THE INFLUENCE OF EXTRA ORAL FORCE ON VARIOUS CRANIOFACIAL DIMENSIONS DURING GROWTH AND TREATMENT

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INTRODUCTION

The objective of the orthodontic treatment of a Class II malocclusion is to achieve an improved dental relationship between the maxilla and the mandible. Since the introduction of cervical traction, correction once assumed to be confined to the alveolar process[6,7] has been reported to also involve the spatial relationship of the craniofacial complex and the jaws[8,10,11,16].

Several investigations[6,15,16] utilizing cephalometric roentgenology concluded that the effects of cervical traction were primarily one of suppressing the anterior advancement of the developing maxilla and concomitant alteration of molar eruption. Data from recent studies[12,20,21,22] involving patients treated with cervical traction indicated and subsequently verified a compound effect of treatment on the facial skeleton as well as changes in direction of growth of the maxilla.

The purpose of this investigation was to study the effect of force upon basal maxillary structures and adjacent facial junctions on treated patients in more detail.

LITERATURE REVIEW

Theories involving the correction of a Class II malocclusion began appearing in the literature as early as 1899 when Edward Angle[1] verbalized that the objective of treatment was to establish a "normal occlusion". Later formulating the "functional concept of development" Angle instilled in the profession the belief that teeth placed in ideal occlusion would induce normal development of the facial skeleton[2].

Following Broadbent's[3] introduction of cephalometric roentgenology it was disclosed that the skeletal confirmation of the face was extremely stable during growth and treatment had little, if any, effect on the developing facial skeletal relationships. Further investigations by Brodie[5] revealed that orthodontic treatment had no influence on future growth of the osseous structures of the face beyond the confines of the alveolar process.

Prior to Brodie's disclosure reporting the limited effect of orthodontic treatment, Oppenheim[4] alleged that occipital anchorage allowed the correction of Class II malocclusion by distal movement of the maxillary teeth without disturbing their mandibular antagonists. Clinical investigations by Kloehn[6] and King[14] established that the correction occurred principally as a result of inhibited anterior growth of the maxilla while allowing mandibular growth to proceed normally.

Both Klein[8] and Rickets[11] speculated that maxillary skeletal alterations resulted when extraoral force was employed, inasmuch as changes observed in the convexity of the face were greater than growth could correct even if all the mandibular growth was expressed in a forward direction. Moore[10] and Sandusky[16] demonstrated that treatment in the mixed dentition reduced the facial convexity in a manner that cannot be attained with later correction. Utilizing the constructed CBR point-basion plane for tracing superimposition, Weislander[12] discovered that a correlation existed between changes in position of basion relative to changes in position of pogonion, ANS, and the mandibular plane in the cervical traction group of the investigation. The significant correlations found in the treated group as compared to no interrelation between the same measurements in the control group, provided evidence that a rotation of the craniofacial skeleton may have occurred. PTM was consistently found to be in a more posterior position relative to the cranial base in the past treatment group. Since the pterygoid processes and the body of the sphenoid bone are fused at age nine any change in position of the pterygoid processes will likely be transmitted to the remainder of the sphenoid bone. Hence, Weislander inferred that at this age, with active growth, the craniofacial structures would be subject to adjustment as a result of pressure applied in a constant direction.

Kraus, Wise and Frei[9] postulated, using comparisons of triplets with known zygosities as evidence, that heredity played the predominant role in the formation of the individual bones of the craniofacial complex. Utilizing cephalometric roentgenology they examined the individual elements of the complex within the limitations of their radiographic investigation. They discovered the various contours of individual bones reflect the strong control of the genes, while their various inter- and intrarelationships, which make up the overall facial pattern, are the result of environmental influences. Therefore, though heredity governs morphology, environment is primarily responsible for the resultant spatial relationships of the individual bony elements.

Weislander concluded that cervical traction, though unable to alter the individual bone morphology, theoretically should have an effect on the direction or spatial interrelationships of the components of the facial complex during growth. The results of his initial investigation[12] made him question the validity of the registration techniques and the uses of normal occlusions as the control. Another disclosure that would require further investigation concerned the long term stability of the altered spatial relationships of the craniofacial complex influenced during the mixed dentition period.

