Long-term stability of mandibular incisors following successful treatment of Class II, Division 1, malocclusions

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Several researchers have demonstrated a reduction of mandibular dental arch length and width dimensions[1-12] and an increase of mandibular incisor irregularity[3-13] long-term following orthodontic treatment and retention. However, the results regarding the amount of irregularity at the time of follow-up are conflicting. Some studies conclude a minor tendency for posttreatment relapse of mandibular incisor alignment,[4,5,13] while others indicate a wide individual variation of incisor irregularity long-term, with a high proportion of the patients having unsatisfactory incisor alignment after more than 10 years postretention.[3] Aims at identifying clinically useful predictors for relapse of mandibular incisor alignment and associations between such relapse and other postretention changes have not been successful.[3,8-10]

Sample selection has frequently been based on extraction decisions rather than type of malocclusion; samples in various studies have been limited to cases treated only nonextraction,[5,8] with the extraction of four first premolars,[3] with the extraction of maxillary first and mandibular second premolars,[9] or with the extraction of one or two mandibular incisors.[10] Such an approach may facilitate samples that are homogeneous with respect to mandibular arch length deficiency prior to treatment. However, inclusion of cases with different Angle classifications[3-6,8-10,13]

Abstract

The purpose of this study was to evaluate the long-term stability of mandibular anterior alignment in a large group of Class II, Division 1, patients who demonstrated successful occlusal results at the end of active treatment. The specific aim was to search for predictors of relapse and associations between relapse and other postretention changes. The sample of 78 adolescents was limited to successfully treated cases as judged by subjective evaluation of intercuspation and incisor occlusion of posttreatment study models. Neither cephalometric characteristics nor postretention occlusion were considered in sample selection. Of these patients, study models and cephalograms were available pretreatment, at the end of active treatment, and a mean of 14 years postretention. The results demonstrated an increase of incisor irregularity and a reduction of intercanine width and arch length postretention. At postretention, 9.0% had Irregularity Index values of 6.5 mm or more and 47.4% had values equal to 3.5 mm or less. Stepwise backward multiple regression analyses revealed that narrow pretreatment intercanine width and high pretreatment incisor irregularity were significant predictors of relapse. Treatment increase of intercanine width and postretention decrease of intercanine width and arch length were associated with relapse.

Key Words

Long-term stability

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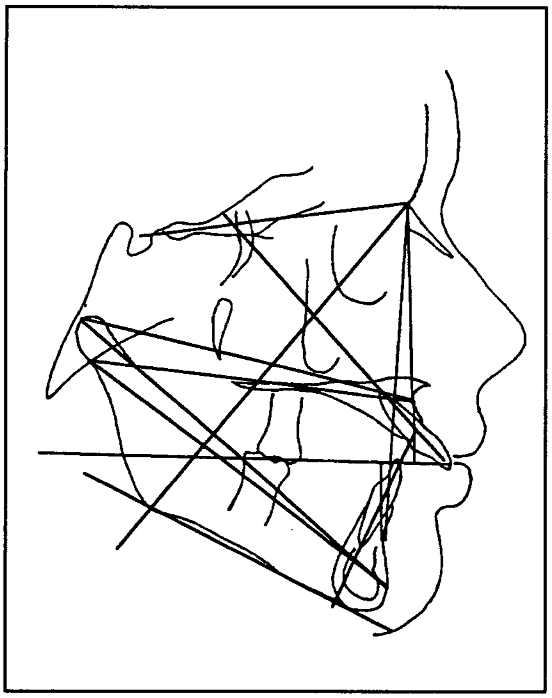


Figure 1

Figure 1
Cephalometric tracing illustrating nine angular (SNA, SNB, ANB, Int. inc. Angle, Mn1/MnPl, Mx1/SN, OcclPl/SN, MnPl/SN, MnPl/GoN) and five linear (Co-A, Ar-A, Co-Pg, Ar-Pg, Wits) measurements used to describe skeletal and dental relationships.

may produce samples with wide variations in skeletal relationship, growth pattern, and need for dental compensations. The extraction decision is typically made to facilitate treatment to accepted standards and is likely to be determined by factors such as amount of arch length deficiency, positions of incisors and canines, and facial form. If this is the case, and the treatment goals are met, cases with similar malocclusion classification may be expected to have similar tooth positions at the end of active treatment, regardless of the extraction approach. Samples selected according to type of malocclusion may therefore be more homogeneous than samples selected according to the type of extraction, facilitating detection of predictors and associations.

Treatment quality has rarely been a criterion for sample selection. A frequent speculation is that more relapse may occur in cases with compromised results at the end of active treatment. The purpose of the current study was to evaluate the long-term stability of mandibular anterior alignment in a large group of cases with successful occlusal results at the end of active treatment for Class II, Division 1, malocclusion, to compare the amount of relapse with that found in a sample selected according to less rigorous criteria for treatment quality, to search for predictors of relapse, and to search for associations between relapse and other postretention changes.

