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Compliance-free Class II correction and its relationship to vertical facial characteristics

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Compliance-free Class II correction and its relationship to vertical facial characteristics

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Abstract

COMPLIANCE-FREE CLASS II CORRECTION AND ITS RELATIONSHIP TO VERTICAL FACIAL CHARACTERISTICS

By Michael C. Shoff, D.D.S.

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University, 2012

Thesis Director: Steven J. Lindauer, D.M.D., M.Dent.Sc.
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Background

While efficacy of the Forsus appliance has been shown, there are disagreements on its mechanism for Class II correction. Class II studies have been criticized for ignoring potential differences in results based on differing vertical facial phenotypes. The purpose of this study was to better understand the effects of Class II correction using the Forsus appliance and relate changes during and at the completion of treatment to initial MP-SN angles.

Materials and Methods

Records of 59 patients obtained at 4 different time points were examined retrospectively. ANOVA was used to describe the cephalometric changes and Pearson's correlation tested for any relationship between patients' pretreatment MP-SN angle and other selected measures.

Results/Conclusions

Class II correction was achieved by mesial movement of the mandibular dentition, differential mandibular growth, and clockwise rotation of the occlusal plane. There was no correlation between pre-treatment MP-SN angles and any selected cephalometric measure.

Introduction

Class II malocclusion is one of the most common clinical presentations observed in patients seeking orthodontic treatment.[1] Traditional approaches for correction have involved combinations of fixed edgewise appliances to align the teeth, with anterior-posterior (A-P) correction from use of inter- or intra-arch elastics, extraoral appliances such as headgear, fixed or removable functional appliances, extraction of teeth, or orthognathic surgery.

Elastics and headgear wear are both fully dependent on patient compliance and understanding, which are difficult to predict.[2,3] Fixed intermaxillary appliances such as the Herbst, MARA, Jasper Jumper, and Eureka Spring are all compliance-free alternatives to elastics and headgear for correcting A-P discrepancies in the dentition. Use of these appliances has been shown to result in mesial movement of the lower dentition, including proclination of the lower incisors in combination with mandibular growth.[4,5,6,7,8,9] Variable effects have been shown in maxillary skeletal and dental change.[4,5,6,7,8,9] Disadvantages of these fixed appliances include bulkiness, lack of durability, patient discomfort, and/or necessity of complicated laboratory procedures. The Forsus Fatigue Resistant Device (Forsus) from 3M Unitek (Monrovia, CA) is a relatively new alternate fixed appliance designed to obtain compliance-free Class II correction. It utilizes a 3-piece semirigid telescoping system incorporating a superelastic nickel-titanium coil spring that can be assembled and delivered chairside. Studies have shown nearly no statistical differences in the Class II corrective mechanism when comparing Forsus to the Jasper Jumper and to Class II intermaxillary elastics.[10,11]

While anterior-posterior correction often becomes the focus of orthodontic treatment and several different devices can be used for such correction, consideration of the patient’s skeletal phenotype and control of the vertical dimension are both of significant importance. Many studies have attempted to define how different treatment modalities vary in their effect on the vertical dimension. Nelson et al[9] found significant vertical changes due to Class II elastic use. Specifically, increased mandibular plane angle and anterior lower facial height were observed, compared to no such effects in a Herbst treated group. With use of high-pull headgear, Firouz[12] found intrusion of the maxillary first molar and restriction of growth in the vertical dimension. Baumrind et al[13] had similar findings with high pull headgear and reported extrusion of the upper first molar with use of cervical-pull headgear. However, Gkantidis et al[14] demonstrated that there were no appreciable differences in vertical outcomes of Class II correction when either intrusive (e.g. high pull headgear) or extrusive mechanics (e.g. cervical headgear, Class II elastics) were used.

Patients with different facial growth patterns (hypo vs. hyperdivergent) may respond differently to the same Class II correction treatment. Traditional thinking in orthodontics is that hyperdivergent patients will not respond favorably to extrusive mechanics such as Class II elastics, and that anteroposterior correction should be achieved with high pull headgear, bite blocks, and/or other modalities which will also prevent iatrogenic eruption of posterior teeth.[15] Conversely, hypodivergent patients are thought to be best treated with extrusive mechanics to promote vertical elongation of posterior teeth.[15] Additionally, extractions are often advocated in the treatment of hyperdivergent patients while being avoided if at all possible in the hypodivergent population.[16]

Despite these traditional beliefs, recent studies have shown that patients with steep and flat mandibular planes responded more similarly than differently to the same treatments. Haralabakis and Sifakakis[17] found that there was no difference in vertical growth characteristics when high plane and low plane patients were treated with cervical pull headgear. Another study evaluated lower incisor proclination during Class II correction with the Xbow appliance, and found no significant difference between high and low plane patients.[18]

Despite these recent reports, some continue to believe that patients with different vertical growth patterns do indeed respond differently to commonly used orthodontic treatment modalities. Findings from traditional Class II studies have been criticized with claims that actual results have been diluted when treatment changes were reported as mean values, without attention paid to each patient's pretreatment vertical growth pattern.[19,20]

With increasing popularity in the use of the compliance-free Forsus device to correct Class II malocclusions, a complete description of its effects, and how outcomes may differ on patients of different phenotypes should be understood. In recent studies, Karacay et al[10] and Jones et al[11] disagreed on various consequences in the vertical dimension during horizontal correction with the Forsus. However, one methodologic difference between these two studies was the timing of when records were obtained. While one study obtained records pre- and post-orthodontic treatment,[11] the other examined records taken after initial leveling and immediately after the Forsus was removed.[10] The incomplete documentation of dento-skeletal changes in these studies due to timing of records could be a weakness in each study.

Currently, there are conflicting reports of the vertical side effects associated with anterior-posterior correction using the Forsus appliance. Better understanding of treatment outcomes is critical for treatment planning, especially when considering a patient presenting with an already increased or decreased lower facial height. No study has looked closely at treatment outcome differences in patients with hypo- or hyperdivergent growth patterns or documented changes after each stage of treatment. The purpose of this study was to better understand the effects of Class II correction using the Forsus appliance, and to evaluate changes in pre-selected measures as a function of pre-treatment mandibular plane angulation.

