3.05

Bold = significant difference between T1-T2 means (p<0.05)
***** = significant difference between time point and normal mean (p<0.05)

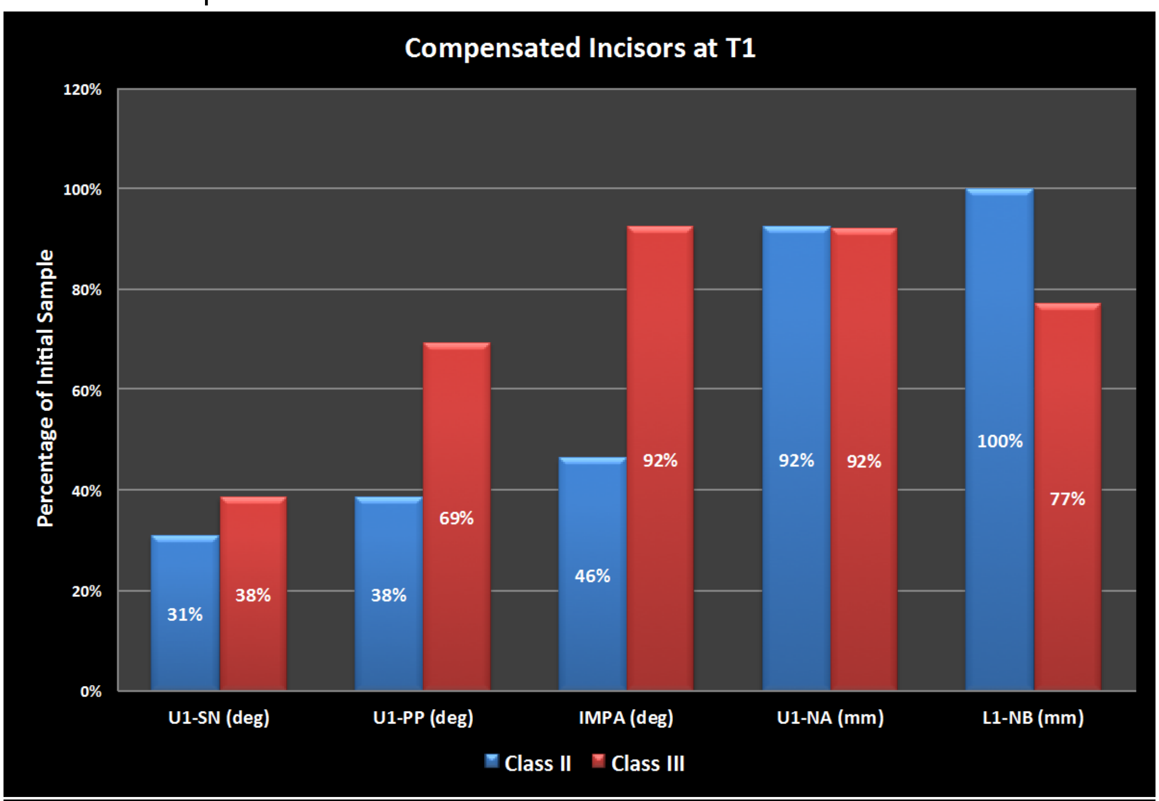
IV. RESULTS

A. Class II Group

U1-SN

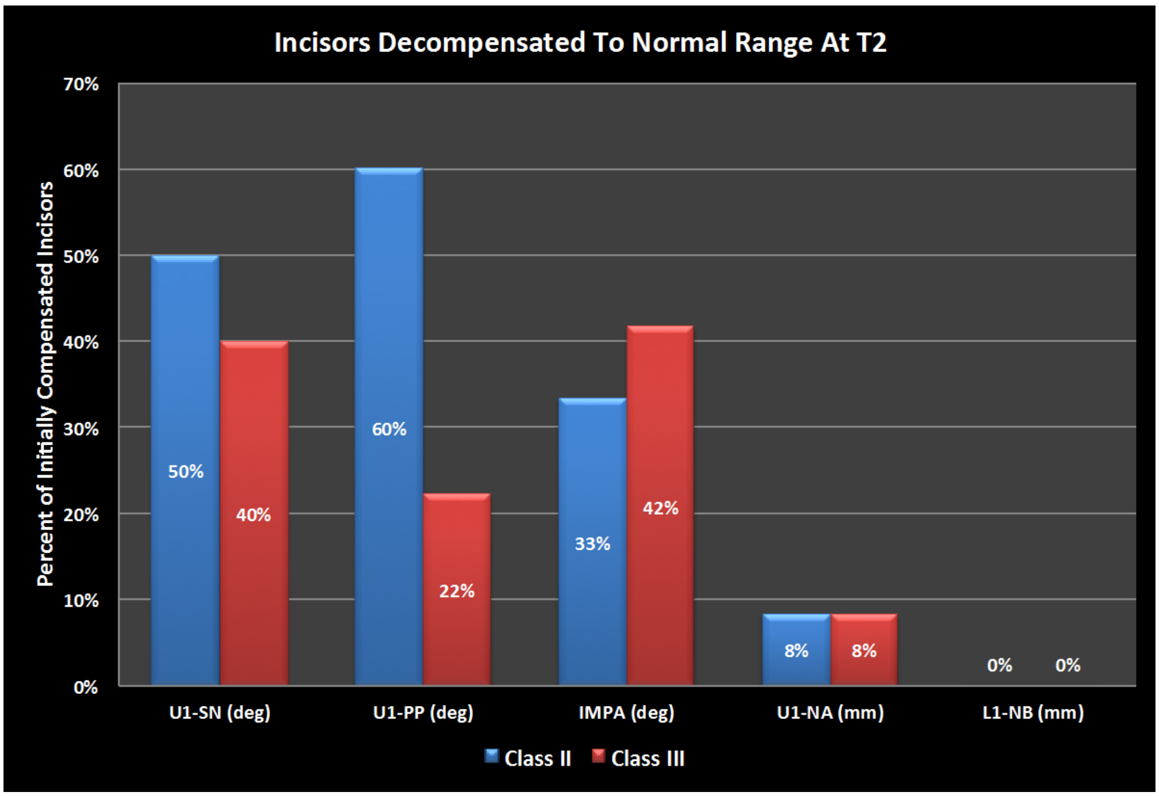
In the Class II group, 31 percent (n=4) of the subjects had maxillary incisors that fell outside the range of normal at T1 for U1-SN. Chart 1 gives a graphical representation of compensated incisors at T1 for both Class II and Class III groups. Incisors were considered compensated if their cephalometric measures were greater than one standard deviation above or below the normal value as shown in Table 2.

Chart 1. Compensated Incisors at T1



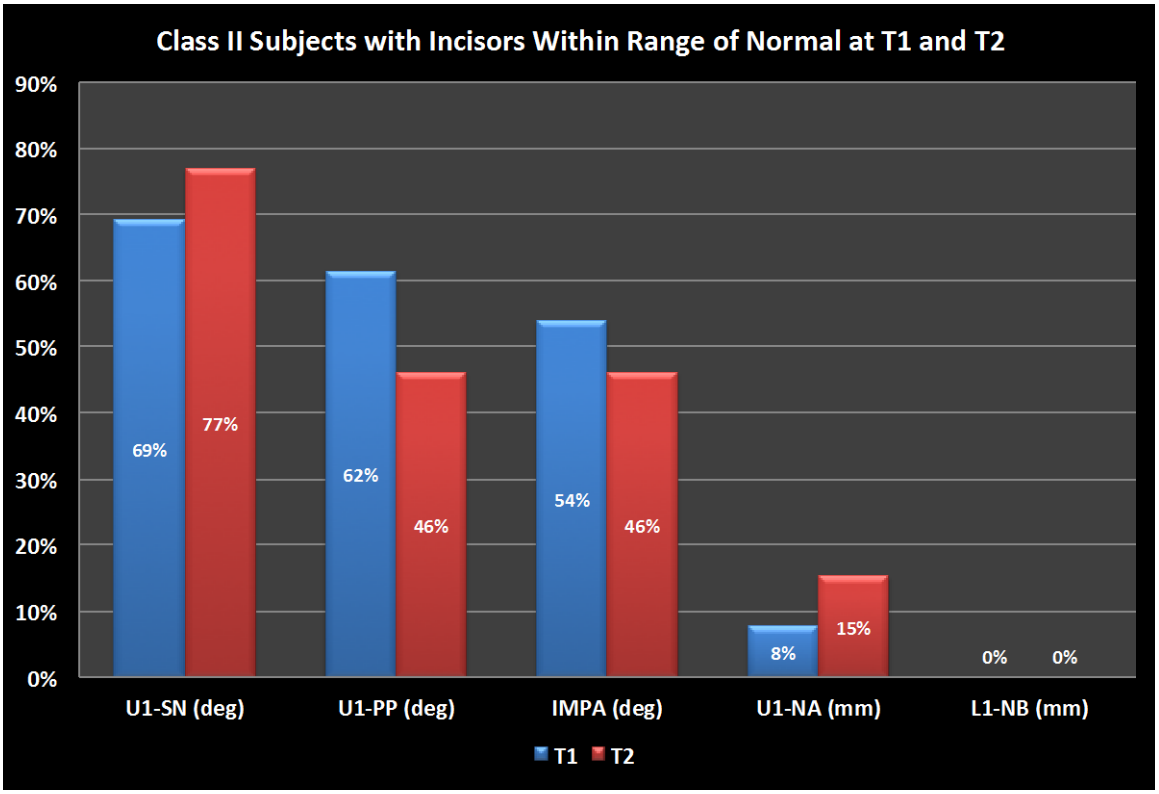
Of those starting outside the range of normal, 75 percent (n=3) were proclined and 25 percent (n=1) were retroclined. Of these subjects, 50 percent (n=2) were decompensated to within the range of normal at T2. Chart 2 illustrates the percentage of initially compensated incisors that were decompensated to within one standard deviation of the normal value at T2.

