Original Article

Postretention assessment of deep overbite correction in Class II Division 2 malocclusion

Tae-Woo Kim, DDS, MSD, PhD; Robert M. Little, DDS, MSD, PhD

Abstract: The purposes of this study were to evaluate the long-term stability of deep overbite correction in Class II Division 2 malocclusion and to search for predictors of postretention overbite. The sample of 62 (31 males, 31 females) was limited to Class II Division 2 patients with initial deep overbite and successful orthodontic treatment as judged clinically at the end of treatment. Study models and cephalograms were analyzed before treatment, after treatment, and out of retention (average 15 years). The sample was divided into two groups according to the degree of postretention overbite: Group 1 (N = 33; overbite ≥4.0 mm at T3, mean = 5.17 ± 0.87) and group 2 (N = 29; overbite <4.0 mm at T3, mean = 2.95 ± 0.87). The results showed that patients with very upright pretreatment maxillary and mandibular incisors tended to have deeper initial overbite and a tendency to return to their original relationship by the postretention stage. Posttreatment vertical growth contributed to maintenance of overbite correction. By stepwise multiple regression analysis, initial overbite was selected as the most important predictor of postretention overbite. Initial overbite was positively related with postretention overbite.

Key Words: Long-term stability, Class II Division 2, Deep overbite, Relapse

Difficulties in the treatment and stability of deep overbite have been perplexing to the clinician. The literature shows ample evidence of this concern.[1-3] Changes in overbite and/or vertical dimensions may not be stable, and many patients demonstrate a tendency to relapse in the direction of pretreatment values during the postretention period.[4-10] Scientific information regarding the long-term stability of corrected deep overbite, especially Class II Division 2 cases, is limited. Clinically useful predictors for the amount of relapse have not been established. Clinical studies have examined postretention overbite changes, but small sample size,[4,9] inhomogeneous samples,[7,8,11,15] and short postretention periods[5,15] have limited progress in this area.

This study was designed to answer some common clinical questions. What pretreatment variables are related to relapse of deep overbite in Class II Division 2 malocclusion? Are some cases more prone to relapse than others? Does gender influence overbite relapse? Is extraction therapy related to relapse? Can we predict the postretention overbite before treatment, and if so, how well?

Some researchers[7,9,15] have tried to answer these questions, but most used samples that included different types of malocclusion. Simons[7] investigated postretention changes in overbite. His sample of 68 included 33 subjects with deep overbite, but it also included Class I, Class II Division 1, and Class III patients. He found that there were significant differences in mean initial overbite between each type of malocclusion. Because of differences in dentofacial characteristics between Angle classes, his findings can be considered only as a general guide in diagnosis and treatment of deep overbite malocclusion.

Berg[9] investigated 26 deep overbite cases. He tried to assess the effect of several factors, such as intrusion of upper and/or lower incisors, extrusion of upper and/or lower buccal teeth, changes in the labiolingual position of the lower incisors during treatment, posttreatment size of the interincisal angle, postretention mandibular growth, changes of the occlusal plane during treatment, extraction or nonextraction and over-

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Submitted: October 1997, **Revised and accepted:** September 1998
Angle Orthod 1999;69(2):175-186.

correction during active treatment. But since his sample included only seven Class II Division 2 cases (the remaining cases were Class II Division 1), it is not surprising that a considerable range of variation was found.

When samples are not homogeneous, it is harder to find clinically valuable information because dentoskeletal patterns and treatment mechanics are different in each class. In the present study, we focused on typical Class II Division 2 cases.

The purposes of this study were to evaluate the long-term stability of deep overbite correction in Class II Division 2 malocclusion and to search for predictors of postretention stability.

Materials and methods

Sample

The material used in this study was selected from the long-term sample collected at the University of Washington Department of Orthodontics, Seattle, Wash. The long-term sample contains sets of study casts and cephalograms from before (T1) and after (T2) orthodontic treatment and long-term postretention (T3) of patients treated by faculty members and/or graduate students of the department.

Criteria for selection of cases were as follows:

1. Class II Division 2 malocclusion pretreatment with deep overbite (≥4.0 mm)
2. No labial or palatal cleft, and no serious disease that could affect growth
3. Treatment with edgewise technique
4. Posttreatment dental casts revealing acceptable orthodontic results for overbite, overjet, crowding, and correction of canine and molar relationships (Angle Class I relationship)

The sample for this study consisted of 62 patients, 31 males and 31 females. Mean age was 12.7 years (SD 2.6) at T1, 15.7 (SD 2.4) at T2, and 30.9 (SD 5.0) at T3. The mean postretention period was 15.2 years (SD 4.5) with a minimum of 8.6 years. The sample was divided into two groups according to T3 overbite: Group 1 (N = 33; overbite ≥4.0 mm at T3, mean = 5.17 ± 0.87) and group 2 (N = 29; overbite <4.0 mm at T3, mean = 2.95 ± 0.87). Thirty-seven cephalometric variables and 12 dental cast measurements were compared at each stage between the two groups.

The entire sample was also divided according to sex (31 males and 31 females), and these groups were compared for overbite and changes in overbite. Mean age of each group did not differ significantly at T1 (male 12.6, female 12.7), T2 (male 15.7, female 15.7), or T3 (male 31.9, female 29.8).

The sample was further divided based on extraction or nonextraction treatment. Twenty-nine patients were treated nonextraction and 23 were treated with the extraction of four premolars. The remaining 10 patients had extractions with other options. The mean ages of the groups did not differ significantly at T1 (nonext 12.2, four-premolar ext 12.5), T2 (nonext 15.2, four-premolar ext 15.8), or T3 (nonext 30.9, four-premolar ext 30.4). These groups were compared for overbite and its changes.

Cephalometric measurements

Lateral cephalometric radiographs evaluated in this study were taken using the standardized Broadbent technique. All radiographs were traced by hand on frosted acetate tracing paper using a 0.5 mm, 2H mechanical pencil. Landmarks were digitized using the Numonic Digitizer (Numonics Co, Montgomeryville, Pa). Thirty-seven variables were measured using the Quick Ceph II software program (Orthodontic Processing, Chula Vista, Calif).

Definitions for cephalometric analysis

See Table 1.

Dental cast measurements

Overbite: With the casts in centric occlusion, the amount of greatest vertical overlap of right and left maxillary central incisors was marked on the corresponding mandibular central incisor parallel to the occlusal plane using a soft lead pencil. The distance between the mark and the incisal edge of the corresponding mandibular central incisor was measured to the nearest 0.01 mm. Right and left measures were averaged.

Overjet: The greatest amount of horizontal overlap was recorded from the labial surface of the mandibular central incisor to the lingual surface of the maxillary central incisor. The casts were occluded and inverted so that the base of the maxillary cast rested on a flat surface. Paralleling the occlusal plane, overjet was recorded to the nearest 0.01 mm. Right and left measures were averaged.