Materials and Methods

Patients and Study Design

Prior to this retrospective study, approval was granted by the Institutional Review Board from the Research Office of Virginia Commonwealth University. The records used in this study were obtained from one private practice office in Sidney, Ohio. Subjects were required to be at least end-on Class II at the start of treatment with a maximum age of 16 years. Patients were excluded if they were congenitally missing teeth, required extractions or surgery as part of their treatment, or if they were diagnosed with any craniofacial syndrome. A total of 59 consecutively treated patients met the inclusion and exclusion criteria. All patients were treated with preadjusted Smartclip brackets (3M Unitek; Monrovia, CA) with a standard MBT prescription. After initial leveling and alignment, Forsus appliances were delivered in conjunction with lower 0.019" x 0.025" stainless steel or TMA wire, which was cinched distal to the molars. The upper wire varied according to individual upper incisor torque needs for each patient. The Forsus springs were connected from tubes in upper first molar bands to the archwire distal to the lower first premolars. Forsus springs were left in place until Class II occlusion was corrected to a Class I canine relationship or slight overcorrection in some cases. The appliance was removed and patients were then finished and detailed using straight wire mechanics. Each patient had cephalometric radiographs taken at the following timepoints: pretreatment (T1), Forsus insertion (T2), the appointment after Forsus removal (T3), and post treatment (T4).

Cephalometric radiographs were traced using Dolphin Imaging 11.5 (Chatsworth, CA) by one of the authors (MCS) for each time point. Due to the radiographic presence of bands, lack thereof, or a fixed lingual retainer, the author could not truly be blinded to the particular phase in treatment. They were, however, blinded to every other characteristic including any pre-treatment measurement, which was the basis of comparison in this study. If a landmark was in question, the point was discussed with another author (SJL) until the position was agreed upon. Points traced and their definitions can be found in Table 1.

Cephalometric Analysis

T1 radiographs were traced and used to obtain patients' pre-treatment skeletal and dental characteristics. A total of 23 dental and skeletal measurements were made (7 angular, 16 linear) at each timepoint using a custom cephalometric analysis. They are described in Table 2. T3 – T2, T4 – T3 and T4 – T2 changes were evaluated. Horizontal and vertical changes of skeletal landmarks were measured along a horizontal plane (SN – 7°) and a perpendicular vertical plane through Sella. Dental movements in the maxilla were measured using the horizontal plane of ANS-PNS with a vertical perpendicular dropped through A point. Movement of the mandibular dentition was measured on the horizontal plane of Go-Me with the perpendicular vertical plane passing through Pogonion. These planes can be visualized in Figure 1. 10 radiographs were selected randomly and retraced to determine the intra-rater reliability and average error of the tracing method.

Table 1. Cephalometric landmarks and definitions

Landmark	Abbreviation	Definition
A point	A	Deepest point on the curve of the maxilla, between anterior nasal spine and dental alveolus
Anterior nasal spine	ANS	Tip of the anterior nasal spine
B point	B	Most posterior point in the concavity along the anterior border of the symphysis
Gonion	Go	Most convex point where the posterior and inferior curves of the ramus meet
Horizontal Plane	HP	Sella to Nasion line minus 7°
Lower first molar	L6	Mesial buccal cusp tip of the mandibular molar
Lower first premolar	L4	Buccal cusp tip of the lower first bicuspid
Lower incisor apex		Root apex of the lower central incisor
Lower incisor tip	L1	Tip of the lower central incisor
Menton	Me	Most inferior point of the mandibular symphysis
Nasion	N	Intersection of the internasal suture with the nasofrontal suture in the midsagittal plane
Pogonion	Pg	Most anterior point of the mid-sagittal symphysis
Posterior nasal spine	PNS	Tip of the posterior nasal spine
Sella	S	Center of the pituitary fossa of the sphenoid bone
Upper first molar	U6	Mesial buccal cusp tip of the maxillary molar
Upper first premolar	U4	Buccal cusp tip of the upper first bicuspid
Upper incisor apex		Root apex of the upper central incisor
Upper incisor tip	U1	Tip of the upper incisor

Table 2. Cephalometric measurements and definitions

Measurement	Description
SNA	Angle formed by lines S-N and N-A
SNB	Angle formed by lines S-N and N-B
Convexity	Angle formed by lines N-A and A-Pg
A Horiz	Horizontal distance of A point from line through Sella perpendicular to HP
B Horiz	Horizontal distance of B point from line through Sella perpendicular to HP
Po Horiz	Horizontal distance of Pogonion from line through Sella perpendicular to HP
MP-SN	Angle formed by lines Sella-Nasion and Gonion-Menton
N-Me	Linear measurement of Nasion to Menton
ANS-Me	Linear measurement of ANS to Menton
U1-SN	Angle formed by the lines of upper incisor apex-upper incisor tip and S-N
IMPA	Angle formed by the lines of the upper incisor apex-upper incisor tip and Go-Me
OP-HP	Angle formed by the lines of the functional occlusal plane and HP
L1 Horiz	Horizontal distance of L1 from line through Pg perpendicular to Go-Me
L1 Vert	Vertical distance of L1 from line Go-Me
L6 Horiz	Horizontal distance of L6 from line through Pg perpendicular to Go-Me
L6 Vert	Vertical distance of L1 from line Go-Me
U1 Horiz	Horizontal distance of U1 from line through A point perpendicular to ANS-PNS
U1 Vert	Vertical distance of U1 from line ANS-PNS
U6 Horiz	Horizontal distance of U6 from line through A point perpendicular to ANS-PNS
U6 Vert	Vertical distance of U6 from line ANS-PNS