Chart 2. Percent of Initially Compensated Incisors Decompensated at T2



Of the 9 subjects that had normal incisor inclination at T1, one (8 percent) was overcorrected at T2. Chart 3 shows the changes in the percent of incisors that fell within one standard deviation of the normal value at T1 and T2 for the Class II group.

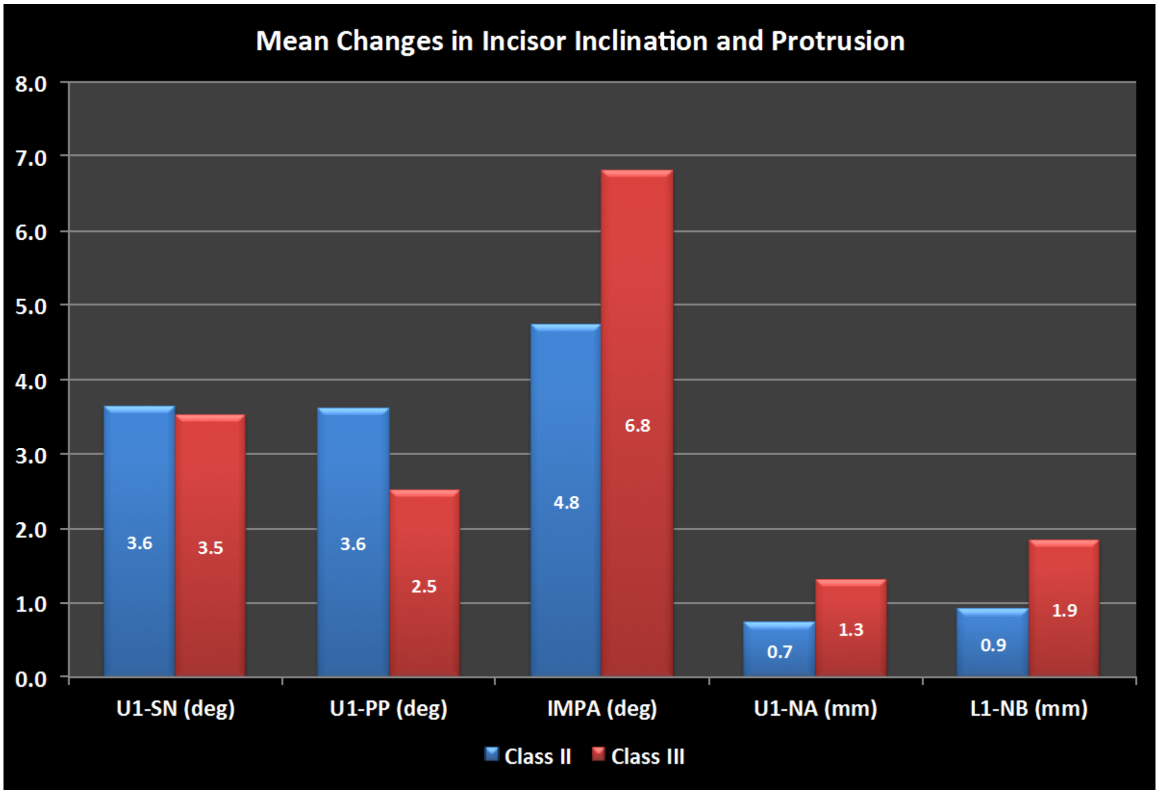
Chart 3. Class II normal incisors at T1 and T2



For all 13 subjects, 69 percent were within the normal range for U1-SN at T1 and 77 percent at T2 representing an overall 12 percent increase or improvement. On average, however, upper incisors began treatment near ideal inclination and were proclined during pre-surgical orthodontics. The mean U1-SN value at T2 was statistically significantly greater, or more proclined, than the normal value. Upper incisors were proclined an average of 3.64 degrees during treatment. Chart 4 demonstrates the mean changes in incisor position for both the Class II and Class III groups. As one might expect, the change in degrees for Class II maxillary incisors was the same whether it was based on U1-SN or U1-PP, despite the finding that the percentages of maxillary incisors that started treatment compensated and were decompensated at T2 were different for U1-SN and

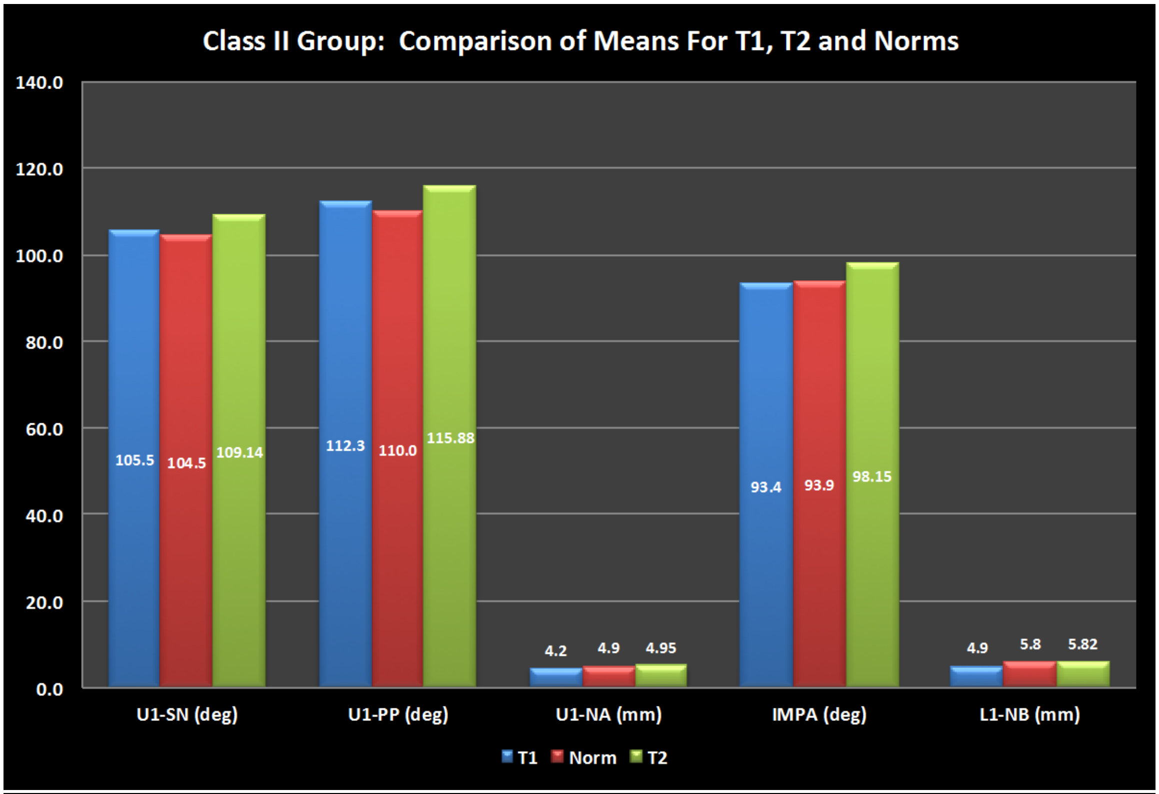
U1-PP. This was not the case for Class III maxillary incisors, which showed a mean change of 3.5 degrees for U1-SN, and 2.5 degrees for U1-PP.

