Effects of cervical headgear and edgewise appliances on growing patients

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Maxillary basal bone, dentoalveolar, and dental changes in Class II Division 1 patients treated to normal occlusion by using cervical headgear and edgewise appliances were retrospectively evaluated. A sample of 45 treated patients was compared with a group of 30 untreated patients. Subjects were drawn from the Department of Orthodontics, Araraquara School of Dentistry, Brazil, and ranged in age from 7.5 to 13.5 years. The groups were matched based on age, gender, and malocclusion. Roughly 87% of the treated group had a mesocephalic or brachicephalic pattern, and 13% had a dolicocephalic pattern. Cervical headgear was used until a Class I dental relationship was achieved. Our results demonstrated that the malocclusions were probably corrected by maintaining the maxillary first molars in position during maxillary growth. Maxillary basal bone changes (excluding dentoalveolar changes) did not differ significantly between the treated and the untreated groups. Molar extrusion after the use of cervical headgear was not supported by our data, and this must be considered in the treatment plan of patients who present similar facial types. (Am J Orthod Dentofacial Orthop 2001;119:531-9)

Skelet al Class II malocclusion may be characterized by maxillary protrusion, mandibular retrusion, or a combination of both.1 Although there is no rigorous operational rule for differentiating skeletal and dental limits in Class II malocclusion,2 according to Angle’s classification scheme, the Class II Division 1 malocclusion most likely includes some degree of incisor overjet. Overjet of 3 mm or more is present in 55% of the US population,3 suggesting that the incidence of Class II Division 1 malocclusion in the US population is significant. The incidence of skeletal Class II malocclusion in growing Brazilian patients who seek orthodontic treatment is also significant.4,5 When radiographic and clinical assessments show maxillary skeletal protrusion, the main treatment goal for growing patients is correction of the abnormal maxillofacial relationship. This is often done by applying orthopedic forces to the maxilla.

Headgear appliances are frequently used to apply orthopedic forces to the maxilla. It has been demonstrated that headgear appliances produce important changes in growing and adult animals.6-12 Distal movement of the maxillary molars occurs, and the normal downward and forward growth of the nasomaxillary complex can be changed, with significant resorption occurring at the maxillary sutures and the flexure of the cranial base.6-12 However, human studies have not clearly demonstrated that maxillary basal bone changes (excluding dentoalveolar bone changes) are possible.

Experimental models provide important biological information, but they cannot be directly compared with human studies. First, the force applied in patients is lighter than the force used in animal protocols.13 Second, treated patients have malocclusions; experimental animals do not. Third, the therapeutic limits are different because in human studies the application of force is deemphasized when a dental Class I relationship is achieved.13 Some authors claim that headgear therapy causes skeletal maxillary changes in humans, but others deny its effects.2,13-17 In fact, dentoalveolar changes have been clearly demonstrated concomitantly with the downward relocation of the palatal plane in the anterior region and remodeling of A point.2,14,15,17-21 In growing patients who have skeletal Class II malocclusions, dentoalveolar headgear effects alone appear to be less than the ideal goal; however, changes in the eruption pattern may be a suitable mechanism to compensate for skeletal maxillomandibular discrepancies.22,23

Normal dental eruption contributes significantly to individual facial features.23 Posterior alveolar height is directly related to mandibular rotation, which influences...
the anteroposterior chin projection and, consequently, the overall facial profile.\textsuperscript{24-26} Because dental eruption does not strictly follow genetic patterns but is strongly influenced by forces governing occlusal development,\textsuperscript{23} headgear appliances may affect the path and the degree of dental eruption and thus the facial growth pattern.

Headgear dental effects can be academically divided into horizontal and vertical components. Horizontal effects, maintaining or moving maxillary first molars distally, have been extensively described.\textsuperscript{2,13-21,27-33} However, vertical effects, especially when cervical headgear appliances are used, are not well understood. Extrusion of the maxillary molars has been described as an important side effect of cervical headgear.\textsuperscript{2,21} In other studies, extrusion of the maxillary molars has been suspected or negated.\textsuperscript{16,19,27} Clinically, understanding the effects of cervical headgear is vital for its correct application.