Intercanine width: Both maxillary and mandibular intercanine widths were recorded from crown tip to crown tip. If the maxillary canines were unerupted, the data were treated as missing.

Intermolar width: Both maxillary and mandibular intermolar widths were recorded from the mesiobuccal cusp tips of the permanent first molars.

Canine relationship: The distance between the cusp tip of the maxillary canine and the distal anatomic contact point of the mandibular canine was measured. Right and left measures were averaged.

Premolar relationship: The distance between the buccal cusp tip of the maxillary second premolar and the distal anatomic contact point of the mandibular second premolar was measured. Right and left measures were averaged.

Molar relationship: The distance between the mesiobuccal cusp tip of the maxillary first molar and mesiobuccal groove of the mandibular first molar was measured. Right and left measures were averaged.

In molar, premolar, and canine relationships, a positive reading indicated a Class II relationship, and a negative reading indicated a Class III relationship.

Curve of Spee: A flat plastic plate was placed over the occlusal surface of the mandibular arch. The plate usually touched only the incisal edges of the mandibular incisors and the distal cusps of the permanent first molars. The plate was recessed in the canine area to prevent rocking over the cusp tips. On each side, the depth of the curve of Spee was determined by measuring the distance from the side of the plate facing the teeth to the buccal cusp tip farthest from it. Right and left measures were averaged.

Lower arch irregularity index: Displacements of the mandibular arch anterior contact points were summed.[12]

Upper arch irregularity index: Displacements of maxillary arch anterior contact points were summed.

All measurements were made to the nearest 0.01 mm with the Mitutoyo digital caliper (Mitutoyo Co, Minato-Ku, Japan). The measuring blades, except for the faces, were ground slender to facilitate the measurements and not interfere with adjacent anatomic structures.

Statistical analyses

Thirty-seven cephalometric measurements and 12 model measurements were evaluated at each of three time periods (T1, T2, T3) for the entire sample (N = 62). Paired *t*-tests were done to find any significant changes during each period (T1-T2, T2-T3).

Independent *t*-tests for 37 cephalometric measurements and 12 model measurements were performed in order to compare two groups at each of three time periods (T1, T2, T3).

Multiple stepwise regression analysis was used in an attempt to identify any clinically useful predictors of the postretention overbite by using

Table 1
Definitions for cephalometric analysis

Relationship of maxilla and mandible to cranial base	
SN-to-mandibular-plane angle	Angle between SN plane and mandibular plane
SN-to-palatal-plane angle	Angle between SN plane and palatal plane
Palatomandibular plane angle	Angle between palatal plane and mandibular plane
SN-to-occlusal-plane angle	Angle between SN plane and occlusal plane. Occlusal plane obtained by connecting midpoints of central incisor tips and mesiobuccal cusp tips of first molars
Size and form of mandible	
Gonial angle	Gonial angle
Upper gonial angle	Angle formed by articulare, gonion, and nasion
Lower gonial angle	Angle formed by nasion, gonion, and menton
Ramus height	Distance between articulare and gonion
Mandibular body length	Distance between gonion and menton
Vertical height and ratio	
Anterior facial height (AFH)	Distance from nasion to menton
Posterior facial height (PFH)	Distance from sella turcica to gonion
PFH/AFH ratio	Facial height ratio = PFH/AFH x 100 (percent)
Upper anterior facial height (UAFH)	Length of upper portion of AFH, which is divided into two parts by palatal plane.
Lower anterior facial height (LAFH)	Length of lower portion of AFH, which is divided into two parts by the palatal plane
UAFH/LAFH ratio	UAFH/LAFH x 100 (percent)
Anteroposterior relationship of maxilla and mandible	
SNA	
SNB	
ANB	
Wits	Value from Wit's appraisal
Maxillary and mandibular incisor position	
Upper-1-to-FH-plane angle	Angle between Frankfort horizontal plane and long axis of upper central incisor
Upper-1-to-palatal-plane (mm)	Vertical distance from upper central incisor tip to palatal plane
IMPA	Incisor mandibular plane angle (Tweed)
Lower-1-to-mandibular-plane (mm)	Vertical distance from lower central incisor tip to mandibular plane
Upper-1-to-A-pog (mm)	Vertical distance from upper central incisor tip to A-Pog plane
Lower-1-to-A-pog (mm)	Vertical distance from lower central incisor tip to A-Pog plane
Interincisal angle	
Maxillary and mandibular first molar position	
Upper-6-to-FH-plane angle	Angle between FH plane and long axis of upper first molar (buccal groove to bifurcation)
Upper-6-to-occlusal plane angle	Angle formed by occlusal plane and long axis of upper first molar (buccal groove to bifurcation)
Upper-6-to-palatal-plane (mm)	Vertical distance from mesiobuccal cusp tip of the upper first molar to palatal plane
Lower-6-to-mandibular-plane angle	Angle between mandibular plane and long axis of lower first molar(mesiobuccal groove to bifurcation)
Lower-6-to-occlusal-plane angle	Angle formed by occlusal plane and long axis of lower first molar (mesiobuccal groove to bifurcation)
Lower-6-to-mandibular-plane (mm)	Vertical distance from mesiobuccal cusp tip of lower first molar to mandibular plane
Soft tissue profile	
Upper lip (mm)	Distance from upper lip to facial esthetic line
Lower lip (mm)	Distance from lower lip to the facial esthetic line
Other	
Facial depth	Length from nasion to gonion
Facial length	Length from the sella turcica to gnathion
Overbite Depth Indicator (ODI)	

