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Long-term follow-up of orthodontically treated deep bite patients

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SUMMARY The aim of this study was to evaluate the long-term stability of corrected deep bite and mandibular anterior crowding in a sample of 62 subjects (30 patients and 32 controls). The patients began treatment at a mean age of 12.2 years (SD 1.56). The treatment consisted of non-extraction and fixed appliances in 23 subjects and functional appliances in seven. The treatment group was compared with the control group with normal molar occlusion, normal overjet and overbite, no crowding, and without an orthodontic treatment need. The registrations were made on four occasions: before treatment (T1), after treatment (T2), and at two long-term follow-ups (T3 and T4). Four registrations were also made in the control group. All measurements were undertaken on plaster models and lateral cephalograms.

Treatment was found to have normalized the overbite and overjet and to have eliminated the space deficiency in the mandibular anterior region. At T4, there was a minor relapse in overbite in the treatment group (mean 0.8 mm). In the control group, the overbite underwent reverse development (bite opening by 0.7 mm) during the same period. The available mandibular incisor space, however, was –0.9 mm in the treatment group and –1.8 mm in the control group. The long-term stability of the treatment results was thus good.

Introduction

In many long-term studies of orthodontic correction of overbite, a relapse is observed (Simons and Joondeph, 1973; Rönnerman and Larsson, 1981; Little *et al.*, 1990; Canut and Arias, 1999). The improvement in the overbite achieved during active treatment tends to regress completely. Even over-correction of overbite has been observed to relapse (Canut and Arias, 1999).

Opinions on changes in the overbite after orthodontic treatment differ (Blake and Bibby, 1998). One important factor seems to be the interincisal angle. Because of the axial inclination of the maxillary and mandibular incisors, an upright incisor position translates into a higher interincisal angle, making the overbite more prone to relapse (Riedel, 1960). Ludwig (1967) found a positive correlation between changes in overbite and interincisal angle. The importance of not increasing the interincisal angle above 140 degrees after treatment to prevent overbite relapse has also been discussed (Berg, 1983). Other studies have found no correlation between the interincisal angle established following orthodontic treatment and post-retention changes in overbite (Simons and Joondeph, 1973).

Another factor discussed is protrusion of the mandibular incisors during orthodontic treatment to correct the overbite. This is correlated with overbite relapse (Simons and Joondeph, 1973). To enhance the long-term stability of overbite correction, protrusion of the mandibular anterior segment should be avoided.

The space available for the mandibular anterior teeth decreases as overbite increases (Zachrisson, 1997). If the deep bite in a treated malocclusion returns, the incisal edges of the mandibular incisors will occlude against a labiolingually thicker portion of the maxillary incisors. This will restrict their space and produce mandibular incisor crowding. Canut and Arias (1999) found a significant correlation between increases in post-retention overbite and post-retention crowding of the mandibular incisors.

Årtun *et al.* (1996) demonstrated that increases in mandibular intercanine width after treatment were associated with relapses in the alignment of the mandibular incisors when post-retention decreases in intercanine width and arch length occurred. In long-term studies, the number of years out of retention was also correlated with overbite relapse and mandibular anterior crowding (Canut and Arias, 1999). Patients who have had deep overbites may require an indeterminate length of time in retention to attain the greatest possible vertical development in the buccal segments while the anterior teeth are held in a minimum amount of overbite. Even growth is an important factor in determining the permanency of the result (Riedel, 1960).

The aim of this study was to evaluate the long-term stability of corrected deep bite and mandibular incisor crowding and to compare the transverse and sagittal development of the jaws between these deep bite patients and a control group.

Subjects and methods

The subjects comprised 62 children, 30 who had undergone orthodontic treatment (15 boys and 15 girls) and 32 controls (18 boys and 14 girls) at the Department of Orthodontics,

the Institute for Postgraduate Dental Education, Jönköping, Sweden. The children in the treatment group had a deep bite with an overbite of 4.5 mm or more. The control group, from records at the Department of Orthodontics which have been used in many former studies, had a normal molar occlusion with a normal overjet and overbite, no crowding, and without an orthodontic treatment need.

In the treatment group, one child had an Angle Class I malocclusion, 20 an Angle Class II division 1, and nine an Angle Class II division 2.

