Original Article

Spatial changes in the relationship of the mandible and maxilla with different extraction patterns and techniques

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ABSTRACT

Objective: To assess the spatial changes in the relationship of the mandible to the maxilla with different extraction patterns and techniques when treated Class II patients are compared with untreated subjects.

Materials and Methods: Pretreatment and posttreatment cephalometric radiographs of 125 Class II adolescent patients and 30 untreated Class II patients were traced. The treated patients were divided by technique and extraction pattern into four groups: preangulated appliance with four first premolar (4/4) extractions, preangulated appliance with maxillary first and mandibular second premolar (4/5) extractions, standard edgewise (Tweed-Merrifield technique) with four first premolar (4/4) extractions, and standard edgewise (Tweed-Merrifield technique) with maxillary first and mandibular second premolar (4/5) extractions. The mandibular displacement vector angle was determined by using two different superimposition methods: the superimposition on the cranial base and the superimposition on the maxillary base.

Results: The differences in the mean vector angles of mandibular displacement in the two superimposition methods were statistically compared. There was a significant difference between the vector angle of mandibular displacement in each treated group when the superimposition techniques (ie, cranial base and maxillary base) were compared. Significant differences between the standard edgewise treated group and the preangulated treated group were found using both superimposition methods.

Conclusions: The standard edgewise appliance groups showed a more forward horizontal displacement of the mandible than the preangulated appliance groups. Within the standard edgewise sample, the patients with four first premolars extracted had a greater horizontal mandibular displacement than did the maxillary first, mandibular second premolar extraction sample. (*Angle Orthod.* 2011;81:584–591.)

KEY WORDS: Mandibular displacement; Extractions; Superimpositions

INTRODUCTION

Class II malocclusions are frequently treated in an orthodontic practice. A Class II malocclusion is normally characterized by a combination of multiple components which involve teeth and bones. The orthodontic literature presents multiple studies which characterize the malocclusion.[1–3]

Successful treatment of Class II malocclusions can be achieved by different methods of treatment, with the removal of permanent teeth being one of those. The extraction of maxillary or maxillary and mandibular teeth has been widely used with the objective to obtain excellent dental and facial results. Among the different patterns of extractions cited and widely used in orthodontics are the maxillary and mandibular first premolars and the maxillary first and the mandibular second premolars. Do these two different extraction patterns performed with two distinct orthodontic techniques result in a more or less favorable spatial mandibular displacement?

For years, orthodontists have relied on cephalometric radiographs to evaluate growth and treatment of Class II patients.[4,5] Since Broadbent[6] first developed

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the cephalometric technique in 1931, stable landmarks of the cranial base have been utilized as a diagnostic tool to identify a patient's dental and skeletal relationships and also to analyze through cephalometric superimpositions the effect of treatment on an individual. The cranial base has also been used for superimposition in order to examine skeleton changes.[7,8] The cranial base is widely employed to record the status, progress, and mode of dentofacial developmental changes of the orthodontic patient.

Regional superimposition is used to evaluate the dental movements within the elements of the craniofacial complex. The maxilla and mandible are usually evaluated separately. Methods for superimposing on the maxilla have been identified,[9] and most agree that the best fit method combined with alignment on the anterior surface of the zygomatic process is informative with regard to changes in the maxilla.[10,11] Regional mandibular superimposition utilizes the inner cortical structure of the inferior symphyseal border and tip of the chin, the mandibular canal, and the lower contour of the germ of a developing molar to evaluate the dentoalveolar changes that occur within the mandible.[8] A cranial base superimposition method is useful in describing the change in mandibular displacement relative to the cranial base, but it is not informative as to how the mandible relates to the maxilla. Likewise, a cranial base superimposition does not account for the changes of the maxilla as it relates to the mandible.[12]

Johnston[5,11] was one of the first to recognize the importance of relating the mandible to the maxilla and not just to the cranial base. The "pitchfork" analysis utilizes the relationship between the maxilla and the mandible on the level of the occlusal plane to evaluate the growth and treatment of the mandible. Johnston used the functional occlusal plane when the maxillary base was superimposed because that is where the maxillary and mandibular changes are integrated in treatment.