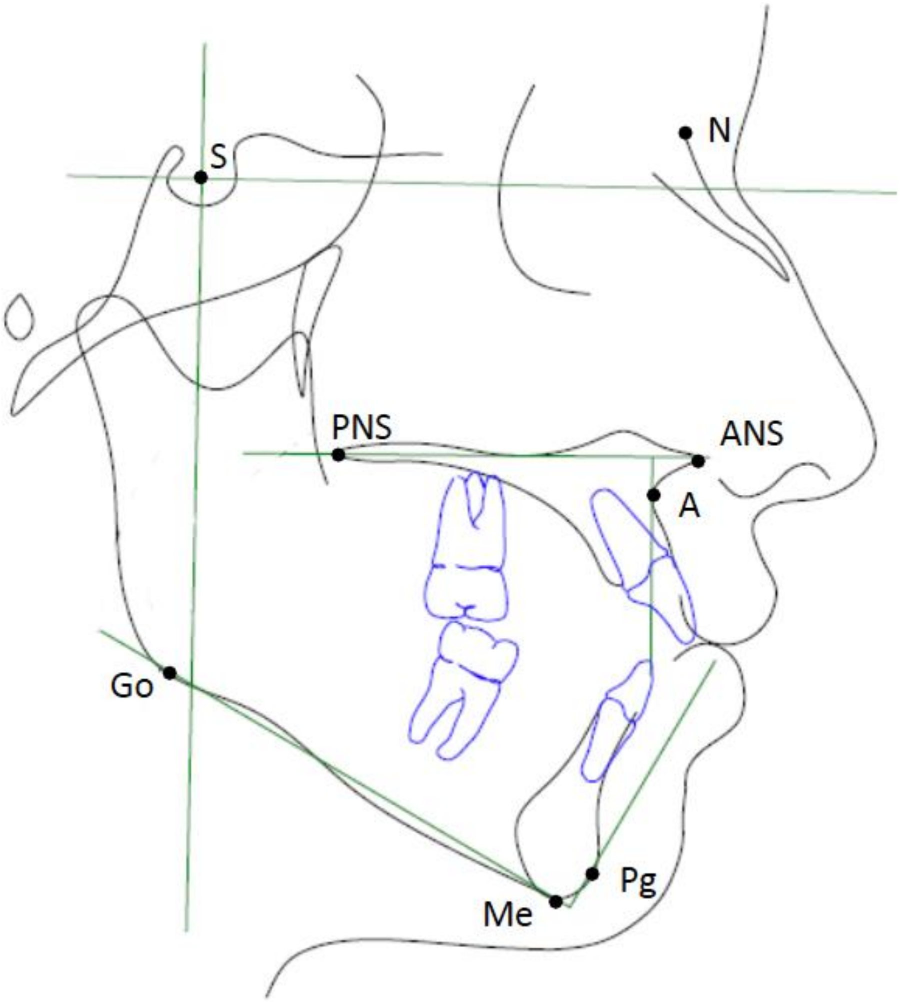

Figure 1: Horizontal and vertical reference planes used in cephalometric analysis

Statistical Analysis

Mean values were calculated to describe the overall change in each measurement for the patients treated. Changes between the timepoints were modeled using repeated-measures ANOVA. Changes in cephalometric measurements that occurred during treatment were tested for using specific contrasts in the repeated-measures analysis. Additionally, Pearson's correlation was used to estimate the relationship between the pretreatment mandibular plane angle and changes in the following selected measures: lower incisor inclination (IMPA), occlusal plane angulation (OP-SN), mandibular plane angle (MP-SN), and lower facial height (ANS-Me). All analyses were done using SAS software (SAS version 9.3, SAS Institute Inc., Cary, NC).

Power analysis revealed that in order to have an 80% power at alpha = 0.05 with correlations as large as r = 0.4, a sample of n = 48 was necessary.

Results

Measurement Error

In order to determine measurement error associated with the tracing method, ten radiographs were randomly chosen and the landmarks were redigitized. Table 3 shows the intra-class correlations between the duplicate measurements (ICC), the maximum absolute difference between duplicate measurements, and the median of the absolute deviations.

Table 3. Measurement Error

Measurement	ICC	Maximum Difference	Median Absolute Deviation
SNA	0.962	1.3	0.40
SNB	0.981	0.9	0.35
Convexity	0.993	1.1	0.55
A Horiz	0.992	1.0	0.30
B Horiz	0.988	1.1	0.55
Po Horiz	0.986	1.5	0.55
MP-SN	0.987	0.9	0.50
N-Me	0.998	0.8	0.35
ANS-Me	0.998	0.8	0.30
U1 - SN	0.956	2.7	0.85
IMPA	0.948	3.4	0.95
OP - SN	0.977	2.0	0.70
L1 Horiz	0.985	0.9	0.30
L1 Vert	0.993	0.8	0.35
L6 Horiz	0.989	1.1	0.20
L6 Vert	0.986	0.8	0.35
U1 - Horiz	0.927	0.9	0.30
U1 - Vert	0.986	0.8	0.40
U6 Horiz	0.974	1.4	0.30
U6 Vert	0.969	0.9	0.15

Description

A total of 59 patients' records were evaluated for this study. Due to poor diagnostic quality, two patients' T3 and T4 radiographs were excluded. Additionally, one patient's T2 data were not used due to anterior positioning of the mandible during the radiograph. All other data on all 59 subjects were used in the analyses. The mean age of patients at the start of treatment was 12.6 ± 1.3 years with a range of 10.5 – 15.6 years. The mean time that the Forsus was in place was 5.8 ± 2.2 months. The mean duration of treatment was 28.5 ± 6.1 months. Duration of treatment between various time points can be seen in Table 4. The mean averages and standard deviations (SD) for each of the measurements at each of the time points are shown in Table 5. The p-value in the right-hand column of the table indicates if there was a significant change in each of the measured variables across the time points as determined by repeated measures ANOVA.

Table 4. Duration of Treatment

T1 – T4	T2 –T3	T3 – T4	T2 – T4
28.5 ± 6.1 months	5.8 ± 2.2 months	8.4 ± 2.2 months	14.2 ± 4.4 months

Table 5. Averages at each time point

	T1		T2		T3		T4		
Measurement	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p-value
SNA (°)	79.99	2.73	80.32	2.68	79.56	2.58	79.54	2.86	<.001
SNB (°)	74.75	2.55	75.06	2.51	75.57	3.14	75.45	2.78	<.001
Convexity (°)	9.08	4.78	8.59	5.32	6.42	5.22	6.55	5.45	<.001
A Horiz (mm)	63.25	4.23	64.20	4.21	63.98	4.34	64.33	4.87	<.001
B Horiz (mm)	53.58	4.77	54.55	4.96	55.28	5.45	55.65	6.11	<.001
Po Horiz (mm)	53.59	5.83	54.82	6.07	55.75	6.57	55.93	7.34	<.001
MP-SN (°)	31.89	5.52	31.72	5.76	31.31	6.11	31.40	5.97	0.059
N-Me (mm)	104.67	5.92	107.78	6.60	108.75	7.33	110.33	7.62	<.001
ANS-Me (mm)	55.12	4.75	57.45	5.42	57.62	5.70	58.63	5.98	<.001
U1 - SN (°)	101.00	9.08	106.04	6.18	101.39	6.73	101.91	6.43	<.001
IMPA (°)	96.66	7.55	99.02	6.95	104.53	6.42	103.60	7.41	<.001
OP-HP (°)	11.22	4.27	8.45	4.47	13.19	4.79	10.84	4.54	<.001
L1 Horiz (mm)	6.86	3.08	6.49	2.95	4.57	2.98	4.90	3.36	<.001
L1 Vert (mm)	37.23	2.72	37.87	2.78	36.21	3.01	37.19	3.03	<.001
L6 Horiz (mm)	31.89	2.97	31.85	2.93	30.27	3.21	31.09	3.33	<.001
L6 Vert (mm)	27.15	1.92	28.18	2.19	29.11	2.37	29.51	2.42	<.001
U1 Horiz (mm)	-3.08	2.61	-3.69	1.82	-2.39	2.03	-2.42	1.96	<.001
U1 Vert (mm)	25.72	2.99	25.81	3.18	26.44	3.22	26.58	3.18	<.001
U6 Horiz (mm)	28.36	2.15	27.05	2.25	27.74	2.26	28.02	2.26	<.001
U6 Vert (mm)	19.13	2.29	20.56	2.42	19.95	2.30	20.61	2.57	<.001