Chart 4. Mean changes in Incisor Position



Finally, Chart 5 below gives a graphical representation of the mean values for T1, T2 and the normal value for the Class II group.

Chart 5. Comparison of Class II Means for T1, T2 and Normal Values



<u>U1-PP</u>

When upper incisor inclination was related to palatal plane, 38 percent (n=5) of the subjects fell outside the range of normal at T1. 60 percent (n=3) were proclined and 40 percent (n=2) were retroclined. Of the three that were proclined, only one was adequately decompensated, while both subjects with initially retroclined upper incisors were decompensated to within the range of normal. Interestingly, five of the eight subjects who started within the range of normal at T1 were outside that range at T2; all were excessively proclined. If we consider only the five subjects that fell outside the normal range for U1-PP at T1, three, or 60 percent, were adequately decompensated at T2. For the entire group of 13 Class II subjects, 62 percent had normal incisor inclination at T1, but only 46 percent at T2. This represents an overall 26 percent decrease in the number of subjects with normal maxillary incisor inclination relative to palatal plane. Similar to U1-SN measures, however, on average, upper incisor inclination began near ideal at T1 and incisors were proclined during treatment. When measured using U1-PP, incisors were proclined an average of 3.62 degrees, very comparable to U1-SN measures. The mean measure at T2 remained within the normal range.

IMPA

Lower incisor inclination was evaluated relative to the mandibular plane. In the Class II group, 46 percent (n=6) had lower incisor inclinations outside the normal range at T1. Half of those had retroclined incisors and half had proclined incisors relative to normal values. At T2, incisor decompensation to within normal limits had only been achieved in two of the six subjects (33 percent). In all but one of those six cases, the incisors were proclined during treatment; there was essentially no change in the sixth case. Three subjects that began treatment within the normal range had lower incisor inclinations outside the normal range at T2; in two of those three cases, the lower incisors were proclined beyond the norms, while in the third, the incisors were retroclined. For all 13 subjects, 54 percent had normal incisor inclinations at T1, but only 46 percent at T2. This represents an overall 14 percent decrease in the number of Class II subjects with adequately decompensated mandibular incisors at T2. The mean amount of proclination of the lower incisors in the Class II group was 4.75 degrees and they were proclined a statistically significant amount greater than the normal value. On average, lower incisors in the Class II group began near ideal and were proclined during treatment.

U1-NA and L1-NB

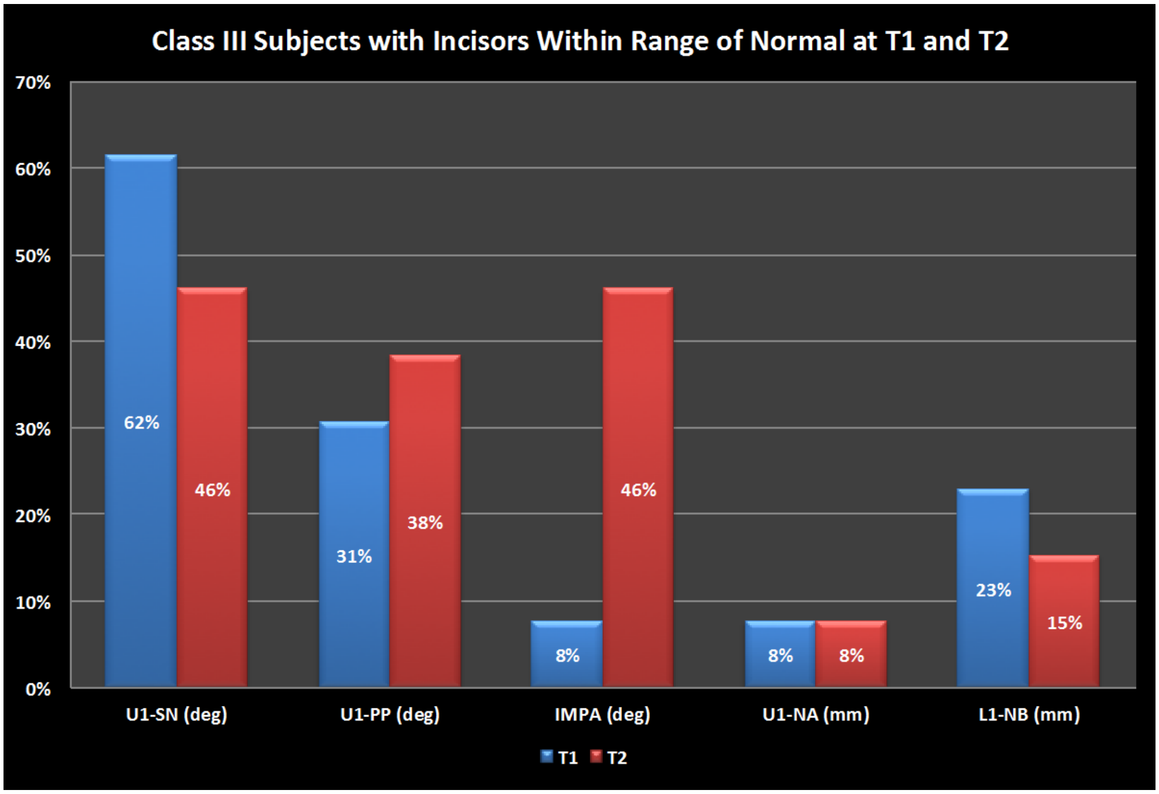
The normal values for the anteroposterior bodily position of the maxillary (U1-NA) and mandibular incisors (L1-NB) used by Steiner did not have standard deviations and ranges as they were simply clinical guides and not derived from a clinical sample (Casko & Shepherd, 1984). Therefore it was not possible to compare changes in incisor inclination relative to a range, or standard deviation, of normal for Caucasian subjects. Ethnic-appropriate normal ranges for incisor inclination were used for non-Caucasian subjects. Upper and lower incisors were protruded an average of 0.74 and 0.92 millimeters, respectively. There was no statistically significant difference between either the T1 or T2 mean measure and the normal mean.

B. Class III Group

U1-SN

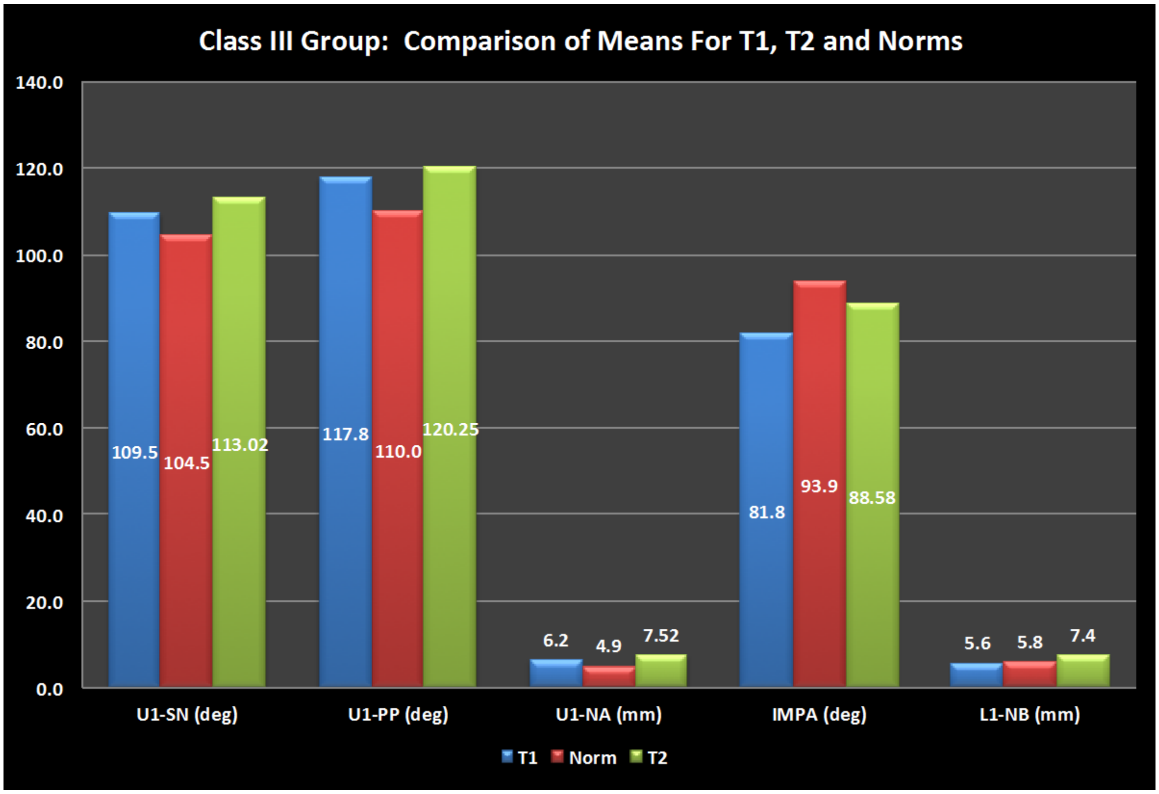
In the Class III group, 31 percent (n=4) of the subjects had maxillary incisors that fell outside the range of normal at T1 for U1-SN. Of those starting outside the range of normal, all were proclined relative to normal values. Of those subjects, 50 percent (n=2) were decompensated to within the range of normal at T2. Of the nine subjects that had normal maxillary incisor inclination at T1, five (56 percent) fell outside the normal range at T2 and in all cases the incisors were overly proclined. For all 13 subjects, 69 percent were within the normal range for U1-SN at T1, but only 46 percent at T2. This represents a 33 percent decrease in the number of subjects with upper incisors within the range of normal for inclination. Chart 6 compares the percent of incisors that fell within one standard deviation of the normal value at T1 and T2 for the Class III group.

