Original Article

Analysis of Class II patients, successfully treated with the straight-wire and Forsus appliances, based on cervical vertebral maturation status

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ABSTRACT

Objective: To assess skeletal and dental changes in patients successfully treated with the Forsus appliance based on cervical vertebral maturation status.

Methods: Forty-seven Class II patients, successfully treated with the Forsus appliance, were divided into peak and postpeak growth groups determined immediately prior to Forsus placement. The mean (SD) ages of the peak and postpeak groups were 13.4 (1.0) and 14.1 (1.3) years, respectively. Superimpositions of initial, Forsus placement, Forsus removal, and final cephalometric radiographs were completed, allowing the measurement of changes during three treatment phases.

Results: There were no significant differences between groups during treatment phase 1 (alignment/leveling), with both groups demonstrating a worsening of the Class II molar relationship. However, during treatment phase 2 (Class II correction), patients within the peak group demonstrated significantly higher mean apical base, mandibular and molar changes, and an increased rate of change compared with those in the postpeak group. No significant differences were observed during treatment phase 3 (detail/finishing).

Conclusions: Following an initial worsening of the Class II molar relationship as a result of straight-wire appliance effects, Forsus appliance treatment initiated during cervical vertebral maturation status (CS) 3–4 elicits more effective and efficient correction of Class II molar relationships than when initiated during CS 5–6. Data support that these effects are due mainly to maxillary skeletal and dentoalveolar restraint during a period of more rapid mandibular growth. (*Angle Orthod.* 2015;85:80–86.)

KEY WORDS: Forsus, Class II; Growth status; Class II correction; Growth modification

INTRODUCTION

Attempts to modify growth to correct Class II skeletal and dental relationships have followed two main approaches, both timed ideally to coincide with the patient's circumpubertal growth period.[1] The first approach has been directed at orthopedic restraint of forward maxillary growth, via a headgear appliance, with a minimum force level of 250 g per side.[2] The second has included the use of functional appliances, including a variety of appliances designed to displace the mandible forward, translating the condyle out of the condylar fossa, while transmitting forces to the dentition and basal bone.[3] Although forces directed against the maxilla with functional appliances have been shown to elicit a headgear-like effect, it can only be assumed that the same, previously described 250 g force per side would be indicated, since the force level has yet to be documented.

A recent study compared patients, consecutively treated with the Forsus appliance, to a matched sample of untreated Class II patients. This study demonstrated an 87.5% success rate, maxillary restraint during treatment, and effects in the mandibular arch that were mainly dentoalveolar in nature.[4] A cervical vertebral maturation index was utilized to

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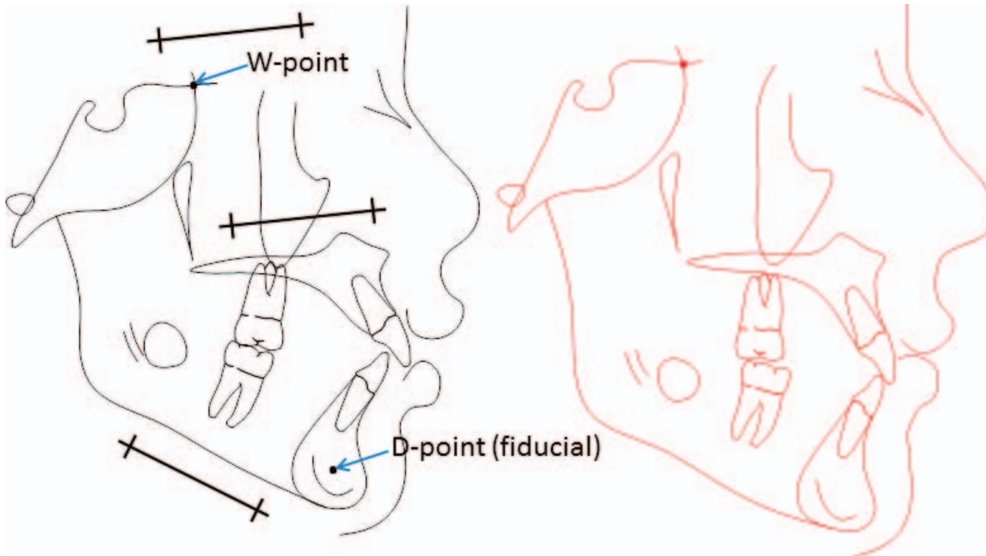


Figure 1. Tracings for successive time points using fiducial lines and points (for future registration and measurement) prior to cranial base and regional superimpositions.

assist in matching groups; however, both groups contained a larger number of patients in the postpubertal rather than the pubertal stage of maturation.