Abbreviations: SD=standard deviation, T1=pretreatment, T2=at Forsus insertion, T3=at Forsus removal, and T4=post treatment. Change across time was tested using repeated-measures ANOVA. Negative numbers denote distal or intrusive changes.

Analysis of change

The specific aim of the study was to determine the skeletal and dental changes that occurred in the correction of Class II malocclusions with the Forsus appliance. Specifically, three contrasts were of interest: the change between Forsus insertion and Forsus removal (T3 – T2), the change between Forsus removal and post treatment (T4 – T3), and the overall treatment change after initial leveling (T4 – T2). Repeated-measures ANOVA was used to evaluate the changes specified. These mean changes and significance levels are presented in Table 6. A Bonferroni correction was applied to account for separate tests being used to evaluate each of the 3 treatment intervals, requiring a p-value of (0.05/3 = 0.017) to attain statistical significance. Significant treatment changes are displayed visually in Figures 2-4.

Table 6. Changes between timepoints

Measurement	T3 - T2 Mean	T3 - T2 SD	T3 - T2 p-value	T4 - T3 Mean	T4 - T3 SD	T4 - T3 p-value	T4 - T2 Mean	T4 - T2 SD	T4 - T2 p-value
SNA (°)	-0.76	1.00	<.001	-0.02	1.18	0.878	-0.78	1.13	<.001
SNB (°)	0.51	1.65	0.022	-0.12	1.87	0.623	0.39	1.13	0.012
Convexity (°)	-2.18	2.01	<.001	0.13	1.51	0.526	-2.05	2.22	<.001
A Horiz (mm)	-0.22	1.08	0.139	0.35	1.34	0.049	0.13	1.45	0.496
B Horiz (mm)	0.73	1.88	0.005	0.38	1.82	0.122	1.11	2.29	<.001
Po Horiz (mm)	0.93	1.94	<.001	0.18	1.88	0.468	1.11	2.44	0.001
MP-SN (°)	-0.41	1.34	0.025	0.09	1.38	0.619	-0.31	1.38	0.092
N-Me (mm)	0.97	1.90	<.001	1.58	2.03	<.001	2.55	2.38	<.001
ANS-Me (mm)	0.17	1.21	0.303	1.02	1.38	<.001	1.18	1.76	<.001
U1 - SN (°)	-4.64	4.22	<.001	0.52	4.46	0.382	-4.12	4.08	<.001
IMPA (°)	5.51	4.81	<.001	-0.93	4.40	0.113	4.58	4.92	<.001
OP-HP (°)	4.74	3.32	<.001	-2.34	2.96	<.001	2.40	3.17	<.001
L1 Horiz (mm)	1.92	1.19	<.001	-0.33	1.06	0.023	1.59	1.27	<.001
L1 Vert (mm)	-1.67	1.63	<.001	0.98	1.09	<.001	-0.69	1.54	0.001
L6 Horiz (mm)	1.58	1.24	<.001	-0.82	1.15	<.001	0.76	1.44	<.001
L6 Vert (mm)	0.93	0.91	<.001	0.40	0.82	<.001	1.32	0.97	<.001
U1 Horiz (mm)	-1.30	1.42	<.001	0.03	1.22	0.845	-1.27	1.12	<.001
U1 Vert (mm)	0.63	1.08	<.001	0.15	0.89	0.215	0.78	1.12	<.001
U6 Horiz (mm)	-0.69	1.84	0.006	-0.29	1.58	0.177	-0.98	1.70	<.001
U6 Vert (mm)	-0.61	1.16	<.001	0.66	0.96	<.001	0.05	1.13	0.742

Abbreviations: Mean=estimated change using repeated-measures ANOVA. SE=standard error of the estimate, T1=pretreatment, T2=at Forsus insertion, T3=at Forsus removal, and T4=post treatment. Changes across time were tested by contrasting the specified time points using repeated-measures ANOVA. Negative changes denote distal or intrusive movements while positive changes describe extrusive and mesial movements.