Treatment comprised fixed edgewise appliances in 23 subjects and functional treatment with an Andresen activator in seven. All treatment was carried out non-extraction. A retention plate in the maxilla in combination with a bonded mandibular retainer from canine to canine was used in 13 patients. Nine patients had a retention plate in the maxilla but no retention in the mandible. One patient received a lingual retainer in the mandible but no retention in the maxilla. Seven patients had no retention (Table 1).

Treatment began when the patients were a mean age of 12.2 years (SD 1.56). The mean treatment time was 2.3 years (SD 0.83). In the maxilla, the retention appliances were used for a mean of 1.6 years (SD 1.16) and in the mandible for a mean of 2.7 years (SD 1.71). The 23 patients with retention appliances used the retainer for a mean of 2.7 years (SD 1.45).

Measurements on plaster models were carried out to evaluate vertical, transverse, and sagittal changes in intermolar and intercanine widths, and changes in lateral arch lengths (Figure 1). Available mandibular incisor space (mandibular incisor crowding), overjet, and overbite were also measured.

Eleven variables were measured on lateral cephalograms to determine the sagittal and vertical relationship between the jaws and incisor inclination and vertical and horizontal growth. The reference lines and points are shown in Figure 2. The registrations and measurements were made by one author (USF).

The cephalometric reference points and measurements were used according to Björk (1947) and Solow (1966) with the following additions:

NL/ML: The angle from anterior nasal spine-posterior nasal spine to the mandibular line
ANS–Me: The distance from anterior nasal spine to menton
Ar–B: The distance from articulare to point B

All measurements on the lateral cephalograms were made to the nearest half degree or 0.5 mm without correction for enlargement, and on the dental casts using a sliding calliper to the nearest 0.1 mm.

For the treatment group, measurements were made before treatment (T1), mean age 12.2 years (SD 1.56); after treatment (T2), mean age 14.8 years (SD 1.45); and at the two long-term follow-ups (T3 and T4), mean ages 19.4 years (SD 2.22) and 26.1 years (SD 2.74), respectively. The controls were examined at the mean ages of 8.8 (SD 0.49), 13.6 (SD 2.01), 20.7 (SD 1.89), and 30.6 (SD 0.97) years (Table 2).

During the first follow-up period (T2–T3), retention appliances were used in the treated group. The period after retention for the different retention modalities, as well as the treatment times in the different groups can be seen in Table 1. Of seven patients without any retention, six were treated with functional appliances. The period after retention for the 23 patients who had had any type of retention was a mean of 2.0 years (SD 1.64) during T2–T3 and a mean of 8.2 years (SD 3.55) between T2 and T4. The period out of retention for those patients who had had retention appliances was 8.2 years (SD 3.55) between T2 and T4.

Statistical analyses

The Statistical Package for Social Sciences computer program (SPSS Inc. Chicago Illinois, USA, version 13.0) was used for the statistical analyses.

Table 1 Treatment time (T1), retention time (T2), and time after retention to registrations at T3 and T4 (years), grouped according to type of retention.

Type of retention	T1			T2			T3			T4		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Plate maxilla and wire mandible	13	1.9	0.62	13	3.2	1.39	13	1.8	1.25	10	6.8	3.79
Plate maxilla and no retention mandible	9	2.4	0.87	9	1.9	1.25	9	2.3	1.51	7	10.1	2.48
Wire mandible and no retention maxilla	1	1.4	—	1	4.0	—	1	2.2	—	1	9.8	—
No retention	7	2.9	0.95	—	—	—	7	5.1	1.55	6	11.6	2.13
Total, all cases with any type of retention	23	2.1	0.75	23	2.7	1.45	23	2.0	1.64	18	8.2	3.55
All treated cases	30	2.3	0.85	30	2.1	1.75	30	2.7	2.07	24	9.1	3.54