The purpose of this study was to evaluate skeletal and dental changes in the maxillary and mandibular first molar regions of growing Class II Division 1 patients treated with cervical headgear and edgewise appliances.\textsuperscript{27}

**MATERIAL AND METHODS**

A sample of 75 Brazilians of European descent with ages ranging from 7.5 to 13.5 years was divided into 2 groups: 45 subjects who had been treated with cervical headgear and fixed edgewise appliances and 30 subjects who had not been treated (Table I).\textsuperscript{27} Records were collected retrospectively from the database of the Department of Orthodontics, Araraquara Dental School (UNESP), São Paulo, Brazil. The patients were treated by graduate students enrolled in the orthodontic program.

The criteria for selection in the treated group were that the patient have a Class II Division 1 (molar and canine) malocclusion, with an overjet of 3 mm or greater, that had been treated to a Class I relationship with nonextraction therapy. The untreated group was matched to the treated group by age, gender, and malocclusion. Rejection criteria included poor-quality records, craniofacial disorders, or previous orthodontic or orthopedic treatment. The cephalometric landmarks and measurements used for this study are described in Table II.\textsuperscript{34}

After the selection, the sample was classified according to the Siriwat and Jarabak index.\textsuperscript{35} This index is defined as the proportion between posterior facial height (sella to gonion) and anterior facial height (nasion to menton) \( \times 100 \). Dolicocephalic subjects tend to have a smaller proportion of posterior facial height to anterior facial height than do mesocephalic subjects, and brachicephalic subjects tend to have a larger proportion of posterior facial height to anterior facial height than do mesocephalic individuals. The treated group included 26 mesocephalic (58%), 6 dolicocephalic (13%), and 13 brachicephalic (29%) patients; the untreated group included 20 mesocephalic (67%), 5 dolicocephalic (17%), and 5 brachicephalic (17%) subjects. The cephalometric indices measured in the treated and untreated groups did not present a statistically significant difference between the groups. All the cephalograms were traced by the same operator (M. S. G.). Ten cephalograms were randomly chosen and measured twice, 1 week apart, to calculate the systematic and random errors. Systematic error was not significant for any of the variables. Random error was calculated by the Dahlberg\textsuperscript{36} method

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(ME = \sqrt{\sum(x_1 - x_2)^2/2n})
\]

and ranged from 0.16 to 0.38. The changes were annualized, that is, alterations in millimeters were divided by the observation period, which allowed for comparison of the changes observed in different intervals.

Cervical headgear appliances were adjusted to have a 20° upward angulation of the headgear external bow, to apply 400 g of force per side on the maxillary first molars for 14 to 18 hours per day until a Class I relationship was achieved, and to apply the same force for
8 to 10 hours per day thereafter. The edgewise appliance prescription presented a –6° angulation (distal tip) on the mandibular first molars.

Lateral cephalograms were taken at the beginning and at the end of treatment. Cranial base (Fig 1), maxillary (Fig 2), and mandibular superimpositions were performed to evaluate maxillary basal bone and dental changes. Total superimposition was based on the cranial base and included dental, dentoalveolar, and maxillary basal bone changes. Partial superimpositions were used to evaluate dentoalveolar and dental changes in the maxilla and the mandible because differentiation between the two was not possible. Maxillary basal bone changes were calculated as the difference between the total and the partial superimpositions and represent the skeletal maxillary alteration or, in other words, the repositioning of the upper jaw. The results were represented by pitchfork diagrams. DFP Plus software (Dentofacial Software, Toronto, Ontario, Canada) was used to digitize the landmarks, and all data were computed with the use of SPSS 9.0 software (SPSS, Chicago, Ill).

Mean and SDs were used to describe central tendencies and dispersion of the variables. Variables that presented positive skewness or kurtosis were compared by the Mann-Whitney U test. A Student t test was used for variables that presented normal distribution (P < .05).