Materials and methods

Sample

Sets of study models and cephalograms made before (T-1) and after (T-2) orthodontic treatment and long-term postretention (T-3) of patients treated by faculty members and/or graduate students in the Department of Orthodontics at the University of Washington were examined. Sample criteria were limited to patients with a significant Class II, Division 1, malocclusion at T-1 who were treated to a successful occlusal result at T-2, either nonextraction or with the extraction of four premolars. A Class II molar relationship of at least "end-on" and an overjet of at least 5 mm were considered significant. A successful occlusal result was based on a subjective evaluation of intercuspation, tooth alignment and incisor relationship. The occlusal status at T-3 or cephalometric characteristics were not considered in the sample selection. A total of 33 males and 45 females, 7.3 to 17.3 years old at T-1 (mean 11.2, SD 2.4), 23.4 to 49.6 years old at T-3 (mean 31.1, SD 5.0) and 8.5 to 32.8 years out of retention (mean 14.0, SD 4.6) were included in the study. The extraction of four premolars was performed in 37 patients, and 41 patients were treated without extractions.

Measurements on study models

The Irregularity Index was measured as the sum of the linear displacements of the anatomic contact points of each mandibular incisor from the adjacent tooth anatomic point.[14] Dental arch length was calculated as the sum of the distances from the mesial anatomic contact point of right and left first molars to the mesial midpoint of the incisal edge of the right and left central incisor.[1] Intercanine width was measured as the distance between the cusp tips of the mandibular canines, and intermolar width was measured as the distance between the mesiobuccal cusp tips of the mandibular first molars.[1] The estimated cusp tips were used in cases with excessive wear.[3] Overbite was measured as the mean overlap of maxillary to mandibular central incisors, and overjet was measured as the distance parallel to the occlusal plane from the incisal edge of the most labial maxillary central incisor to the most labial mandibular central incisor.[15] The measurements were made to the nearest half millimeter for overjet and overbite and to the nearest tenth of a millimeter for the remaining measurements, using a digital caliper (Fred V. Fowler Co, Inc, Newton, Mass).

Measurements on cephalograms

Cephalometric landmarks were digitized with the Numonic Digitizer (Numonics Corp,

Table 1
Mean measurements on study models made before treatment (T-1), after treatment (T-2), and a mean period of 14 years out of retention (T-3) in patients successfully treated for Class II, Division 1, malocclusion with (ex, n=37) and without (non, n=41) extraction of four premolars.

	T - 1		T - 2		T - 3	
	ex (x ± SD)	non (x ± SD)	ex (x ± SD)	non (x ± SD)	ex (x ± SD)	non (x ± SD)
Irreg index	5.27 ± 3.52	2.77 ± 2.40**	0.91 ± 0.66	1.08 ± 0.79	4.05 ± 2.03	3.63 ± 1.86
3-3 width	26.22 ± 2.40	26.15 ± 1.97	27.10 ± 1.74	26.58 ± 1.44	25.35 ± 2.01	25.25 ± 1.62
6-6 width	42.35 ± 2.82	43.68 ± 2.75*	41.07 ± 2.09	44.84 ± 2.27***	40.20 ± 2.62	44.71 ± 2.20***
Arch length	30.51 ± 2.75	31.47 ± 1.48*	25.06 ± 1.05	30.70 ± 1.22***	24.29 ± 1.36	29.49 ± 1.17***
Overjet	8.78 ± 2.60	8.68 ± 2.38	2.45 ± 0.50	2.49 ± 0.72	3.11 ± 0.79	2.87 ± 0.67
Overbite	4.24 ± 1.74	4.48 ± 1.52	3.05 ± 1.00	2.80 ± 0.87	3.91 ± 1.26	3.77 ± 1.08

*P <0.05; **P <0.01; ***P <0.001
P values refer to differences between subgroups at each time period

Montgomeryville, Penn). Using the Macintosh Quick Ceph Program (Orthodontic Processing, Chula Vista, Calif), nine angular and five linear measurements were calculated (Figure 1).

Error of the method

The reproducibility of the measurements was assessed by statistically analyzing the difference between double measurements taken at least one week apart on 20 study models and 20 cephalograms selected at random (10 at T-1 and 10 at T-2). The error of the method was calculated from the equation:

$$S_x = \sqrt{\frac{\Sigma D^2}{2N}}$$

where D is the difference between duplicated measurements and N is the number of double measurements.[16]

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 0.31 mm with a range of 0.11 mm (intercanine width) to 0.68 mm (overbite). The mean error for the cephalometric measurements was 1.20 mm for linear measurements and 1.30° for angular measurements, with ranges from 0.58 mm (Wits) to 1.98 mm (Co to Pg) and 0.51° (Mn Pl / Go N) to 2.09° (Occl Pl / SN), respectively.

