Skeletal changes associated with extraoral appliance therapy: an evaluation of 200 consecutively treated cases

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The response of the craniofacial skeleton to extraoral appliances continues to be a major concern of orthodontists; numerous studies on this matter have been reported. Positional changes in the maxilla, the mandible, and the cranial base have been shown by Blueher,[1] Jakobsson,[2] Newcome,[3] Poulton,[4-6] Watson[7] and Weislander.[8] Investigations by Badell,[9] Barton,[10] Baumrind,[11-15] Brown,[16] Chaconas,[17] Droschl,[18] Mays,[19] Schudy[20] and Zingeser[21] have focused on the effects of different types of extraoral forces on treatment response. The direction of extraoral force application has been shown to influence the orientation of the palatal plane, the occlusal plane, and the mandibular plane. It has been a common conclusion that cervical forces tipped the palate downward anteriorly, opened the mandibular plane angle, and encouraged increased vertical development. Merrifield,[22] Poulton,[5] Root,[23] Schudy[24] and Weislander[25] have suggested that it is possible for the orthodontist to alter predictably vertical development in the growing face by using extraoral forces directionally.

There now appears to be sufficient evidence that specific methods of orthodontic therapy can produce craniofacial alterations in humans; however, a great deal of controversy remains regarding the magnitude and direction of these changes. The situation is complicated by those factors which alter or influence the effects of treatment on craniofacial growth, such as age, maturational status, sex, and facial morphology.[26]

The purpose of this investigation was to test the hypotheses that (1) vertical skeletal relationships can be modified predictably by orthodontic treatment, and (2) that skeletal starting form is an effect modifier on skeletal change during such treatments.

Abstract

Questions exist concerning the degree to which orthodontic treatment alters facial form. This study has attempted to discern changes in several measures of vertical facial form which might be influenced by varying vectors and amounts of extraoral force. The data were collected from pre- and posttreatment lateral cephalograms of 200 children treated consecutively with full edgewise orthodontic appliances.

The sample was divided into three pretreatment groups based on the type of extraoral force delivered; cervical, "combi," and no-headgear. All groups showed a wide range of variation in treatment response, but did not demonstrate significant differences. While the extraoral forces predictably improved horizontal maxillo-mandibular discrepancies, there was too much variation in response to predict vertical changes.

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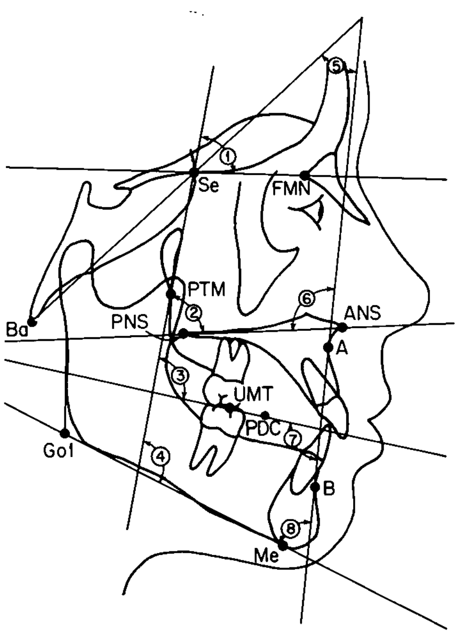
Key Words

Extraoral force • Cervical headgear • "Combi" headgear • Vertical skeletal relationship • Maxillo-mandibular horizontal discrepancy



Vertical Skeletal Relationships
1) PTM-se/Se-FMN
Pterygro-Maxillary Fissure Inferior — Sphenoid Ethmoid Registration Point — Frontomaxillary Nasal Suture
2) PTM-Se/ANS-PNS
Pterygo-Maxillary Fissure Inferior — Sphenoid Ethmoid Registration Point / Anterior Nasal Spine — Posterior Nasal Spine
3) PTM-Se/PDC-UMT
Pterygo-Maxillary Fissure Inferior — Sphenoid Ethmoid Registration Point / Premolar Distal Contact Point on the Functional Occlusal Plane — Maxillary Molar Mesial Cusp Tip
4) PTM-Se/Go-Me
Pterygo-Maxillary Fissure Inferior — Sphenoid Ethmoid Registration Point / Gonial Intersection — Menton