**RESULTS**

SNA and ANB angles and Wits distances changed significantly (Table III). Moreover, slight counterclockwise rotation of the occlusal plane and clockwise rotation of the palatal plane were observed (Table III).

Partial superimposition showed significant distal relocation (negative sign) in the apex, center of resistance (furcation region), and cusp of the maxillary first molars, including dentoalveolar and dental changes. However, maxillary basal bone changes were not significantly different between the treated and untreated groups (Table IV). Distal dental relocation was more significant in the apex of the maxillary molars and gradually decreased in the center of resistance and in the molar cusp (Table IV). On the other hand, potential skeletal changes were more pronounced in the region of the molar cusp and gradually decreased in the region of the center of resistance and the apex. Vertically, none of the skeletal or dental changes in the apex, center of resistance, or molar cusp were significant (Table V). Combined horizontal and vertical effects on the maxillary molars are illustrated in Figure 3.
Mandibular skeletal or dental horizontal changes were not significant when the treated and untreated groups were compared (Table VI). Furthermore, the mandibular molars did not present any significant vertical change (Table VII). The mandibular molar cusp showed a tendency to move back, but the center of resistance and especially the apex displayed a tendency to move forward. Combined horizontal and vertical effects on the mandibular molars are shown in Figure 4.

Horizontal maxillomandibular changes (skeletal and dental) are shown in Figures 5 and 6, and vertical changes (skeletal and dental) are shown in Figures 5 and 7.

DISCUSSION

Angular and linear changes support the notion that cervical headgear appliances may have corrected the Class II Division 1 malocclusion to Class I. Such a suggestion must be differentiated from a clear conclusion. The limitation is based on a lack of independence between our selection criteria and our results. Because only Class II Division I patients who had been successfully treated by cervical headgear were included in our sample, the possible efficiency of the cervical headgear was known before the material was analyzed, and such bias does not allow certainty.

The changes observed in A point do not necessarily confirm alterations of the maxillary basal bone because they may be due to distal relocation of the dentoalveolar bone.40 The differences between experimental and clinical studies are explained by the lack of matched protocols, and results cannot be directly compared.13 Skeletal
changes have been described in human studies; however, the term skeletal may include alterations on the maxillary basal bone or in the dentoalveolar region.2,14-16,21 There is no clear description of the nature of the effect. Our results did not show significant maxillary basal bone differences (again, excluding dentoalveolar bone changes) between the treated and the untreated groups, supporting the results of Bernstein et al13 and Sandusky,17 who evaluated the repositioning of the maxillary basal bone, but not dentoalveolar changes. Conversely, maxillary dental changes (including dentoalveolar changes) were confirmed, agreeing with results extensively demonstrated in other studies.13-20 Maxillary superimposition showed significant distal relocation in all 3 dental areas (ie, the apex, the center of resistance, and the molar cusp). The most significant change occurred in the apex area, which suggests distal apex tipping. Changes observed in the apex are due to the 20° upward angulation of the headgear external bow combined with the backward and downward pull of the cervical headgear. The overall results show that the headgear appliances maintained the position of the maxillary molars but did not significantly influence the

| Table III. Jaw relationship (degrees per year and Wits in millimeters per year) |
|----------------------------------|-----|------|-----|
| Variables                        | Mean | SD   | Mean | SD   | Difference |
| SNA                              | -0.58| 0.53 | 0.28 | 0.66 | 0.86** |
| SNB                              | 0.23 | 0.38 | 0.35 | 0.69 | 0.12    |
| ANB                              | -0.81| 0.53 | -0.07| 0.60 | 0.88** |
| SN.PP                            | 0.25 | 0.60 | 0.09 | 0.76 | 0.16*   |
| SN.OP                            | -0.81| 0.94 | -0.46| 0.78 | 0.35*   |
| SN.GoMe                          | -0.07| 0.74 | 0.03 | 1.2  | 0.1     |
| Wits                             | -0.44| 0.63 | 0.12 | 0.71 | 0.56**  |

*P < .05; **P < .01.