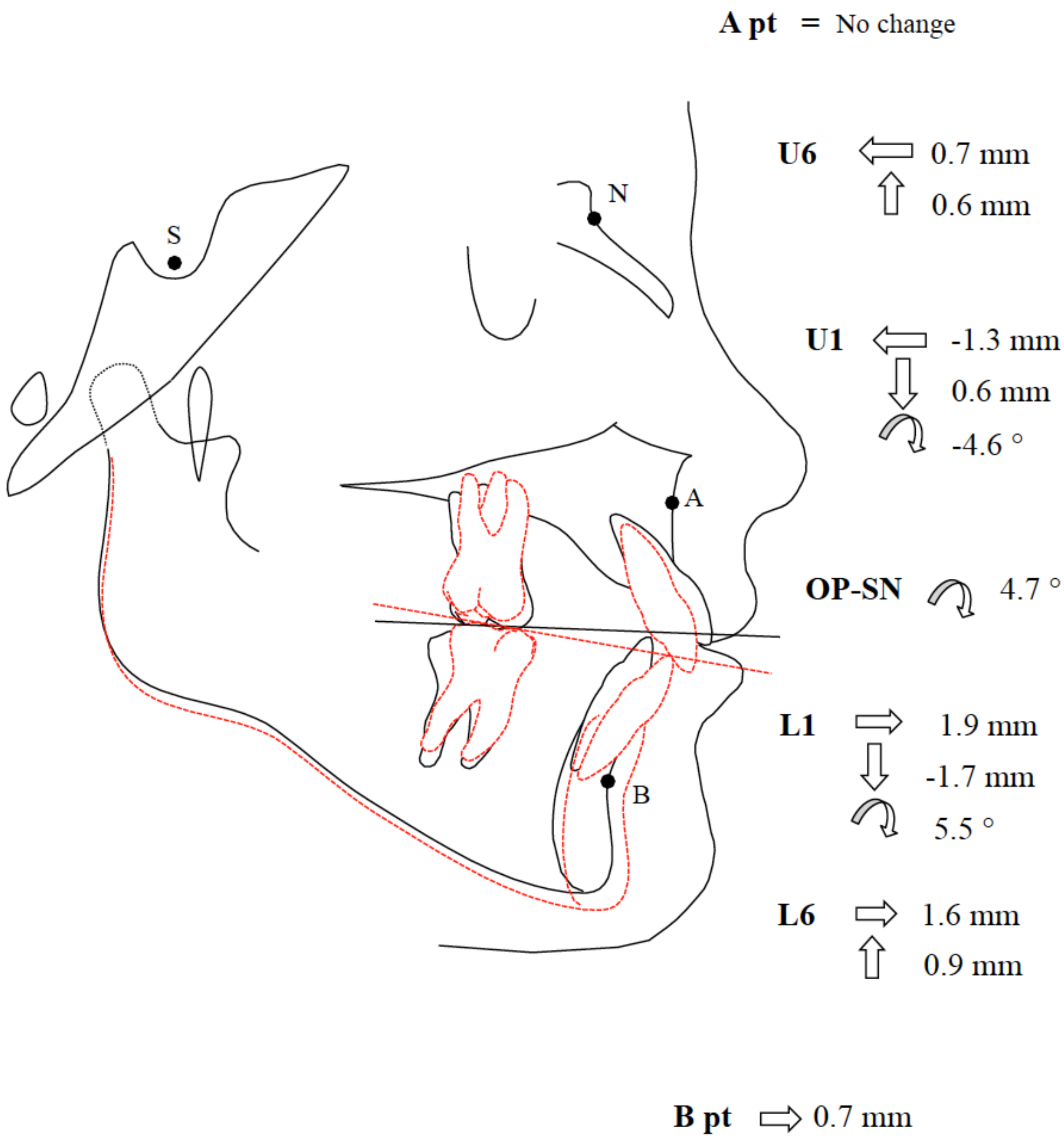

Figure 2. Mean changes during treatment with Forsus in place (T3 - T2)

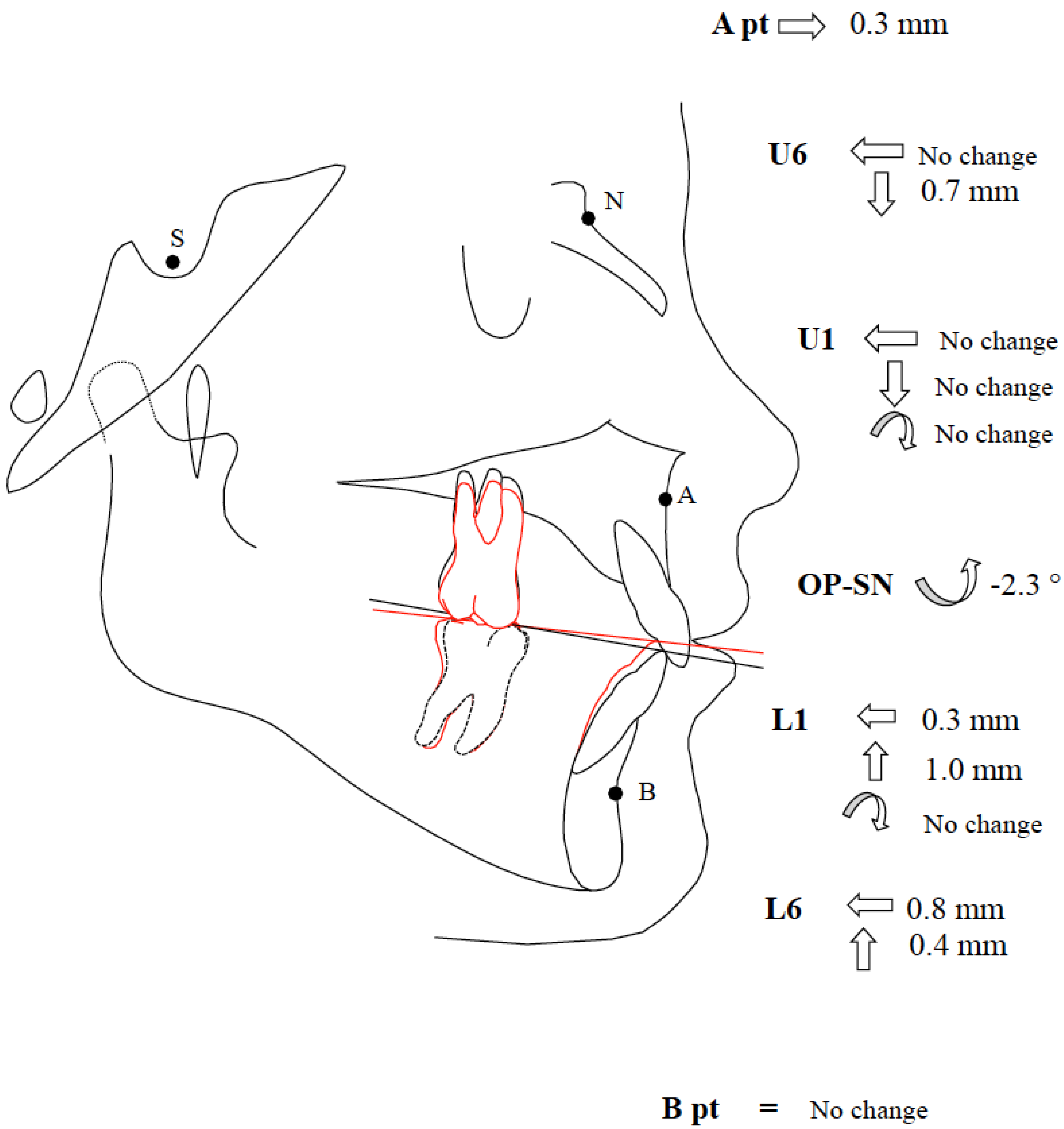

Figure 3. Mean changes observed after Forsus was removed (T4 - T3)