A second study was initiated by Weislander[20] utilizing the same format but employing a different technique of landmark registration. It was his belief that the new registration system, for tracing superimposition, would reduce or eliminate the possible artifact, involving measurement magnitude, produced as a result of the perceived sphenoid rotation detected in the first investigation. In this study the control utilized consisted of 28 untreated patients with a full Class II malocclusion in the mixed dentition obtained from the Child Study Clinic of the University of Oregon Dental School.

The utilization of the newly devised registration design incorporating the anterior cranial base fine structures, F point, and basion plus a grid system based on Frankfort horizontal, permitted the magnitude of the influence of cervical traction to be more clearly visualized. This investigation did more than increase the mean difference between the control and treated groups, it revealed a statistically significant vertical descent of nasion, clockwise rotation of the sphenoid bone and an orthopedic movement of the maxilla as a result of cervical traction[18].

The long term stability of the effect of force on the maxilla during growth became the subject for Weislander's[21] third study involving cervical traction. The same control group, treatment group, and reference system for superimposition were utilized as in the preceding investigation. In addition to the pretreatment and post treatment cephalometric films, twenty-three of the treated group and twelve of the control group provided post retention cephalograms at an average age of eighteen years. This longitudinal study statistically documented that changes in the posterior movements of the maxillary molar, the basal maxillary changes revealed by point A and PTM, and the surrounding anatomic structures demonstrated by rotation of the sphenoid bone are relatively stable with minimal physiologic recovery six years post treatment.

Weislander's[22] most recent cervical force study supported the earlier findings of Moore[10] and Sandusky[16]. This investigation evaluated the effects of cervical traction in Class II malocclusions in which treatment was started either early or late in the mixed dentition. Since dental development was considered to allow a more accurate determination of skeletal age than did chronological age, an established dental score based on the developmental stages of the permanent teeth was utilized in selecting the two groups of patients. Both groups were subjected to cervical traction 12 to 14 hours per day for an average treatment time of 2 years and 3 months.

Analysis of the data indicated that the amount and direction of growth were of the greatest importance for effective treatment.

Vertical growth appeared to be of particular importance and correlated to the anteroposterior improvement of the relationship between the maxilla and mandible. Great individual variability was observed, but in cases in which there was a severe discrepancy in the relationship between the maxilla and mandible, treatment in the early mixed dentition may be essential.

MATERIALS AND METHODS

The material for the investigation consisted of cephalograms of boys and girls with Class II malocclusions. The sample of twenty-six cases in the treated group were children who had received orthodontic treatment at the Graduate Orthodontic Clinic, University of Oregon Dental School requiring Kloehn cervical traction. All patients were instructed to wear the headgear at least 12-14 hours per day with 10-15 ounces of force. The average time of treatment was 2 years 6 months. In most instances four bicuspids had been extracted and simultaneous Class II correction was taking place utilizing appliance therapy incorporating all remaining erupted teeth.

The control group utilized in this investigation was the sample of twenty-eight untreated patients with full Class II malocclusions compiled by Weislander for use in his second cervical force study[20]. These untreated patients in the mixed dentition were cases collected from the Child Study Clinic of the University of Oregon Dental School.

Both control and cervical traction groups were matched with regard to the same general characteristics, such as age, ANB differences, malocclusion, and similarly were composed of North American caucasians of middle socioeconomic standing.

The material for analysis consisted of oriented lateral head radiographs. Because the two groups of patients were registered with different cephalometers, the amount of the enlargement was calculated, and a correction factor was included in the data computation. For the control cases studied, the first headfilms were taken at an average age of 9 years, and the second films were taken approximately 3 years later. The first and second films of the treatment group were taken prior to start of therapy at an average age of 12 years 9 months and 15 years 7 months, respectively.

Tracings of the anatomic landmarks were performed after careful study of both lateral headfilms for each patient. To enable changes in the position of the maxilla and the surrounding structures to be examined and assessed, a specific area of superimposition of the pretreatment and post treatment films, as described by Weislander[20], was employed in this study. Anatomic fine structures of the anterior cranial base, with the most posterior point of the posterior outlines of the frontal sinus, were utilized for reference purposes. Growth changes in this area have been studied which reveal it to be acceptable for reference of this design[19]. In addition the Bolton point was registered for orientation of the reference line. Measurements were recorded in relation to a constructed grid system based upon Frankfort horizontal plane and a line perpendicular to it were transfered from the first tracing to the second, so that all measurements referred to the area of superimposition. Vertical and horizontal changes were measured in relation to the grid system and recorded to the nearest 0.1 mm. A few angular measurements were used (Figure 1).