In 1989, Ghafari and Efstratiadis[13] revisited a superimposition method which focused on the superimposition on the maxillary base. The authors assessed the displacement of the mandible by comparing the superimposition using the anterior cranial base with superimposition on the maxillary base. Pogonion, gnathion, and menton had linear and angular measurements that were compared between the pretreatment and posttreatment time periods. There was a remarkable difference between the two superimposition methods. Evaluating the mandibular displacement by superimposing on the maxillary base avoids the masking of the rotational and remodeling growth that may occur in the maxilla when superimposed on the anterior cranial base. Taylor[14] showed similar findings when he compared the two superimposition methods during a study of Herbst treated patients and untreated controls. Class III patients were evaluated by Araujo et al.[15] using the same method. A difference in mandibular displacement between the two superimposition methods in treated Class III patients as compared with an untreated control was found.

The purpose of this study is to evaluate the spatial change in the relationship of the mandible to the maxilla in Class II patients who were treated with different extraction patterns and "techniques." Also, the cranial base superimposition and maxillary base superimposition methods are to be compared.

MATERIALS AND METHODS

Untreated Sample

A sample of 30 untreated Class II adolescent subjects was obtained from the Bolton–Brush Growth Study Center in Cleveland, Ohio. Cephalometric records were taken at two established time points, age 12 and 15 years, with an overall difference of 3 years between time points. These time points were selected to closely match the treatment timing of the other samples used in this study. The subjects were identified to have at least an end-on Class II molar relationship at the time the first radiograph was taken. In order to closely match the treated samples, the untreated Class II sample included 19 girls and 11 boys.

Preangulated Appliance Treated Sample

A sample of 63 orthodontically treated Class II adolescent subjects with pretreatment and posttreatment cephalometric records was obtained from the archives of a private office. The subjects were selected successively by the primary investigator from the archives available to closely match the control and other treated samples. The samples included 31 patients treated with 4/4 extractions and 32 patients treated with 4/5 extractions. The 4/4 extraction sample was divided into 20 female and 11 male subjects, while the 4/5 extraction sample was divided into 23 female and 9 male subjects. The mean treatment time of the 4/4 extraction sample was 42.8 months; mean treatment time for the 4/5 extraction sample was 45.3 months.

All subjects were identified by the private practitioner as having at least a Class II end-on molar relationship at the initial exam. All subjects were treated by one experienced orthodontist using a Roth prescription 0.022 $\times$ 0.028-inch bracket slot appliance with the combination of cervical headgear and intermaxillary elastics. The subjects were all treated to a dental Class I occlusion.

Standard Edgewise Appliance Treated Sample

A treated Class II sample which consisted of 62 adolescent subjects was obtained from another private office. These subjects were randomly chosen by the practitioner until a sample of 29 subjects treated with the 4/4 extraction and 33 subjects treated with 4/5 extraction was obtained. The samples were divided into 19 girls and 10 boys in the 4/4 extraction group and 25 girls and 8 boys in the 4/5 extraction group. The mean treatment times for the maxillary and mandibular first premolars and for the maxillary first premolars and mandibular second premolars were 34.5 months and 35.1 months, respectively.

All subjects were identified by the private practice orthodontist to have at least an end-on Class II molar relationship at the start of treatment. The subjects were treated with Tweed-Merrifield mechanics (J hook headgear and intermaxillary elastics) with a neutral 0.022 $\times$ 0.028-inch bracket slot appliance to a Class I molar relationship by one experienced orthodontist.