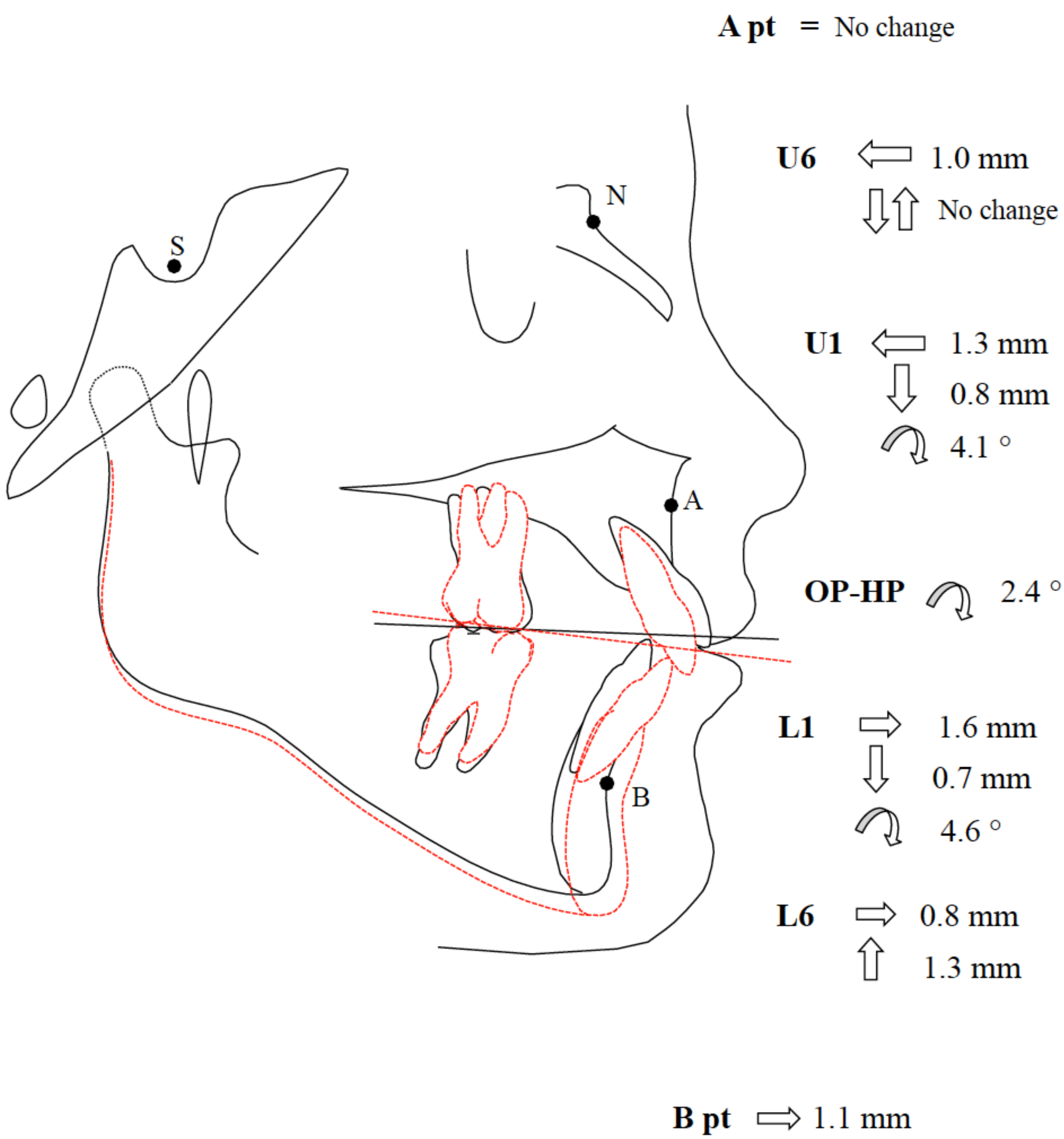

Figure 4. Mean total changes observed during treatment after leveling (T4 - T2)

Correlation with MP-SN

The correlation between the four selected measures and the baseline MP-SN is shown in Table 6. Pretreatment mandibular plane angle was not significantly correlated with changes in MP-SN, ANS-Me, IMPA, or OP-SN at any timepoint ($p > 0.05$).

Table 7. Correlation of change in selected variables to baseline MP-SN

	T3-T2 change		T4-T3 change		T4-T2 change	
Measurement	r	P	r	P	r	P
MP-SN	0.14	0.307	-0.13	0.329	-0.01	0.934
ANS-Me	-0.16	0.243	-0.14	0.312	-0.19	0.164
IMPA	0.21	0.123	-0.26	0.055	-0.04	0.766
OP-SN	-0.10	0.470	0.09	0.486	-0.01	0.918

Abbreviations: r=Pearson's product moment correlation, P=p-value testing significance of the correlation.

Discussion

Previous studies evaluating the Forsus appliance have compared its efficacy to that of other Class II correction appliances such as elastics and the Jasper Jumper, and also to untreated controls. This study was not intended to test whether the Forsus was effective in the treatment of Class II malocclusion. The purpose was to describe accurately how Class II correction was achieved and the resultant changes at each stage in treatment and, further, to determine if treatment response was correlated to the patients' pretreatment mandibular plane angle.

While previous studies[10,11,22,26] disagreed on exact mechanisms of Class II correction achieved by the Forsus appliance, all found it effective in the treatment of Class II malocclusions. Discrepancies in the findings between previous studies may have been due to differences in the timing of when records were obtained during treatment. One of the strengths of the current study was that records were made at 4 different time points during treatment, allowing the mechanisms of Class II correction to be described for each stage. T3-T2 changes, for example, were attributable specifically to effects of the Forsus appliance itself, since leveling and aligning had already been completed by T2.

Changes in cephalometric measurements from the T2-T1 leveling phase were not evaluated because they were perceived to have little importance in explaining how Class II correction was achieved. This was the period where each patient had their own variable and individual response to initial leveling and aligning, dependent on pretreatment crowding, tooth angulations, and curve of Spee. These effects are irrelevant to Class II correction and are potential confounders to those orthodontic studies trying to describe accurately the corrective mechanism of a specific treatment.