To assess changes within the sphenoid bone, the antero-inferior outline of sella turcica and the outline of planum sphenoidale anterior to tuberculum sella were used to represent the base of the sphenoid bone. The position of the pterygomaxillary fissure was studied in relation to this area, and an attempt was also made to register rotation of the sphenoid bone in relation to the surrounding structures.

The reproducibility of the system of registration was tested by estimating the combined error in landmark location, the error in superimposition, and the measurement error. Cephalograms of twelve randomly chosen patients before and after treatment were traced and superimposed with measurements recorded on two separate occasions. The combined standard error for landmark location, superimposition, and measurement was 0.5 mm in both vertical and horizontal dimensions.

$$SEMeas = \sqrt{\frac{\Sigma d^2}{2N}} .$$

A statistical analysis of the data was applied according to accepted standard procedure. The difference in changes between the two groups was subjected to analysis. A one way analysis of variance was performed in which the F test estimated the significance of difference obtained. The F values were converted to student t values to permit statistical comparison with previous cervical force studies. The null hypothesis was rejected at the 0.05 per cent level of confidence.

RESULTS AND DISCUSSION

Individual variation in growth patterns can produce changes in muscle balance that may be expressed in post-eruptive changes in tooth position[13]. Thus some orthodontic treatment successes may be more the result of normal variation in vertical or horizontal growth of the mandible than of the concurrent therapy.

To more accurately assess the influence of orthodontic treatment on the craniofacial complex requires the recognition and subsequent removal of those changes produced as a result of normal variation in growth and development. This task is exceedingly difficult inasmuch as during therapy both components are exerting their influence simultaneously which may either mask or magnify the effects of treatment. To reduce the magnitude of this inherent normal growth variability in this investigation a control group was utilized[20] possessing the same general characteristics as those found in the cervical traction group. Therefore any significant differences in mean changes between the control and treatment group revealed by this study was considered the result of cervical traction (Figures 2, 3 and 4).

Both the control and the treatment group had the same average ANB difference and malocclusion. At the time of the pretreatment cephalogram however, the two groups differed in their average dental age as expressed by the significant mean difference in their dental scores[18], and an average chronological age difference of 45 months (Table I).

The differences in mean changes found between the control and treatment groups disclosed that an influence upon the growth pattern of the cranio-facial complex had occurred as a result of the cervical traction therapy (Figure 2).

The effect of the cervical traction on the maxilla resulted in a 4 mm more posterior location of point A in the treatment group with a subsequent reduction in the ANB angle disclosed by a mean difference of 3.9 degrees between the control and treated groups. The mean difference in the vertical descent of ANS and the angulation of the palatal plane with the constructed Frankfort horizontal plane was not statistically different from that of the control (Table I).

The difference in mean changes of 0.67 mm, though small, resulted in a more posterior location of sella in the control that was significant at the 0.05 level of confidence (Table I).

Although the inferior movement of nasion observed following cervical traction therapy tends to substantiate the findings of earlier studies[20], the increment involved both the mean changes and the mean difference of 0.35 mm between the control and treatment groups, though statistically significant, was less than the 0.5 mm standard error of the measure of the study (Table I).

A significant mean difference of 0.97 mm in the dimension PTM-sphenoid was found between the control and cervical traction groups. As the mean posterior change of PTM in both control and treatment groups was nearly the same increments, 0.79 mm and 1.07 mm respectively, and not statistically significant it became apparent that the major contribution to the mean dimensional difference was provided by the larger mean posterior change of 0.99 mm in the control group of the antero-inferior outline of sella turcica (Table I).

The maxillary first molars of the treatment group descended vertically an average distance of 5.3 mm and exhibited a mean difference less than that of the control group of 0.67 mm which was not statistically significant. The mean difference of 2.5 mm between the control and cervical traction group in the horizontal position of the maxillary first molars was significant and coincided with the 2.7 mm more posterior location of point A in the cervical traction group (Table I).

A significant mean difference in the length of the maxilla, as measured from ANS to the palatal plane-PTM perpendicular (Figure 1), of nearly 2 mm less in the treated group was recorded during this investigation (Table I).