Superimpositions

The superimposition protocols followed those previously described in the literature.[13–16] Each pretreatment (T1) and posttreatment (T2) radiograph was hand traced on acetate paper. Both anatomic landmarks, pogonion (the most anterior point on the bony chin) and menton (the most inferior point on the bony chin) were identified. Each set of two tracings was first superimposed using a best fit method based on the anterior cranial base (Figure 1). Subsequently, the two tracings were superimposed using a best fit method on the maxillary base (Figure 2). Maxilla and mandible were superimposed as a unit using the maxilla best fit method as a reference. The landmarks were digitized with a Numonic digitizing machine (Montgomeryville, PA, model IPS/BL.E-A30BL.H). The landmarks were then transferred to a computer which placed them onto an x-y coordinate system. Dentofacial Planner 7.0 software (Toronto, ON, Canada) was used to obtain the linear measurements.

The assessment of the x-y coordinates of the landmarks was based on two constructed reference planes. The horizontal reference line was SN-7°, a plane forming a 7° angle with the sella-nasion line. The vertical reference line was constructed as a perpendicular to SN-7° through sella (Figure 3). The landmarks were then measured from the x-y coordinates which were determined by the reference lines.

The horizontal and vertical changes in distance from pretreatment pogonion and menton to posttreatment pogonion and menton were measured and used to form a right triangle (Figure 4). Using the trigonometric formula tan α = opposite/adjacent, the angles of the pogonion and menton vectors were established.

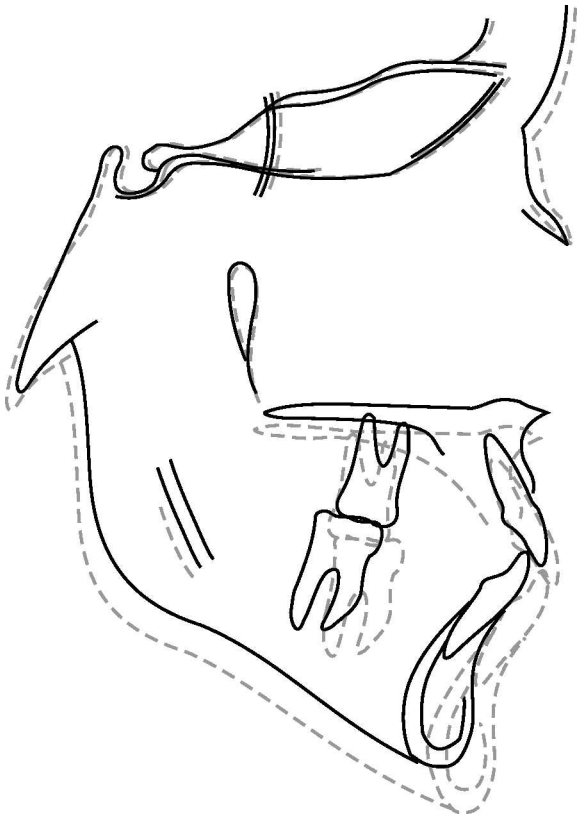

Figure 1. Superimposition on the cranial base.

Analysis

A descriptive analysis was performed for all subjects (Table 1). Independent *t*-tests were used to analyze the vector angle of pogonion and menton in each of the five samples. The cranial base and maxillary base superimposition methods were compared. A Kruskal-Wallis one-way analysis of variance followed by a

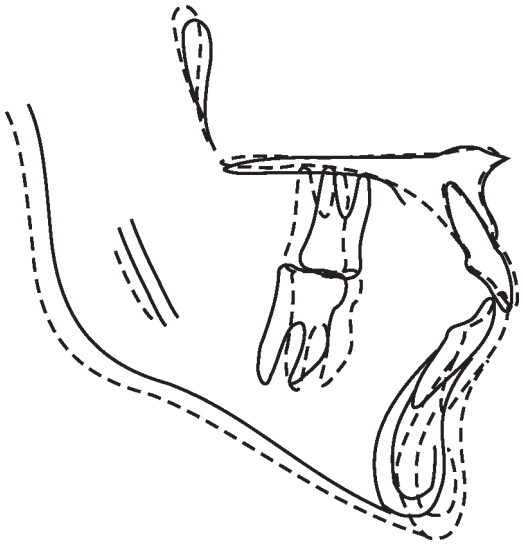

Figure 2. Superimposition on the maxillary base.