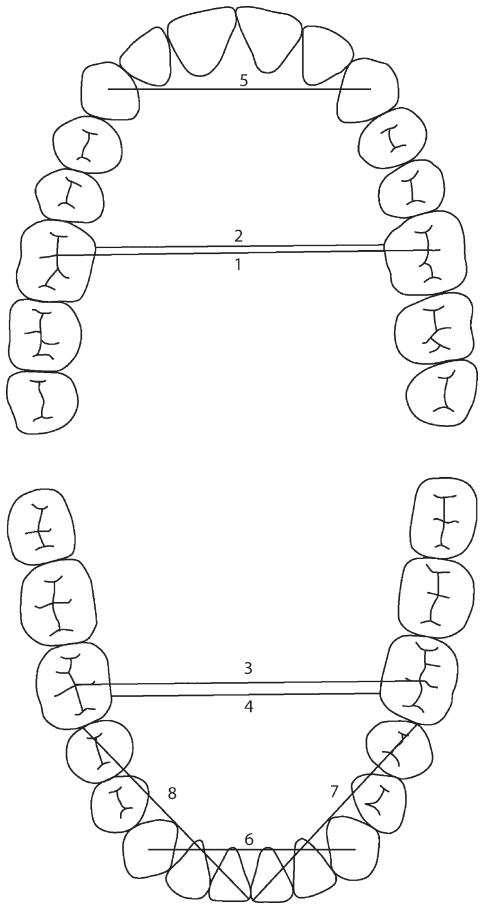

Figure 1 Reference points and distances used for measurements on dental casts. (1) Maxillary intermolar width, central fossa: the distance between the central fossae of the maxillary first molars. (2) Maxillary intermolar width, gingival crest: the distance between the maxillary first molars at the gingival crest. (3) Mandibular intermolar width, central fossa: the distance between the central fossae of the mandibular first molars. (4) Mandibular intermolar width, gingival crest: the distance between the mandibular first molars at the gingival crest. (5) Maxillary intercanine distance: cusp tip to cusp tip of the maxillary canines. (6) Mandibular intercanine distance: cusp tip to cusp tip of the mandibular canines. (7) Mandibular lateral arch length, left side: mesial contact point of mandibular first molar to mesial contact point of central incisor, left side. (8) Mandibular lateral arch length, right side: mesial contact point of mandibular first molar to mesial contact point of central incisor, right side.

Chi-square analyses were used to analyse dichotomous variables and the data was measured on an ordinal scale. The Student's *t*-test was used to determine the significance of differences between two independent samples, and paired sample *t*-tests to analyse longitudinal changes within the groups. Significance tests were two-tailed, and $P < 0.05$ was considered significant (Nie *et al.*, 1975).

Intraclass correlation coefficients were used to compute test–retest reliability estimates.

These measurements were made after a 1-month interval on the dental casts of 15 patients in the control group and on the lateral cephalograms of 15 patients in the treatment group.

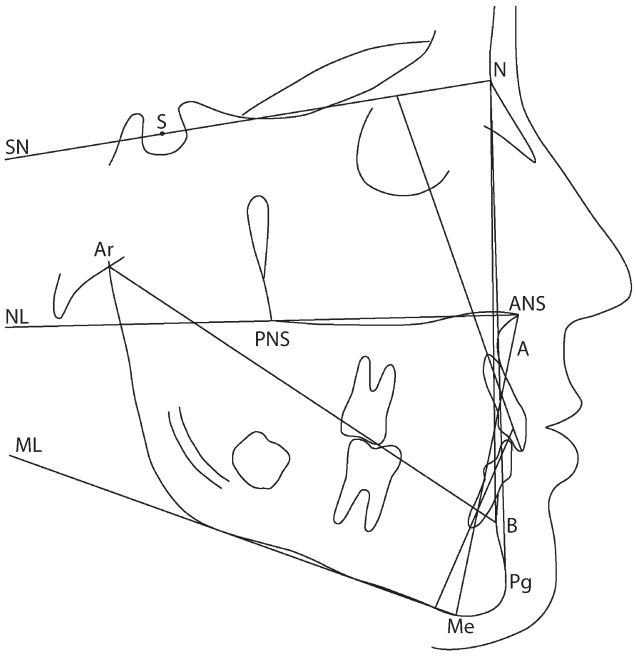

Figure 2 Reference points and lines used for measurements on the lateral cephalograms. Ar, articulare; S, sella; N, nasion; A, subspinale; B, supramentale; Pg, pogonion; Me, menton; ANS, anterior nasal spine; PNS, posterior nasal spine; ML, mandibular line; NL, nasal line; SN, nasion sella line.

Results

In the treatment group, overbite as well as overjet was normalized during treatment. At the last two registrations, overbite was significantly larger in the treatment group compared with the control group (Table 3), but in most patients, the reduction in overbite was stable within a normal range.