Point basion was found to undergo a mean posterior change of 2.64 mm in the control group with mean difference of 1.32 mm greater than that of the cervical traction group which was statistically significant. A smaller mean change of 1.6 mm in the vertical descent of basion in the treatment group resulted in a mean difference between the two groups of 0.86 mm that was not statistically significant (Table I).

The cervical traction group demonstrated a mean positive change in the mandibular plane angle of less than 0.5 degrees resulting in a mean difference of 0.8 mm in the vertical descent of menton neither of which was statistically different from that of the control group (Table I).

In this investigation the mean difference in the angulation of the palatal plane to the constructed Frankfort horizontal plane between the control and treatment groups was less than 1 degree which was insufficient to break the null hypothesis established for the study (Table I).

Although not statistically significant there was an implied clockwise rotation of the base of the sphenoid bone exceeding 1 degree in the cervical traction group.

The pretreatment lateral cephalometric films disclosed a 4.2 ~~mm~~ degree mean difference in the palatal plane-mandibular plane angle between the control and the treatment group (Table I). Though statistically significant this increased angulation found in the treatment group was likely an inherent artifact resulting from sample selection.

SUMMARY AND CONCLUSION

It was the purpose of this investigation to examine the effects of extra-oral force applied to the maxillary first molars and transmitted to the maxilla and surrounding craniofacial skeleton in greater detail. A group of twenty-six Class II malocclusions treated with Kloehn cervical headgear were compared to a group of twenty-eight untreated Class II malocclusions. The patients utilized in the treatment group were selected so that the general characteristics of their malocclusion was similar to that of the control group. A second criteria that was required of the cervical traction group was a subjective assessment of the patients' records by the author indicating good cooperation during the cervical traction treatment period. Comparison of lateral cephalometric films before and after treatment disclosed the following clinically and statistically significant differences between the headgear group and the control group:

1. The effect of cervical traction on the maxilla resulted in an alteration of the growth pattern with a subsequent more posterior position of the maxilla.

2. Consequently the mean change of the ANB angle was 4 degrees less than that of the control which resulted in a 4 mm more posterior location of point A.

3. The post treatment location of sella was 0.6 mm anterior to that of the control with a 1.0 mm more reduction in the dimension PTM-sphenoid, both of which may have resulted from a rotational difference in the

sphenoid body of 1.2 degrees which in itself was not statistically significant.

4. An inferior movement of nasion was recorded of 0.35 mm which was less than the SEMeas of 0.5 mm.

5. A more posterior location of the maxillary first molars of 2.4 mm was registered in the cervical traction group.

6. Point basion was found to undergo a 1.3 mm smaller horizontal change in the treatment group which may be related to the higher dental score difference of 11.6 in the treated group.

7. The maxilla registered a nearly 2 mm smaller mean length change in the cervical traction group which may again be related to the higher dental score of this group.

8. A 4.2 degree mean difference in the palatal plane - mandibular plane angle was observed in the pretreatment cephalograms.

The mean difference involving mandibular plane angle, maxillary first molar extrusion and tipping of the palatal plane were found to be not statistically significant. This investigation could be improved by a closer age matching of the treatment and control groups. However, until that is accomplished this is believed to be the best available valid data because of the uniqueness of this longitudinal control sample.