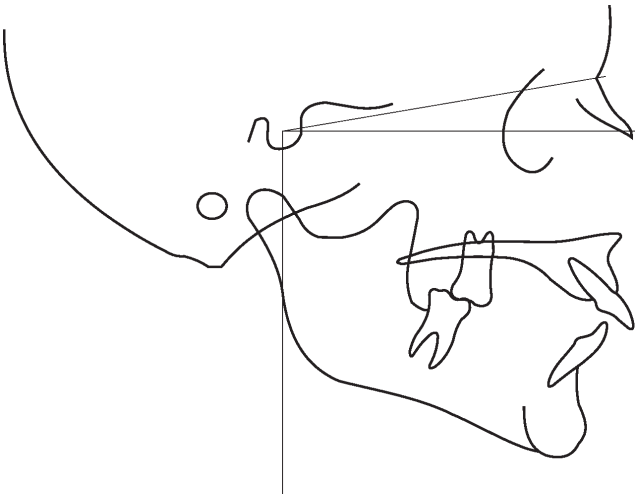

Figure 3. Reference planes.

Mann-Whitney *U*-test was used to compare all samples. To determine statistical significance, a *P* level was set at $P \leq .05$. This *P* level will determine that there is a statistical difference at the 95% level of confidence.

RESULTS

The mean vector angles of displacement for pogonion and menton for the cranial base superimposition method and the maxillary base superimposition method in the control sample (Table 2) were not significantly different.

The mean vector angles for mandibular displacement for pogonion and menton in the treated groups were compared (Table 3) and all were significant. There was a significant difference between the two superimposition methods in all of the treated samples, preangulated with 4/4s extracted, preangulated with 4/5s extracted, standard edgewise with 4/4s extracted, and standard edgewise with 4/5s extracted. The mean vector angles of mandibular displacement were lower in the maxillary superimposition method when compared with the cranial base superimposition method.

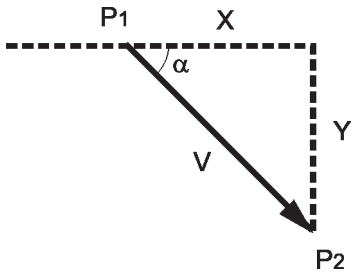

Figure 4. Horizontal and vertical components of treatment vector.

When comparing all groups (Table 4), there was no significant difference in the mean vector angle between the untreated control group superimposed on the cranial base and both standard (Tweed-Merrifield) extraction groups. There was a significant difference between the cranial base superimposition of the control group and both preangulated extraction groups with the mean vector angle being larger in the preangulated groups.

Using the maxillary base superimposition method, the control (untreated) subjects showed a significant difference in the mean vector angle of mandibular displacement only with the standard (Tweed-Merrifield) treated group with 4/4s extracted. The standard (Tweed-Merrifield) treated group with 4/4s extracted had a smaller mean vector angle.

When evaluating the extraction patterns in the preangulated treated group, there was no significant difference in the mean vector angle between the two extraction patterns when using the cranial base superimposition method. The same was observed when the superimposition was based on the maxillary base. In the standard appliance groups there was no significant difference between the extraction patterns based on the cranial base superimposition method, but a significant difference was found using the maxillary base superimposition method.

