ORIGINAL ARTICLE

Cephalometric appraisal of posttreatment vertical changes in adult orthodontic patients

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The purpose of this study was to evaluate vertical facial changes in adult orthodontic patients and to evaluate the stability of these changes. Thirty-three patients (8 males and 25 females) were examined. The patients had been treated with full fixed edgewise appliance mechanics and exhibited at least 1.0° of clockwise rotation of the mandible during treatment. Mandibular rotation was determined by the angular change in the Y-axis to the Frankfort plane. Twelve angular and 14 linear skeletal and dental measurements and 3 skeletal ratios were derived from pretreatment (T1), posttreatment (T2), and postretention (T3) cephalometric radiographs. Paired *t* tests were used to compare vertical changes that occurred as a result of orthodontic treatment and their stability or relapse tendency during the retention and postretention periods. Twenty-five percent ($P < .001$) of the opening rotation of the mandible recovered during the posttreatment period, resulting in a significant overall rotation that was maintained. Both treatment and posttreatment changes in the Y-axis angle showed a high correlation with the horizontal position of pogonion ($r = -0.797$ and -0.889, respectively). Only overjet showed a low correlation between treatment changes and posttreatment changes in the Y-axis angle. Stepwise regression analysis of pretreatment variables and treatment changes failed to predict the behavior of the Y-axis angle change. (Am J Orthod Dentofacial Orthop 2000;118:378-84)

Orthodontists have long been interested in the vertical changes caused by orthodontic treatment, not only when they occur but also what their long-term effects are. Orthodontic treatment is usually planned to prevent an increase in vertical facial height because the stability of this movement is not always reliable, and because of the deleterious side effects that occur in some patients. Increases in vertical facial height usually result in clockwise rotation of the mandible. To date, most studies of these changes have looked at growing patients. Far fewer have examined adults. Mandibular clockwise rotation in growing patients is believed to be the result of molar extrusion that exceeds posterior facial growth.[1-4] Some investigators have reported that the mandible usually returns to its original position after treatment.[5,6] Other investigators have reported that mandibular opening as a consequence of orthodontic treatment does not invariably return to pretreatment values.[1,2,7,8]

Because of the increased number of adults undergoing orthodontic treatment, it is important to evaluate the vertical changes that occur in adults during treatment as well as posttreatment. An intentional increase in facial height can be produced by raising the bite in fixed prosthodontics or by the orthodontic extrusion of posterior teeth that develops when correcting deep overbite. Either of these remedies can lead to a clockwise rotation of the mandible and an increase in facial height. These changes will tend to return to their original position as teeth intrude and relapse occurs.[9-11] However, it has been postulated that positional as well as structural changes in the musculoskeletal complex are quickly established and may allow alterations in the vertical dimension.[12-14] In addition, Sim et al,[15] studying adult rhesus monkeys, found that adaptive remodeling of the condyle occurred in response to an alteration of mandibular posture via increase in vertical dimension. Harris et al[16] reported that treatment changes in the mandibular plane and Y-axis angles were stable in adults during the posttreatment period, and this differed from adolescent patients.

A better understanding of posttreatment stability of increased vertical dimension in adult orthodontic patients is important because some adult patients would benefit from an increase in vertical occlusal height. The purpose of this study was to evaluate skeletal and dental changes in adult patients who underwent clockwise rotation of the mandible during orthodontic treatment and to evaluate the stability of vertical changes.

MATERIAL AND METHODS

The Sample

A cephalometric study of 33 white adults (25 females and 8 males) was undertaken. The mean age was 28.4 years (20.1 to 47.3) at pretreatment (T1) and

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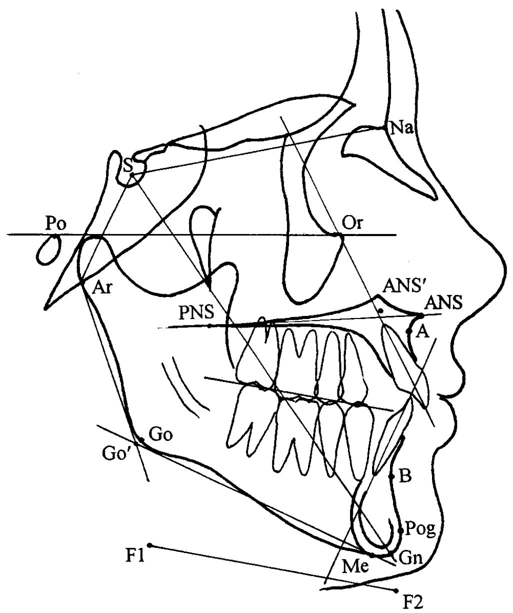

Fig 1. Lateral cephalometric landmarks and angular measurements.