Maxillary-Mandibular Horizontal Relationships
5) A-B/Ba-Se
"A" Point — "B" Point / Basion — Sphenoid Ethmoid Registration Point
6) A-B/ANS-PNS
"A" Point — "B" Point / Anterior Nasal Spine — Posterior Nasal Spine
7) A-B/PDC-UMT
"A" Point — "B" Point / Premolar Distal Contact Point on the Functional Occlusal Plane — Maxillary Molar Mesial Cusp Tip
8) A-B/Go-Me
"A" Point — "B" Point / Gonial Intersection — Menton

Figure 1
Cephalometric points and angles used to assess morphologic change.

Materials and methods

The sample

The data used in this investigation were obtained from pre- and posttreatment lateral cephalograms of 200 children who received comprehensive edgewise treatment in a university orthodontic department. The sample represented consecutively treated children with intact records (biographical information, diagnostic findings, treatment plan, and pre- and posttreatment lateral cephalograms taken with the teeth in occlusion). Seventy-six of the patients were boys and 124 were girls. The boys' ages ranged from 120 months to 191 months (mean age of 156 months); the girls' ages ranged from 120 months to 202 months (mean age of 153 months) — see Table 1. The duration of treatment for the boys ranged from 14 months to 58 months (average treatment time: 30 months); treatment time for the girls ranged from 10 months to 59 months (average treatment time: 31 months) — see Table 2.

In order to evaluate skeletal changes associated with different extraoral forces, the sample was divided into three groups: (1) those treated using a Kloehn facebow with cervical traction,[24] (2) those treated with a "combi" facebow appliance — a combination of forces from one occipital and one cervical elastic strap[10] (see Figure 1), and (3) those treated without the aid of extraoral forces. There were no "high-pull" headgear cases in this study.

While the exact force application and amount of appliance wear for individual patients was not available, the amount of force in each appliance was preset to 16 ounces. The patients were instructed to wear their appliance from 12 to 14 hours per day.

The groups were analyzed for pretreatment differences. Chi-square tests were performed to determine if sex, carpal age (as assessed by the fusion of the epiphyses of the phalanges of the hand), or extraction of first premolar teeth was associated with treatment groups. In addition, Analyses of Variance (ANOVA) was used to test treatment group differences with respect to starting values of the angular measures of interest, age, and duration of treatment. Table 3 indicates none of the tests were significant.

Morphologic assessment

The pre- and posttreatment lateral cephalograms for all subjects were traced and the landmarks, as described by Riolo, et al.,[27] identified by one investigator (PRB) — see Figure 1. All tracings were digitized by one technician at the Center for Human Growth and Development, University of Michigan.

Four angular measurements were selected to assess vertical morphology, and an additional four angular measurements were selected to assess maxillary to mandibular horizontal relationships (Fig. 1).

Tracing and digitizing error study

Twenty lateral cephalograms were randomly selected, retraced, and redigitized in order to assess overall (tracing and digitizing) and digitizing error for the angular measurements in

Table 1
Age (months) characteristics of the sample.

	N	Min	Max	Mean	S.D.
Total	200	120	202	154	15.9
Male	76	120	191	156	15.6
Female	124	120	202	153	16.1

Table 2
Treatment duration (months) characteristics of the sample.

	N	Min	Max	Mean	S.D.
Total	200	10	59	31	9.2
Male	76	14	58	30	8.8
Female	124	10	59	31	9.5

Table 3
Characteristics of the treatment groups. There was no significant difference among treatment groups at the p=.05 level.

	N	Cervical	"Combi"	No-hdgr
Total	200	89	78	33
Sex				
Male	76	35	30	11
Female	124	54	48	22
Growth potential				
Epiphyses fused	109	48	40	21
No epiphyses fused	91	41	38	12
Extractions				
First premolars	110	52	37	19
No extractions	90	37	41	14
Mean age (months)		156	150	151
Mean treatment time (months)		33	30	30

this study. The greatest overall error involved the location of the FMN point; the greatest digitizing error involved the location of the functional occlusal plane. The mean overall error for all eight angles combined was 0.83 degrees, while the mean digitizing error was 0.44 degrees.[28]

Statistical analysis

The eight angular measures previously described were examined for differences in pretreatment morphology and treatment change among the treatment groups, using analysis of variance (ANOVA) F tests and the Scheffe multiple comparisons procedure.