Comparison of values from the group treated with fixed appliances and those treated with functional appliances showed no significant differences.

At the end of treatment there was almost no difference between the patients in the treatment or control group with Class I occlusions without malocclusions and no need for orthodontic treatment.

Measurements of study models

Overbite, overjet. The overbite was reduced from a mean of 5.8 mm (SD 1.35) to a mean of 2.8 mm (SD 0.90), and the overjet from a mean of 7.0 mm (SD 2.91) to a mean of 3.4 mm (SD 1.09) during treatment. At T4, a mean 11.3 years after treatment, minor relapses were observed (Table 3). The overbite in the control group was approximately half a millimetre larger, a significant amount, at T2 than at the other three registrations (Table 3).

The overjet in the controls was significantly reduced at the last three registrations compared with that at T1, at the mean age of 8.8 years (Table 3).

Comparisons of the treatment and control groups revealed significant differences at T1 for both overbite and overjet.

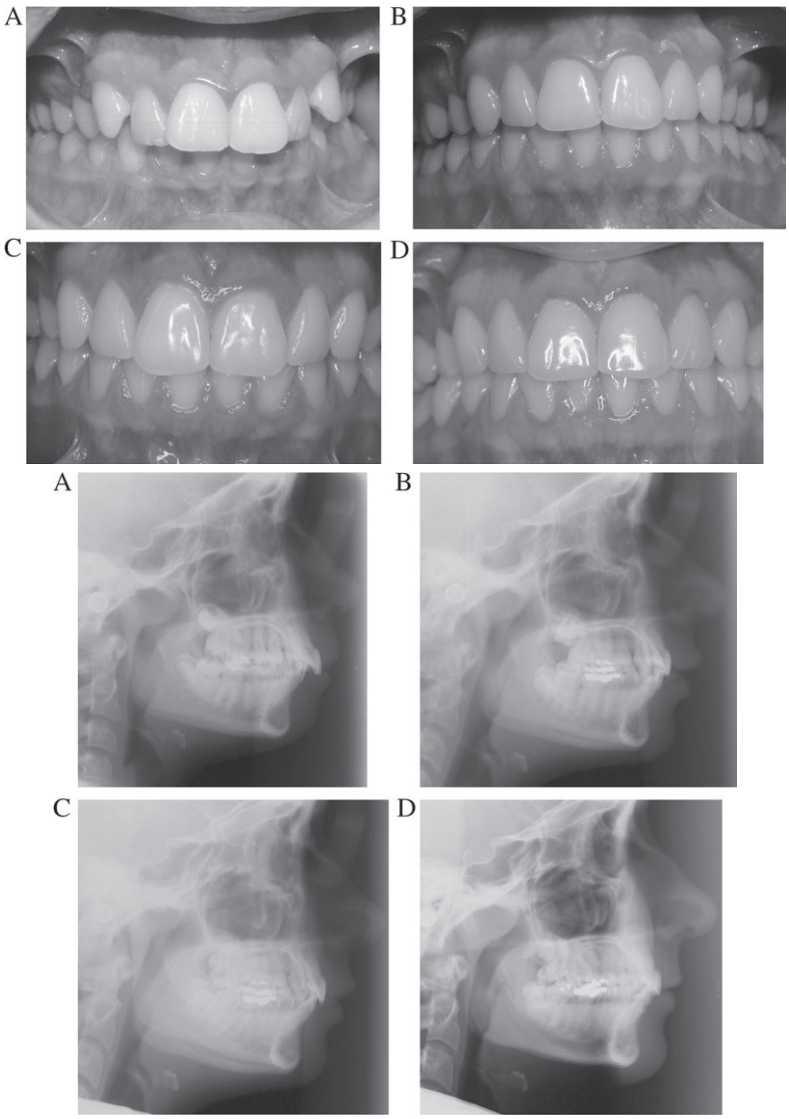

Figure 3 Cephalograms and intraoral photographs illustrating the mean values at the four registrations. (A) First registration at 12.2 years, deep bite. (B) Second registration, corrected overbite, 14.8 years. (C) Third registration, 5 years after treatment. (D) Last registration at 26.1 years of age, a minor relapse (0.8 mm) of the overbite.

At T3 and T4, overbite in the treated group was larger than in the control group (Table 3). No differences in overjet, however, were observed at T2, T3, or T4.