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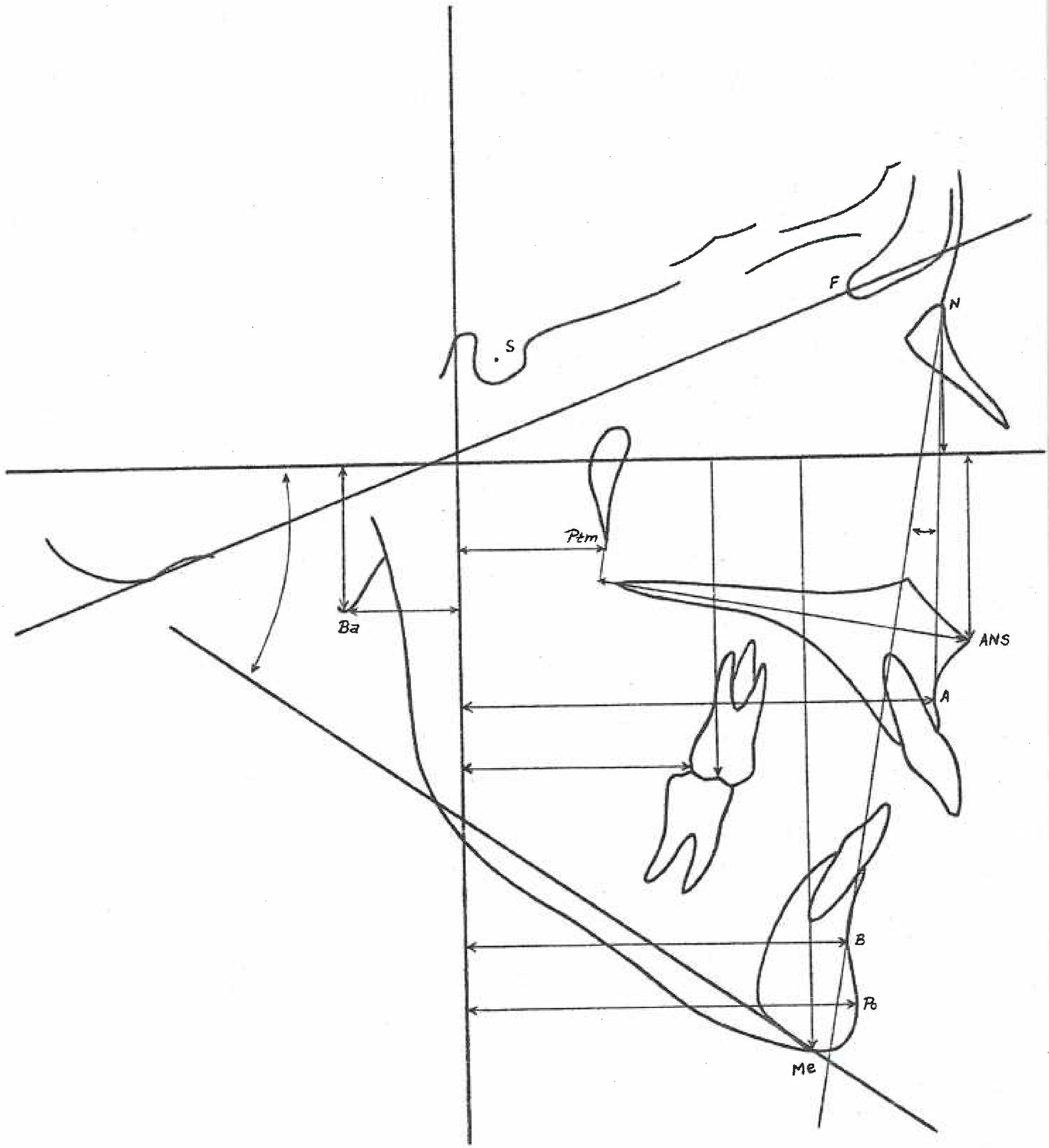

Figure 1 Area of registration for superimposition and grid system for measurements recorded. Changes registered in millimeters and degrees.