Table 2
Mean measurements and comparison at T1, T2, and T3 stage

	T1 Mean	T1 SD	$p^{\dagger}$	T2 Mean	T2 SD	$p^{\ddagger}$	T3 Mean	T3 SD
Cephalometric analysis								
Relationship of maxilla and mandible to cranial base								
SN-to-mandibular-plane angle	30.2	5.2	NS	29.8	5.3	***	27.2	6.6
SN-to-palatal-plane angle	7.9	3.4	***	8.7	3.3	*	8.4	3.2
Palatomandibular plane angle	22.3	5.0	***	21.0	5.3	***	18.8	6.2
SN-to-occlusal-plane angle	14.5	4.7	**	16.2	4.8	***	13.9	5.4
Size and form of mandible								
Gonial angle	122.3	7.9	**	121.5	7.9	***	119.9	8.0
Upper gonial angle	52.7	5.2	***	51.1	5.0	NS	50.8	4.5
Lower gonial angle	69.7	4.6	***	70.5	4.8	***	69.1	5.4
Ramus height	45.0	5.2	***	49.8	5.5	***	53.7	7.0
Mandibular body length	70.5	5.9	***	74.0	5.7	***	76.3	6.2
Vertical height and ratio								
Anterior facial height(AFH)	112.7	8.1	***	119.3	7.9	***	121.5	8.1
Posterior facial height(PFH)	75.4	7.1	***	80.9	7.0	***	84.9	8.0
PFH/AFH	67.6	4.6	***	68.6	4.6	***	71.2	5.8
Upper anterior facial height(UAFH)	51.9	3.8	***	54.3	3.4	***	55.1	3.4
Lower anterior facial height(LAFH)	60.9	5.3	***	65.0	5.7	***	66.4	6.2
UAFH/LAFH	85.5	6.4	**	84.0	6.9	NS	83.6	7.4
Anteroposterior relationship of maxilla and mandible								
SNA	82.2	3.0	***	80.8	2.9	NS	81.0	3.0
SNB	76.6	2.8	***	77.4	3.0	***	78.2	3.3
ANB	5.6	2.1	***	3.4	2.1	**	2.9	2.5
Wits	3.4	2.5	***	0.9	2.1	NS	1.3	2.5
Maxillary and mandibular incisor position								
Upper-1-to-FH-plane angle	98.2	8.0	***	106.4	7.7	NS	105.3	8.1
Upper-1-to-palatal plane (mm)	28.1	2.5	NS	27.9	3.2	***	29.0	3.4
IMPA	90.3	7.0	***	94.8	6.4	***	91.2	6.9
Lower-1-to-mandibular plane (mm)	40.1	3.7	NS	40.1	3.4	***	41.6	3.5
Upper-1-to-A-Pog (mm)	2.2	2.8	NS	2.3	2.2	***	1.6	2.6
Lower-1-to-A-Pog (mm)	-2.6	2.6	***	-0.6	2.2	***	-1.9	2.6
Interincisal angle	149.4	12.2	***	137.1	9.7	***	144.3	10.7
Maxillary and mandibular first molar position								
Upper-6-to-FH-plane angle	78.7	5.6	NS	79.7	12.7	***	87.5	6.0
Upper-6-to-occlusal-plane angle	85.1	5.2	NS	87.9	12.7	**	93.4	6.2
Upper-6-to-palatal-plane (mm)	21.4	3.0	***	23.1	2.6	***	24.3	3.0
Lower-6-to-mandibular-plane angle	87.3	7.0	**	92.6	11.9	NS	90.9	6.7
Lower-6-to-occlusal-plane angle	71.6	7.3	***	79.1	12.5	NS	77.7	6.3
Lower-6-to-mandibular-plane (mm)	30.4	3.0	***	33.4	3.8	***	34.6	4.0
Soft tissue profile								
Upper lip (mm)	-2.2	2.7	***	-5.5	2.5	***	-8.4	3.3
Lower lip (mm)	-2.5	2.8	***	-5.0	2.4	***	-7.2	3.2
Others								
Facial depth	116.1	9.8	***	121.8	10.1	***	126.1	10.5
Facial length	121.7	8.0	***	129.2	7.6	***	132.9	8.6
Overbite depth indicator (ODI)	81.5	6.1	***	78.6	6.1	**	79.5	6.1
Model analysis								
Overbite	6.2	1.4	***	2.7	1.2	***	4.1	1.4
Overjet	3.1	1.3	***	1.7	0.6	**	2.0	0.6
Upper intercanine width	32.9	2.9	***	34.9	2.7	*	34.4	2.6
Lower intercanine width	26.1	5.2	NS	26.6	1.6	***	25.0	1.8
Upper intermolar width	48.9	2.7	***	50.4	2.4	***	49.7	2.7
Lower intermolar width	43.0	2.2	NS	42.7	2.4	NS	42.4	2.7
Canine relation	5.3	1.8	***	1.6	1.7	NS	1.6	1.6
Premolar relation	4.6	1.6	***	2.2	2.4	NS	2.5	2.3
Molar relation	3.4	1.7	***	1.3	2.5	NS	1.2	2.6
Curve of Spee	2.0	1.0	***	0.3	0.4	***	0.6	0.6
Upper irregularity index	9.6	5.0	***	1.9	1.2	***	3.1	2.1
Lower irregularity index	5.5	3.8	***	1.5	1.1	***	4.1	2.1

* $p<0.05$; ** $p<0.01$; *** $p<0.001$; NS - not significant
† significance of paired t-test between T1 and T2
‡ significance of paired t-test between T2 and T3

T1 variables. The variables showing p-values less than 0.1 in the previous independent t-tests at the T1 stage were included to get a regression equation for predicting T3 overbite.

Independent t-tests for overbite were done to compare males and females at each time period (T1, T2, T3, T1-T2, and T2-T3).

Independent t-tests for overbite were performed in order to compare the four-premolar extraction group and the nonextraction group at each time period (T1, T2, T3, T1-T2, and T2-T3).

Error of the method

Reproducibility of the measurements was assessed by statistically analyzing the difference between measurements taken at least 1 week apart on 30 study models and 30 cephalograms, selected randomly (10 at T1, 10 at T2, and 10 at T3). The standard error of a single determination was calculated from the equation: $Sx = \sqrt{\Sigma D^2 / 2N}$, where D is the difference between duplicate measurements and N is the number of double measurements.

The error was calculated for each of the model measurements and each of the cephalometric measurements. The mean error for the study model measurements was 0.24 mm, and ranged from 0.10 mm (overbite) to 0.60 mm (canine relation). The mean error for the cephalometric measurements was 1.41 mm for linear measurements and 0.61° for angular measurements, with ranges from 0.40 mm (upper lip) to 0.90 mm (anterior facial height), and 0.40° (SNB) to 3.40° (lower-6-to-mandibular-plane angle), respectively.

Results

Dental and skeletal changes from T1 to T3 (Table 2)

During treatment, the SN-to-mandibular-plane angle was maintained, but during the postretention period, it decreased by an average of 2.6°. SN-to-palatal-plane angle increased during treatment, but decreased after treatment. The palatomandibular plane angle decreased both from T1 to T2 and from T2 to T3. SN to occlsual plane angle increased from 14.5° to 16.2° during treatment, but decreased to 13.9° during the postretention period.

Ramus height and mandibular body length increased significantly during both periods, but gonial angle decreased significantly.

Anterior and posterior facial height increased during each stage. Posterior facial height increased more than anterior facial height. Upper and lower anterior facial height increased during each stage. Lower anterior facial height increased more than upper anterior facial height during treatment, but showed no significant difference after treatment.

SNA decreased significantly during treatment, but showed no significant change after treatment. SNB increased during both treatment and postretention, while ANB decreased. The value from Wit's appraisal showed a significant difference between T1 and T2, but no significant difference between T2 and T3.