Pearson product-moment correlations between the initial values of the eight angles and the changes in them were analyzed.

Results

Pretreatment morphologic comparisons of the groups

Descriptive data for each pretreatment morphological measure within each treatment group are presented in Table 4 in addition to the p-values associated with ANOVA F-tests. The data revealed no statistically significant differences among the groups in the vertical skeletal relationships of the cranial base (Se-FMN), the Palatal Plane (ANS-PNS), and the Occlusal Plane (PDC-UMT) to the PTM-Vertical Plane (PTM-Se). A statistically significant difference among the groups ($p<.02$) was observed for the vertical relationship of the mandibular plane (Go-me) to the PTM-vertical plane. The group means for this measure indicate that the cervical group showed the "flattest" mandibular plane angle which significantly (Scheffe comparison: $p<.05$) differed from the "steepest" mean angle exhibited by the no-headgear group.

The measures of maxillary to mandibular horizontal relationship showed much variation. Statistically significant overall F-tests were observed for three of the four angles evaluated: "A-B" to palatal plane ($p<.01$), "A-B" to occlusal plane ($p=.05$), and "A-B" to mandibular plane ($<.01$). The Scheffe pairwise group comparisons of these angles revealed that both the cervical and "combi" groups had more severe Class II discrepancies of the maxilla to the mandible, compared to the no-headgear group.

Posttreatment comparison of angular changes among treatment groups

The minimum, maximum, mean, and standard deviation of the changes in each angular measure for each of the three groups following orthodontic treatment are presented in Table 5 with ANOVA data for comparison of the changes among groups. All eight angles exhibited a wide range of changes during treatment. No statistically significant differences in treatment change were observed among the groups for any of the measures of vertical relationships.

The measures of maxillary to mandibular horizontal relationship revealed statistically significant differences among the groups with respect to changes in the "A-B" to cranial base ($p<.02$) and palatal plane ($p<.02$) angles. Scheffe pairwise comparisons of the group means showed

Table 4
Pretreatment means and standard deviations (within parentheses) for angular measures by treatment groups and corresponding ANOVA statistics. Comparisons were significant at the .05 level using the Scheffe multiple comparisons procedure.

Table 4

Angle	Cervical	Combi	No-headgear	Overall F (p)	Significant Pairwise Comparisons[1]
PTM-Se/Se-FMN	82.9 (5.9)	83.1 (3.8)	85.1 (6.2)	1.84 (.16)	
PTM-Se/ANS-PNS	82.2 (5.0)	83.1 (3.8)	84.0 (4.1)	1.94 (.15)	
PTM-Se/PDC-UMT	102.5 (6.4)	103.1 (5.8)	103.7 (4.5)	.51 (.60)	
PTM-Se/Go-Me	106.8 (6.4)	108.8 (6.7)	110.1 (5.2)	4.01 (.02)	Cervi-None
A-B/Ba-Se	37.5 (5.5)	37.6 (5.3)	39.4 (6.3)	1.50 (.22)	
A-B/ANS-PNS	101.1 (4.3)	101.6 (4.4)	98.3 (5.3)	6.19 (.01)	Cervi-None Combi-None
A-B/PDC-UMT	99.3 (5.8)	98.7 (5.4)	101.6 (4.8)	3.03 (.05)	Combi-None
A-B/Go-Me	75.7 (5.6)	75.0 (6.1)	71.8 (5.5)	5.18 (.01)	Cervi-None Combi-None

Table 5
Treatment and sex specific means, standard deviations, and sample sizes (the latter two are within parentheses) for changes in A-B/Go-Me, A-B/ANS-PNS, and A-B/PDC-UMT angles and corresponding F-tests for group x sex interactions. Treatment and age specific results are displayed for change in A-B/Ba-Se angle.