| A, Apex; CR, center of resistance; C, cusp. |

| Table IV. Horizontal changes of maxillary molars (millimeters per year) |
|-------------------------------|-----|------|-----|
| Variables                   | Mean | SD   | Mean | SD   | Difference |
| A, skeletal                  | 0.46 | 0.78 | 0.85 | 1.81 | -0.39     |
| A, dental                    | -0.47| 0.75 | 0.33 | 1.33 | -0.80*    |
| A, total                     | 0.03 | 0.79 | 0.97 | 1.19 | -0.94*    |
| CR, skeletal                 | 0.48 | 0.77 | 0.88 | 1.46 | -0.40     |
| CR, dental                   | -0.34| 0.71 | 0.29 | 1.20 | -0.63*    |
| CR, total                    | 0.17 | 0.79 | 1.01 | 1.14 | -0.93*    |
| C, skeletal                  | 0.45 | 0.82 | 1.14 | 1.80 | -0.69     |
| C, dental                    | 0.25 | 0.75 | 0.29 | 1.22 | -0.54*    |
| C, total                     | 0.31 | 0.85 | 1.27 | 1.21 | -0.96*    |

*P < .01.

| A, Apex; CR, center of resistance; C, cusp. |

| Table V. Vertical changes of maxillary molars (millimeters per year) |
|-----------------------------|-----|------|-----|
| Variables                   | Mean | SD   | Mean | SD   | Difference |
| A, skeletal                 | 0.66 | 1.10 | 0.49 | 1.09 | 0.17*   |
| A, dental                   | 1.16 | 0.75 | 1.14 | 0.95 | 0.02*   |
| A, total                    | 1.82 | 0.73 | 1.81 | 1.07 | -0.01*  |
| CR, skeletal                | 0.67 | 1.09 | 0.44 | 0.93 | 0.23*   |
| CR, dental                  | 1.19 | 0.76 | 1.07 | 0.94 | 0.12*   |
| CR, total                   | 1.87 | 0.71 | 1.78 | 1.03 | 0.09*   |
| C, skeletal                 | 0.73 | 0.94 | 0.45 | 1.12 | 0.28*   |
| C, dental                   | 1.16 | 0.78 | 1.12 | 1.02 | 0.04*   |
| C, total                    | 1.86 | 0.71 | 1.77 | 1.08 | 0.09*   |

*NS.

A, Apex; CR, center of resistance; C, cusp.
Vertical extrusion of the maxillary molars has been reported as a detrimental effect of cervical headgear appliances.\textsuperscript{2,15,19,32} Such an effect was not confirmed by our study, which agrees with the results of Boecler,\textsuperscript{16} Weinberger,\textsuperscript{20} and Ringenberg and Butts.\textsuperscript{28} Extrusion of the maxillary molars is not necessarily unfavorable. Brachicephalic patients have low anterior–posterior height proportions, and extrusion of the maxillary molars would compensate for excessive vertical mandibular ramus growth, increasing the anterior facial height and consequently improving the facial profile.\textsuperscript{25,26}

Because the maxillary molars did not significantly extrude, mandibular molars are not expected to change vertically, and the mandibular rotation pattern is not expected to change. Mandibular molars did not present horizontal or vertical changes. The tendency for forward movement of the mandibular molar apex is possibly due to the 6° angulation in the edgewise prescription and may not be related to headgear mechanics.

Clinically, our results demonstrated that the cervical headgear appliances corrected the Class II malocclusion to a Class I relationship (molars and canines) in the successful cases. The lack of statistically significant maxillary basal bone changes does not necessarily mean that the treatment was unsuccessful because dentoalveolar corrections may camouflage skeletal discrepancies.\textsuperscript{1}

A limitation of this study was that the changes were annualized, a choice of method based on the assumption...
that growth rate is linear, which may not be true. However, this was the best way to compare the experimental and the control groups that had had significantly different observation periods. Furthermore, our data do not evaluate pure headgear effects because lateral cephalograms taken immediately after the Class I relationship had been achieved were not available. The overall change for the entire period of treatment may hide the headgear effects because patients may have resumed normal growth patterns during the period in which headgear was used only to maintain the achieved Class I relationship.