Upper-1-to-FH angle increased significantly during treatment. Upper-1-to-A-Pog distance showed no significant change during treatment, but decreased after treatment. IMPA and lower-1-to-A-Pog distance increased during treatment, but decreased significantly during the postretention period. Upper-1-to-palatal-plane distance and lower-1-to-mandibular-plane distance showed no significant difference between T1 and T2, but increased significantly after T2. Interincisal angle decreased significantly during treatment, but increased after treatment.

Upper-6-to-FH-plane angle increased (mesial tipping) during the postretention period. Lower-6-to-mandibular-plane angle increased (distal tipping) during treatment. Upper-6-to-palatal-plane and lower-6-to-mandibular-plane distance increased during both periods, T1 to T2 and T2 to T3.

Both upper lip and lower lip distance decreased significantly from T1 to T2 and from T2 to T3.

Facial depth and facial length increased during both periods. ODI showed a decrease during treatment but an increase after treatment.

Overbite and overjet decreased during treatment but increased after treatment. Overbite improved an average of 3.5 mm during treatment and relapsed an average of 1.4 mm during the postretention period. The net overbite decreased 2.1 mm from T1 to T3 (Table 2, Figure 1).

Upper intercanine width increased during treatment, but decreased slightly posttreatment. Lower intercanine width showed no significant change during treatment, but decreased during the postretention period. Upper intermolar width increased significantly during treatment, but decreased during the postretention period. Lower intermolar width showed no significant change. Canine, premolar, and molar relationships all showed significant decreases during treatment, but no significant changes after treatment. Curve of Spee, upper arch irregularity index and lower arch irregularity index decreased during treatment, but increased during the postretention period.

Comparison between group 1 and group 2 (Table 3)

Group 1 consisted of 33 cases (15 males, 18 females) with T3 overbite greater than 4.0 mm. Group 2 consisted of 29 cases (16 males, 13 females) with T3 overbite less than 4.0 mm. These two groups showed no intergroup difference in age.

At the T1 stage, palatomandibular plane angle, lower gonial angle, upper-1-to-FH angle, upper-1-to-A-pog distance, lower-1-to-A-pog distance, interincisal angle, overbite, and overjet showed significant intergroup differences. Palatomandibular plane angle and lower gonial angle were

Table 3
Variables that showed significant differences between group 1 (N = 33, overbite ≥4.0 mm at T3) and group 2 (N = 29, overbite <4.0 mm at T3). Means, showing the significant difference between two groups, are indicated in bold

	T1				T2				T3			
	Group 1		Group 2		Group 1		Group 2		Group 1		Group 2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Palatomandibular plane angle	**21.1**	4.4	**23.7**	5.3*	20.1	5.3	22.1	5.1	17.5	6.1	20.2	6.0
Lower gonial angle	**68.6**	3.8	**70.9**	5.1*	**69.2**	4.4	**72.0**	4.9*	**67.5**	5.1	**70.9**	5.3*
Anterior facial height	112.2	8.3	113.4	7.9	117.8	7.0	121.0	8.6	**119.4**	6.7	**123.9**	8.9*
Lower anterior facial height	60.5	5.3	61.3	5.3	63.9	4.9	66.2	6.5	**64.8**	4.8	**68.2**	7.1*
Upper-1-to-FH-plane angle	**96.2**	8.0	**100.4**	7.4*	105.0	6.9	108.1	8.3	**102.0**	6.4	**109.0**	8.4*
Upper-1-to-A-Pog (mm)	**1.5**	2.9	**3.1**	2.6*	2.0	2.0	2.7	2.3	**0.8**	2.5	**2.4**	2.4*
Lower-1-to-A-Pog (mm)	**-3.4**	2.3	**-1.7**	2.6**	-1.0	2.1	-0.1	2.2	**-3.0**	2.4	**-0.7**	2.2**
Interincisal angle	**153.1**	11.1	**145.2**	12.2*	139.1	7.9	134.8	11.0	**148.9**	9.8	**139.1**	9.3**
Upper-6-to-palatal-plane (mm)	21.3	3.0	21.6	3.1	22.6	2.4	23.7	2.8	**23.5**	2.7	**25.2**	3.2*
Lower lip (mm)	**-3.1**	2.3	**-1.8**	3.2^{+}	-4.9	2.4	-5.0	2.5	-7.4	3.5	-7.0	3.0
Facial length	121.2	8.5	122.2	7.5	127.6	6.9	131.1	8.1	**130.6**	7.9	**135.6**	8.7*
Overbite depth indicator (ODI)	82.7	5.9	80.2	6.2	80.1	5.3	76.9	6.7	**82.0**	5.2	**76.7**	5.8*
Overbite	**6.6**	1.4	**5.8**	1.3*	**3.0**	1.2	**2.3**	1.1*	5.2	0.9	3.0	0.9
Overjet	**2.8**	1.2	**3.5**	1.4*	1.7	0.6	1.6	0.7	2.1	0.6	1.9	0.5
Lower intercanine width	**25.0**	2.1	**25.9**	2.1^{+}	26.5	1.5	26.5	1.8	24.8	1.7	25.2	1.8
Canine relationship	5.4	2.1	5.2	1.5	**1.9**	1.8	**1.2**	0.7*	1.9	2.0	1.2	1.0
Curve of Spee	2.2	1.2	1.7	0.8	0.3	0.4	0.2	0.5	**0.8**	0.5	**0.4**	0.5**

$^{+}p<0.1$, $^{*}p<0.05$, $^{**}p<0.01$ indicates the significance between groups 1 and 2 at each stage.

higher in group 2. The mean palatomandibular plane angle was 21.1° in group 1 and 23.7° in group 2. Mean lower gonial angle was 68.6° in group 1 and 70.9° in group 2. Mean upper-1-to-FH-plane angle was greater in group 2. Mean upper-1-to-FH angle was 96.2° in group 1 and 100.4° in group 2. Group 2 also had greater upper-1-to-A-Pog and lower-1-to-A-Pog distances. Interincisal angle and overbite were greater in group 1, and overjet was smaller.

At the T2 stage, only lower gonial angle, overbite, and canine relationship showed significant differences between groups. Lower gonial angle was greater in group 2. Group 1 had greater overbite and a higher canine relationship.

At the T3 stage, 11 variables showed significant differences. Group 2 had a larger lower gonial angle than group 1. Anterior facial height and lower anterior facial height were also greater in group 2. Upper-1-to-FH angle, upper-1-to-A-Pog, lower-1-to-A-Pog, and interincisal angle showed significant intergroup differences. The mean upper-6-to-palatal-plane distance (mm) was larger in group 2 and facial length was greater. ODI was greater in group 1 and the curve of Spee was deeper.