As with any adjunctive appliance that is utilized in conjunction with a straight-wire appliance, there is difficulty in differentiating the effects during the active Forsus phase from those during fixed appliance treatment prior to and following the active phase. Study design has also been influenced by the fact that the Forsus was not initially introduced as a growth modification appliance[5] and has only recently been shown to elicit a skeletal effect.[4] Theoretically, a growth modification effect from the Forsus can be supported, since in vitro force-deflection characteristics have demonstrated that 226 g of force is delivered when the spring is compressed to 12 mm, a force that closely approximates the previously mentioned, minimum orthopedic force required for maxillary restraint.[6]

This study was designed to retrospectively evaluate consecutive Class II patients who were successfully treated with the Forsus appliance. The goal was to quantify and compare the specific skeletal and dental effects observed during the Forsus treatment phase, separate from the alignment/leveling and finishing phases of treatment, to determine if differing treatment effects are observed when patients are grouped according to cervical vertebral maturation status (CS) development.

MATERIALS AND METHODS

This study evaluated 47 patients, successively treated from a Class II to Class I molar relationship with the MBT prescription and Forsus appliances (3M Unitek, Monrovia, Calif). The research protocol received institutional review board approval as a human-exempt study.

All patients were treated in the private practice of the author using a standardized protocol. Inclusion criteria included: correction to Class I from at least a half-step molar Class II relationship at initial presentation, Forsus treatment greater than 3 months, completion of orthodontic treatment and diagnostic radiographs at all time points. Patients were grouped according to cervical vertebral maturation status as determined on the cephalometric radiograph taken at the time of Forsus appliance placement (T_1). Due to subjective variation in assessing a specific CS,[7] patients were categorized into CS ranges. Patients in the peak growth group (N = 25) included patients in CS 3 and 4. Patients in the postpeak group (N = 22) included patients in CS 5 and 6. Assessment of CS, as defined by a previous report[8] was performed by the primary investigator and verified by the secondary investigator; differences were resolved to their mutual agreement.

A comparison of the two groups was completed, based on mean ANB and MP-SN initial measurements, to ascertain similarity in relation to Class II severity. Additionally, the initial and pre-Forsus molar discrepancies were measured from the T_0 and T_1 radiographs and compared to determine the severity of the molar relationship at initial presentation and at the time of Forsus placement. These comparisons were accomplished via unpaired *t*-tests with the level of significance set at $P \leq .05$.

As part of a standardized protocol, patients completed initial alignment and leveling of their dental arches, and progressed in wire size to either 0.019 ×