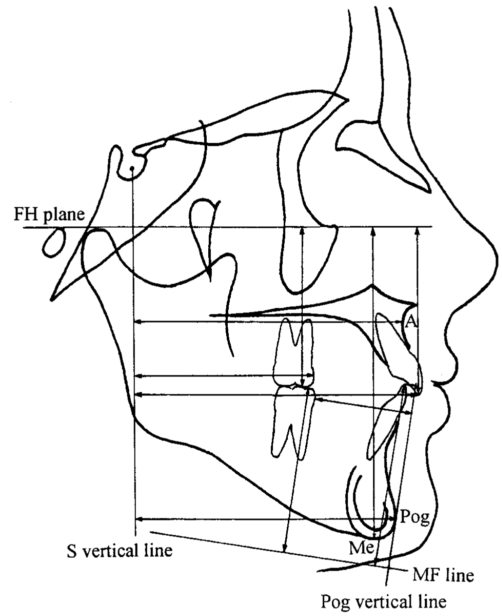

Fig 2. Linear measurements using overall and mandibular coordinate systems.

33.2 years (22.3 to 52.5) at posttreatment (T2). Postretention (T3) cephalometric radiographs were taken an average of 5.6 years after T2. All subjects had been treated in the private practice of a former faculty member using conventional standard edgewise appliances.

The criteria for sample selection were as follows:

1. Orthodontic treatment was initiated when the patient was over 20 years of age.
2. Full arch mechanics were applied and limited tooth movement cases were excluded.
3. Good cephalometric records at T1, T2, and T3 were available.
4. Posttreatment results showed opening rotation of the mandible. The criterion for mandibular opening rotation was an increase of at least 1° in the Y-axis angle (S-Gn to the FH plane) in each patient during treatment.
5. Final records were taken at least 3 years posttreatment and at least 1 year out of retention.
6. Patients were treated without surgery. The sample consisted of 8 patients with Class I malocclusion, 22 with Class II, and 3 with Class III. Twenty-eight patients used Class II elastics during treatment for variable periods.

Cephalometric Analysis

All headfilms were traced by 1 investigator, digitized with SummaSketch II digitizer, and processed with the 2D Ceph program developed by Dr B. Kusnoto. Fig 1 shows the location of landmarks and angular measurements on a T1 tracing. The definitions of these landmarks have previously been detailed.[17,18] Anterior nasal spine prime (ANS') is the point at which a perpendicular line from ANS intersects N-Me (line). All bilateral structures were bisected. Fiduciary points (F1 and F2)[19] were arbitrarily located below the lower border of the mandible and approximately parallel to the occlusal plane. Angular measurements of the Y-axis, mandibular plane (MP), functional occlusal plane (FOP), facial plane (FP), palatal plane (PP), and mandibular fiduciary (MF) line connecting 2 fiduciary points were measured to Frankfort horizontal (FH) plane. Other angular measurements included SNA, SNB, ANB, inclination of upper incisor (U1:SN), inclination of lower incisor (IMPA), articular angle (S-Ar-Go), and gonial angle (Ar-Go-Me).

The overall superimposition[20] using structural landmarks of the anterior and middle cranial fossae allowed transfer of FH plane from T1 to T2 and T3 tracings. Mandibular superimposition using Björk's structural method[21] was used to transfer the MF line. A coordinate system using FH plane and a perpendicular line through S was used for measuring maxillary teeth and chin position. Mandibular tooth positions were measured from MF line and a perpendicular line tangent to Pog. Mesiobuccal cusp tips and mesial convex points of maxillary and mandibular first molars were used to measure vertical and horizontal

Table I. Mean measurements of skeletal and dental variables at pretreatment (T1), posttreatment (T2), and postretention (T3)