Table 5

Angle	Males			Females			F-stat for interaction (p)
	Cervical	Combi	No-headgear	Cervical	Combi	No-headgear	
A-B/Go-Me	-2.93 (3.20) (31)	-2.99 (4.26) (30)	-2.22 (2.31) (11)	-1.27 (3.03) (53)	-2.21 (3.02) (41)	-.59 (2.39) (19)	.03
A-B/ANS-PNS	-4.71 (4.06) (31)	-4.26 (3.86) (30)	-2.06 (3.08) (11)	-1.97 (3.44) (52)	-2.95 (3.44) (41)	-.85 (3.71) (21)	.06
A-B/PDC-UMT	4.20 (5.86) (30)	1.42 (5.03) (27)	-1.05 (7.64) (11)	.74 (4.42) (52)	1.43 (4.98) (40)	1.97 (4.09) (20)	.004
	Younger			Older			
A-B/Ba-Se	1.43 (3.80) (42)	3.26 (4.03) (44)	.15 (2.78) (13)	2.49 (3.78) (40)	1.72 (4.25) (28)	.59 (3.10) (19)	.01

that the anteroposterior discrepancy previously reported for the cervical and "combi" groups was significantly reduced relative to the change observed in the no-headgear group. The treatment groups did not significantly differ with regard to changes in the A-B to occlusal and mandibular plane angles, possibly because of the relatively large within-group variation in these measures.

Correlations between initial form and net change within groups

Correlation coefficients between initial form and net change for each of the three test groups are presented in Table 6. The negative correlations indicate that subjects with the most extreme deviations from initial mean values exhibited the most change toward the mean irrespectivive of the size of the angle.

The strongest correlations between initial form and net change found for the occlusal plane in both the cervical (r=-.49) and "combi" (r=-.56) groups. Here, the negative values indicate that extremely large angles more likely corresponded to larger changes since the mean changes for the angles decreased. Other measures of vertical relationships did not exhibit significant correlations between initial form and net change.

All measures of maxillary to mandibular horizontal relationship exhibited strong negative correlations between initial form and net change for both the cervical and "combi" groups. The correlations for A-B/ANS-PNS and A-B/Goi-Me angles revealed that large initial values of these measures were associated with the most change since these angles incurred a mean net decrease with treatment. The negative correlations for the A-B/Ba-Se and A-B/PDC-UMT angles indicate that small angles corresponded to larger changes since these angles incurred a mean net increase with treatment. The maxillary to mandibular horizontal correlations were not significant for the no-headgear group.

Table 6

Angle	Cervical	Combi	No-headgear
PTM-Se/Se-FMN	-.19	-.37	-.37
PTM-Se/ANS-PNS	-.33	-.16	-.11
PTM-Se/PDC-UMT	-.49*	-.56*	-.22
PTM-Se/Go-Me	.02	-.02	-.08
A-B/Ba-Se	-.41*	-.44*	-.02
A-B/ANS-PNS	-.44*	-.53*	-.35
A-B/PDC-UMT	-.63*	-.68*	-.35
A-B/Go-Me	-.40*	-.53*	-.26

Table 6
Correlations between each pretreatment angular measure and its corresponding net change during orthodontic treatment by treatment group. Figures marked * were significant at the .05 level.

Discussion

The data presented in this study do not support the popularly held theory that vertical skeletal relationships in the growing face can be altered predictably by controlling the direction of extraoral force. Little or no difference in the altered vertical relationships was observed between the use of cervical or "combi" appliances. On the basis of this investigation, it can be concluded that little or no clinical advantage is obtained through the use of the more cumbersome "combi" appliance.

It should be noted that the children in this study did not demonstrate pretreatment differences in the vertical relationships of the cranial base, the palatal plane, or the occlusal plane to the PTM-vertical plane. In two other measurements, however, pretreatment differences were observed between the extraoral groups and the no-headgear group: the latter group exhibited a steeper mandibular plane angle and also displayed a better maxilli-mandibular horizontal relationship. The cervical and "combi" groups manifested a more clearly discernible Class II skeletal discrepancy than the no-headgear group. Although this skeletal difference was noted, the impact this difference might have on the present study could not be determined.