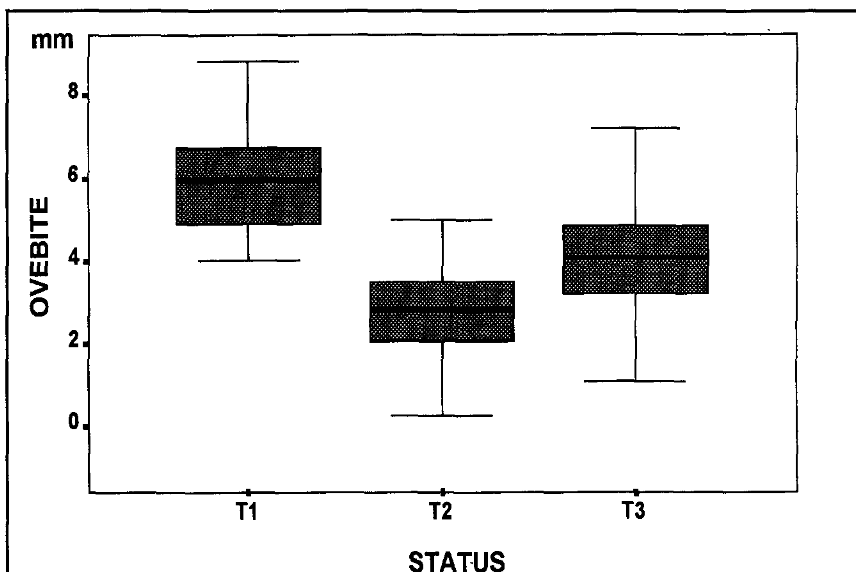

Figure 1
Overbite at T1, T2, and T3

Prediction of postretention overbite at T1 stage (Table 4)

The variables showing p-values less than 0.1 in the previous independent t-tests at the T1 stage were palatomandibular plane angle, lower gonial angle, upper-1-to-FH-plane angle, upper-1-to-A-Pog, lower-1-to-A-Pog, interincisal angle, lower lip distance, overbite, overjet, and lower intercanine width. These variables were included to get a regression equation for predicting T3 overbite.

Using multiple stepwise regression analysis, overbite was selected at the first step, followed by lower intercanine width and palatomandibular plane angle. R^2 was 0.42 ($p<0.001$, Table 4). Initial overbite was the most important factor in predicting postretention overbite.

Table 4
Multiple regression analysis for prediction of T3 overbite by T1 measurements

	Parameter estimate	Standard error	*P*
Overbite	0.37	0.11	***
Lower intercanine width	-0.13	0.03	***
Palatomandibular plane angle	-0.07	0.04	*
(Constant)	6.86	1.71	***
R square	0.42		***

*$p<0.05$, **$p<0.01$, ***$p<0.001$

Comparison of overbite between sexes (Table 5)

Overbite differed significantly between males and females at T1, with males having a greater overbite. The amount of treatment change was significantly greater in males. However, there was no difference in the amount of overbite or overbite relapse during the postretention period.

Table 5
Comparison of overbite between sexes (Mean ± SD, mm)

	Male (N=31)		Female (N=31)	
	Mean	SD	Mean	SD
T1	6.6	1.5	5.8	1.2*
T2	2.7	1.3	2.7	1.1
T3	4.1	1.7	4.2	1.1
T1-T2	-3.9	1.6	-3.1	1.5*
T2-T3	1.4	1.5	1.5	1.3

*$p<0.05$

Comparison of overbite between the four-premolar extraction group and the nonextraction group (Table 6)

Of 62 cases, 29 were treated without extraction and 23 were treated after four-premolar extraction (Table 6). The nonextraction group showed deeper overbite than the extraction group at T2 and T3. There was no significant difference between the two groups at T1.

Table 6
Comparison (Mean ± SD, mm) of overbite between nonextraction group (N=29) and four-premolar extraction group (N=23)†

	Nonextraction		Four-premolar extraction	
	Mean	SD	Mean	SD
T1	6.6	1.5	6.0	1.4
T2	3.3	0.9	2.1	1.2***
T3	4.6	1.3	3.8	1.2*
T1-T2	-3.3	1.5	-4.0	1.6
T2-T3	1.3	1.2	1.7	1.7

*$p<0.05$, ***$p<0.001$
† including 44/44, 44/55 and other four-premolar extraction cases

Examples (Figures 2, 3, 4)

Case No. 164 (female, 16.1 years old at T1, 20.6 at T2, and 31.1 at T3) demonstrated severe relapse of deep overbite during the postretention period. She showed typical pretreatment characteristics of group 1 with greater initial deep overbite and very upright incisal relationships compared with group 2. Even though a good result was obtained during treatment, uprighting of upper and lower incisors and minimal lower anterior facial growth occurred during the postretention period, along with relapse of the deep overbite (Figure 4A-C).

Case No. 30 (male, 14.7 years old at T1, 17.0 at T2, and 28.6 at T3) showed characteristics typical of group 2. This patient's treatment result was similar to that of Case No. 164, but with minimal overbite deepening during the postretention period. Pretreatment characteristics were typical of group 2, with less initial deep overbite and less upright incisal relationships than group 1. In the postretention stage, this patient showed more favorable vertical growth (Figure 4 D-F).

Discussion

Sampling and grouping

Simon[7] found statistically significant differences in mean initial overbite between different types of malocclusions. Class II Division 2 cases had deeper initial overbite than other classes and, therefore, also had the greatest amount of treatment correction. Berg[9] observed that in the seven Class II Division 2 cases of his sample, treatment changes were greater than those found in 19 Class II Division 1 cases, but posttreatment relapse was also greater. Magill[11] suggested that a study of changes in anterior overbite relationship be made on a large number of Class II Division 2 cases because this group represents a specialized type of deep overbite. He believed that inclusion of cases with different Angle classifications may produce samples with wide variations in skeletal relationship, growth pattern, and treatment modalities, making it difficult to obtain clinically useful information about the postretention overbite change in Class II Division 2 malocclusion with initial deep overbite. In the present study, we included only Class II Division 2 cases with deep overbite at T1 in an attempt to identify any clinically useful predictors of overbite relapse in this specialized group.