	T1		*T2*		*T3*	
Measurement	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Skeletal vertical						
MP angle (°)	23.44	5.49	24.89	5.80	24.67	5.79
PP angle (°)	1.91	2.60	1.74	2.79	1.62	2.84
Y-axis angle (°)	58.51	2.82	60.01	2.81	59.64	2.80
Articular angle (°)	143.99	6.40	144.36	6.81	144.41	6.83
Gonial angle (°)	128.24	7.10	128.43	7.41	128.20	7.12
AFH (mm)	111.68	7.00	114.16	7.39	114.24	7.39
LAFH (mm)	68.75	3.14	72.79	3.67	71.09	3.93
PFH (mm)	71.73	6.08	72.56	6.08	72.62	6.26
LAFH/AFH (%)	61.79	4.75	64.03	5.38	62.51	5.58
PFH/AFH (%)	64.30	4.74	63.65	4.92	63.66	4.98
FHI (%)	73.93	9.17	72.81	9.29	73.02	9.46
Skeletal horizontal						
FP angle (°)	88.81	3.31	87.65	3.34	87.83	3.20
SNA (°)	82.11	4.00	81.48	3.74	81.56	3.53
SNB (°)	77.99	4.84	77.15	5.07	77.39	5.00
ANB (°)	4.12	4.04	4.34	3.68	4.17	3.75
S vertical-Pog (mm)	63.25	5.90	61.55	5.87	62.41	5.63
Dental vertical						
FOP angle (°)	8.53	3.51	10.39	4.88	9.88	3.74
FH-U1 (mm)	49.41	3.66	51.50	3.65	52.02	3.69
FH-U6 (mm)	45.85	2.75	46.75	2.88	46.98	3.01
FL-L1 (mm)	48.39	6.33	46.04	6.67	47.34	6.58
FL-L6 (mm)	44.90	6.54	45.93	6.24	45.93	6.42
Overbite (mm)	3.08	3.54	0.51	0.88	2.50	1.64
Dental horizontal						
U1:SN (°)	103.26	11.40	99.51	11.57	98.02	9.68
IMPA (°)	93.59	11.51	100.00	10.64	94.04	8.19
S vertical-U1 (mm)	71.29	4.80	68.92	4.16	68.97	4.02
S vertical-U6 (mm)	46.19	2.99	46.07	4.32	47.19	4.07
Pog vertical-L1 (mm)	–1.27	5.40	0.34	3.64	–0.93	3.73
Pog vertical-L6 (mm)	–21.54	4.08	–20.14	5.52	–20.25	5.59
Overjet (mm)	4.93	3.37	1.97	0.87	2.84	1.41

tooth positions, respectively. For the consistent location of this landmark, gnathion was transferred using mandibular superimposition. Tooth landmarks were also transferred using tooth tracings of T1 as templates under best fitting crown and tooth long axis.

Various linear measurements were made (Fig 2), including anterior facial height (AFH, Na-Me), lower anterior facial height (LAFH, ANS'-Me), posterior facial height (PFH, S-Go), overbite, and overjet. Facial ratios were calculated for lower anterior facial height ratio (LAFH/AFH), posterior facial height ratio (PFH/AFH), and facial height index (FHI),[22] designated as ramus height divided by the distance from menton measured to the palatal plane. All linear measurements to be reported were multiplied by the appropriate magnification factor; therefore, the reported measurements indicate the actual linear dimensions.

Statistical Analysis

Descriptive statistics for absolute dimensions and incremental changes of each variable were calculated at each stage. Skeletal and dental changes that occurred as a result of orthodontic treatment and their stability or relapse tendency during the posttreatment period were evaluated using a paired *t* test. The $P < .05$ significance level was used. Correlation coefficients (r) were computed between the Y-axis angle and the other cephalometric variables. Correlations greater than 0.75 (or –0.75) are regarded as a very good relationship and those from 0.50 to 0.75 (or –0.50 to –0.75) indicate a moderate relationship.[23] Stepwise regression analysis was carried out designating change of Y-axis angle as the dependent variable, with the pretreatment measurements and treatment changes of the remaining variables as independent variables to determine if any variable or change was associated with the change in the Y-axis angle.

Table II. Treatment (T2-T1), posttreatment (T3-T2), and overall (T3-T1) changes in skeletal and dental variables