Lastly, when comparing the mean vector angles of the standard edgewise (Tweed-Merrifield) groups and the preangulated appliance groups, there was a significant difference when superimposition was based

Table 1. Mean Vector Angles of Pogonion (Pg) and Menton (Me)*[a]

	Control (n = 30)		Preangulated 4/4 (n = 31)		Preangulated 4/5 (n = 32)		Standard 4/4 (n = 29)		Standard 4/5 (n = 33)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cranial base										
Pogonion	69.56	20.73	84.34	15.10	85.31	20.00	60.52	17.18	68.32	17.41
Menton	69.27	19.71	84.70	16.50	85.24	19.89	61.95	15.93	67.81	16.49
Maxillary base										
Pogonion	70.55	29.40	69.76	21.00	64.54	25.00	44.95	16.39	57.44	22.82
Menton	68.44	29.01	70.14	20.00	64.25	23.74	46.26	15.00	57.46	20.06

[a] Standard includes Tweed-Merrifield technique. SD indicates standard deviation.

Table 2. Comparison of Cranial Base and Maxillary Base Superimposition in the Untreated Group (Degrees)*

Vector	Cranial Base	Maxillary Base	*P*
Pogonion	69.56	70.55	.881
Menton	69.27	68.44	.898

on the cranial base. The mean vector angles were smaller in both standard appliance treated extraction groups when compared with both preangulated appliance treated extraction groups. The same is true when using the maxillary base superimposition except that there was no significant difference between the preangulated treated group with 4/5s extracted and the standard treated group with 4/5s extracted.

DISCUSSION

This study evaluated the spatial changes in the relationship of the mandible to the maxilla with different extraction patterns and techniques when treated Class II patients are compared with untreated subjects. Two superimposition methods were used to assess all groups in the study. Since both pogonion and menton are perimeter points that follow similar paths of displacement on the same bone, the figures display only the vector that represents movement of pogonion. The difference in treatment time between the preangulated and the Tweed-Merrifield groups can be explained by the fact the Tweed-Merrifield practitioner tends to wait for the onset of the permanent dentition, while the preangulated practitioner starts sooner. The mean difference did not show any clinical relevance. In the control group, there was no significant difference between the cranial base superimposition and the maxillary base superimposition method. As shown in Figure 5, although the mandible is displaced anteriorly over time, as expected, the vector also has a downward, vertical component. Taylor[14] showed similar findings in an untreated Class II group.

The results of this study indicate that all treated patients, unlike untreated patients, show statistically significant different vector angles for mandibular displacement when the cranial base and maxillary base superimposition methods are used. The mean vector angle was smaller when using the maxillary base superimposition method (Figures 6 through 9). The vectors seen in all samples present a more anterior projection when compared with controls. A smaller vector angle implies a more horizontal displacement of the mandible, which in a Class II patient would be advantageous in terms of correction of the malocclusion. Similar results were found by Efstratiadis et al.[16] In their evaluation of Class II treated patients, the mean vector angles were smaller when the maxillary base superimposition method was used.

Table 3. Comparison of Cranial Base With Maxillary Base Superimposition in the Treated Groups (Degrees)*

Preangulated extraction 4/4			
Vector	Cranial base	Maxillary base	*P*
Pogonion	84.34	69.76	.003*
Menton	84.70	70.14	.003*
Preangulated extraction 4/5			
Vector	Cranial base	Maxillary base	*P*
Pogonion	85.31	64.54	.001*
Menton	85.24	64.25	.001*
Standard extraction 4/4			
Vector	Cranial base	Maxillary base	*P*
Pogonion	62.29	46.23	.000*
Menton	63.50	47.35	.000*
Standard extraction 4/5			
Vector	Cranial base	Maxillary base	*P*
Pogonion	68.32	57.44	.036*
Menton	67.81	57.46	.028*

* $P \leq .05$.
[a] Standard includes Tweed-Merifield technique.

This finding would indicate that in the treated groups a more horizontal displacement aided in the correction of the Class II. The maxillary base superimposition method allows for the true displacement of the mandible to be expressed because the vertical movement of the maxilla is not translated to the mandible and allows the direction of mandibular change to be clearly observed in orthodontically treated subjects.