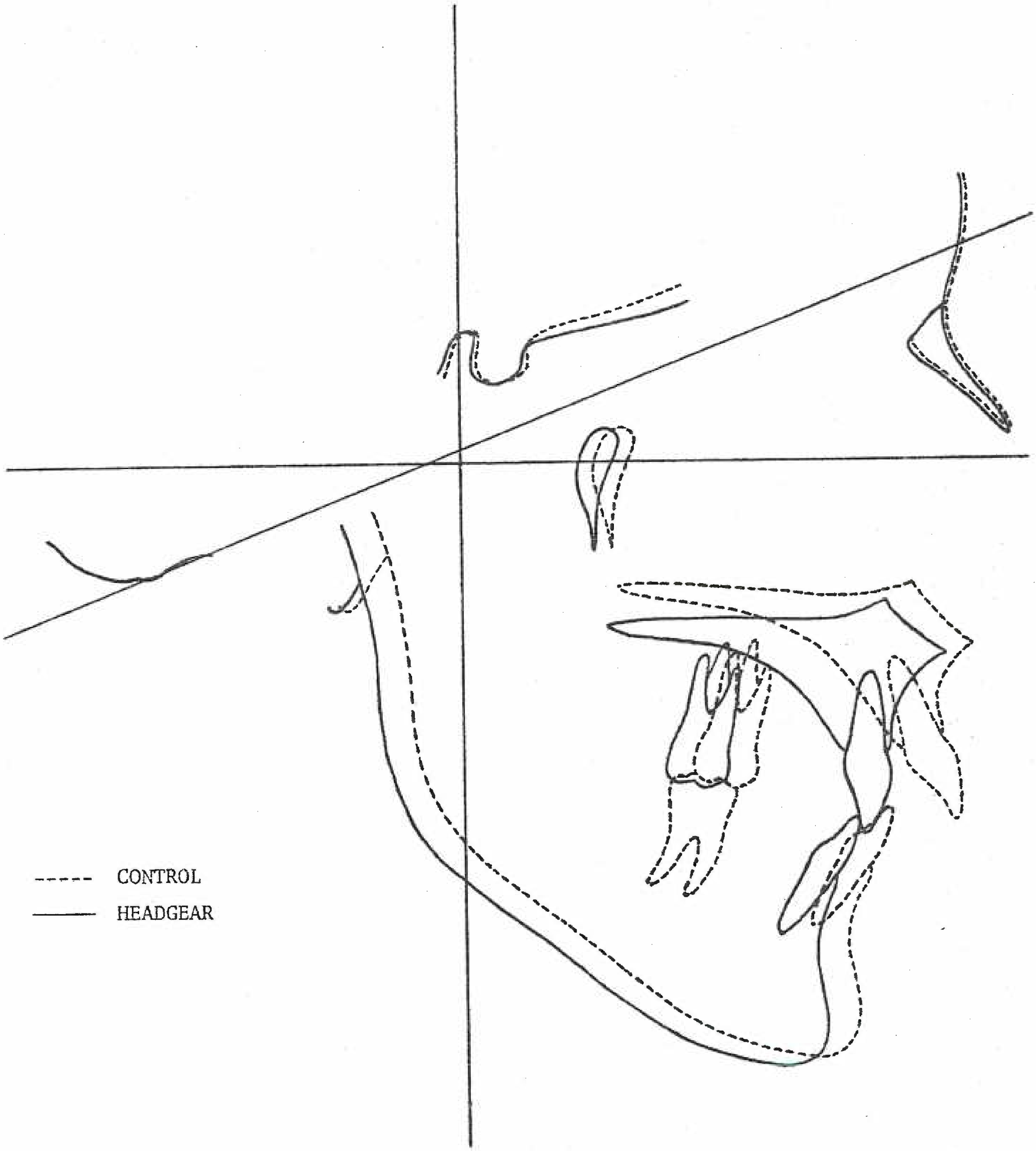

Figure 2 Schematic diagram of mean differences between the control group and the headgear group after treatment.