Another limitation is the potential treatment bias; mesocephalic or brachicephalic patients, for whom the cervical headgear is indicated, may have less of a tendency for extrusion of the maxillary molars because they have different masticatory forces than do dolicocephalic patients. Future studies evaluating a larger number of all facial types are suggested.

CONCLUSION

In this study, statistically significant maxillary basal bone changes did not occur. Cervical headgear appliances corrected the Class II Division 1 malocclusion to a Class I relationship by maintaining the maxillary first molars and redirecting dentoalveolar growth in the maxilla, rather than by significantly changing the growth of the maxillary jaw base. Vertical changes were not supported by our data. Absence of statistically significant extrusion of the maxillary molars after the use of cervical headgear in patients with Class II Division 1 malocclusion is a valuable piece of information for the clinician.

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Fig 6. Horizontal changes for the maxillary basal bone, mandibular basal bone, and maxillary and mandibular first molars. Arrows represent repositioning in space (forward or backward). Circles represent differences between maxillary and mandibular arches. Difference diagram shows differences between untreated and treated groups.

Fig 7. Vertical changes for maxillary basal bone, mandibular basal bone, and maxillary and mandibular first molars. Arrows represent the repositioning in space (upward or downward). Circles represent differences between the maxillary and mandibular arches. Difference diagram shows differences between untreated and treated groups.
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COMMENTARY: RETROSPECTIVE STUDY
REQUIRES CAREFUL INTERPRETATION

The authors of this article have collected data from two types of Class II Division 1 subjects: those who wore cervical headgear and those who remained untreated. Although the groups were matched “by age, gender, and malocclusion,” we are not told specifically what that means. At the end of the observation periods, certain differences between the groups were observed, and the authors suggest that these differences can be attributed to the headgear. However, the use of cervical headgear was not the only difference between the groups. The time interval for the observation group was longer than that for the control subjects, and only those subjects who successfully achieved a Class I relationship were allowed to remain in the treated group. This limits the conclusions as to a “cause” that can appropriately be drawn from the study.

The error the authors have made is somewhat subtle and is extremely common—my impression is that the same mistake has been made in more than half the clinical studies published during the past 30 years. It is good that the sophistication of our readers is such that we now detect errors of this sort. On the other hand, I believe it is dangerous to dismiss a report out of hand because it is not perfect. It is all very well to say that, on theoretical grounds, randomized clinical trials are the
gold standard in human research and, by implication, are the best or even the only way to go. Twelve years ago, I believed that the best answers for orthodontics could be achieved only by textbook-perfect prospective studies, and I strongly disagreed with those who claimed such studies were not feasible in orthodontics. But experience has convinced me that I was wrong.

To be sure, prospective clinical trials play a valuable role, but they are no more likely to produce perfect answers than are well-conducted retrospective studies. Indeed, there are two practical reasons why orthodontics is unlikely to see large prospective trials in the near future. The first is that, to be meaningful, prospective trials would have to span at least 15 to 20 years, whereas experience shows us that treatment strategies change sufficiently over such a time interval to preclude or seriously limit the generalization of results from one period to another. The second reason is that funding for well-controlled long-term prospective trials in orthodontics is simply not available—and is not likely to become available during the next decade.

This leaves us, as a specialty, with the task of learning how to draw limited conclusions from limited studies, albeit with greater sophistication than was employed earlier. Future studies need to address questions of selection bias much more carefully than the present authors have done. There are strategies for retrospectively controlling for or minimizing the effects of such bias, both at the beginning of studies and, as in the present case, at the end—by limiting our post hoc generalizations.

It seems evident to this reviewer that much careful work has gone into this study, and some meaningful findings regarding patterns of change within the treated group can be gleaned from it. However, I believe there is not sufficient evidence to allow the observed between-group differences to be ascribed to the use of cervical headgear.

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