Overbite can also change with age. Björk[13] and Graber[2] said that overbite generally decreases somewhat with

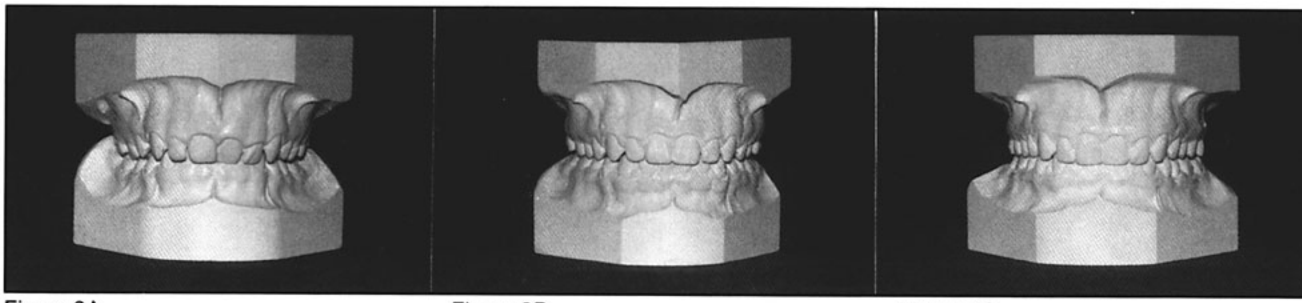

Figure 2A Figure 2B Figure 2C

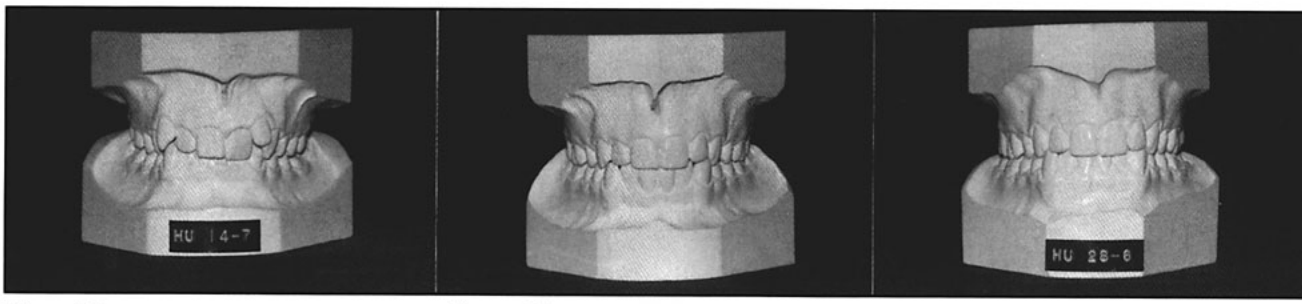

Figure 2D Figure 2E Figure 2F

Figure 2
Pretreatment (A), posttreatment (B), and postretention (C) casts of case No. 164 showing postretention relapse of deep overbite. Pretreatment (D), posttreatment (E), and postretention (F) casts of case No. 30 showing long-term stability.

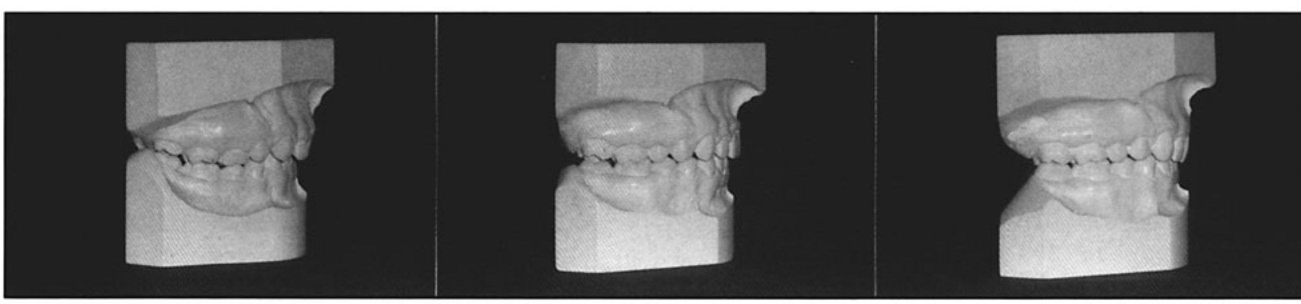

Figure 3A Figure 3B Figure 3C

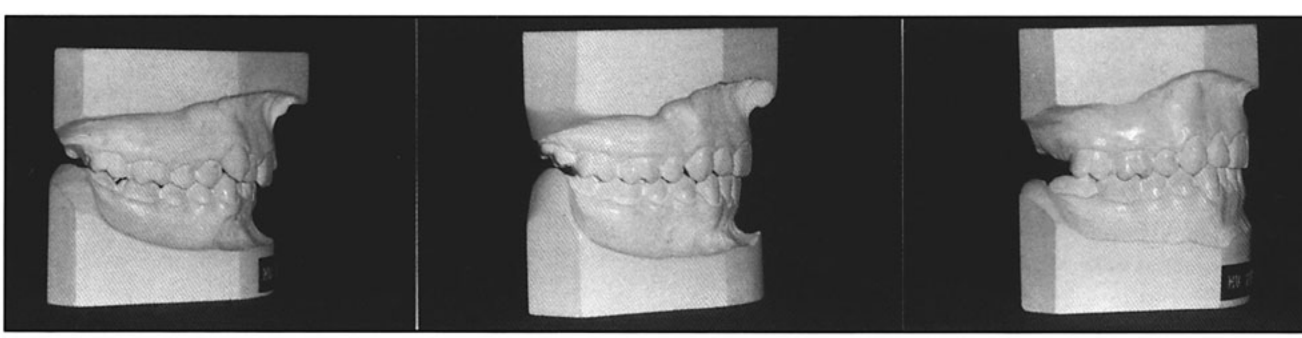

Figure 3D Figure 3E Figure 3F

Figure 3
Pretreatment (A), posttreatment (B), and postretention (C) casts of case No. 164 showing postretention relapse of deep overbite. Pretreatment (D), posttreatment (E), and postretention (F) casts of case No. 30 showing long-term stability of overbite.

age. Individually, age changes of overbite are very great.[13] McDowell[18] noted that the correction of deep overbite is more stable when performed during the growth phase. By considering the results of previous studies, it could be noted that overbite might vary with Angle classification and age. To study any specific postretention overbite change, the sample should comprise the same type of malocclusion and subgroups, with no significant difference in age. In the present study, sample selection was confined to Class II Division 2 subjects with deep overbite. This sample was divided into two groups according to the degree of postretention overbite. There was no significant difference in age at each stage. A more homogeneous sample might facilitate detection of predictors and associations of several variables. Collecting more cases for postretention study will make a breakdown according to age possible. It would be interesting and worthwhile to compare several age groups to evaluate differences in long-term overbite change.