	T2-T1		T3-T2		T3-T1	
Measurement	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Skeletal vertical						
MP angle (°)	1.46***	0.79	–0.22	0.90	1.23***	1.26
PP angle (°)	–0.18	0.86	–0.12	0.70	–0.30	0.87
Y-axis angle (°)	1.50***	0.61	–0.37**	0.66	1.13***	0.92
Articular angle (°)	0.38	1.57	0.04	1.67	0.42	1.88
Gonial angle (°)	0.19	0.89	–0.23	1.03	–0.03	0.99
AFH (mm)	2.48***	1.22	0.08	0.89	2.55***	1.36
LAFH (mm)	4.04***	1.45	–1.70***	0.71	2.34***	1.63
PFH (mm)	0.82***	0.76	0.06	1.05	0.89***	1.18
LAFH/AFH (%)	2.24***	1.57	–1.52***	0.98	0.72*	1.82
PFH/AFH (%)	–0.65***	0.65	0.00	0.81	–0.64**	0.97
FHI (%)	–1.12***	1.30	0.21	1.39	–0.91**	1.84
Skeletal horizontal						
FP angle (°)	–1.15***	0.68	0.17	0.64	–0.98***	0.93
SNA (°)	–0.63*	1.59	0.08	0.88	–0.55*	1.46
SNB (°)	–0.84***	0.87	0.24*	0.54	–0.60**	1.07
ANB (°)	0.22	1.90	–0.16	0.59	0.06	1.92
S vertical-Pog (mm)	–1.70***	1.26	0.85***	1.18	–0.85*	1.82
Dental vertical						
FOP angle (°)	1.86**	3.65	–0.51	2.74	1.35**	2.67
FH-U1 (mm)	2.08***	1.35	0.52**	0.84	2.60***	1.18
FH-U6 (mm)	0.89***	1.18	0.23	0.94	1.13***	1.16
FL-L1 (mm)	–2.35***	3.15	1.30***	1.30	–1.05*	2.53
FL-L6 (mm)	1.04***	1.16	0.00	0.86	1.03***	1.14
Overbite (mm)	–2.57***	3.23	2.00***	1.49	–0.58	2.89
Sum of vertical molar movement (mm)	1.93***	1.36	0.23	0.89	2.16***	1.24
Dental horizontal						
U1:SN (°)	–3.75	13.97	–1.48	4.40	–5.24*	12.11
IMPA (°)	6.41**	10.49	–5.97***	5.16	0.45	8.57
S vertical-U1 (mm)	–2.37**	4.09	0.05	1.34	–2.32**	3.71
S vertical-U6 (mm)	–0.12	2.67	1.12***	1.22	1.00	2.30
Pog vertical-L1 (mm)	1.61**	3.28	–1.28***	1.36	0.34	2.96
Pog vertical-L6 (mm)	1.40**	2.29	–0.11	1.15	1.30**	2.06
Overjet (mm)	–2.95***	3.56	0.87***	1.50	–2.09***	2.72

$^*P < .05$; $^{**}P < .01$; $^{***}P < .001$.

RESULTS

Cephalometric Error Testing

To determine the reliability and reproducibility of the measurements, 15 pairs of cephalometric radiographs from 5 patients selected at random were retraced and redigitized by the same investigator, with a 3-week interval between tracings. A combined error of landmark identification, tracing, and digitizing was determined by conducting a paired *t* test of differences between the initial tracings. The mean measurement error was less than 0.5° for all angular measurements except FOP, U1:SN, and IMPA, which were less than 0.65°. The error for all linear measurements was less than 0.5 mm.

The absolute dimensions of each variable at each stage are shown in Table I. Table II lists the result of paired *t* tests for skeletal and dental changes during treatment, posttreatment, and the overall period.

The Y-axis angle showed a significant increase (ξ = 1.50°) during treatment, while the MP angle increased 1.46°. This produced a backward movement of the chin. The FP angle decreased 1.15° and Pog moved backward 1.70 mm relative to the S perpendicular line. Anterior facial height, LAFH, and PFH all increased during treatment.

During the posttreatment period, the Y-axis angle showed a statistically significant relapse of 0.37°. Anteroposterior chin position also relapsed, but a significant amount of overall change in the angular (FP angle, –0.98°) and spatial (S vertical-Pog, 0.85 mm) position of the Pog remained. Anterior facial height, PFH, and their ratio demonstrated insignificant changes posttreatment,

Table III. Correlation coefficients for the relationships (1) between treatment changes (T2-T1) in variables and treatment change in the Y-axis angle, (2) between posttreatment changes in variables and posttreatment change in the Y-axis angle, and (3) between treatment changes in variables and posttreatment change (T3-T2) in the Y-axis angle (n = 33)