Data analysis

Mean values for the measurements on study models and cephalograms were calculated for the subgroups treated with and without extraction at T-1, T-2 and T-3. Unpaired Student's t-tests were employed to test for any intergroup differences. For the remaining statistical analyses the two subgroups were combined, and the two linear measurements for midface and mandibular length and the two angular measurements for inclination of the mandibular border (Figure 1) were averaged to one value for each. Paired Student's t-tests were employed to test for changes in means from T-1 to T-2 and from T-2 to T-3. Pearson's product-moment correlation coefficients were calculated to test for association between the change in the two time periods for each variable. Finally, a stepwise backward elimination procedure was employed to develop a multiple regression model. With this procedure, variables were successively eliminated from the model if their effects were not significant at level 0.20.[17] This approach was used to investigate associations between the Irregularity Index at T-3 and changes in the remaining variables from T-1 to T-2 and T-2 to T-3, and characteristics at T-1.

Results

Measurements of study models

The extraction cases had higher Irregularity Index values than the nonextraction cases at T-1 (Table 1). Irregularity Index values of 6.5 mm or more and 3.5 mm or less were observed in 27.0% and 45.9% of the extraction cases and 7.3% and 75.6% of the nonextraction cases, respectively. The extraction cases also had narrower

Table 2
Mean linear and angular measurements on cephalograms made before treatment (T-1), after treatment (T-2), and a mean period of 14 years out of retention (T-3) in patients successfully treated for Class II, Division 1, malocclusion with (ex, n=37) and without (non, n=41) extraction of four premolars (see Fig. 1 for definitions).

	T - 1		T - 2		T - 3	
	ex (x ± SD)	non (x ± SD)	ex (x ± SD)	non (x ± SD)	ex (x ± SD)	non (x ± SD)
Mn1/MnP1	98.80 ± 7.05	98.07 ± 6.45	97.38 ± 5.45	99.07 ± 5.07	97.66 ± 6.22	98.22 ± 5.88
Mx1/SN	111.60 ± 8.39	111.08 ± 7.95	96.98 ± 7.26	99.17 ± 6.77	98.35 ± 6.64	100.55 ± 7.59
Mx1/Mnl	114.88 ± 6.68	119.23 ± 9.65*	130.84 ± 7.83	128.78 ± 7.06	130.52 ± 7.69	129.40 ± 7.99
SNA	82.05 ± 3.73	81.94 ± 3.55	79.43 ± 3.77	79.33 ± 3.72	79.73 ± 3.28	79.35 ± 3.36
CO-A mm	90.72 ± 5.08	91.11 ± 4.34	91.66 ± 5.82	93.05 ± 3.89	94.04 ± 5.20	95.14 ± 5.10
AR - A mm	86.94 ± 5.25	87.00 ± 4.35	87.46 ± 5.31	88.63 ± 3.52	89.57 ± 5.24	91.73 ± 4.72
SNB	75.49 ± 3.21	76.30 ± 3.58	75.35 ± 3.93	75.71 ± 3.36	75.72 ± 3.40	76.00 ± 3.41
Co-Pg mm	109.94 ± 6.18	110.98 ± 6.23	116.32 ± 6.69	118.03 ± 5.73	119.41 ± 6.84	122.54 ± 7.17*
Ar-Pg mm	100.74 ± 5.97	101.45 ± 6.50	106.47 ± 6.17	108.08 ± 6.28	109.39 ± 7.08	113.69 ± 7.32**
ANB	6.56 ± 2.04	5.63 ± 1.98*	4.10 ± 2.06	3.63 ± 2.01	4.02 ± 2.18	3.35 ± 2.36
Wits mm	3.44 ± 2.65	3.35 ± 2.07	0.39 ± 2.76	0.13 ± 1.92	1.53 ± 2.62	1.72 ± 2.24
OcclPl/SN	19.02 ± 3.74	17.35 ± 4.15*	20.54 ± 4.61	19.93 ± 4.26	18.67 ± 4.70	17.10 ± 5.31
MnPl/SN	34.72 ± 5.99	31.62 ± 3.57**	34.82 ± 6.46	32.98 ± 3.92	33.45 ± 6.47	31.13 ± 5.74
MnPl/GoN	73.29 ± 4.05	71.65 ± 2.52*	74.09 ± 4.92	73.49 ± 2.60	73.23 ± 5.73	72.39 ± 3.75

*P < 0.05; **P < 0.01; **P < 0.001

P-values refers to differences between subgroups at each time period

Table 3
Association between mean changes from before to after treatment (ΔT-1 to T-2), and from after treatment to a mean period of 14 years out of retention (ΔT-2 to T-3). Measurements were made on study models and cephalograms for 78 patients successfully treated for Class II, Division 1, malocclusion with and without extraction of four premolars.