During the T3-T2 interval, the direct effects of the Forsus appliance alone were ascertained. Skeletal movement was favorable toward Class II correction where A Point did not change and B point moved forward 0.73 mm. The upper dentition moved distally, on average 0.69 mm and 1.30 mm for the molar and incisor, respectively. The upper incisor moved more than the molar because it also uprighted an average of 4.64°. The lower molar and incisor both moved mesially, 1.58 mm and 1.92 mm, respectively. Similarly to the maxillary changes, the lower incisor moved forward a greater distance due to its mean proclination of 5.51°. Adding the growth of the mandible to the forward movement of the lower dentition, the lower arch played the greater role in the anterior-posterior correction. Examining the vertical dimension, the Forsus spring intruded the upper molar an average of 0.63 mm and also the lower incisor 1.66 mm. These intrusive mechanics promoted eruption in the opposing anterior maxilla and posterior mandible. The result of this was an occlusal plane steepening of 4.74° which also contributed to the Class II correction.[21]

Between time points T3 and T4, Class II correction was being held as treatment was completed. The greatest rebound effects were seen in the vertical positions of the teeth that were intruded during active treatment. The upper molar extruded an average of 0.66 mm, fully negating the intrusion observed from T3-T2. The lower incisor extruded an average of 0.82 mm, about half the amount it was intruded. Consistent with the vertical rebound described, the occlusal plane steepening observed during active Forsus treatment also relapsed 50%, by 2.34°. There was also a tendency toward rebound of the angular changes seen in the incisors: the upper incisor proclined an average of 0.52° while the lower incisors uprighted 0.93°. However, neither change was statistically significant.

Looking at the overall changes following initial leveling (T4-T2), there were modest but statistically significant skeletal changes observed. The hard tissue convexity decreased 2.05°, while A point did not change, and B point and pogonion came forward an average of 1.11 mm each. There were no statistically significant changes in the MP-SN angulation. Combining the skeletal change with the mesial movement of the lower dentition, the lower molar and lower incisor moved an average of 1.87 mm and 2.70 mm toward class II correction, respectively. The upper molar and incisor distal movement within the maxilla, which itself did not change position, totaled 0.98 mm and 1.27 mm, respectively. The lower incisor flared an average of 4.58° and the upper incisor uprighted 4.12°. As described, the Forsus generally held the vertical development of the posterior maxilla and produced intrusion in the anterior mandible, while promoting eruption of the posterior mandible and anterior maxilla. This led to an overall steepening of the occlusal plane of 2.40°.

The skeletal changes observed in this study were consistent with other reports in which changes were evaluated immediately before to after Forsus use,[10,26] and were similar to, but less pronounced than, those reported in studies that evaluated changes before and after the entire orthodontic treatment.[11,22] A reason that skeletal changes observed in this study may have been less than those reported by Jones et al[11] may be due to differences in the techniques used to gather data from individual cephalograms. Jones et al[11] used the Pitchfork Analysis superimposition technique, which has been shown to overestimate skeletal changes and underestimate dental changes when compared to implant guided superimposition methods used by Bjork and Skieler.[23,24,25]

Dental movement observed was also consistent with those studies that focused on the effects of the Forsus alone.[10,26] Each of those studies was able to eliminate “noise” in the data by evaluating changes that were seen after initial leveling which is an individual and variable response. Karacay et al[10] and Aras et al[26] found retroclining of the upper incisor of 4.9 and 3.81°, respectively, which was similar to the T4-T2 change of -4.12° seen in this study. On the other hand, studies that looked at changes before and after complete fixed appliance treatment were unable to isolate the effects of the Forsus alone and, thus, the specific mechanism for achieving Class II correction was hidden by the movements occurring during other phases of treatment. Again, comparing to the angular change in the upper incisor of -4.12° seen in the current study, Franchi et al[22] observed only modest retroclination of 1.2° while Jones et al[11] reported 3.7° of proclination. Another inconsistency reported with use of the Forsus has been regarding the vertical changes seen in the upper first molar. Karacay et al[10] reported intrusion of the molar while Jones et al[11] found significant extrusion. During the time that the Forsus was in place (T3-T2), the current study found a similar change to that reported by Karacay et al[10] with an average intrusion of 0.69 mm. While looking at treatment effects after leveling and aligning (T4-T2), there was no statistically significant measured difference in vertical position of the molar observed. Lastly, when looking at the overall treatment change (T1-T4) similar to Jones et al, an identical 1.5 mm of extrusion was found in the current study.

In this study and others investigating the mechanism of action of the Forsus appliance, proclination of the lower incisors was significant. The amount of proclination seen, however, was similar to studies of other Class II correction modalities. Again, in the current study, the total lower incisor proclination from T2-T4 was 4.58 ± 4.92°. Schaefer et al[27] reported 4.5 ± 6.0° of proclination with a Twin-block appliance, and 3.8 ± 6.8° with a Herbst. Similarly, Ghislanzoni et al[28] found 5.5 ± 7.2° of proclination from a Mandibular Anterior Repositioning Appliance (MARA). One area of interest was the high variability seen in these reported values with the large standard deviations. Certainly the range of severities of the malocclusions treated played a significant role in the variability seen, but another factor could have been the amount of mandibular growth that occurred during treatment. If the timing of treatment was such that the appliance was placed during a period of peak growth, each of these fixed appliances may simply have held back the normally mesially migrating maxillary dentition, while allowing the lower to move “passively” with the forward growing mandible and correct the Class II malocclusion. Two representative cases from this study are shown in Figures 5 and 6 that demonstrate this concept. In Figure 5, Patient 1 had nearly full cusp Class II correction with very little mandibular growth (B-point moved forward only 1.0 mm). Consequently, there was significant lower incisor proclination of 11.1°. Figure 6 shows the superimposition of Patient 3, who also had nearly full cusp Class II correction, but also had significant mandibular growth (B point forward 3.6 mm). With the Forsus used in this favorably growing patient, the lower incisors proclined a modest 2.0°. Future studies should investigate the role of forward mandibular growth in its relationship to proclination of the mandibular incisors during compliance-free Class II correction.