When all groups were compared using the cranial base superimposition method, the mean vector angle of the standard appliance (Tweed-Merrifield) treated group was not significantly different than the control group's (Figure 10); however, there was a significant difference between the control and the preangulated appliance groups. The preangulated appliance group

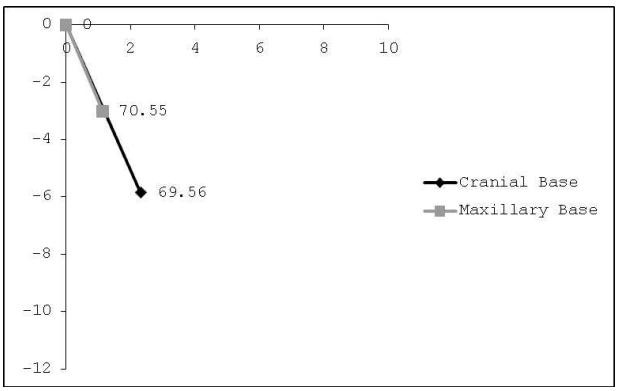

Figure 5. Mean displacement vectors for pogonion in untreated control (degrees).

Table 4. Comparison of All Groups*

Treatment	Cranial Base Asymp Sig (2-Tailed)		Maxillary Base Asymp Sig (2-Tailed)	
	Pogonion	Menton	Pogonion	Menton
Control untreated				
Preangulated 4/4 extraction	.001*	.001*	.897	.792
Preangulated 4/5 extraction	.007*	.003*	.517	.844
Standard 4/4 extraction	.056	.084	.000*	.001*
Standard 4/5 extraction	.978	.888	.057	.108
Preangulated 4/4 extraction				
Control untreated	.001*	.001*	.897	.792
Preangulated 4/5 extraction	.611	.690	.450	.578
Standard 4/4 extraction	.000*	.000*	.000*	.000*
Standard 4/5 extraction	.001*	.000*	.026*	.025*
Preangulated 4/5 extraction				
Control untreated	.007*	.003*	.517	.844
Preangulated 4/4 extraction	.611	.690	.450	.578
Standard 4/4 extraction	.000*	.000*	.001*	.001*
Standard 4/5 extraction	.002*	.001*	.188	.143
Standard 4/4 extraction				
Control untreated	.056	.084	.000*	.001*
Preangulated 4/4 extraction	.000*	.000*	.000*	.000*
Preangulated 4/5 extraction	.000*	.000*	.001*	.001*
Standard 4/5 extraction	.100	.137	.033*	.019*
Standard 4/5 extraction				
Control untreated	.978	.888	.057	.108
Preangulated 4/4 extraction	.001*	.000*	.026*	.025*
Preangulated 4/5 extraction	.002*	.001*	.188	.143
Standard 4/4 extraction	.100	.137	.033*	.019*

* $P \leq .05$.
[a] Asymp Sig denotes Asymptoic Significance.
[b] Standard includes Tweed-Merifield technique.

had a much larger mean vector angle, which indicated a more vertical direction of displacement. This finding is a reflection of a greater increase in the vertical dimension in the preangulated appliance group. Vertical dimension increase is not necessarily advantageous to the correction of the Class II malocclusion.

When comparing extraction patterns, there was no significant difference between the two preangulated appliance groups when either superimposition method was used. In the standard (Tweed-Merrifield) group, there was not a significant difference when the superimposition was based on the cranial base, but there was a significant difference between the two extraction patterns when superimposition was based on the maxillary base. The standard (Tweed-Merrifield) group with 4/4s extracted had a much smaller vector

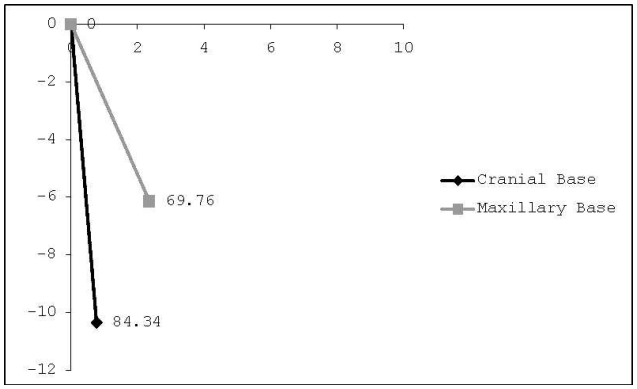

Figure 6. Mean displacement vectors for pogonion in preangulated 4/4 extraction group (degrees).