	ΔT-1 to T-2 x + SD	Δ T-2 to T-3 x+ SD	Pearson's r
Irreg Index	-3.22 ± 3.26***	2.86 ± 2.03***	-0.38**
3-3 Width	0.64 ± 1.98*	-1.53 ± 1.16***	-0.51***
6-6 Width	-0.01 ± 2.65	-0.48 ± 1.29**	-0.21
Arch Length	-2.99 ± 2.97***	-1.02 ± 0.79***	-0.44***
Overjet	-6.25 ± 2.40***	0.51 ± 0.80***	-0.09
Overbite	-1.45 ± 1.80***	0.91 ± 1.16***	-0.46***
Mn1/MnPl	-0.15 ± 6.78	0.05 ± 4.56	-0.44***
Mx1/SN	-13.20 ± 9.33***	1.38 ± 5.64*	-0.28*
SNA	-2.61 ± 3.07***	0.15 ± 2.26	-0.45***
Midface Length	1.28 ± 3.09***	2.43 ± 2.89***	-0.21*
SNB	-0.38 ± 2.37	0.33 ± 2.35	-0.14
Mn Length	6.47 ± 4.49***	4.08 ± 4.82***	0.05
ANB	-2.22 ± 1.68***	-0.18 ± 1.59	-0.08
Wits	-3.14 ± 2.67***	1.38 ± 2.44***	-0.36***
OcclPl/SN	1.20 ± 3.61***	-1.48 ± 8.38***	-0.16
Inclination MnPl	1.05 ± 2.14***	-1.31 ± 2.69***	0.08

*P < 0.05; **P < 0.01; ***P < 0.001

intermolar widths and shorter arch lengths than the nonextraction cases at T-1, T-2, and T-3. No other intergroup differences were found (Table 1). From T-2 to T-3 the nonextraction cases had more reduction in arch length than the extraction cases (P<0.05), and an intergroup difference in change of intermolar width was found (P<0.01). No intergroup differences in change of Irregularity Index, intercanine width, overjet, and overbite were found from T-2 to T-3.

Irregularity Index, overjet, and overbite increased, whereas intercanine width, intermolar width, and arch length decreased from T-2 to T-3 (Table 3). The ranges of the changes were from 0 to 9.64 mm for the Irregularity Index, from -2.0 to 3.0 mm for overjet, from -1.5 to 4.5 mm for overbite, from -3.8 to 0.9 mm for intercanine width, from -3.9 to 2.5 mm for intermolar width, and from -3.0 to 0.5 mm for arch length. At T-3, 9.0% of the cases had Irregularity Index values of 6.5 mm or more and 47.4% had values of 3.5 mm or less (10.8% and 43.2% of the extraction cases and 7.3% and 51.2% of the nonextraction cases, respectively).

Measurements of cephalograms

No intergroup differences were found at T-2. However, at T-1 the extraction cases had smaller

Table 4
Irregularity Index associations. Measurements were made on study models a mean period of 14 years postretention and on study models and cephalograms before treatment in 78 Class II, Division 1, patients successfully treated with and without extraction of four premolars.

	Parameter estimate	Standard error	P
Intercept	22.470	6.364	
3-3 width	-0.215	0.010	< 0.05
Irreg index	0.161	0.071	< 0.05
Mx1/SN	0.057	0.028	< 0.05

Table 5
Irregularity Index associations. Measurements were made on study models a mean period of 14 years postretention and on study models and cephalograms before and after treatment in 78 Class II, Division 1, patients successfully treated with and without extraction of four premolars.

	Parameter estimate	Standard error	P
Intercept	3.013	0.517	
3-3 width	0.314	0.111	< 0.01
Mx1/SN	-0.057	0.023	< 0.01

interincisal angles, more pronounced distal skeletal relationships, and were more hyperdivergent than the nonextraction cases. At T-3, the nonextraction cases had longer mandibles than the extraction cases (Table 2).

At T-1, the average patient included in the sample had a distal skeletal relationship due to a retrognathic mandible, normal vertical relationships, and proclined maxillary incisors (Table 2). Few cases were severely hyperdivergent. The malocclusion was corrected through reduction of maxillary prognathism and retroclination of the maxillary incisors, while mandibular prognathism and incisor inclination remained unchanged. Also, a slight opening of the occlusal and mandibular planes occurred relative to the anterior cranial base, and maxillary and mandibular length increased from T-1 to T-2 (Table 3). The Wits appraisal value increased from T-2 to T-3. However, no posttreatment changes were observed in maxillary and mandibular prognathism. A slight proclination of maxillary incisors occurred, whereas mandibular incisor inclination remained unchanged. A closure of mandibular and occlusal plane angles was observed, and maxillary and mandibular length continued to increase (Table 3).