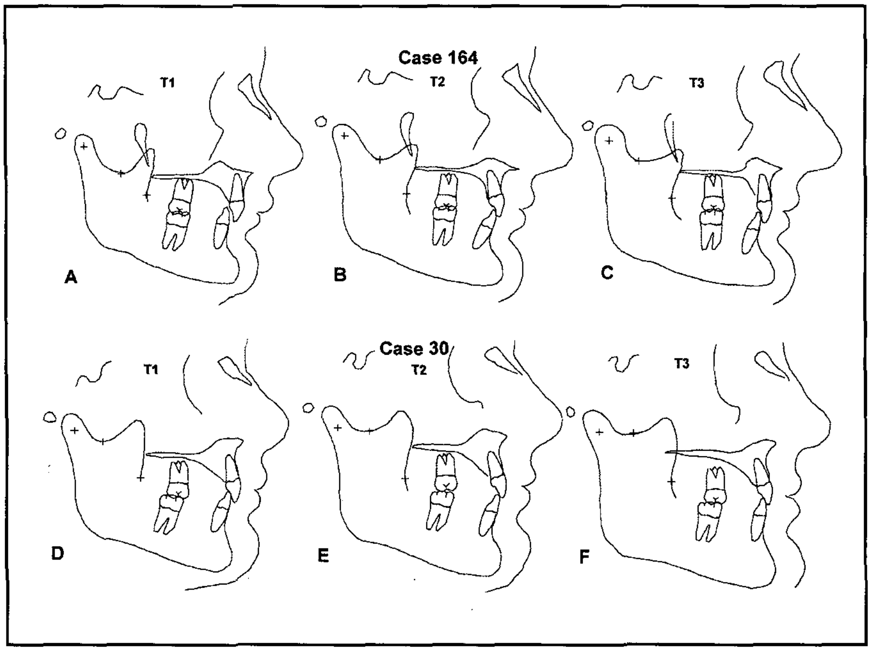

Figure 4
Pretreatment (A), posttreatment (B), and postretention (C) cephalometric tracings of case No. 164 showing postretention relapse of deep overbite. Pretreatment (D), posttreatment (E), and postretention (F) cephalometric tracings of case No. 30 showing long-term stability of overbite.

Dental and skeletal changes from T1 to T3 (Table 2)

The results of most studies concerning the stability of overbite correction indicate a decrease in overbite during treatment followed by an increase in overbite during the postretention period.[4-10] Simons[7] studied correlations between incisal overbite and other craniofacial characteristics. He found that patients who had a deep initial overbite prior to treatment also had the deepest overbite 10 years postretention, but such cases also maintained the greatest amount of correction or overall net decrease in overbite. Berg[9] found 22.2% relapse of overbite correction, with a net total of 42.2% overbite correction in seven Class II Division 2 cases. Mean overbite was 8.3 mm at T1, 3.8 mm at T2, and 4.8 mm at T3. Burzin[15] investigated overbite stability after using anterior intrusion mechanics. He noted that overbite relapse was 24.2% (0.8 mm), and mean overall reduction of overbite was 43.5% (2.51 mm).[15] In the present study, the mean relapse was 42.9% (1.5 mm) and the mean overall reduction was 33.9% (2.1 mm, Table 2, Figure 1). This study showed a greater percentage of relapse than other studies.[9,15] However, this must be interpreted with caution because of differences in duration of postretention and sample size. Berg[9] examined only seven Class II Division 2 cases for 5 to 9 years. Burzin[15] observed only 2 years after treatment, and he corrected the overbite using anterior intrusive mechanics.[9] In the present study, mean postretention duration was 15 years with a minimum of 8.6 years.

Comparison between group 1 and group 2 (Table 3, Figures 2, 3, 4)

Simons[9] noted that lack of mandibular growth in a predominantly horizontal direction was associated with overbite relapse. He suggested that individuals who had experienced continued vertical growth postretention seemed to maintain the correction 10 years out of retention.[9] In the present study, the stable group showed slightly greater means in SN-to-mandibular-plane angle, palato-mandibular plane angle, gonial angle, and lower gonial angle at T1, which may indicate that vertical growth is favorable. But differences in SN-to-mandibular-plane and gonial angles were not great enough statistically to draw any conclusions. At the T3 stage, group 2 showed more vertical growth than group 1, and anterior facial height, lower anterior facial height, and facial length were all greater. It seemed that more favorable growth in the vertical direction might contribute to the maintenance of the overbite correction.

At T1, upper-1-to-FH plane angle, upper-1-to-A-Pog distance, lower-1-to-A-Pog distance, and interincisal angle showed significant intergroup differences. Group 1 had a smaller upper-1-to-FH-plane angle and upper-1-to-A-Pog distance, indicating that the upper incisors were more upright and retruded. Group 1 also had a smaller lower-1-to-A-pog distance than group 2, indicating that the lower incisors were more retruded. Consequently, the interincisal angle was much greater in group 1 than in group 2. As Graber[2] stated, "the more upright the incisors, the greater the likelihood of excessive overbite." At T2, these variables showed no significant intergroup differences. But during postretention, the initial incisal relationship reappeared and the groups showed a significant difference in axial inclination of the maxillary and mandibular teeth at the T3 stage, as they did at T1. There was a strong tendency for maxillary and mandibular positions to return to their original relationship.

The interincisal angle is believed to play a critical role in the stability of deep overbite correction. Riedel[12] noted that tipping maxillary and mandibular incisors into too upright a relationship usually leads to a deep anterior overbite. Burzin[15] emphasized that good axial inclination of the incisors at the end of treatment might be a factor in the stability of the final result. Berg[9] considered the fact that interincisal angle was less than 140° after treatment in 23 stable cases an important factor in the amount of stability achieved. Hasstedt[5] noted that there was no apparent relationship between the interincisal angle at the end of treatment and the subsequent relapse in degree of overbite. It was concluded that no apparent relationship was evident between the change in incisor angulation subsequent to treatment and the amount of relapse in overbite.[9] Simons[7] also noted that there was no correlation between the interincisal angle established following orthodontic treatment and postretention changes in overbite. In the present study, group 1 showed a greater interincisal angle than group 2, but the difference was not statistically significant. Although both groups achieved an average interincisal angle of less than 140° at T2 as Berg[9] emphasized, this did not seem to guarantee a stable postretention overbite. On the basis of clinical experience or intuition,[9,15,12] some authors have emphasized the importance of a "good" interincisal angle at T2. But long-term postretention stability of overbite cannot be obtained by achieving only one factor, such as the posttreatment interincisal angle.