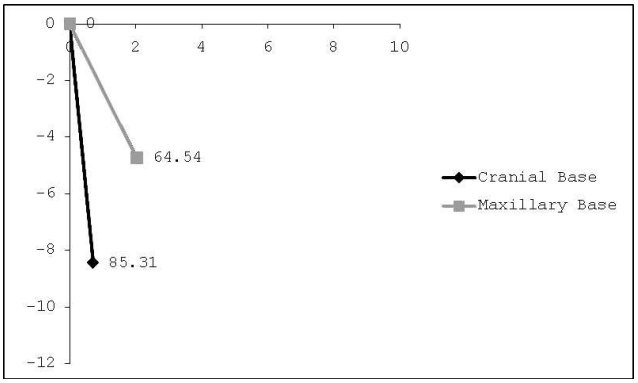

Figure 7. Mean displacement vectors for pogonion in preangulated 4/5 extraction group (degrees).

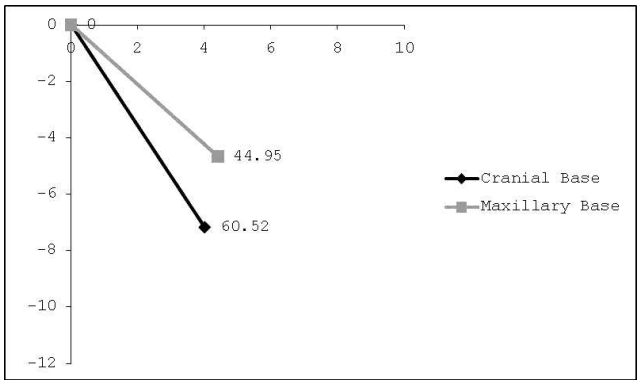

Figure 8. Mean displacement vectors for pogonion in standard (Tweed-Merrifield) 4/4 extraction group (degrees).

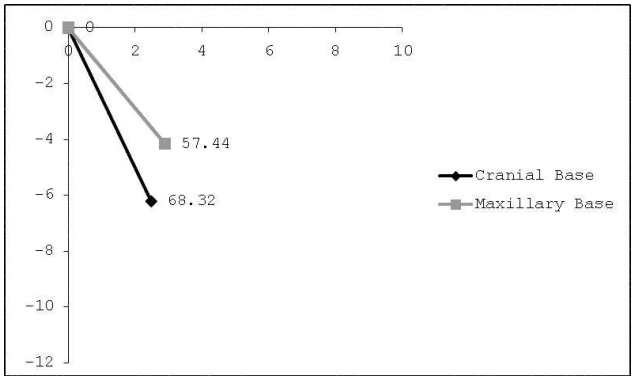

Figure 9. Mean displacement vectors for pogonion in standard (Tweed-Merrifield) 4/5 extraction group (degrees).

angle, which represents a more horizontal displacement of the mandible.

Tweed-Merrifield directional force mechanics places a lot of emphasis on anchorage preparation prior to the correction of the anteroposterior discrepancy, especially when 4/4s are extracted.[17] The extraction pattern of 4/5s uses the space previously occupied by the mandibular second premolars to mesialize the mandibular first molar to help with the Class II correction. Therefore, in patients on whom 4/4s were extracted, the treating orthodontist would most likely establish more anchorage control (ie, vertical control) and prevent the extrusion of the posterior dentition when a great amount of Class II intermaxillary elastics were to be used.