Associations

Negative associations were found between treatment and postretention changes in Irregularity Index, intercanine width, arch length, overbite, inclination of maxillary and mandibular incisors, maxillary prognathism, maxillary length, and Wits appraisal (Table 3).

The increase in the Irregularity Index from T-2 to T-3 was negatively associated with intercanine width and positively associated with Irregularity Index and inclination of maxillary incisors at T-1 (Table 4).

Table 6
Irregularity Index associations. Measurements were made on study models a mean period of 14 years postretention and on study models and cephalograms after treatment and postretention in 78 Class II, Division 1, patients successfully treated with and without extraction of four premolars.

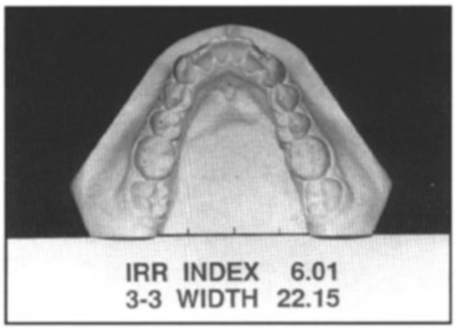
	Parameter estimate	Standard error	P
Intercept	2.050	0.441	
3-3 width	-0.792	0.159	< 0.001
Arch length	-0.285	0.121	< 0.05
Midface length	0.316	0.103	< 0.01
Mn length	-0.183	0.070	< 0.01

The change in the Irregularity Index from T-2 to T-3 was positively associated with change in intercanine width and negatively associated with change in maxillary incisor inclination from T-1 to T-2 (Table 5).

The change in the Irregularity Index from T-2 to T-3 was negatively associated with changes in intercanine width, arch length, and mandibular length, and positively associated with change in maxillary length from T-2 to T-3 (Table 6).

Discussion

Our results support previous research, concluding that a significant increase in incisor irregularity[3,5-13] and a significant reduction in arch length and width[1-13] occur long-term following



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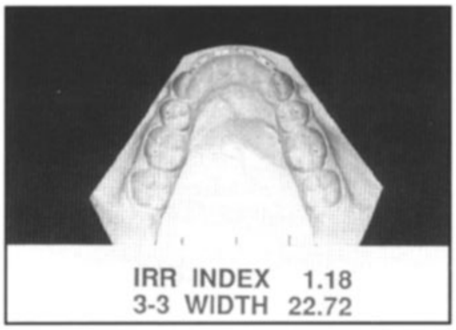

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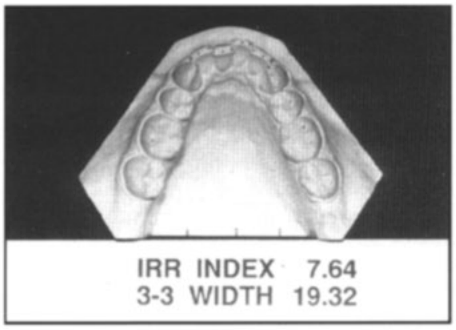

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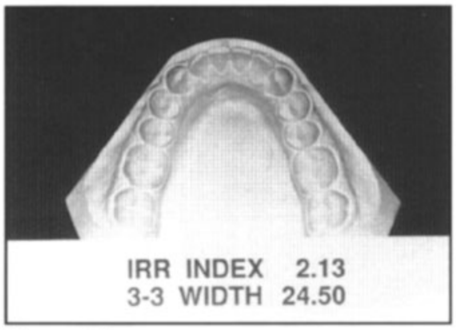

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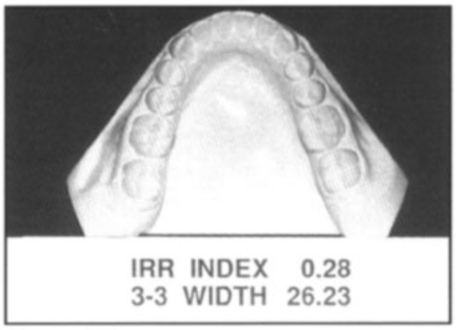

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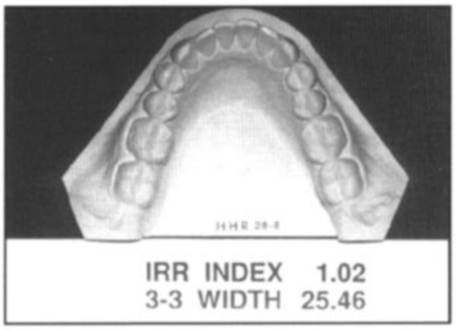

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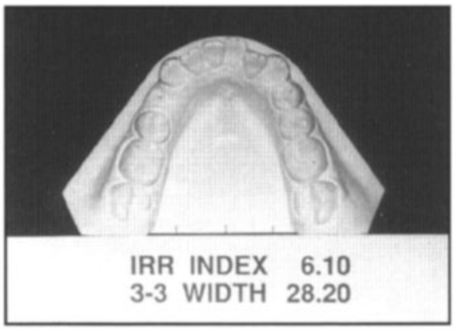