Does overcorrection of the initial deep overbite result in a more satisfactory postretention overbite relationship? Dona[4] suggested that overcorrection was probably a sound clinical philosophy. Riedel[14] also noted that overcorrection of a malocclusion was a safety factor in retention, and that it was prudent to overcorrect the various malpositions and malrelationships of teeth and jaws.[14] Simons[7] stated in his study that, on average, patients with a deep initial overbite also had a deeper final overbite, but they also maintained the greatest amount of net correction in overbite as a result of orthodontic therapy. But in his study, a statistical correlation between overcorrection and overbite stability could not be made because the sample did not contain a sufficient number of cases. Berg[9] found good stability after deep overbite correction in his sample of 26 Class II individuals. Long-term stability of incisor occlusion was obtained in 24 of the 26 cases. He stated that since overtreatment was not carried out in his sample, the benefit of this procedure is questionable. In the present study, interest was focused primarily on the prediction of postretention overbite at T1, while the comparison of treatment modalities, such as overcorrection, was not taken into account. In the present study, overbite was greater in group 1 than in group 2 at T1, T2, and T3, and canine relationship was greater in group 1 at the T2 stage. These findings suggest that a greater number of stable cases were overcorrected compared with unstable cases, and that overcorrecting a deepbite at the end of treatment may be a good clinical strategy. No general conclusions can be drawn about the importance of overcorrection in this study. For this purpose, it is recommended that another statistical study using regression analysis be made to examine the relationship between overcorrection and changes in anterior overbite.

Numerous methods have been used to correct deep overbite. Helmley[16] described the use of a bite plate to retard the growth of the anterior alveolus and to allow the posterior alveolus to increase, thereby allowing for the eruption of the posterior teeth. Sleighter[17] stated that anterior bite planes increase alveolar height in the molar region. Another common treatment option is leveling the curve of Spee. This can be accomplished using an intrusion arch[2,15] or by placing a continuous wire with a reverse curve of Spee. The force system created by a reverse curve of Spee wire is such that an intrusive force is delivered to the incisors and an extrusive force is applied to the molars and premolars. Since extrusion is more easily achieved than intrusion, a reverse curve of Spee wire will extrude posterior teeth, and deep overbite correction will occur. In this study, numerous variables were included to measure the positions of the maxillary and mandibular incisors and first molars, especially intrusion and extrusion (upper-1-to-palatal-plane, lower-1-to-mandibular-plane, upper-6-to-palatal-plane, and lower-6-to-mandibular-plane distances). It does not seem possible to study this using conventional cephalograms without also using metallic implants. While accepting the limitations of the methods employed, it is worthwhile to note that upper-6-to-palatal-plane distance was greater in group 2 than in group

1 at T3. This suggests that deep overbite correction by extrusion of posterior teeth would be stable in the patients with considerable vertical growth potential even after treatment. Hemley,[16] Sleichter,[17] Burstone,[3] and McDowell[18] have also indicated that deep overbite can be successfully corrected by molar extrusion, with the greatest success associated with patients who exhibit considerable mandibular growth.

Prediction of postretention overbite at T1 (Table 4)

Researchers have tried to predict postretention stability, such as mandibular anterior alignment, but no predictors are available for the postretention stability of overbite in Class II Division 2 patients. Årtun[19] evaluated the long-term stability of mandibular anterior alignment in Class II Division 1 cases and searched for predictors of relapse. Franklin[20] investigated dental and skeletal parameters to identify any clinically useful predictors of postretention mandibular incisor alignment in 114 subjects with various malocclusions. El-Mangoury[8] noted in his postretention study of overjet, overbite, and canine/molar relationships that relapse or stability can be neither predicted nor judged from one set of records alone. But he suggested that relapse or stability can be predicted by comparing posttreatment and pretreatment variables. In the present study, multiple stepwise regression analysis was used to search for any clinically useful predictors of the postretention overbite with T1 variables. The variables showing *p*-values less than 0.1 in the previous independent *t*-tests at T1 (Table 3) were included to get a regression equation for predicting T3 overbite. Using the stepwise procedure, overbite was selected at the first step, followed by lower intercanine width and palatomandibular plane angle. R^2 was 0.42 ($p<0.001$, Table 4). This means that initial overbite is the most important factor in predicting postretention overbite. However, this predictability is not particularly high, indicating that there could be many other factors during the treatment and postretention periods that influence the final overbite. In this study we did not use posttreatment variables because we focused on predictability using pretreatment variables. It would be interesting and clinically useful to search for predictors at the T2 stage. Predictability would be higher if several posttreatment variables were included.

Comparison of overbite between sexes (Table 5)

Simons[7] noted that there was no difference between males and females when initial overbite and treatment change in overbite were compared. However, he found that females did exhibit more overbite relapse during the postretention period, while males maintained greater overbite correction 10 years postretention.[7] El-Mangoury[8] stated that there were no interactions between relapse (or stability) and the sex of the patient. In the present study, the greater amount of overbite correction in males during treatment was maintained after treatment. No significant relationship between relapse and the sex of the patient was found during the postretention period, even though males exhibited greater initial overbite and treatment change.

Comparison of overbite between the four-premolar extraction group and the nonextraction group (Table 6)

Extraction orthodontic therapy has been criticized as a factor leading to relapse in overbite. Many clinical orthodontists, as well as many researchers, look with a critical eye on the removal of teeth in deep overbite cases. Such treatment, it is felt, can only increase the excessive anterior overbite relationship. Among the many issues raised concerning overbite, one of the most challenging is the effect of extraction treatment on the overbite, both after active treatment and several years after retention is discontinued. Magill[11] noted that tooth extraction should not cause an increase in overbite if "adequate therapy" is employed. Deep overbite, per se, before treatment is not necessarily a contraindication to extraction therapy.[11] Simons[7] noted that postretention change in overbite was not related to whether or not permanent teeth were extracted during orthodontic treatment.[7] El-Mangoury[8] found that there was no significant interaction between relapse (or stability) and whether or not extraction was included as part of the mechanotherapy. He concluded that pretreatment deep overbite is not necessarily a contraindication to extraction.[8] Burzin[15] stated that there was no difference in stability between extraction and nonextraction groups. He also found that the extraction group had more intrusion than the nonextraction group.

The present study showed no significant differences in the T1 overbite between the nonextraction group and the four-premolar extraction group. But the nonextraction group showed statistically significant deeper overbite at T2 and T3. The two groups showed no significant differences in amount of treatment change and overbite relapse. Since we could not find a greater incidence of overbite relapse in extraction cases, tooth extraction does not seem to cause an increase in overbite if adequate therapy is employed.

Although this study included more Class II Division 2 cases than any previous study, its main limitation is still the small sample size, which did not allow breakdown of the two groups into more subgroups according to treatment (extraction versus nonextraction), sex, and age.

Conclusions

1. Long-term changes in overbite in Class II Division 2 cases were highly variable. The chance of maintaining an overbite smaller than 4.0 mm was less than 50%.

2. Maxillary and mandibular incisors that were very upright pretreatment tended to have deeper initial overbite and showed a tendency to return to their original relationship by the postretention stage.

3. A favorable vertical growth pattern contributed to the maintenance of a stable overbite.

4. By stepwise multiple regression analysis, initial overbite was selected as the most important predictor of postretention overbite. Initial overbite was positively correlated with postretention overbite.

5. No significant interactions were found between relapse and the sex of the patients.

6. Tooth extraction does not seem to cause an increase in pretreatment overbite.

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