Chart 6. Class III Normal Incisors at T1 and T2



The means for T1 and T2 incisor inclination relative to SN showed that, on average, maxillary incisors began treatment proclined relative to the normal value and were further proclined during treatment. This was born out by statistical analysis, which showed mean values for U1-SN at both T1 and T2 that were statistically significantly larger than the mean normal value. Maxillary incisors in the Class III group were proclined an average of 3.52 degrees. Chart 7 gives a graphical comparison of the means for T1, T2 and the normal value for the Class III group.

Chart 7. Comparison of Class III Means for T1, T2 and Normal Values



<u>U1-PP</u>

For upper incisor inclination related to the palatal plane, 62 percent (n=8) of the subjects fell outside the range of normal at T1. All of these subjects had overly proclined incisors at T1. Of these eight subjects, only 25 percent (n=2) were decompensated to within the normal range at T2. The incisors of only two of the remaining six subjects were uprighted during pre-surgical orthodontic treatment. The incisors of the remaining four subjects were proclined even further from the normal range at T2. Two of the five subjects who were within the range of normal at T1 were outside that range at T2. In both instances, the incisors were proclined beyond normal. If we only consider the eight subjects that fell outside the normal range for U1-PP at T1, only 25 percent (N=2) were adequately decompensated at

T2. For the entire group of 13 Class III subjects, only 38 percent had normal incisor inclination at T1 and T2. There was no overall improvement of upper incisor inclination during pre-surgical orthodontic treatment. Similar to U1-SN, upper incisors began treatment proclined relative to palatal plane and were proclined further during treatment. The mean values for U1-SN at both T1 and T2 were statistically significantly larger than the mean normal value. Upper incisors relative to the palatal plane were proclined an average of 2.5 degrees.

IMPA

As with the Class II group, lower incisor inclination was evaluated relative to the mandibular plane. In the Class III group, 92 percent (n=12) had lower incisor inclinations outside the normal range at T1. All were retroclined relative to normal values. At T2, incisor decompensation to within normal limits had been achieved in 42 percent (n=5) of those twelve subjects. The lower incisors in all but one of the remaining subjects were proclined, but not to within the normal range; there was essentially no change in incisor inclination in the seventh case. The incisors of the single subject that began treatment within the normal range were uprighted during treatment, but remained in the normal range at T2. For all 13 Class III subjects, only one began treatment within the normal range for mandibular incisor inclination, however, 46 percent (n=6) were decompensated to within the normal range at T2. The lower incisors in the Class III group began treatment retroclined relative to ideal and were proclined an average of 6.81 degrees toward, but not completely to, the ideal. There was a statistically significant difference between the means for T1 and T2 and for T1 and the normal value.

U1-NA and L1-NB

The data describing the anteroposterior position of the maxillary and mandibular incisors in the Class III group were treated in the same manner as those for the Class II group. Upper and lower incisors in the Class III group were protruded an average of 1.32 and 1.85 millimeters, respectively. As with the Class II group, T1 measures were significantly different from the normal value. However, Class III group incisors were protruded a statistically significant distance beyond the normal value at T2.

C. Treatment Efficacy Analysis

An alternative method of evaluating the effectiveness of pre-surgical orthodontic incisor decompensation was used in this study. It was modeled after those used by Proffit et al (1992) and Potts (2009). In this method the actual distance an incisor moved was calculated as a percentage of the distance required to reach the ideal position. A value of 100% would indicate that an incisor had been moved to the ideal position. Positive values represent movement toward the ideal and negative values represent movement away from ideal. This method evaluates proclined or retroclined incisors and retroclined or proclined incisors independently. They were further subdivided into groups based on whether the incisors moved away from or toward the ideal during treatment. Tables 6 and 7 below show the data for the Class II and Class III groups, respectively, including the number of subjects in each subcategory, the mean percent movement toward or away from ideal as a portion of the total distance to reach ideal, and the mean amount of movement.

Table 5. Class II – Alternate Treatment Efficacy Analysis

Retroclined Upper Incisors (U1-SN)		**Proclined Upper 1 (U1-SN)**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	423.50%	-26.58%	64.68%
n=0	n=9	n=2	n=2
0 deg	7.2 deg	1.0 deg	-9.6 deg
Retroclined Upper 1 (U1-PP)		**Proclined Upper 1 (U1-PP)**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	431.48%	-676.05%	48.00%
n=0	n=6	n=4	n=3
0 deg	8.5 deg	4.4 deg	-7.2 deg
Retroclined Lower 1		**Proclined Lower 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	203.65%	-35.81%	112.06%
n=0	n=7	n=4	n=2
0 deg	8.5 deg	2.9 deg	-4.7 deg
Retruded Upper 1		**Protruded Upper 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	103.67%	-46.03%	104.41%
n=0	n=8	n=3	n=2
0 mm	1.8 mm	0.3 mm	-2.8 mm
Retruded Lower 1		**Protruded Lower 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
-26.43%	140.28%	-462.17%	0.00%
n=3	n=4	n=5	n=0
-1.3 mm	1.6 mm	1.9 mm	0 mm

Table 6. Class III – Alternate Treatment Efficacy Analysis

Retroclined Upper 1 (U1-SN)		**Proclined Upper 1 (U1-SN)**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
-187.50%	404.90%	-138.05%	54.07%
1	3	7	2
-3.0 deg	6.7 deg	5.8 deg	-6 deg
Retroclined Upper 1 (U1-PP)		**Proclined Upper 1 (U1-PP)**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	198.27%	-178.41%	28.60%
0	2	7	4
0 deg	2.8 deg	5.8 deg	-3.5 deg
Retroclined Lower 1		**Proclined Lower 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
-4.17%	62.36%	0.00%	62.16%
1	11	0	1
-0.3 deg	8.3 deg	0 deg	-2.3 deg
Retruded Upper 1		**Protruded Upper 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
-150.00%	278.38%	-114.87%	47.06%
1	3	7	2
-0.9 mm	3.1 mm	1.7 mm	-1.6 mm
Retruded Lower 1		**Protruded Lower 1**	
Away from ideal	Towards ideal	Away from ideal	Towards ideal
0.00%	157.26%	-201.99%	0.00%
0	7	6	0
0 mm	2.0 mm	1.7 mm	0 mm

Note that in the Class II group, retroclined and retruded incisors were most often moved toward the ideal, but were often overcorrected by as much as 430% or 8.5 degrees. Retruded upper incisors were decompensated closest to the ideal with average movement of 1.8 millimeters (mm). Proclined and protruded incisors, on the other hand, were generally moved away from the ideal (18 measurements versus 9 for towards ideal) in the Class II group by as much as 676% or 4.4 degrees. Proclined lower incisors and protruded upper incisors were decompensated closest to the ideal with average movements of 4.7 degrees and

2.8 mm. The majority (26 measurements versus 3) of retroclined and retruded incisors in the Class III group were moved towards the ideal. Upper incisors inclination was overcorrected by 405% or 6.7 degrees. 11 of 12 retroclined lower incisors were proclined 62% or 2.3 mm of the total distance to ideal. Proclined and protruded incisors in the Class III group were generally proclined and protruded further from the ideal (27 measurements versus 9) with upper incisors proclining an average of 5.8 degrees and protruded incisors moving an average of 1.7 mm.