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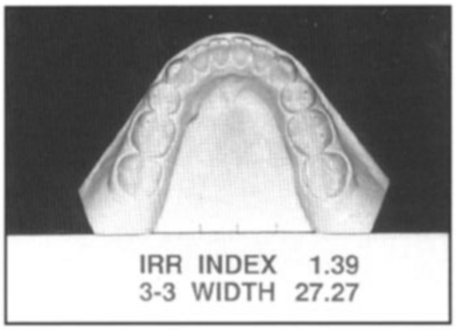

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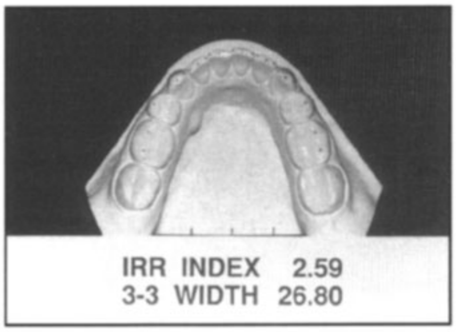

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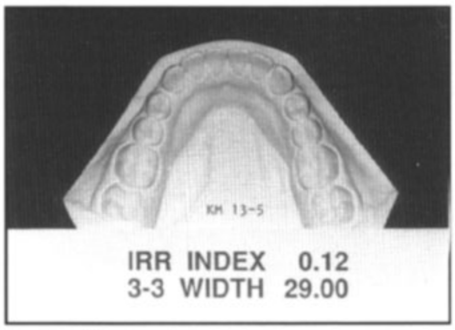

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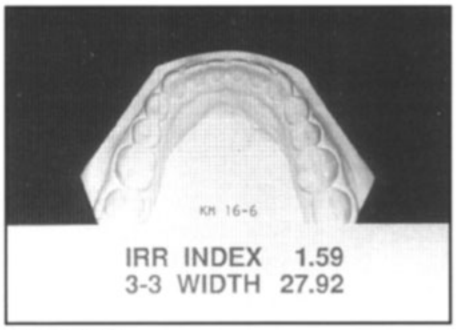

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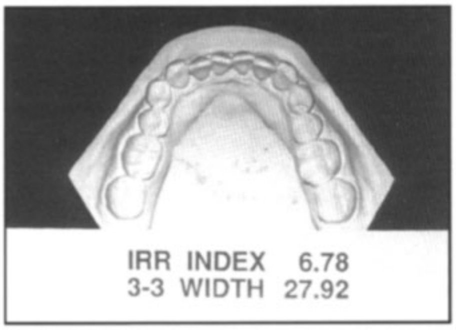


Figure 5C

Figure 2A-C
Study models made before (A) and after (B) treatment and 12 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note large treatment and postretention changes in incisor irregularity.

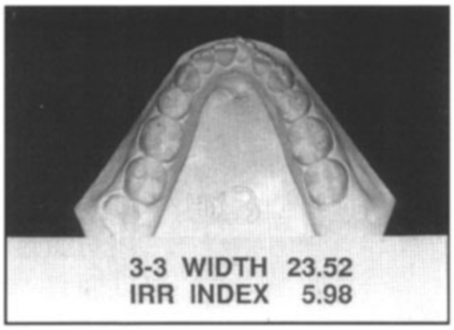
Figure 3A-C
Study models made before (A) and after (B) treatment and 11 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note minor treatment and postretention changes in incisor irregularity.

Figure 4A-C
Study models made before (A) and after (B) treatment and 12 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note large treatment and minor postretention change in incisor irregularity.

Figure 5A-C
Study models made before (A) and after (B) treatment and 14 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note minor treatment and large postretention change in incisor irregularity.

Figure 6A

Figure 6B



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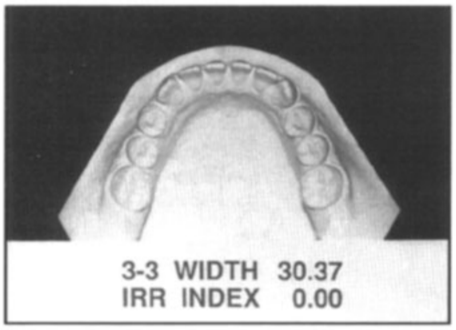
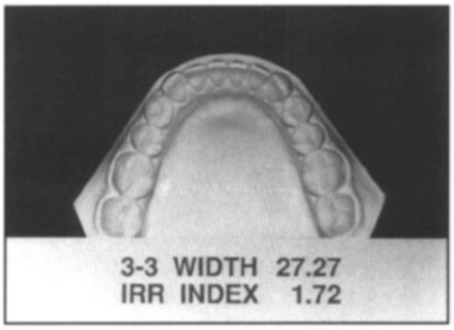