Intermolar width. Only for mandibular intermolar width, measured between the central fossae, was there a small but significant difference between the two groups: a mean of 40.8 mm (SD 2.45) in the treatment group and 42.1 mm (SD 2.29) in the control group (Table 3).

In the treatment group, both variables for intermolar width in the maxilla and the mandible were largest at T2. Similar results were found for the controls (Table 3).

Intercanine distance. Only at T1 there was a significant difference between the treatment and control groups in maxillary intercanine distance. The mean distance was 34.0 mm (SD 2.09) and 32.6 mm (SD 2.24), respectively (Table 3).

In the treatment group, the small but significant increase in maxillary intercanine distance between T1 and T2 had decreased at T3 and T4. Registration at T1 was different from that at T2; T2 was also different from T3 and T4. Significant differences in mandibular intercanine distances were found only between T2 and T3 and T4 registrations (Table 3).

In the control group, the maxillary intercanine distance was the least at T1 and was different from T2, T3, and T4. For mandibular intercanine distance, the registrations at T1 and T2 were different from those at T3 and T4 (Table 3).

Lateral arch length. There was a significant difference between the treatment and control groups in mandibular lateral arch length at T1 (Table 3). When the four registrations were compared, the mandibular lateral arch length on the

Table 2 Mean age in years, standard deviations (SD), and number of children (*n*) at the four registrations for the subjects in the treatment and control group.

Registration	Treatment group			Control group		
	n	Mean	SD	*n*	Mean	SD
Before treatment, (T1)	30	12.2	1.56	32	8.8	0.49
After treatment, (T2)	30	14.8	1.45	30	13.6	2.01
Follow-up I, (T3)	30	19.4	2.22	29	20.7	1.89
Follow-up II, (T4)	24	26.1	2.74	23	30.6	0.97

left side in the treatment group was significantly smaller at T4 than at T1 or T2. On the right side, however, the measurements at T1 and T2 were significantly larger than at T3 and T4 (Table 3).

In the control group, mandibular lateral arch length also decreased significantly from T1 to T4. The measurements at T1 and T2 were significantly different from those at T3 and T4 both for the left and the right sides (Table 3).

Mandibular incisor crowding. For the treatment group the available space for the mandibular incisors was −0.5 mm (SD 1.51) at T1, 0.1 mm (SD 0.74) at T2, and −0.9 mm (SD 1.31) at T4. The available space was thus greatest at T2 and lowest at T3 and T4 (Table 3). The value at T2 was significantly separated from those at T3 and T4 (Table 3).

The space available for the mandibular incisors in the control group decreased continually from T1 to T4 (Table 3). Only at T4 there was a small but significant difference between the mean values in the treatment and control groups.

Cephalometric measurements

Intermaxillary relationship. At T1, ANB angle was significantly larger in the treatment group than in the control group. The differences between the two groups were not significant at T2, while at T3 and T4 the treatment group again had significantly larger values (Table 4). ANB angle was largest at T1 in both the treatment and control group. Comparison between the four different registrations showed that these mean values were significantly separated from the mean values at T2, T3, and T4 (Table 4).

SNB angle in the treatment group differed significantly from that in the control group at T1, T2, and T3 with the greatest difference at T3. The control group had the highest values. SNB angle was smallest at T1 in both groups. These mean values were significantly separated from those at T2, T3, and T4 (Table 4). In the treatment group, the mean value at T2 was also significantly separated from the mean values for the other three registrations (Table 4).

No differences in SNA angle were observed between the treatment or control group at any of the registration periods (Table 4).

Mandibular plane angle. At T1, the mandibular plane angle was smaller in the deep bite patients than in the control group. During T2 and T3, the angle decreased in both groups (Table 4). The measurements at T1 were significantly different from T3 and T4. In the treatment group, the difference between T2 and T3 was also significant (Table 4).

Intermaxillary angle. The angle between ANS-PNS (NL) and the mandibular line (ML) was significantly larger in the control group than in the treatment group at T1 (Table 4). The values for the two groups then became increasingly similar, and at T3 and T4 the differences were not significant. A comparison between the four registrations showed that the measurements at T1 had the highest mean value. Registration at T1 was significantly separated from T2, T3, and T4 both for the treated and control group (Table 4).