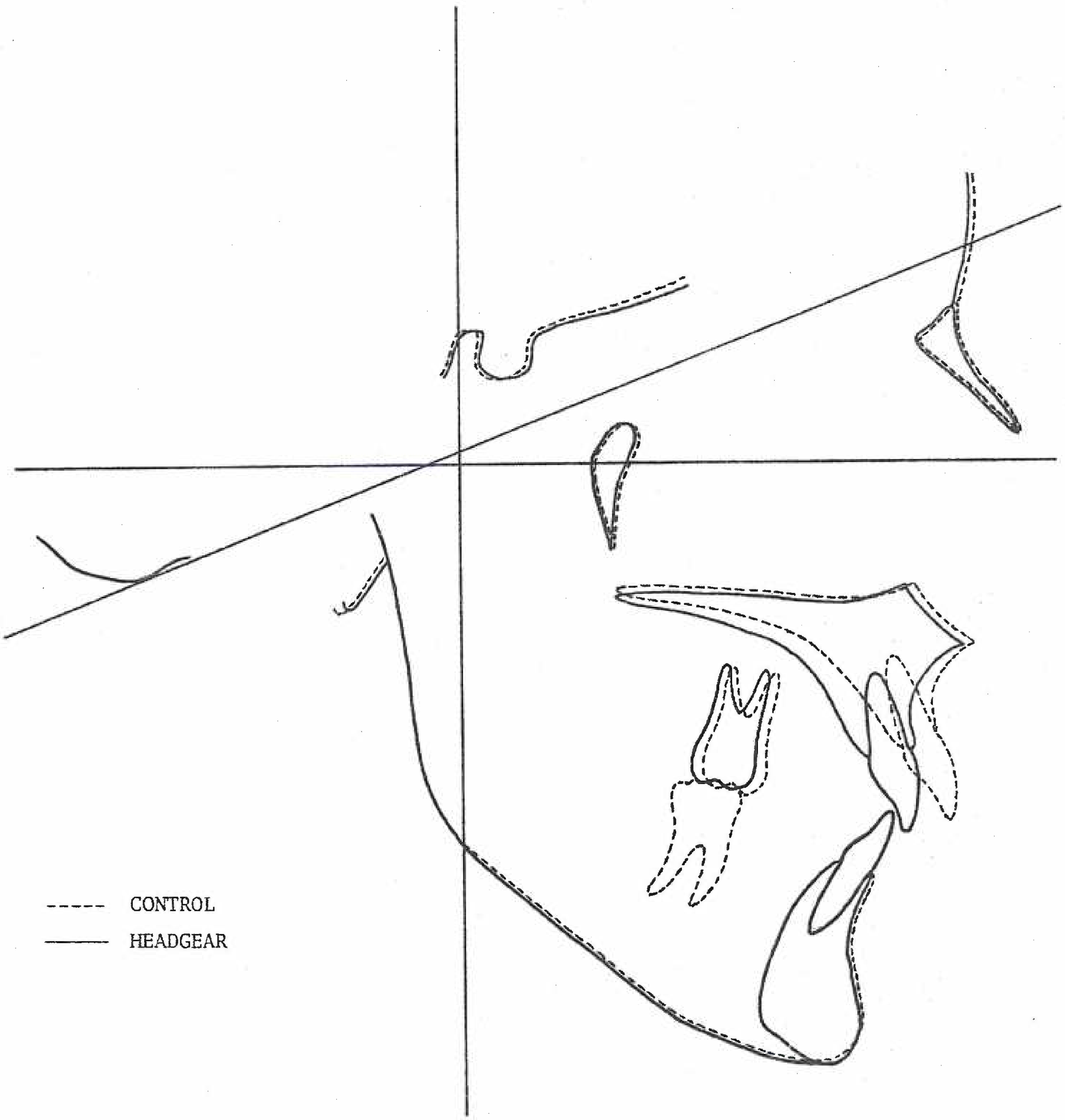

Figure 3 Schematic diagram of the larger mean changes found in the headgear group compared with the mean changes of the control group after treatment.