Figure 7A

Figure 7B



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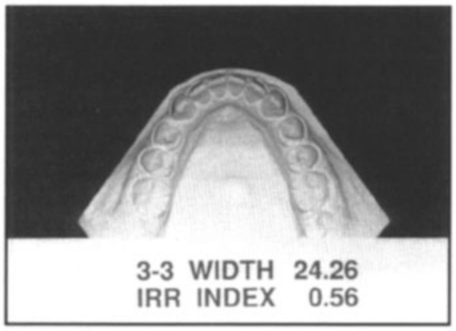

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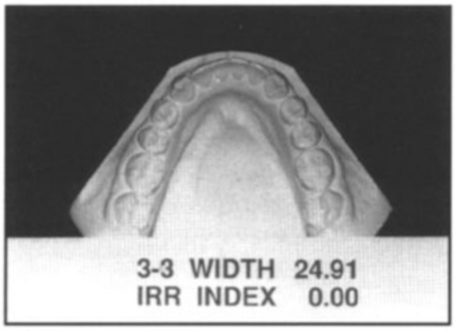

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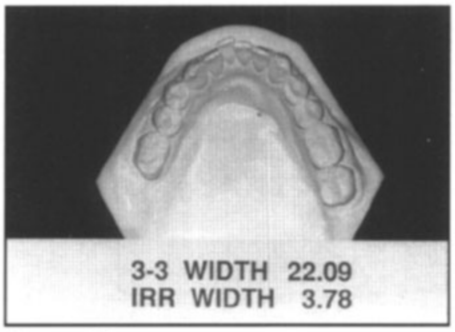

Figure 8C

Figure 9A

Figure 9B

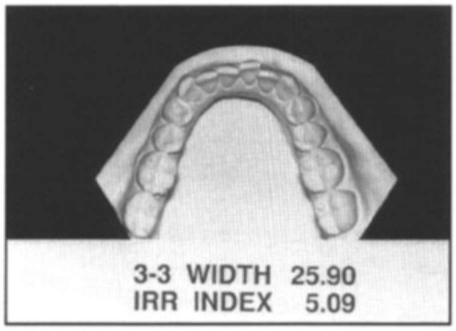

Figure 9C

Figure 6A-C
Study models made before (A) and after (B) treatment and 10 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note large treatment increase and postretention decrease in intercanine width.

Figure 7A-C
Study models made before (A) and after (B) treatment and 12 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note minor treatment and postretention changes in intercanine width.

Figure 8A-C
Study models made before (A) and after (B) treatment and 15 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note minor treatment increase and large postretention decrease in intercanine width.

Figure 9A-C
Study models made before (A) and after (B) treatment and 13 years postretention (C) of adolescent patient successfully treated for severe Class II/1 malocclusion. Note large treatment and minor postretention increase in intercanine width.

orthodontic treatment. Our results also confirm that the individual response is highly variable.[3,5-13] However, incisor irregularity always increased during the follow-up period. Also, with the exception of intermolar width, which increased in about 32.1% of the cases, increases in arch length and width measurements from posttreatment to postretention were rare.

The mean postretention Irregularity Index of 3.83 mm in our sample, which was not markedly smaller than 4.63 mm, as reported by Little et al.[3] in a similar study in which the sample was selected according to less rigorous criteria for treatment quality. Similarly, the number of patients with a postretention Irregularity Index of 3.5 mm or less or 6.5 mm or more, which may be considered either clinically acceptable or unacceptable incisor alignment,[3] was 47.4% and 9.0% in our sample, respectively, as opposed to 28% and 16% in the sample of Little et al. According to these results, ideal intercuspation and incisor occlusion at the time of appliance removal may be considered a factor, but should not be considered of major clinical importance for the long-term stability of mandibular incisor alignment. A few studies have reported markedly lower tendencies for posttreatment relapse of mandibular incisor irregularity.[4,5,13] Frequently mentioned explanations for the favorable results include reshaping of the interproximal tooth surfaces[4] and ideal occlusion at time of appliance removal.[13] However, the representativity of the samples[4,5,13] may be questioned, and in two of the studies[5,13] the postretention period may be considered short. The present results are comparable to those of Paquette et al.[11] and Lappanapornlarp and Johnston,[12] which were based on samples selected according to similar criteria.