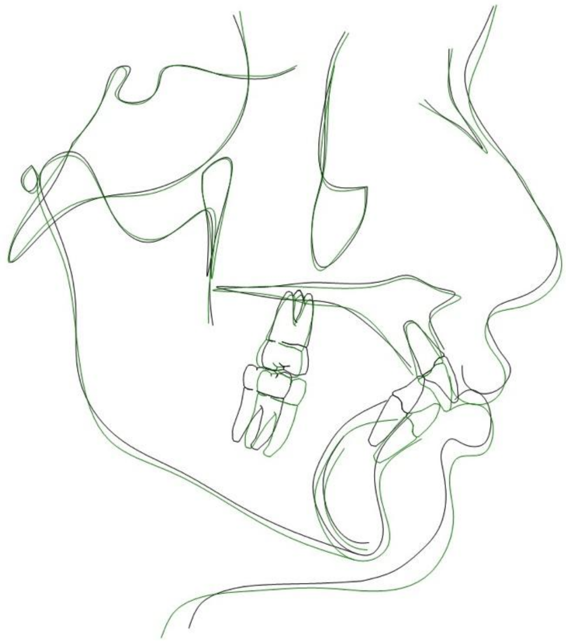

Figure 5. Forsus correction in a patient with minimal mandibular growth

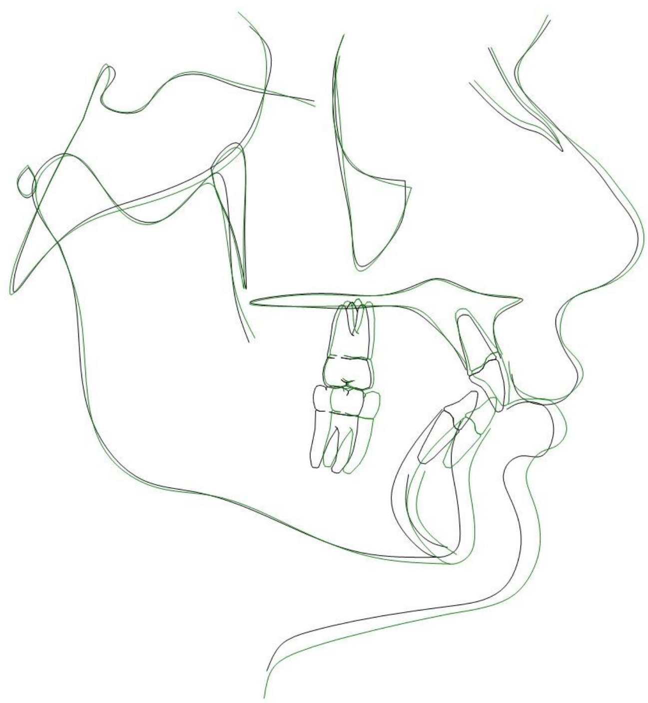

Figure 6. Forsus correction in a patient with favorable mandibular growth

The final contributing effect to the Class II correction seen in this study was the steepening rotation of the occlusal plane observed. As the occlusal plane steepens, the cusps of the upper and lower molars, which help define the plane itself, also steepen. This mesial tip of the lower molar, and distal tip of the upper molar move the occlusal relationship toward Class I.[21] In the current study, there was on average a net steepening of the occlusal plane by 2.40° from the time that the maxillary and mandibular arches were leveled and aligned. This was a similar finding to that of Karacay et al[10] who demonstrated 2.3° of occlusal plane steepening. Jones et al[11] found nearly no change in their study, which included initial leveling in the evaluation period. The timing of their records may have allowed physiologic flattening of the occlusal plane to occur, which is normally seen during periods of mandibular growth, [29] to mask any possible effect on occlusal plane angulation by the Forsus. Braun and Legan[21] have quantified the effect that occlusal plane steepening has on Class II correction and mathematically demonstrated that, for every one degree of occlusal plane steepening, there is a resultant 0.5 mm change toward Class I in the buccal occlusion. Thus, in the current study, the observed 2.40° of occlusal plane steepening would account for 1.2 mm of Class II correction. Using this calculated value, the percentage that each observed effect contributed toward Class II correction can be seen in Table 8. At just over 30%, the rotation of the occlusal plane was the single greatest contributor.

The second primary aim of the current study was to see if patients with different vertical growth patterns would respond differently to the same form of Class II treatment. It was decided from the outset of this study to examine only four variables often implicated as negative side effects of Class II correction, effects that would be particularly pronounced and detrimental in 'vertically-sensitive', high-plane patients. This study found no correlation between the patients' pretreatment vertical growth type (T1 MP-SN angles) and any changes in lower incisor proclination (IMPA), lower facial height (ANE-Me), occlusal plane rotation (OP-SN), or mandibular plane angle (MP-SN) during any period of treatment. These findings support other recent studies concluding that differences in vertical facial characteristics may be overemphasized in traditional treatment planning of Class II correction and that patients with these different phenotypes, on average, respond nearly the same to Class II correction.[17,18]

The methods of the current study allowed demonstrated effects of the Forsus appliance to be seen at each stage of treatment. The current study also set out to examine if patients with differing vertical pheontypes, based on pre-treatment MP-SN angles, responded differently to the same treatment. While moderate variability was seen in the data gathered, no correlation was found between vertical facial type and any of the selected measures examined. It was observed that lower incisor proclination and other dental compensations may have been mitigated when the appliance was used in patients undergoing rapid maxillomandibular growth. Future studies should attempt to correlate lower incisor proclination with mandibular growth during treatment, and attempt to elucidate which characteristics, if any, account for the variability in individual responses to compliance-free Class II correction.

Table 8. Percentage of observed effect toward Class II correction

Effect	Horizontal change (mm)	Percentage (%)
Maxilla	NS	NS
Mandible	1.11	28.3
Upper Molar	0.98	25.0
Lower Molar	0.76	19.3
Occlusal Plane	1.20	30.6

Description: Positive values denote changes toward Class II correction and negative values describe those that worsen Class II relations

Conclusions

- In the adolescent patient population studied, Class II correction using the Forsus appliance, a compliance-free Class II correction device, was achieved by a combination of mandibular growth and mesial movement of the lower dentition including proclination of the lower incisors. The maxillary dentition also moved distally while the upper incisors retroclined.
- There was a significant steepening rotation of the occlusal plane which also contributed to Class II correction.
- There was no correlation found between patients' pretreatment vertical facial phenotype (pretreatment MP-SN angle) and any changes in lower face height (ANS-Me), occlusal plane steepness (OP-SN), lower incisor angulation (IMPA), or mandibular plane angle (MP-SN) throughout treatment.

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Vita

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