Incisors. At T1 and T2, there were no differences between the treatment and control groups for the maxillary incisors in relation to NA. Neither were there any differences between the treatment or control group for the mandibular incisors in relation to the ML at T1 or T4. The mean value for the mandibular incisors in relation to APg was significantly less in the treated than in the control group at T1. In the treatment group, the mandibular incisors were behind APg. The difference in interincisal angle between the two groups at T1 was also significant (Table 4).

No differences between the four registrations for the maxillary incisors were observed in relation to either NA or interincisal angle in the treated group (Table 4).

The mandibular incisors proclined during treatment, and this proclination decreased at T3 and T4. There was no significant difference between T1 and T4.

For the variable, mandibular incisor to APg, there was a significant difference between T1 and T2, T3, and T4 for both the treatment and control groups.

Growth. Vertical growth, measured as the distance ANS to Me, increased significantly in both groups from T1 to T3, which was at the mean age of 19.4 years for the treatment group and 20.7 years for the control group. From T2 to T3, the control group experienced more vertical growth, resulting in a significant difference between the groups at T3 (Table 4).

Growth in the treatment group continued from T3 to T4 while there was no change in the control group (Table 4).

Horizontal growth, measured as the distance Ar to B, continued throughout the observation period in the treatment group. In the control group, growth continued only to T3 (Table 4). The differences between the two groups at T1 and T3 were significant (Table 4).

Discussion

The subjects were a group of children with deep bite malocclusions and a control group with Class I occlusions without treatment need. Treatment for the deep bite patients consisted of fixed appliances in 23 cases and functional treatment in seven. Both groups were measured four times.

Table 3 Comparison between the treatment and control groups for the mean values and standard deviations (SD) of the 11 variables, measured on the plaster models (mm) and differences between the four registrations T1–T4. Treatment time (T1), retention time (T2) and time after retention (T3 and T4).

Variables	T1				T2				T3				T4				Differences at the 5 per cent level between the four registrations T1–T4
	n	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	
Overjet																	
Treatment group	29	7.0	2.91	***	30	3.4	1.09		30	3.7	1.24		25	3.9	1.30		T1 ≠ T2, T3, T4
Control group	32	4.1	2.13		30	3.5	1.39		31	3.2	1.52		23	3.3	1.78		T1 ≠ T2, T3, T4
Overbite																	
Treatment group	29	5.8	1.35	***	30	2.8	0.90		30	3.3	1.03	*	24	3.6	0.92	***	T1 ≠ T2, T3, T4; T2 ≠ T1 T3 T4
Control group	32	2.4	1.97		30	2.9	1.50		31	2.5	1.38		23	2.2	1.42		T2 ≠ T1, T3, T4
Maxillary intermolar width, central fossa																	
Treatment group	29	45.6	2.62		30	47.3	2.54		30	46.7	2.62		25	46.4	2.74		T1 ≠ T2,T3; T2 ≠ T1, T3, T4
Control group	32	46.9	2.62		30	48.3	3.01		31	47.8	3.12		23	47.2	2.68		T1 ≠ T2, T3; T2 ≠ T1, T4; T3 ≠ T1, T4
Maxillary intermolar width, gingival crest																	
Treatment group	29	34.0	2.76		30	35.4	2.57		30	34.9	2.57		25	34.5	2.69		T1 ≠ T2, T3; T2 ≠ T1, T3, T4; T3 ≠ T1, T2,T4
Control group	32	35.2	2.86		30	36.1	3.00		31	35.9	3.02		23	35.0	2.67		T1 ≠ T2; T3 ≠ T4
Mandibular intermolar width, central fossa																	
Treatment group	29	40.8	2.45	*	30	42.0	1.85		30	41.4	2.31		25	41.0	2.51		T1 ≠ T2; T2 ≠ T1, T3, T4; T3 ≠ T2, T4
Control group	32	42.1	2.29		30	42.3	2.87		31	42.1	3.00		23	41.2	2.58		T2 ≠ T4
Mandibular intermolar width, gingival crest																	
Treatment group	29	32.3	2.35		30	33.2	1.84		30	32.8	2.36		25	32.5	2.44		T1 ≠ T2; T2 ≠ T1, T4; T3 ≠ T4
Control group	32	33.2	1.94		30	33.7	2.38		31	33.5	2.65		23	32.6	2.19		T4 ≠ T1, T2, T3
Maxillary intercanine distance																	
Treatment group	20	34.0	2.09		30	34.9	2.01		30	34.4	2.19		25	34.4	2.13		T1 ≠ T2; T2 ≠ T3, T4
Control group	31	32.6	2.24	*	30	34.9	2.56		31	34.6	2.36		23	34.3	2.36		T1 ≠ T2, T3, T4; T2 ≠ T1, T4; T3 ≠ T1, T4
Mandibular intercanine distance																	
Treatment group	26	26.2	1.80		30	26.4	1.49		30	25.6	1.51		25	25.2	1.61		T2 ≠ T3, T4
Control group	29	26.8	1.79		30	27.2	1.93		31	26.2	1.87		23	25.9	1.99		T1 ≠ T3, T4; T2 ≠ T3, T4; T3 ≠ T1, T2, T4
Mandibular lateral arch length, left																	
Treatment group	29	31.1	2.06		30	31.1	1.77		30	30.3	2.02		25	30.1	2.07		T1 ≠ T4; T2 ≠ T4
Control group	32	32.9	1.73	***	30	31.9	1.49		31	30.8	1.30		23	30.4	1.38		T1 ≠ T3, T4; T2 ≠ T3, T4; T3 ≠ T1, T2, T4
Mandibular lateral arch length, right																	
Treatment group	29	30.6	2.04		30	31.1	1.57		30	29.9	1.81		25	29.7	2.03		T1≠ T3,T4; T2≠ T3,T4
Control group	32	32.9	1.72	***	30	32.1	1.81	*	31	30.7	1.73		23	29.5	4.26		T1 ≠ T3, T4; T2 ≠ T3, T4; T3 ≠ T1, T2