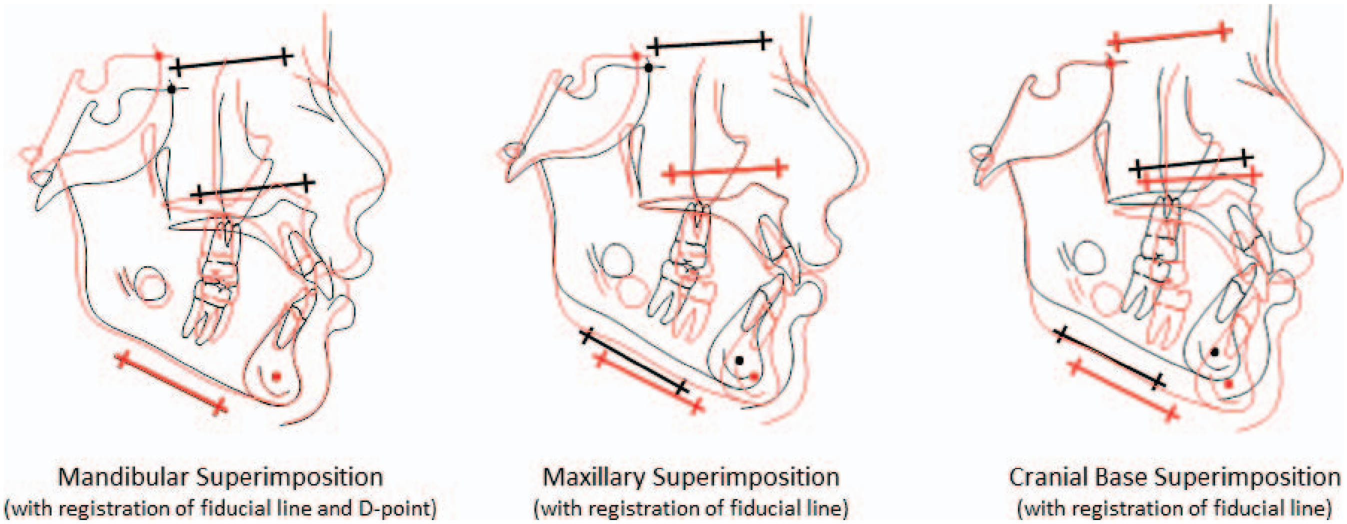


Figure 2. Cranial base and regional superimpositions used for subsequent measurement of change. Mandibular superimposition: for mandibular dental changes (recorded with fiducial). Maxillary superimposition: for skeletal changes and maxillary dental changes (recorded with fiducial). Note: Movement of mandibular fiducial as maxillary superimposition is registered, denoting change in mandibular position relative to the maxilla. Cranial base superimposition: for S-Gn and occlusal plane changes (recorded with fiducial).

0.025-inch stainless steel or beta-titanium arch wires before inserting the Forsus appliance. Once patients were corrected to an end-to-end incisor relationship, the Forsus was removed and detailing/finishing was completed.

Initial, Forsus placement, Forsus removal, and final cephalometric films were recorded with teeth in maximum intercuspation for each patient. As illustrated in Figure 1, initial and progress films were hand traced by the primary investigator, landmarks were confirmed by the secondary investigator, and differences were resolved. Serial tracings were superimposed on stable landmarks to determine changes between successive phases of treatment. The cranial base superimposition utilized ethmoid triad structures as outlined by Elmajian,[9] while regional maxillary structures were superimposed utilizing the structural method outlined by Doppel et al.[10] Lastly, regional mandibular structures