An increased flexure in the cranial base as well as change in the palatal plane seen in the extraoral appliance treatment group, supports the findings of Weislander[8] who first suggested a rotational effect of the sphenoid complex from the use of extraoral forces. Weislander also observed a posterior positioning of the pterygomaxillary fissure, which is relevant to the present study since we used a plane passing through a point on the inferior aspect of the fissure as a reference plane to evaluate vertical relationships. This plane (posterior maxillary plane, Riolo, et al.[27]) was used since it represented a stable vertical plane through the posterior aspect of the face during normal growth without orthodontic treatment. A dorsal positional shift at the site of pterygomaxillary fissure, as postulated by Weislander, might result in understatement of the vertical changes in the headgear groups. This, possibly, accounts for the lack of significant differences in vertical angle changes.

A downward tipping of the anterior nasal spine due to cervical force has been reported by Klein[29], Ricketts [30], Jakobsson[2], Poulton[6], Barton[10], and others. Although evidence of this was observed in the changes of the mean palatal plane angles in both the cervical and "combi" groups, these changes were not significantly different from the mean change observed in the no-headgear group. Therefore, we found no support for the expectation of downward tipping of anterior nasal spine.

The fact that essentially no clinically significant change in the mandibular plane angle was observed with the use of the cervical appliance in the present study is in conflict with the observations of Ricketts[30], Poulton[6], Weislander[8], Barton [10], Schudy[20], and others who have reported that cervical forces tend to increase the mandibular plane angle. Baumrind, et al.[11] however, concluded that the mean change in the mandibular plane angle was no greater than 0.5 degrees for groups treated with various headgears. This study demonstrated similar mean changes — no greater than 0.7 degrees for any of the groups. The fact that there were no significant differences between treatment groups for changes in the mandibular plane angle does not support the general contention that the direction of the applied force elicits a specific and predictable treatment change.

The improved maxillary to mandibular horizontal relationship obtained through the use of the two types of extraoral forces observed in this study, agrees with Kloehn[31], Weislander[25], and others who found a posterior repositioning of "A" point with treatment by cervical headgear. While the data do not describe how the relationship of the maxilla to the mandible was improved, presumably this improvement is a result of maxillary restraint and/or maxillary retraction, concomitant with mandibular growth. The improvement in the Class II relationship observed with extraoral forces was more pronounced than the changes observed in the no-headgear group whose maxillo-mandibular relationship was less severely Class II.

No correlation was found between the initial form of the face and the net change for the vertical relationships of the cranial base, the palatal plane, and the mandibular plane. Pretreatment form was randomly associated with changes in these relationships. However, the cervical and "combi" groups showed strong correlations between initial form and net change for the vertical measure of the occlusal plane and for all horizontal measures of maxillary to mandibular horizontal relationship. The effects of treatment on these measures apparently are influenced, in part, by the initial state of these measures.

The wide range of changes observed in this study corroborates Baumrind's[11] contention that the varying response seen with the cervical and "combi" force systems indicates a need for careful monitoring of these appliances and their associated effect modifiers during clinical use. In order to divide the sample according to these effect modifiers and thus control for them, large sample studies of patients treated with extraoral forces are necessary. For example, dividing a sufficiently large sample by sex, developmental age, and morphological homogeneity would reduce the variability in pre- and posttreatment changes and thus allow more refined conclusions regarding the relationship between extraoral treatments and their effect modifiers.

Conclusions

The purpose of this investigation was to examine the popular contemporary theory that controlling the direction of extraoral force can alter predictably the vertical skeletal pattern of the face. The findings of this study do not support such a theory, for we conclude:

1. Changes in vertical skeletal relationships demonstrated a wide range of variation for each of the different extraoral appliance groups studied.
2. Mean changes in vertical skeletal measures as a result of treatment are negligible.
3. Initial facial form is not a predictable indicator of vertical skeletal change occurring with cervical force, "combi" forces, or no extraoral force.
4. Cervical and "combi" extraoral force systems reduce horizontal skeletal Class II discrepancies.
5. There is no significant difference in the mean changes produced by cervical and "combi" forces in either vertical relationships or maxillo-mandibular horizontal relationships.

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