In keeping with previous studies,[11,12] we did not find any differences in relapse of mandibular incisor alignment between the cases treated with and without four premolar extractions. However, our result does not allow conclusions regarding relative stability of extraction and nonextraction treatment approaches because the cases in the two groups were different prior to treatment. For the cases in our sample, the extraction decision was made to facilitate treatment to accepted standards, and significant aims were to avoid major changes in arch form and mandibular incisor inclination during appliance therapy. Accordingly, the pretreatment differences in incisor irregularity, arch length, and arch width between the extraction and nonextraction cases may be expected.[12] The pretreatment differences in inclination of the occlusal and mandibular planes may reflect an increased tendency to extract in hyperdivergent cases. The fact that we did not find any posttreatment differences in cephalometric measurements or in measurements of the anterior occlusal segments may indicate that individual treatment goals were met. An appropriate interpretation of these results may therefore be that relapse of incisor alignment is unavoidable, regardless of proper diagnosis and successful results at the end of active treatment. This conclusion may be supported by the finding that a high proportion of untreated subjects with ideal occlusion at age 12 develop crowding by age 20.[18-20] However, the amount of relapse may be higher in cases treated with excessive expansion, as described by Tweed[21] when evaluating postretention status of cases treated according to the nonextraction philosophy of Angle. Such arch enlargement treatment was not evaluated in this study.

The relapse of mandibular incisor alignment appears to be a multifactorial problem, which may explain why simple correlations of clinical significance have been difficult to establish.[3,8-10] We found a higher correlation coefficient between treatment and postretention changes of incisor irregularity and intercanine width than previously reported,[3] probably due to a higher degree of homogeneity in our sample. This may indicate that incisors and canines tend to move toward their pretreatment positions if changed during treatment (Figures 2 and 6) or remain unchanged if only minor treatment changes occur (Figures 3 and 7). However, only 26% and 14% of the postretention changes of intercanine width and incisor irregularity could be explained by the corresponding treatment changes (Table 3). We found several cases in the sample with large treatment changes and minor postretention changes (Figures 4 and 8) and vice versa (Figures 5 and 9).

The results of the regression analyses suggest that intercanine width and incisor irregularity prior to treatment are significant predictors for amount of incisor crowding postretention. We could also confirm previous results[5,7] and the general clinical impression that an increase in intercanine width during active treatment is associated with relapse. A recent study[10] concluded that patients treated with incisor extraction were more stable than those treated with premolar extraction.[3,10] Analyses of the pretreatment data show that the incisor extraction cases had narrower pretreatment intercanine width than the premolar extraction cases. Accordingly, the extraction decision was probably influenced by attempts to avoid expansion of the intercanine width during treatment. The results of our study may support that rationale in cases where extraction is judged necessary.

We also found associations between postretention reductions of intercanine width and arch length and relapse of incisor alignment. These findings, in addition to the high tendency for relapse, may be interpreted to support a rationale for "semipermanent" retention of the mandibular anterior segment. Clinical studies have documented no iatrogenic damage following long-term wear of bonded mandibular canine-to-canine retainers, regardless of calculus build-up along the wire, provided the wire and bonding sites do not impinge on the gingiva and the composite at the bonding sites is trimmed to avoid undercut areas for plaque retention.[22,23]

According to Björk's growth studies,[24] forward growth rotation of the mandible may be associated with mandibular incisor crowding and deepening of the bite. Backward rotation may also be associated with incisor crowding due to compensatory retroclination of the incisors in such cases, and opening of the bite.[24,25] The fact that deepbite as well as openbite development may cause mandibular incisor crowding may help explain why we, in keeping with other studies,[3,8-10] could not establish any relationship between changes in overbite and relapse of crowding. Similarly, it may not be unexpected that few associations between skeletal variables and mandibular incisor relapse have been found,[8-10,26] since both forward and backward growth rotation may cause relapse. Our finding that postretention changes of midface and mandibular lengths were positively and negatively associated with relapse, respectively, may be interpreted as an indication that growth changes that tend to cause a return toward relative mandibular retrognathism increase the tendency for incisor irregularity. However, no association was found between postretention changes of anteroposterior skeletal relationship and incisor irregularity, somewhat minimizing the significance of those findings.

Some readers may be critical of the lack of homogeneity in our sample regarding extraction therapy or of the fact that the two subsamples of patients treated nonextraction and with extraction of four premolars demonstrated a few pretreatment differences in skeletal patterns and dental compensations. However, the subsamples had similar dental and skeletal relationships at the end of active appliance therapy. In our opinion the most important factors for postretention stability may be posttreatment relationships and function. The type of appliance used to achieve the result or whether or not extractions were performed may be less important. Accordingly, follow-up studies of samples that are homogeneous regarding initial malocclusion and active treatment result may be as meaningful as the postretention evaluation of samples treated with identical extraction patterns.

Conclusions

Long-term changes in incisor alignment are highly variable, and chances of maintaining incisor alignment are less than 50%, despite successful occlusal results at the time of appliance removal. Narrow intercanine width and high incisor irregularity pretreatment are significant predictors. Also, postretention narrowing of intercanine width and reduction in arch length are associated with relapse. These results may support a rationale for "semi-permanent" retention of the mandibular anterior segment following appliance removal.

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