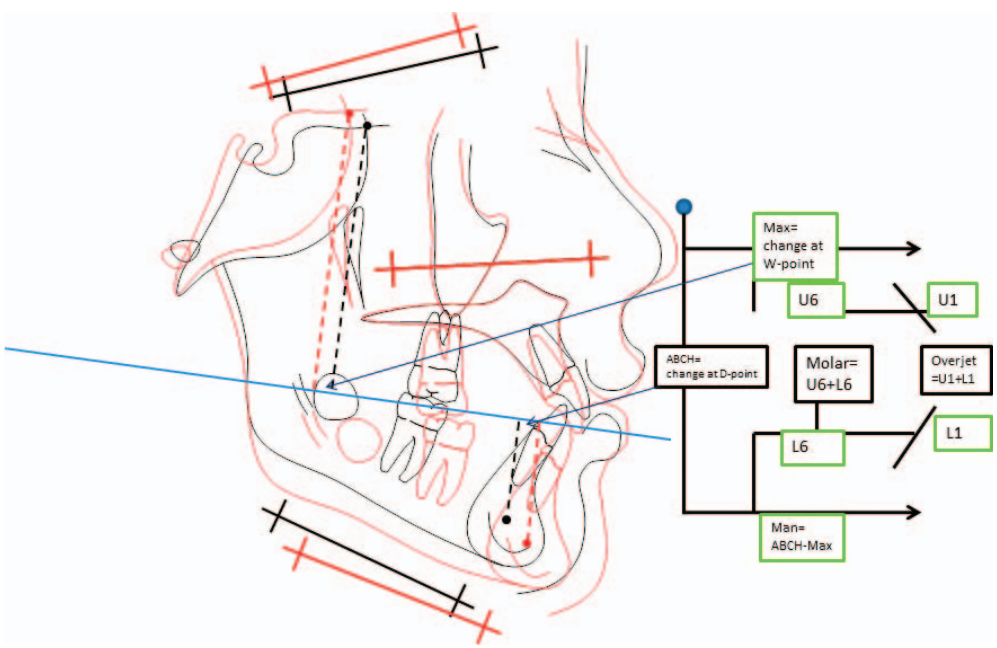
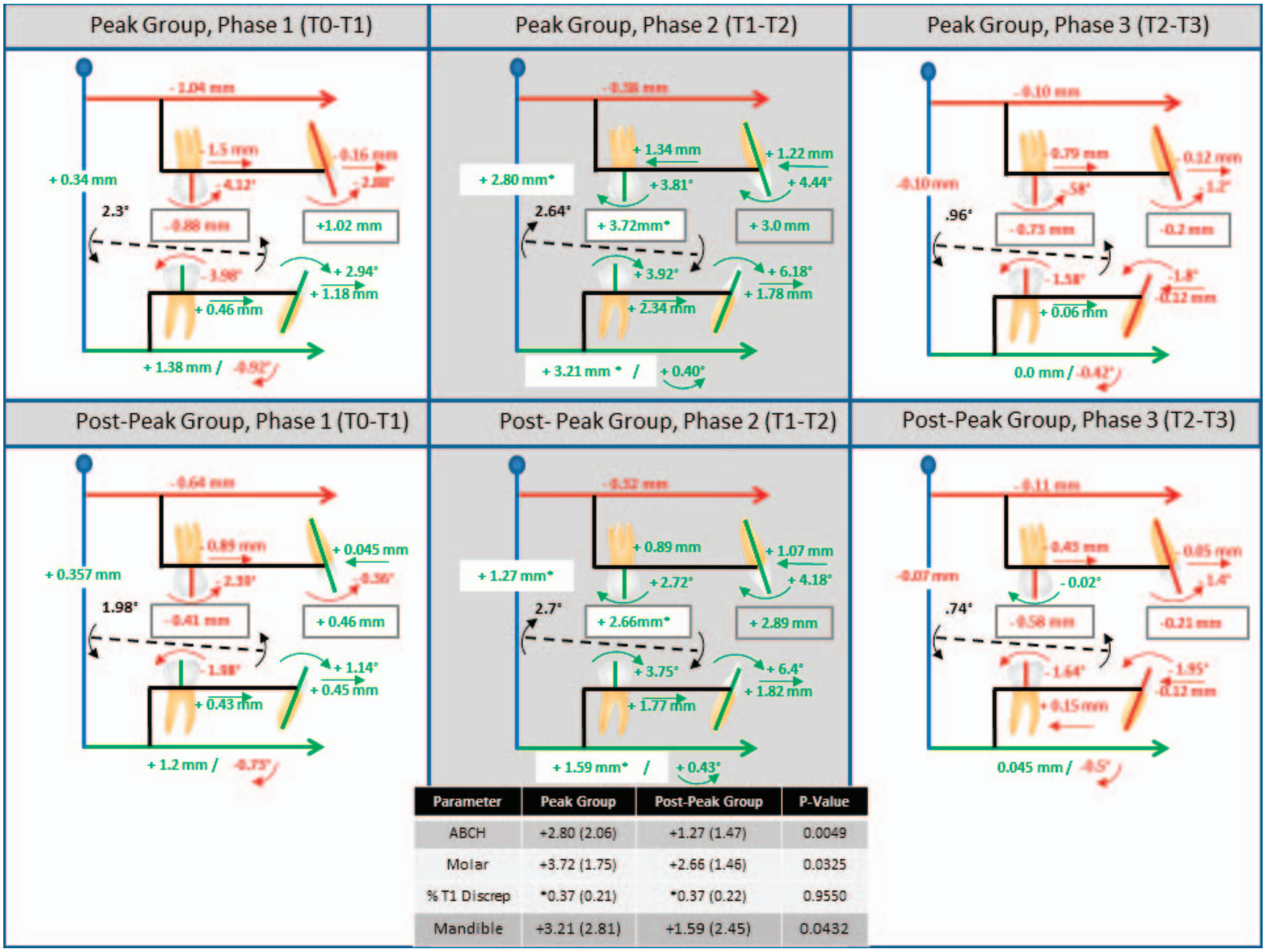