When the standard (Tweed-Merrifield) treated group and the preangulated treated group were compared, based on the superimposition of the cranial base as well as on the maxillary base, there was a significant difference between the 4/4 group but not preangulated or standard 4/5 group when the superimposition was based on the maxilla. The difference was not significant, but as is evident in Figure 10, the mean vector angle was lower in the standard (Tweed-Merrifield) treated group with 4/5s extracted. The mean vector angles of the standard (Tweed-Merrifield) groups were smaller than those of the preangulated group, an indicator of a greater horizontal displacement of the mandible. The difference in the spatial changes of the mandible in the different treatment groups can be explained by the

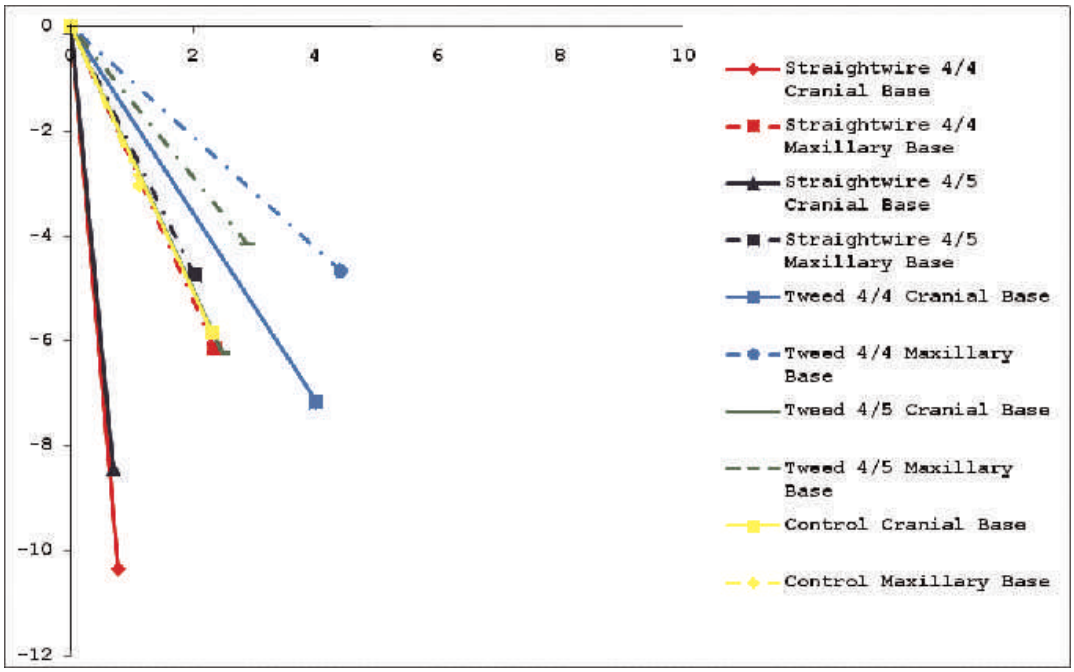

Figure 10. Comparison of all groups (degrees).

vertical control performed in the Tweed-Merrifield groups.

CONCLUSIONS

- In the treated groups there is a significant difference in the mean vector angle for mandibular displacement between superimpositions based on the cranial base and the maxillary base.
- The mandibular displacement angle was more horizontal when using the superimposition method based on the maxillary base compared with the superimposition method based on the cranial base.
- There was no significant difference in mandibular displacement when the two extraction patterns in the preangulated treatment groups were compared.
- Mandibular displacement in the standard (Tweed-Merrifield) group treated with the extraction of 4/4s had a more horizontal mandibular displacement than the standard (Tweed-Merrifield) group treated with the extraction of 4/5s when superimposition was based on the maxilla.
- There was a significant difference in the mean vector angle of mandibular displacement between the standard (Tweed-Merrifield) and the preangulated treated groups using both superimposition methods. Mandibular displacement was more horizontal in the standard (Tweed-Merrifield) group when compared with the preangulated group.

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