Table 3 Continued.

Variables	T1				T2				T3				T4				Differences at the 5 per cent level between the four registrations T1–T4
	n	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	
Available mandibular incisor space																	
Treatment group	29	−0.5	1.51		29	0.1	0.74		29	−0.7	0.83		25	−0.9	1.31		$T2 \neq T3, T4$
Control group	32	0.2	1.31		29	0.0	1.41		30	−0.1	1.17		22	−1.8	1.54	*	$T1 \neq T3, T4; T2 \neq T3, T4; T3 \neq T1, T2, T4$

$^*P < 0.05$; $^{***}P < 0.001$.

At T1, there was discrepancy between the mean ages of the groups. The children in the control group were younger, mean age 8.8 years (SD 0.49), compared with those in the treatment group, mean age of 12.2 years (SD 1.56). This may, of course, have influenced some of the comparisons, for example, intercanine distance. It is likely that the children in the control group would have had a larger overbite at 12 years than at 9 years of age. Bergersen (1988) found an increase in overbite of 0.3 mm from 9 to 12 years of age. A similar change was also found in the control group in the present study where the overbite increased by 0.5 mm from 9 to 13.5 years of age. This initial discrepancy in age between the control and treatment groups has thus a minor effect on overbite compared with the treatment effects. At T3, the mean ages were almost equal, and differed by just 1 year. At T4, however, the difference between the mean ages was approximately 4.5 years. These differences occurred because of the difficulties in finding completely matched groups. The dropout of patients was of course larger at T4 and was equally large in both the treatment and control groups.

At T1, there was a significant difference between the treatment and control groups in overbite and overjet. This was because the treatment group comprised patients with a deep bite and an overbite of 4.5 mm or more, and most had an Angle Class II division 1 malocclusion with increased overjet.

The overjet increased in the treatment group from T2 to T4. The same tendency has been seen in other studies (Little *et al.*, 1981; Rönnerman and Larsson, 1981; Udhe *et al.*, 1983). Little *et al.* (1981) especially found the overjet relapse to be larger in Class II division 1 subjects.

This was not seen in the control group where the overjet decreased from T1 to T3 and changed very little between T3 and T4.

As found in a number of investigations (Simons *et al.*, 1973; Little *et al.*, 1981, 1990; Uhde *et al.*, 1983; Shields *et al.*, 1985; Fidler *et al.*, 1995) overbite increases after orthodontic treatment. In the present study, there was a small but significant increase at the 5 per cent level between T2 and T4, from 2.8 mm at T2 to 3.6 mm at T4. Overbite in the control group increased by approximately 0.5 mm at T2. This increase occurred because some of the patients were still in the mixed dentition at T1, but this change was small compared with the treatment effects. At the two follow-up registrations, T3 and T4, the overbite was decreased compared with T1 (Table 3).