Figure 3. Measurements recorded from maxillary superimposition perpendicular to the mean functional occlusal plane. [a] Positive (+) measurements indicated improvement of Class II relationship or reduction in overjet. [b] Negative (−) measurements indicated worsening of Class II relationship or increase in overjet.



Parameter	Peak Group	Post-Peak Group	P-Value
ABCH	+2.80 (2.06)	+1.27 (1.47)	0.0049
Molar	+3.72 (1.75)	+2.66 (1.46)	0.0325
% T1 Discrep	*0.37 (0.21)	*0.37 (0.22)	0.9550
Mandible	+3.21 (2.81)	+1.59 (2.45)	0.0432

Figure 4. Comparison of pitchfork diagrams for all treatment phases. Statistical differences between groups (white boxes) only demonstrated in phase 2 (gray shade). [a] Positive (+) measurements indicate improvement of Class II (skeletal or dental) relationship or reduction in overjet. [b] Negative (−) measurements indicate worsening of Class II relationship (skeletal or dental) or increase in overjet.

were superimposed utilizing the structural method outlined by Dibbets.[11]

As illustrated in Figure 2, registration of 141 superimpositions was recorded with the use of three fiducial lines. To determine the error of the measurement method, 20 superimposition sets were randomly selected, retraced, and remeasured to calculate the random error via Dahlberg formula.[12]

A pitchfork analysis was used to summarize a portion of the skeletal and dental changes between each time point, as previously reported by Johnston.[13] As demonstrated in Figure 3, this analysis uses cephalometric superimposition to demonstrate anterior-posterior movement of all first molars and central incisors relative to their skeletal bases, measured perpendicular to the mean functional occlusal plane. It also demonstrates the displacement of the maxilla and mandible relative to the cranial base. Rotational changes of the mandibular and occlusal planes were measured on the cranial base superimposition, and angulation changes of teeth were also measured on each respective regional superimposition. As demonstrated in Figure 4, magnitude and direction (clockwise or counterclockwise) were recorded with each pitchfork. Positive values were designated for movements that corrected Class II or reduced overjet, while negative values indicated a worsening of the Class II relationship or increase of the overjet.

The group sizes provided 80% power to detect a moderate effect size (0.77 standard deviations) difference between means when testing with a Student's *t*-test at the alpha level of .05 (NCSS PASS 2002). Data within each group were analyzed with a paired Student's *t*-test ($P \leq .05$) to compare individual mean changes for each measurement category between phase 1 (T_0–T_1), phase 2 (T_1–T_2), and phase 3 (T_2–T_3). Mean changes measured at the end of each treatment phase were compared between the two study groups, with unpaired *t*-tests set at the same

Table 1. Comparisons of Mean (SD) ANB, SN-MP at T_0, and Molar Discrepancy Measurements at T_0 and T_1

Test Group	ANB	SN-MP	Molar Discrepancy, T_0, mm	Molar Discrepancy, T_1, mm	T0–T1, *P* Value
Peak growth	5.58° (1.48)	31.92° (4.17)	5.16 (1.31)	6.48 (1.64)	.004
Postpeak growth	5.16° (1.41)	34.34° (6.07)	4.27 (1.24)	5.10 (1.77)	.0006
P Value	.33	.11	.02	.007	

level of statistical significance. Rates of change were also calculated for phase 2 (Forsus treatment phase) for each group, and then rates between the study groups were compared with unpaired *t*-tests to determine statistically significant differences ($P \leq .05$).