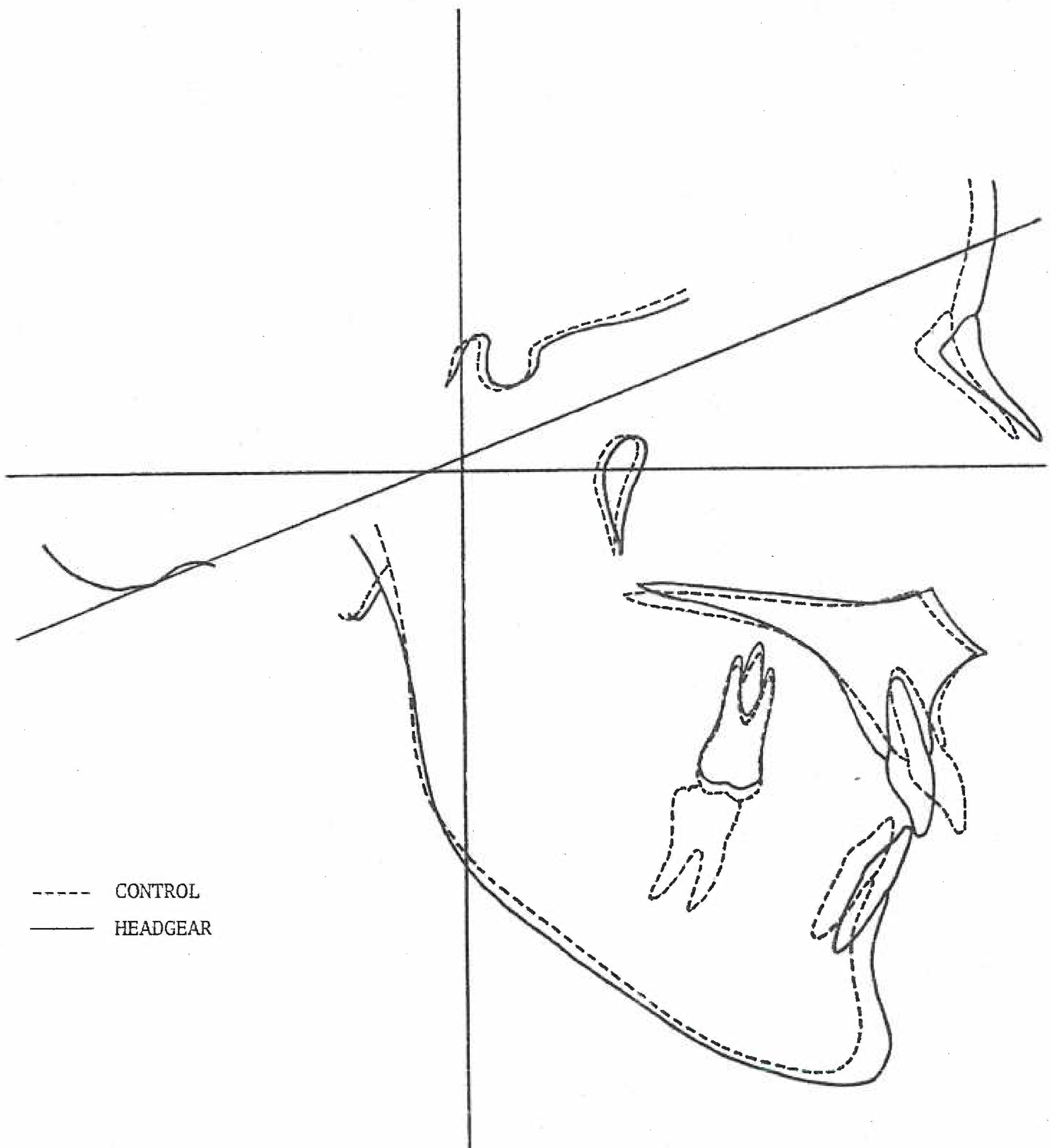

Figure 4 Schematic diagram of the smaller mean changes found in the headgear group compared with the mean changes of the control group after treatment.

TABLE I: A comparison of changes in the cervical traction group and the control group.

Changes (mm or degrees) in horizontal (⇄) or vertical (↑↓) direction	Cervical Group age 12-9 to 15-8 (N=26)		Control Group age 9 - 12 (N=28)		Mean difference between groups	
	$\bar{X}$	SD	$\bar{X}$	SD	$d\bar{X}$	t
ANB	-3.72°	1.51°	0.16°	0.77°	3.88°	12.02*
Point A	←2.70	1.96	→1.73	1.45	4.15	9.47*
PTM	←1.07	1.69	←0.79	0.96	0.28	0.73
Sphenoid rotation	+0.47	2.79	-0.65°	1.26°	1.12°	1.91
Sella horizontal	←0.32	0.85	←0.99	0.59	0.67	3.36*
PTM to sphenoid	←1.15	1.22	←0.18	0.98	0.97	3.23*
ANS	↓3.97	1.91	↓4.03	1.90	0.06	0.12
Palatal plane	-0.32°	2.60	+0.57°	1.35	0.89°	1.59
Nasion	↓0.49	0.79	↓0.07	0.62	0.35	2.20*
	→1.86	1.57	→1.16	0.86	0.70	2.07*
Maxillary molar	↓5.30	2.52	↓5.97	3.42	0.67	0.82
	→0.09	2.56	→2.68	2.28	2.59	3.94*
Mandibular plane	+0.45°	2.25	-0.29°	1.37	0.74°	1.46
Point B	→0.30	2.82	→1.27	2.02	0.97	1.46
Menton	↓8.32	3.42	↓7.52	3.78	0.80	0.81
Basion	←1.32	1.80	←2.64	1.42	1.32	3.00*
	↓1.61	1.69	↓2.47	1.56	0.86	1.96
PTM - ANS	↔1.25	1.95	↔3.18	1.48	1.93	4.12*
Palatal plane - Mandibular plane (Pretreatment)	28.56°	4.92	24.40°	5.09	4.16°	3.05*

Arrows demonstrate the direction of change either anteroposteriorly or superoinferiorly.
* Significant at the 0.05 level of confidence.