Chart 8 is a graphical representation of the treatment efficacy data for retroclined and retruded incisors for both the Class II and Class III groups. Note that the green bars represent movement towards the ideal and the red bars represent movement away from the ideal. Movement away from the ideal occurred in only six measurements, but movement towards the ideal occurred in 60 measurements.

Chart 8. Treatment Efficacy Analysis for Retroclined/Retruded Incisors

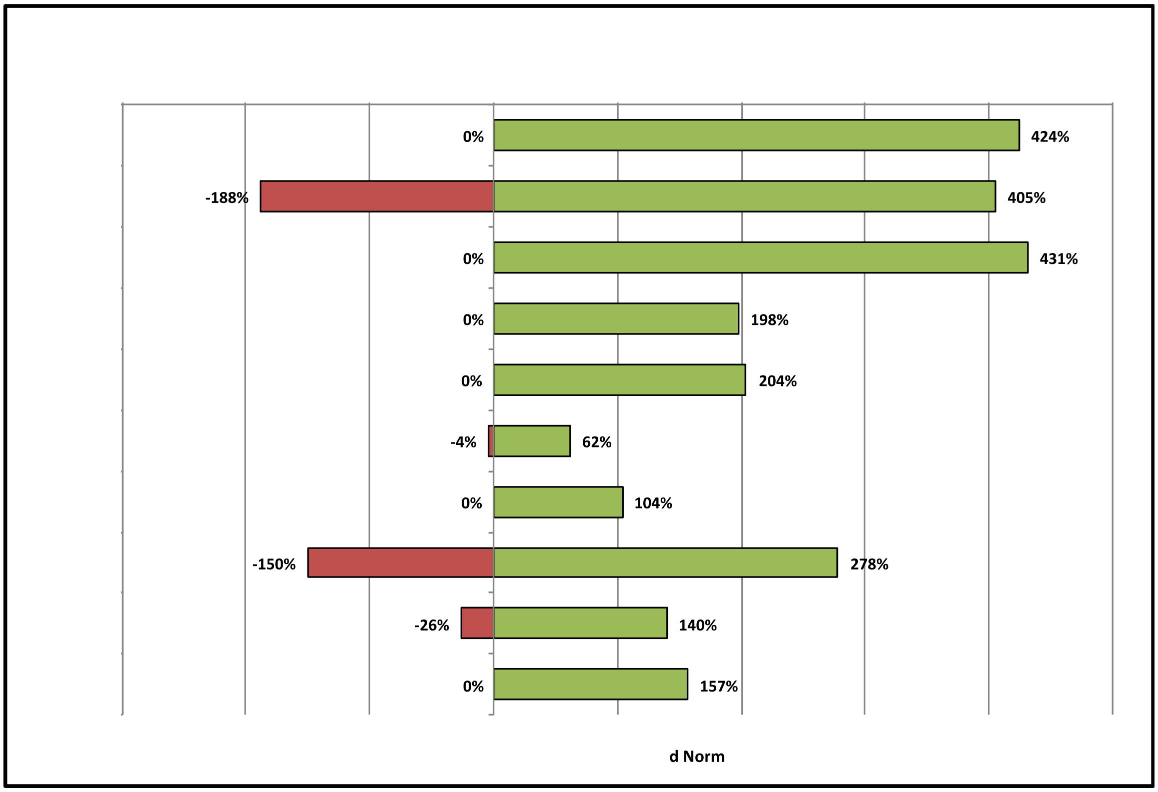
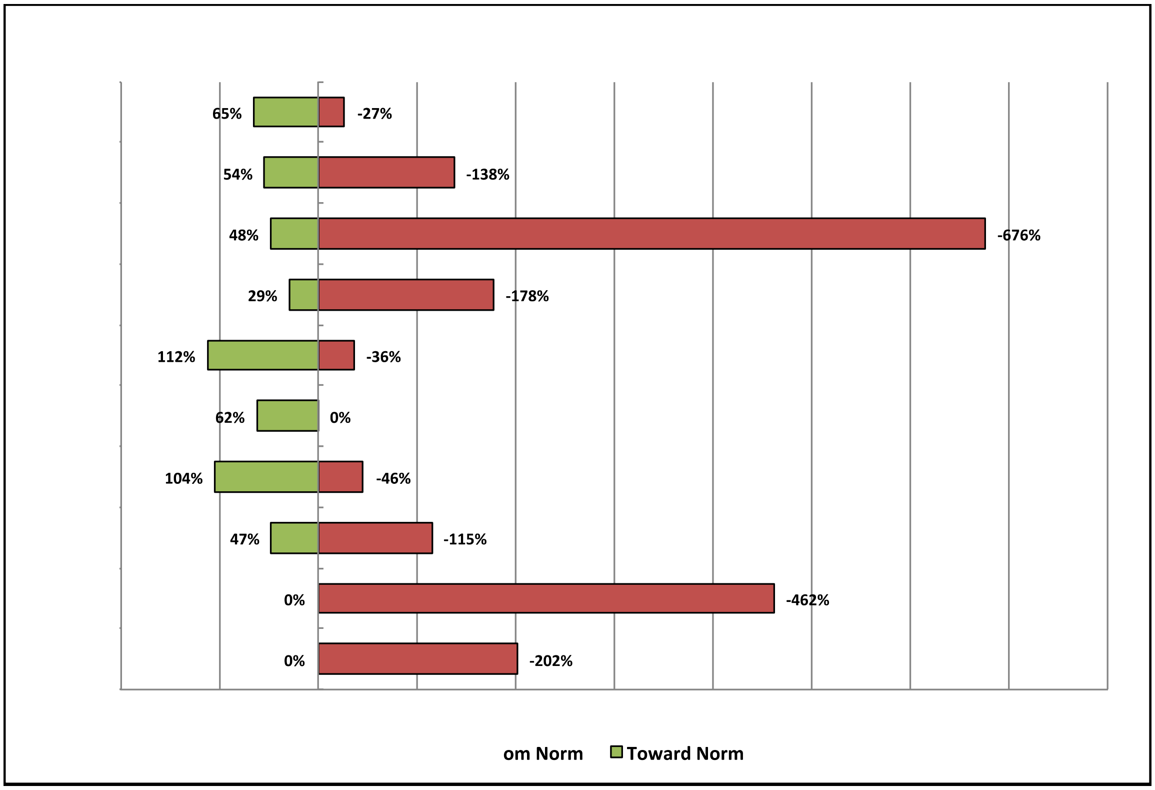


Chart 9 displays the same information as Chart 8 for proclined and protruded incisors. Proclined and protruded incisors tended to be proclined and protruded further from the ideal during treatment (45 measurements versus 18 for incisors moved toward the ideal).

Chart 9. Treatment Efficacy Analysis for Proclined/Protruded Incisors



V. DISCUSSION

The purpose of this study was to evaluate orthodontic incisor decompensation in a population of non-extraction patients who were treatment planned for orthognathic surgery. Subjects selected for the study had pre-treatment and pre-surgical CBCTs from which two-dimensional lateral cephalometric images were reconstructed. The small final sample size of 13 Class II and 13 Class III subjects was due primarily to exclusion of potential subjects who either had a pre-treatment CBCT and a pre-surgical traditional digital lateral cephalogram or vice versa. Other subjects were excluded from the study because the original CBCT data was either corrupt or missing.

Treatment for subjects selected for the study was planned and carried out by residents of TORP under the guidance and supervision of appointed faculty orthodontists. Faculty orthodontists received their training at a variety of different orthodontic programs. Neither treatment records nor information regarding the treating residents and faculty was available for all subjects due to the highly transient nature of military service. Thus it was also not possible to obtain specific details about treatment such as appliance type, archwire sequence, treatment mechanics and duration of pre-surgical orthodontic treatment that might shed additional light on the results of this study. However, traditionally at TORP, a stainless steel, pre-adjusted 0.022 inch slot, McLaughlin, Bennett and Trevisi (MBT) prescription appliance was used. The final surgical archwire is usually 0.019 x 0.025 inch stainless steel, but without treatment records, the actual final archwires could not be ascertained.