RESULTS

Measurements for initial ANB and MP-SN angles, as well as molar discrepancy at T_0 and T_1, are reported in Table 1. Comparison of the skeletal means revealed no statistical difference for either ANB or SN-MP angles. However, there were significant differences between the two groups in the severity of the Class II molar relationship at both T_0 and T_1.

The mean ages at T_0 through T_3 are represented in Table 2, demonstrating that the peak group preceded the postpeak group in the initiation of treatment by approximately 8 months. However, the groups were well matched in the duration of the Forsus phase of treatment and total treatment length.

The error of the measurement method, via Dahlberg formula, revealed random error that ranged from 0.18 mm for U1–SN change to 0.57 mm for ABCH. The random error of angular measurements ranged from 0.25° for SN–SGn change, to 0.97° for L1– MP change.

Comparisons Within Each Study Group

As illustrated in the modified pitchfork diagrams (Figure 4), during phase 1 both groups demonstrated mean skeletal and dental changes that worsened the Class II relationship by continued forward growth of the maxilla and backward rotation of the mandible. The molar relationship worsened, due to forward movement and tipping of the maxillary first molar and distal uprighting of the mandibular first molar. Additionally, the mean apical base change contributed to a slight skeletal improvement, due to positive mandibular growth that exceeded maxillary growth. Overjet decreased due to forward movement and proclination of the mandibular incisor in both groups.

Mean changes during phase 2 contributed toward correction of the Class II skeletal and dental relationships in both study groups. Both groups demonstrated a reduction in forward maxillary movement in comparison to phase 1, as well as backward (clockwise) rotation of the occlusal plane. Apical base change increased significantly ($P = .0019$) in the peak group but not in the postpeak group ($P = .315$) from phase 1 to phase 2. Additionally, a statistically significant increase in mandibular incisor proclination was observed in both the peak ($P = .007$) and postpeak groups ($P = .002$).

Mean changes in phase 3 demonstrated minor relapse movements of the effects seen during phase 2. A comparison of changes observed between phase 2 and phase 3 within both groups, revealed significant differences in all measurements except the forward movement of the maxilla and the angular change of SGn to SN.

Comparisons Between Study Groups

No significant differences ($P \geq .05$) were observed between the groups during phases 1 or 3; however, differences were observed during phase 2. Patients in the peak group showed a significantly higher ($P = .01$) mean apical base change (2.8 mm) than the postpeak group (1.27 mm). Molar change for the peak group was also significantly greater than that observed in the postpeak group ($P = .03$), measuring 3.68 mm vs 2.66 mm, respectively. However, as previously mentioned, the molar discrepancy in the peak group was significantly more severe than the postpeak group at T_0 and T_1. Therefore, as represented in Figure 4, a comparison of the molar change as a percentage of the molar discrepancy at T_1 was completed and revealed no statistically significant difference ($P = .95$) between the two groups.

Table 2. Group Comparisons Based on Gender, Mean Age, and Treatment Duration (SD)

Test Group	Gender[a]	Age at T_0, y	Age at T_1, y	Age at T_2, y	Age at T_3, y	Forsus Phase, mo	Treatment Duration, y
Peak	17 m, 8 f	12.2 (1.1)	13.4 (1.0)	13.8 (0.9)	14.5 (0.9)	5.67	2.3 (0.4)
Postpeak	3 m, 19 f	12.9 (1.4)	14.1 (1.3)	14.5 (1.3)	15.2 (1.3)	5.49	2.2 (0.3)
P Value		.03	.037	.05	.04	.95	.21

[a] m indicates male; f, female.

Table 3. Mean (SD) Skeletal and Dental Change as a Percentage of Molar Discrepancy at T_1

Test Group	ABCH-Skeletal, mm	Molar-Dental, mm	Skeletal, %
Peak group	+2.80 (2.06)	+3.72 (1.75)	43 Skeletal (range 0–100)
Postpeak group	+1.27 (1.47)	+2.66 (1.46)	25 Skeletal (range 0–62)
P value	.0049	.0325	.10

To evaluate the rate of change during phase 2, comparisons were completed between the two groups.