Measurement	*(1)*	*(2)*	*(3)*
Skeletal vertical			
MP angle (°)	0.824***	0.716***	0.144
PP angle (°)	0.007	–0.273	–0.077
Y-axis angle (°)	1.000	1.000	0.058
AFH (mm)	0.592***	0.288	–0.139
LAFH (mm)	–0.165	–0.121	–0.269
PFH (mm)	0.033	–0.303	–0.136
LAFH/AFH (%)	0.393*	–0.223	–0.143
PFH/AFH (%)	–0.547**	–0.512**	0.006
FHI (%)	–0.111	–0.107	–0.205
Skeletal horizontal			
FP angle (°)	–0.679***	–0.867***	–0.064
SNA (°)	0.209	–0.569***	0.252
SNB (°)	–0.235	–0.745***	–0.152
S vertical-Pog (mm)	–0.797***	–0.889***	–0.173
Dental vertical			
FOP angle (°)	–0.201	0.322	–0.172
FH-Ul(mm)	0.180	0.547**	–0.101
FH-U6 (mm)	0.014	0.156	–0.099
FL-L1 (mm)	0.271	–0.270	0.310
FL-L6 (mm)	0.283	–0.113	0.101
Overbite (mm)	0.089	–0.213	0.228
Sum of vertical molar movement (mm)	0.251	0.061	0.002
Dental horizontal			
U1:SN (°)	–0.196	–0.324	0.327
IMPA (°)	0.214	0.106	0.121
S vertical-U1 (mm)	–0.075	–0.751***	0.245
S vertical-U6 (mm)	–0.223	–0.732***	0.171
Pog vertical-L1 (mm)	0.277	–0.034	–0.054
Pog vertical-L6 (mm)	–0.476**	–0.027	–0.050
Overjet (mm)	–0.190	–0.190	0.352*

*$P < .05$; **$P < .01$; ***$P < .001$.

Table IV. Stepwise regression analysis for treatment change in the Y-axis angle from pretreatment measurements in the independent variables

Variable	*R*	*Cumulative R^2*
Gonial angle (°)	0.376*	0.142
FL-L6 (mm)	0.507*	0.257
S vertical-U1(mm)	0.648**	0.420
IMPA(°)	0.731*	0.534

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

Table V. Stepwise regression analysis for posttreatment change in the Y-axis angle from pretreatment measurements in the independent variables

Variable	*R*	*R^2*
S vertical-Pog (mm)	0.363*	0.131

*$P < .05$.

Table VI. Stepwise regression analysis for posttreatment change in Y-axis from treatment changes in the independent variables

Variable	*R*	*R^2*
Overjet (mm)	0.352*	0.124

*$P < .05$.

but overall significant increases remained. Articular, gonial, PP, and ANB angles showed no significant changes during any stage of this study.

During treatment, the FOP angle tipped down 1.86° in the front, the maxillary incisors retroclined 3.75°, and the mandibular incisors proclined 6.41°, resulting in a 2.95 mm decrease in overjet. Overbite decreased 2.57 mm during treatment. This occurred despite the 2.08 mm extrusion of the maxillary incisors. The mandibular incisors intruded 2.35 mm, and the actual overbite correction due to the incisor movements was 0.27 mm. Most of overbite correction was accomplished as a result of maxillary and mandibular molar extrusion. The maxillary molars moved 0.89 mm occlusally, and the mandibular molars experienced 1.04 mm of extrusion.

During the posttreatment period, the FOP angle and the vertical position of the maxillary and mandibular molars were stable. Overbite and overjet both relapsed (78% and 29%, respectively), with the mandibular incisors contributing most of the relapse, 1.30 mm of vertical movement and 5.97° of lingual inclination. Overall changes included a significant tipping of the FOP angle, an insignificant change in overbite, and a significant decrease in overjet.

Correlation Analysis

Changes in the Y-axis angle during treatment were associated with changes in the horizontal position of Pog (r = –0.797) and the FP angle (r = –0.679, Table III). Smaller associations were found in variables of AFH, LAFH/AFH ratio, PFH/AFH ratio, and Pog vertical-L6. Correlations between changes in Y-axis angle and horizontal position of the chin during the posttreatment period were also very good. Some of the other variables showed smaller correlations. Only overjet showed a significant correlation (r = 0.352) between posttreatment changes in the Y-axis and treatment changes of the other variables.

Stepwise Regression Analysis

Stepwise regression analysis examining pretreatment values as independent variables in an attempt to predict the behavior of the Y-axis during treatment revealed that 4 variables explained 53.4% of the variability (Table IV). These included gonial angle, FL-L6, S vertical-U1, and IMPA. However, pretreatment characteristics and treatment changes in independent variables were not predictive of the behavior of the Y-axis angle after treatment (Tables V and VI).

DISCUSSION

The purpose of this study was to examine the stability of vertical changes that occurred in adult orthodontic patients and to see if skeletal and dental variables could explain the behavior of these changes. The 33 adult patients who underwent at least 1.0° of clockwise rotation after orthodontic treatment represent less than half the patients available for study.