One aspect of this study that made interpretation of the data somewhat challenging was the use of both the Sella-Nasion plane and Palatal Plane to assess the inclination of maxillary molars. Normally, the angular difference between the two planes is approximately seven degrees, which also corresponds to the difference between the normal values for U1-SN (103 degrees) and U1-PP (110 degrees). If the angular difference between the two planes is less than or greater than the normal value, it is possible that one measurement may show that an upper incisor is within normal limits while the other may show that the same incisor is compensated. We did find this type of contradictory data in this study. For example, for the Class II group, 31 and 38 percent of maxillary incisors were compensated at T1 relative to U1-SN and U1-PP, respectively. In the Class III group, this difference was even greater with 38 and 69 percent of maxillary incisors compensated at T1 relative to U1-SN and U1-PP, respectively.

When using the objective of plus or minus one standard deviation of the cephalometric normal value as adequate incisor decompensation, the results of this study showed that Class III subjects had a greater percentage of compensated incisors at T1 than Class II subjects for both maxillary and mandibular incisors. It would be difficult to ascertain the exact reasons for the greater percentage of compensated Class III subjects. Subjects were not selected based on the severity of the initial presentation, only on the basis that they had an underlying skeletal defect severe enough to warrant orthognathic surgery. Future studies may consider limiting subject selection based on severity of the skeletal discrepancy to help control for this variable.

The data also showed that 50-60 percent of Class II maxillary incisors and 33 percent of mandibular incisors were decompensated. Profitt et al (1992) found similar acceptable final inclinations for 60 percent of maxillary incisors, but found that 58 percent of mandibular incisors were decompensated. Potts et al (2004) also had similar findings in a Class II group of 56 and 36 percent, of upper and lower incisors, respectively. In the Class III group, lower incisors were decompensated 42 percent of the time while upper incisors were decompensated 22-40 percent of the time. Troy et al (2009) also found that the mandibular incisors were decompensated to a greater extent than the maxillary incisors in Class III subjects.

The efficacy analysis confirmed what is already known; it is generally easier, and we were more effective at, decompensating retroclined and retruded incisors than proclined and protruded incisors. Theoretically, in Class II Division 1 and Class III subjects, by definition, the only retroclined incisors should be the lower incisors in Class III individuals. The fact that there is more than just Class III lower incisors included in the efficacy analysis indicates that this was not a pure sample. While the majority of retroclined and retruded incisors were proclined and protruded during treatment, some retroclined and retruded Class III maxillary incisors were retroclined and retruded further during treatment. However, the amounts were relatively small; only one retroclined and retruded maxillary incisor in the Class III group was further retroclined and retruded by three degrees and 0.9 mm, respectively. In a small number of instances, retruded Class II lower incisors were further retruded an average of 1.3 mm. These instances may be explained by the presence of pre-treatment spacing, widening of the arches during treatment, with a subsequent increase in arch perimeter, allowing uprighting of the incisors, or possibly the use of distalizing mechanics. The majority of initially retroclined and retruded incisors were proclined and/or protruded during pre-surgical orthodontics and often beyond the ideal several fold. Movement of incisors beyond the ideal is likely due to pre-treatment crowding and perhaps a deep curve of Spee that necessitates the proclination and protrusion of the incisors in order to align them. Those decompensated closest to the ideal in the Class II group were retruded upper incisors (n=8, 104%, 1.8 mm), protruded upper incisors (n=2, 104%, 2.8 mm), and proclined lower incisors (n=2, 112%, 4.7 degrees); In the Class III group it was retroclined lower incisors (n=11, 62.4%, 8.3 degrees) and proclined lower incisors (n=1, 62.2%, 2.3 degrees).

As mentioned previously, a variety of factors come in to play when considering the degree to which orthodontic incisor decompensation is achieved prior to orthognathic surgery. One potential variable is torsional play of the archwire within the bracket slot. In a systematic review evaluating torque expression in stainless steel brackets, Archambault et al (2010) found that the engagement angle between the archwire and the bracket slot varied from 18 degrees to 6 degrees in 0.018 x 0.025 inch and 0.021 x 0.025 inch stainless steel archwires, respectively. Variations in the initial proclination or retroclination of the incisors will also affect the engagement angle and the amount of torque expression in a given bracket/archwire combination.

Archwire composition can also affect the degree to which the torque built in to an orthodontic bracket is expressed. Even though the standard pre-surgical archwire used at TORP is stainless steel, it is important to understand that different archwire materials have differing abilities to express torque even when comparing archwires of the same dimension. Of the commonly used archwire materials, stainless steel has the greatest stiffness followed by cobalt chromium, beta titanium and nickel titanium with the lowest stiffness. Research conducted by Arreghini et al (2014) showed that the angles that had to be introduced between the bracket slot and the archwire to generate clinically significant degrees of torque were greatest in NiTi archwires followed by beta titanium and stainless steel.

The most commonly used bracket at TORP is a 0.022 slot size stainless steel bracket (Victory Series Twin, 3M Unitek, Monrovia, California). It is important to note, however, that torque expression varies between bracket type and material. Research by Morina et al (2008) compared the torque expression of self-ligating, conventional metallic, ceramic and plastic brackets. They found that a ceramic bracket had the highest torqueing moment and the lowest degree of torque loss. A metallic bracket had a similar degree of torque loss as the ceramic bracket. However, the self-ligating, plastic and other metallic brackets had significantly lower torqueing moments and higher loss of torque. Understanding these bracket characteristics can be clinically useful in selecting treatment mechanics that will achieve adequate pre-surgical dental decompensation.

The position of the bracket on the tooth can also affect torque expression. Meyer and Nelson (1987) found that a change in the vertical position of a bracket on a tooth of three millimeters could change the torque angle by as much as 15 degrees. Others have proposed that a similar degree of change in the torque angle may occur with as little as a one millimeter discrepancy in vertical bracket placement (Miethke, 1997). Germane and Isaacson (1989) also suggested that variation in the facial surface contour at the same point on the same tooth in different individuals and variation in the facial surface anatomy at different vertical points on the same tooth in the same individual could require the use of torqueing, or third order bends, in order to achieve satisfactory inclination of teeth.

Dental crowding or spacing can also affect the degree and the direction in which incisor inclination is modified during pre-surgical orthodontic treatment. It is important to note that none of the subjects in this study had teeth extracted. And, because this was a cephalometric study, there was no ability to assess pre-treatment crowding or spacing in order to evaluate how this affected decompensation of the incisors. In cases with overly proclined incisors at initiation of treatment, the presence of crowding may make it difficult or impossible to upright incisors to within the range of normal. Even when teeth are extracted, much of the space made available from extracting teeth is utilized for resolution of crowding instead of incisor decompensation. Spacing in cases where incisors are retroclined at initiation of treatment may make incisor decompensation a challenge without employing additional measures such as skeletal anchorage in order to procline anterior teeth and protract posterior teeth.

Theoretically, the incisors with the best chance of being decompensated would be those that start out retroclined and/or retruded. In this study, this would include the mandibular incisors in the Class III group. Both upper and lower incisors in Class II Division 1 cases tend to be proclined and/or protruded. Incisors retroclined relative to the norm were present in both Class II and Class III subjects in this study, and, generally speaking, were proclined during treatment. In cases where they were not, there may have been pre-treatment spacing or perhaps dental arch expansion due to archwire progression or expansion, or even surgically assisted rapid palatal expansion during pre-orthognathic orthodontics that would have allowed upper incisors to retrocline.

It is clear that achieving adequate incisor decompensation prior to orthognathic surgery is an endeavor that requires consideration of a variety of factors. Clinicians must carefully evaluate the initial presentation of the patient and determine whether or not extraction of teeth will be necessary in order to resolve any crowding as well as bring the incisors into acceptable position. The clinician may also consider the use of temporary anchorage devices (TADs) or bone plates to retract or protract the dentition to obtain proper incisor position. A thorough understanding of the appliance that the orthodontist selects and its strengths, weaknesses and nuances is critical to being able to manipulate the appliance in order to achieve the desired effects. Although we live in the era of the pre-adjusted appliance, it remains necessary to occasionally apply selective in-out, tip and torque adjustments to place teeth in positions that will allow for the best treatment outcomes.

Finally, the question must be asked whether complete incisor decompensation to normal values in all cases is necessary or even desirable.