As represented in Table 2, the mean treatment times for phase 2 were found to be similar at 5.67 months for the peak group and 5.49 months for the postpeak group. The rate of apical base change was significantly higher ($P = .04$) in the peak group (0.49 mm/mo) than in the postpeak group (0.26 mm/mo). The rate of molar change was also found to be significantly greater ($P = .003$) for the peak group at 1.17 mm/mo in comparison to 0.77 mm/mo for the postpeak group.

DISCUSSION

By analyzing successfully treated cases that were grouped according to CS levels at the time of Forsus placement, this study offers important clinical information regarding skeletal and dental changes that could accompany treatment with this appliance. The orthodontic provider used indicators such as chronologic age, dental development, and secondary sexual characteristics to appropriately time treatment. As demonstrated in Table 2, utilizing these indicators resulted in the majority of female patients reaching CS 5–6 by the initiation of Forsus placement. Conversely, the majority of male patients were in CS 3–4 at the time the Forsus appliance was placed. This finding supports the common tendency to treat Class II female patients later than ideal and demonstrates that use of CS to determine Class II treatment timing may have greater utility in the female population.

Both groups demonstrated similar effects during phase 1, revealing an initial worsening of the molar relationship due to molar tipping as a result of the straight-wire prescription. Additionally, both groups demonstrated similar degrees of relapse in phase 3, indicating that a molar overcorrection of 0.75–1 mm would be indicated for most cases. However, this study revealed important differences between the study groups as a result of growth status during phase 2.

The effectiveness and efficiency of Class II treatment were influenced by the patient's CS stage when the Forsus phase of treatment was initiated. In comparison to phase 1, both groups demonstrated a maxillary restraint effect during phase 2; however, this only contributed to a statistically significant apical base change in the peak group. This "headgear effect" compares favorably to that reported with twin-block and bionator appliances,[14] a previous report on the Forsus,[4] and with use of the mandibular anterior repositioning appliance.[15] Conversely, other studies have failed to demonstrate skeletal change with use of the Forsus appliance.[16–18] However, varying study designs, growth status methodologies, and measurement methods with or without superimpositions were utilized, which could explain the variations in the observations reported.

As demonstrated in Table 3, the mean percentage of skeletal correction in the peak group was 43%, compared to 25% for the postpeak group, which compares favorably to previous studies.[19] However, due to the wide variation of the skeletal response observed in both groups, this difference was not statistically significant ($P = .10$). However, the interesting observation in the present study is the nearly identical skeletal and dentoalveolar effects in the maxilla of both treatment groups during the Forsus treatment phase, even though the apical base change was significantly greater in the peak growth group. This finding is best explained by the increased amount of normal mandibular growth that is occurring during peak growth, more of which is taken advantage of to correct the Class II molar relationship when skeletal and dental maxillary restraint occurs during CS 3–4. In comparing both groups to untreated Class II patients from a previous study of similar design,[14] both peak and postpeak groups demonstrated less mean maxillary growth during the Forsus phase (0.38 and 0.32 mm, respectively) in comparison to untreated controls (1.98 mm) during similar growth stages.

Additionally, in both groups, rotational effects during the Forsus treatment phase demonstrated a forward (counterclockwise) rotation of the mandible and a backward rotation of the occlusal plane, an effect likely due to an anteroposterior restraining effect and slight intrusion of the maxillary molars.

CONCLUSIONS

Within the parameters of this study:

- Following an initial worsening of the Class II molar relationship as a result of straight-wire appliance effects, Forsus appliance treatment initiated during CS 3–4 elicits more effective and efficient correction of Class II molar relationships than when initiated during CS 5–6.

- The enhanced efficiency of skeletal and dental effects accompanying Class II correction with Forsus treatment during CS 3–4 (in comparison to CS 5–6) is due primarily to maxillary skeletal and dentoalveolar restraint during a period of more rapid mandibular growth.

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