Skeletal Changes During Treatment and Posttreatment

Seven patients in this study continued to show an increase in the Y-axis angle after treatment ($\bar{x}$ = 0.56°). In the remaining 26 patients, the Y-axis angle decreased 0.62°. Overall, 29 patients showed increases in the Y-axis angle, and 4 patients showed decreases. Even with a relapse of the clockwise rotation of the Y-axis angle (0.37°) during posttreatment, 75.3% of the treatment change remained. In a comparable study of growing patients, Ryan et al[8] reported that 67.4% of the increases in the Y-axis angle were still present at the end of retention. Of interest was the lack of correlation between treatment changes in the Y-axis angle and horizontal position of Pog and their posttreatment changes (Table III). Large treatment changes in those measurements were not followed by a large amount of relapse.

The increase in the Y-axis angle produced a clockwise rotation of the mandible with a corresponding increase in AFH (2.48 mm) and a decrease in the ratio of PFH to AFH. However, the decrease of FHI and increase of LAFH ratio indicated a greater dimensional increase of the lower anterior face. There was no case where AFH returned to its original value, even though in 4 patients the Y-axis angle was less than its pretreatment value. Mandibular corpus length (Ar-Pog) also increased during treatment (0.74 mm) and during posttreatment (0.55 mm). The most reasonable explanation for these changes is that they are due to growth and this has been reported by other studies.[24-27] Remodeling may also play a role.

The mandibular clockwise rotation led to posterior displacement of the chin. The present study found a high correlation (r = – 0.797) between the treatment change in the Y-axis and the horizontal position of Pog relative to S-vertical line. Lulla and Gianelly[28] found only a moderate correlation (r = 0.683) between these variables, however, their observation period was much shorter.

Dental Changes During Treatment and Retention

Use of the terms extrusion and intrusion does not mean that the tooth literally moved out of or into its alveolus, but merely refers to vertical movement of the tooth toward or away from the occlusal plane. The terms are used for ease of writing.

Steepening of the FOP angle during orthodontic treatment is most likely the result of Class II elastic wear, which has been reported previously.[26,29] Molars were extruded during treatment, and the sum of this movement exceeded the vertical change in the PFH dimension, 1.93 mm versus 0.82 mm, respectively. Although most studies in the literature[1-4] report that excessive vertical molar movement is responsible for a clockwise rotation of the mandible, the present study, along with previous reports,[8,30,31] does not support this assumption; vertical molar movements, either singularly or in sum, were not correlated with changes in the Y-axis angle. The incisors showed the typical effect of Class II elastic wear. The maxillary incisors became retroclined and moved occlusally; the mandibular incisors were proclined and intruded toward the fiduciary line.

Overbite was corrected primarily by molar extrusion in this sample, since vertical incisor movements tended to negate each other. Relapse of overbite during the posttreatment period was the result of incisor movements, since vertical movement of molars ceased during this time. The movement of mandibular incisors is of particular interest. During treatment, these teeth were intruded 2.35 mm and proclined 6.41°. Their vertical extrusion (1.30 mm) and retroclination (5.97°) after treatment were largely responsible for the large (78%) relapse of overbite. Overall, these teeth retained 1.0 mm of intrusion and their inclination did not change. Overall correction of overjet, however, showed a significant reduction, primarily because maxillary incisors continued their retroclination.

Similar to the work of Ryan et al,[8] no treatment variables could predict posttreatment mandibular counterclockwise rotation. Only 12.4% of the variance in the Y-axis angle was explained by changes in the independent variables during treatment.

CONCLUSIONS

This study evaluated the stability of skeletal and dental changes in adult orthodontic patients who underwent a clockwise rotation of the mandible during orthodontic treatment. The following conclusions were reached:

1. Mandibular clockwise rotation, as expressed by a change in the Y-axis angle, relapsed 24.7% after treatment, leaving a significant amount of the treatment changes intact even after the posttreatment period.
2. Anterior and posterior vertical dimension increased, reflecting adult facial growth.
3. Horizontal position of the chin showed a high correlation with change of the Y-axis angle. This means that clockwise rotation of the mandible may produce a detrimental effect in the treatment of patients where an increase in convexity is undesirable.
4. Extrusive movement of the molars was not correlated with changes in the Y-axis angle, even though they exceeded PFH growth.
5. Stepwise regression analysis showed that changes of mandibular position that occurred during treatment were not predictive of the posttreatment movement of this bone.

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