Patients who agree to undergo orthognathic surgery as part of an orthodontic treatment plan deserve our best efforts at achieving the best treatment outcome possible. Generally this entails placing teeth, incisors in particular, in positions that will allow for the best esthetics and maximization of the surgical movements of the jaws. Certainly, in cases with minimal compensation and acceptable alignment of teeth, extraordinary means and perhaps extended treatment timelines to achieve ideal incisor position may not be necessary or prudent. There may also be cases in which efforts to obtain ideal inclination and anteroposterior position of incisors may necessitate surgery of both jaws in order to obtain proper occlusion when surgery of only one jaw may provide a very reasonable esthetic and occlusal result that is perfectly acceptable to the patient. It may be the case that the treatment results obtained with less than ideal incisor decompensation may be completely adequate. Evaluation of the level of incisor decompensation relative to subjective assessments of treatment outcome esthetics may be useful in drawing some conclusions in this area.

This study had several design flaws that limited the usefulness of the data gathered. First was the small number of subjects available for the study. This may have been due in part to lack of accurate treatment information in the patient database at TORP. Subjects may not have been included in the initial search results due to missing or incorrect treatment descriptors. Another weakness was the fact that some of the subjects included in the Class II Division 1 group had upright incisors that are generally indicative of a Class II Division 2 malocclusion. This could have affected the results of this study. A recommendation for future studies of this type would be to carefully evaluate the data as it is gathered and exclude subjects that are found not to meet the inclusion criteria at that point.

Some suggestions for future studies would be to evaluate incisor decompensation in Class II Division 2 subjects and compare them against data from this study. Another suggestion would be to evaluate extraction cases for comparison against the non-extraction cases of this study if a sufficient number of subjects could be obtained. An original intention of this study was to evaluate the effect of the size and composition of the final pre-surgical archwire, how long it was utilized, and if additional torque was added to the wire in order to improve incisor inclination. However, treatment records for all subjects were not available. A recommendation would be to include this information in the treatment database so it is available when records are not. An additional suggestion would be to assess crowding and spacing and evaluate how they affect decompensation of incisors.

VI. CONCLUSIONS

The null hypothesis was rejected. Complete incisor decompensation to race-specific norms was seldom achieved during orthodontic treatment prior to orthognathic surgery. The following conclusions were derived from this study:

- In Class II subjects, maxillary incisors were decompensated to within the normal range more frequently than mandibular incisors
- In Class III subjects, mandibular incisors were decompensated to within the normal range more frequently than maxillary incisors
- Incisors in Class II subjects were decompensated to within the normal range more often than Class III subjects
- Efficacy analyses showed that
    - Retroclined and retruded incisors were generally proclined and/or protruded, but were frequently overcorrected beyond ideal
    - Proclined/protruded incisors were more often proclined/protruded further away from ideal
- The greatest absolute changes in incisor inclination were seen in Class III mandibular incisors

VII. APPENDIX

Table 7. Raw Class II Demographic Data

Subject	Date of Initial CBCT	Date of Pre-surg CBCT	Age at Initial Records (Years)	Age at Pre-Surg Records (Years)	Race	Gender
21001	3-Jul-2008	6-Jul-2010	13.64	15.64	Caucasian	M
210002	1-Jul-2008	21-Sep-2010	25.23	27.45	Caucasian	F
210004	2-Sep-2009	20-Jan-2011	26.89	28.27	Caucasian	M
210005	14-Sep-2009	21-Apr-2011	22.12	23.72	Caucasian	M
210006	24-Jul-2009	16-Aug-2011	38.22	40.28	Caucasian	F
210007	16-Jul-2009	28-Dec-2010	16.98	18.43	Caucasian	F
210008	22-Jul-2011	27-Mar-2013	41.18	42.86	Caucasian	M
210009	29-Jun-2009	25-Jan-2011	21.03	22.61	Caucasian	F
210010	31-Jul-2013	11-Apr-2014	30.67	31.36	Caucasian	M
210011	26-Jul-2007	14-Jul-2011	24.00	27.97	Hispanic	F
210012	1-Oct-2013	10-Sep-2015	14.07	16.01	Caucasian	F
210013	16-Aug-2013	20-Oct-2015	16.01	18.18	Caucasian	F
210014	12-Jul-2011	14-Mar-2013	15.65	17.32	Caucasian	F

Table 8. Raw Class III Demographic Data

Subject	Date of Initial CBCT	Date of Pre-surg CBCT	Age at Initial Records (Years)	Age at Pre-Surg Records (Years)	Race	Gender
30001	13-Nov-07	16-Feb-10	22.23	24.49	Caucasian	M
30002	17-Jul-07	11-Aug-09	28.54	30.61	African-American	F
30003	26-Oct-11	30-May-13	24.25	25.84	Caucasian	F
30004	3-Jul-08	26-Aug-09	25.31	26.46	Caucasian	M
30005	19-Nov-07	2-Jun-09	27.53	29.07	African-American	M
30006	23-Mar-09	3-Apr-11	37.18	39.21	Asian	F
30007	26-Sep-07	4-Aug-08	24.11	24.97	Caucasian	F
30008	23-Mar-09	28-Sep-10	38.28	39.80	Caucasian	M
30009	10-Apr-12	1-May-13	16.07	17.13	Caucasian	F
30010	9-Nov-11	18-Jun-13	34.15	35.76	Hispanic	M
30011	2-Aug-10	4-Jun-12	26.81	28.65	Caucasian	M
30012	29-Jan-13	27-Oct-14	20.00	21.74	African-American	M
30013	5-Aug-14	17-Jun-15	17.36	18.23	Caucasian	F

Table 9. Raw Class II Cephalometric Data

Ceph Measure	Subjects						
	21001	210003	210004	210005	210006	210007	210008
T1 U1-SN (˚)	101.7	104.6	98.9	105.8	104.5	101.9	102.2
T2 U1-SN (˚)	107.1	113.9	112.6	107.0	115.4	103.9	105.2
T1-T2 U1-SN (˚)	-5.4	-9.3	-13.7	-1.2	-10.9	-2.0	-3.0
T1 U1-PP (˚)	112.3	110.3	101.8	115.8	109.2	108.2	109.3
T2 U1-PP (˚)	116.9	117.5	113.9	114.2	119.6	113.6	112.3
T1-T2 U1-PP (˚)	-4.6	-7.2	-12.1	1.6	-10.4	-5.4	-3.0
T1 U1-NA (mm)	2.2	5.2	0.6	2.6	3.4	7.5	4.3
T2 U1-NA (mm)	2.7	5.4	4.7	3.6	7.0	7.7	4.5
T1-T2 U1-NA (mm)	-0.5	-0.2	-4.1	-1.0	-3.6	-0.2	-0.2
T1 IMPA (˚)	94.4	99.1	100.2	95.4	97.8	80.8	82.4
T2 IMPA (˚)	94.8	101.8	100.0	98.3	102.9	95.1	92.0
T1-T2 IMPA (˚)	-0.4	-2.7	0.2	-2.9	-5.1	-14.3	-9.6
T1 L1-NB (mm)	7.8	5.6	2.0	6.3	4.4	6.2	8.1
T2 L1-NB (mm)	9.4	5.2	1.7	7.8	4.5	9.2	11.6
T1-T2 L1-NB (mm)	-1.6	0.4	0.3	-1.5	-0.1	-3.0	-3.5

Table 10. Raw Class II Cephalometric Data (cont.)

Ceph Measure	Subjects					
	210009	210010	210011	210012	210013	210014
T1 U1-SN (˚)	117.5	109.8	101.6	119.6	108.7	94.7
T2 U1-SN (˚)	101.8	110.5	111.3	116.1	113.8	100.2
T1-T2 U1-SN (˚)	15.7	-0.7	-9.7	3.5	-5.1	-5.5
T1 U1-PP (˚)	128.3	116.2	105.8	123.3	115.5	103.4
T2 U1-PP (˚)	111.4	117.7	118.3	120.1	119.9	111.0
T1-T2 U1-PP (˚)	16.9	-1.5	-12.5	3.2	-4.4	-7.6
T1 U1-NA (mm)	7.4	5.4	3.2	5.7	4.3	3.0
T2 U1-NA (mm)	3.5	6.0	6.1	4.1	5.0	4.1
T1-T2 U1-NA (mm)	3.9	-0.6	-2.9	1.6	-0.7	-1.1
T1 IMPA (˚)	88.1	99.8	79.3	87.6	104.1	105.1
T2 IMPA (˚)	100.4	101.7	87.5	95.1	95.0	111.3
T1-T2 IMPA (˚)	-12.3	-1.9	-8.2	-7.5	9.1	-6.2
T1 L1-NB (mm)	1.7	7.3	4.1	1.1	5.2	4.0
T2 L1-NB (mm)	4.0	7.9	6.2	2.0	1.9	4.3
T1-T2 L1-NB (mm)	-2.3	-0.6	-2.1	-0.9	3.3	-0.3

Table 11. Raw Class III Cephalometric Data

Ceph Measure	Subjects						
	30001	30002	30003	30004	30005	30006	30007
T1 U1-SN (˚)	101.3	119.4	105.4	99.4	120.3	116.4	101.7
T2 U1-SN (˚)	112.4	115.7	112.3	101.9	112.1	117.7	108.1
T1-T2 U1-SN (˚)	-11.1	3.7	-6.9	-2.5	8.2	-1.3	-6.4
T1 U1-PP (˚)	108.9	118.2	117.6	107.9	130.6	125.3	117.1
T2 U1-PP (˚)	111.9	115.3	124.9	110.5	124.3	123.9	122.2
T1-T2 U1-PP (˚)	-3.0	2.9	-7.3	-2.6	6.3	1.4	-5.1
T1 U1-NA (mm)	2.1	10.4	4.7	2.7	11.2	7.6	3.5
T2 U1-NA (mm)	8.0	7.2	6.2	3.8	11.2	9.5	5.7
T1-T2 U1-NA (mm)	-5.9	3.2	-1.5	-1.1	0.0	-1.9	-2.2
T1 IMPA (˚)	73.4	103.7	79.3	73.6	90.6	80.3	83.6
T2 IMPA (˚)	82.2	101.4	90.6	78.7	96.2	90.9	88.3
T1-T2 IMPA (˚)	-8.8	2.3	-11.3	-5.1	-5.6	-10.6	-4.7
T1 L1-NB (mm)	-0.8	9.1	4.3	2.0	9.6	6.1	3.8
T2 L1-NB (mm)	2.0	9.6	6.6	4.3	10.3	8.0	4.6
T1-T2 L1-NB (mm)	-2.8	-0.5	-2.3	-2.3	-0.7	-1.9	-0.8

Table 12. Raw Class III Cephalometric Data (cont.)

Ceph Measure	Subjects					
	30008	30009	30010	30011	30012	30013
T1 U1-SN (˚)	105.9	105.4	113.0	101.4	115.9	118.0
T2 U1-SN (˚)	117.1	106.8	127.0	98.4	117.3	122.4
T1-T2 U1-SN (˚)	-11.2	-1.4	-14.0	3.0	-1.4	-4.4
T1 U1-PP (˚)	116.0	110.4	113.2	118.4	122.5	124.7
T2 U1-PP (˚)	126.1	112.4	125.5	115.1	123.4	127.8
T1-T2 U1-PP (˚)	-10.1	-2.0	-12.3	3.3	-0.9	-3.1
T1 U1-NA (mm)	7.2	6.6	6.9	3.4	8.7	5.7
T2 U1-NA (mm)	10.4	6.7	9.5	2.5	9.4	7.7
T1-T2 U1-NA (mm)	-3.2	-0.1	-2.6	0.9	-0.7	-2.0
T1 IMPA (˚)	74.0	73.4	88.4	83.8	82.1	76.8
T2 IMPA (˚)	87.8	83.9	96.1	83.5	89.1	82.8
T1-T2 IMPA (˚)	-13.8	-10.5	-7.7	0.3	-7.0	-6.0
T1 L1-NB (mm)	1.8	5.4	6.1	5.0	13.9	5.9
T2 L1-NB (mm)	6.5	8.1	8.8	5.3	15.4	6.7
T1-T2 L1-NB (mm)	-4.7	-2.7	-2.7	-0.3	-1.5	-0.8

VIII. LITERATURE CITED

1. Archambault A, Lacoursiere R, Badawi H, Major PW, Carey J, Flores-Mir, C Torque Expression in Stainless Steel Orthodontic Brackets. A Systematic Review. Angle Orthod. 2010;80:201–210.
2. Arreghini A, Lombardo L, Mollica F, Siciliani G. Torque expression capacity of 0.018 and 0.022 bracket slots by changing archwire material and cross section. Progress in Orthodontics. 2014;15:53.
3. Arriola-Guillen L, Flores-Mir C. Molar heights and incisor inclinations in adults with Class II and Class III skeletal open-bite malocclusions. Am J Orthod Dentofacial Orthop 2014;145:325-32.
4. Aziz R. Simon P. Hullihen and the Origin of Orthognathic Surgery. J Oral Maxillofac Surg. 2004;62:1303-1307.
5. Capelozza L, Martins A, Mazzotini R, da Silva O. Effects of dental decompensation on the surgical treatment of mandibular prognathism. Int J Adult Orthod Orthognath Surg. 1996;11:165-180.
6. Casko J, Shepherd W. Dental and Skeletal Variation Within the Range of Normal. Angle Orthod. 1984;54:5-17.
7. Drummond, RA. A determination of cephalometric norms for the Negro race. Am J Orthod. 1968;54:670-682.
8. Germane N, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straight-wire appliances. Am J Orthod Dentofac Orthop. 1989;96:312-319.

9. Goldsman S. The Variations in Skeletal And Denture Patterns In Excellent Adult Facial Types. Angle Orthod. 1959;29:63–92.
10. Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S, Tsukada H, and Chu S. Dentoalveolar Compensation in Negative Overjet Cases. Angle Orthod 2000;70(2):145-148.
11. Johnston C, Burden D, Kennedy D, Harradine N, Stevenson M. Class III surgical-orthodontic treatment: A cephalometric study. Am J Orthod Dentofacial Orthop. 2006;130:300-309.
12. Kim J-H, et al. Comparison of cephalometric norms between Mongolian and Korean adults with normal occlusions and well-balanced profiles. Korean J Orthod. 2011;41:42-50.
13. McLaughlin R, Bennett J, Trevisi H. Systemized Orthodontic Treatment Mechanics. St. Louis: Mosby; 2014.
14. McNeil C, McIntyre G, Laverick S. How much incisor decompensation is achieved prior to orthognathic surgery? J Clin Exp Dent 2014;6(2):e225-229.
15. Meyer M, Nelson G. Preadjusted edgewise appliances: Theory and practice. Amer J Orthod. 1978;73(5):485-498.
16. Miethke RR. Third order tooth movements with straight wire appliances. Influence of vestibular tooth crown morphology in the vertical plane. J Orofac Orthop. 1997;58(4):186-97.
17. Morina E, Eliades T, Pandis N, Jäger A, and Bourauel C. Torque expression of self-ligating brackets compared with conventional metallic, ceramic, and plastic brackets. Eur J Orthod. 2008;30:233–238.

18. Obwegeser, J. History and 50 years experience in orthognathic surgery. Stomatologie. 2005;102.2:27-34.
19. Panula, K. Correction of dentofacial deformities with orthognathic surgery [dissertation]. Oulu, Finland. University of Oulu; 2003.
20. Park I-C, Bowman D, Klapper L. A cephalometric study of Korean adults. Am J Orthod Dentofac Orthop. 1989;96:54-59.
21. Peck S. A Biographical Portrait of Edward Hartley Angle, the First Specialist in Orthodontics, Part 2. Angle Orthodontist. 2009;79:1028-1033.
22. Pereira-Stabile C, Ochs M, de Moraes M, Moreira R. Preoperative incisor inclination in patients with Class III dentofacial deformities treated with orthognathic surgery. Br J Oral Maxillofac Surg 2012;50(6):533-536.
23. Phonpraserth A, Cunningham S, Hunt N. Soft tissue changes associated with incisor decompensation prior to orthognathic surgery. Int J Adult Orthodon Orthognath Surg 1999;14(3):199-206.
24. Potts B, Shanker S, Beck FM, Vig KW. Predictors of dentoalveolar outcome of presurgical orthodontic change [abstract 128]. J Dent Res 2004;83 (Spec Iss A).
25. Potts B, et al. Dental and skeletal changes associated with Class II surgical-orthodontic treatment. Am J Orthod Dentofacial Orthop. 2009;135:566.e1-566.e7.
26. Proffit WR, Fields H, Sarver D. Contemporary Orthodontics 5th Edition. St. Louis: Mosby; 2013.

27. Proffit WR, Phillips C, Douvartzidis N. A comparison of outcomes of orthodontic and surgical-orthodontic treatment of Class II malocclusion in adults. Am J Orthod Dentofac Orthod. 1992;101:556-565.

28. Swlerenga D, Oesterle LJ, Messersmith ML. Cephalometric values for adult Mexican-Americans. 1994;106:146-155.

29. Xu B, Ju Z, Hägg U, Tideman H, Piette E. Presurgical Orthodontic Decompensation of Mandibular Incisors. Austr Orthod J. 1995;14:28-33.