In general, overbite increases from 9 to 12 years of age and decreases from 12 to 16 years of age (Björk, 1953; Björk and Skieller, 1972; Bergersen, 1988). Feldmann *et al.* (1999) observed improvements in untreated Class II division 1 deep bite patients from adolescence to adulthood. From the ages of 12–23 years, the patients underwent significant improvements in overbite of 0.6 mm. This supports the improvement observed in overbite for the control group in the present study. Overbite in the

Table 4 Comparison between the treatment and control groups for the mean values and standard deviations (SD) of the 11 variables measured on cephalograms (degrees or mm) and differences between the four registrations T1–T4. Treatment time (T1), retention time (T2) and time after retention (T3 and T4).

Variables	T1				T2				T3				T4				Differences at the 5 per cent level between the four registrations T1–T4
	n	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	*n*	Mean	SD	*P*	
SNA (°)																	
Treatment group	30	82.0	3.72		23	81.1	3.95		19	81.4	3.35		21	82.7	2.96		T1 ≠ T2; T2 ≠ T1, T4
Control group	32	82.0	3.74		20	83.5	4.57		26	83.4	3.83		23	82.7	4.56		T1 ≠ T2; T2 ≠ T1, T4
SNB (°)																	
Treatment group	30	76.1	4.01	*	23	76.9	4.04	**	19	77.3	3.81	***	21	78.5	4.07		T1 ≠ T2, T3, T4; T2 ≠ T1, T3, T4
Control group	32	78.4	3.60		20	80.3	3.70		26	81.7	3.88		23	80.5	4.08		T1 ≠ T2, T3, T4
ANB (°)																	
Treatment group	30	5.9	2.17	***	23	4.1	2.10		19	4.1	2.11	**	21	4.3	2.40	**	T1 ≠ T2, T3, T4; T2 ≠ T1
Control group	32	3.6	2.39		20	3.2	2.34		26	1.7	2.13		23	2.2	2.75		T1 ≠ T2, T3, T4; T2≠ T1, T3, T4
SN/ML																	
Treatment group	30	30.3	6.88	*	23	28.9	7.35		19	27.4	6.85		21	28.5	7.05		T1 ≠ T3, T4; T2 ≠ T3
Control group	32	33.8	5.29		20	31.2	4.77		26	28.1	5.51		23	30.0	6.09		T1 ≠ T3, T4
NL/ML																	
Treatment group	30	24.0	5.60	**	22	21.7	6.62	*	19	20.8	6.40		21	22.3	6.32		T1 ≠ T2, T3, T4
Control group	32	27.7	4.50		20	25.6	4.22		26	23.8	4.96		23	24.5	4.60		T1 ≠ T2, T3, T4
Maxillary incisor/NA (mm)																	
Treatment group	29	3.3	3.67		22	2.8	2.18		19	2.5	2.63	**	21	3.0	2.25	**	No group different
Control group	32	3.8	2.25		20	3.9	2.56		26	5.4	2.69		23	5.5	3.28		T1 ≠ T3, T4; T2 ≠ T3, T4
Mandibular incisor/Apg (mm)																	
Treatment group	30	−1.2	2.68	***	23	2.2	1.68		19	1.4	2.02		20	1.1	1.80	**	T1 ≠ T2, T3, T4
Control group	32	1.8	2.42		19	2.6	2.29		26	2.5	2.56		22	2.7	2.07		T1 ≠ T2, T3, T4
Mandibular incisor/ML																	
Treatment group	30	94.1	7.44		23	103.7	10.13	**	19	102.0	5.24	***	21	97.5	6.85		T1 ≠ T2, T3
Control group	32	95.0	6.36		20	95.8	6.02		26	94.9	6.25		23	94.1	7.12		No group different
Interincisal angle																	
Treatment group	30	132.9	14.35	*	23	126.8	11.18		19	131.1	7.65		21	133.4	6.42		No group different
Control group	32	126.8	8.01		20	127.1	7.59		26	131.1	10.10		23	130.8	9.44		T1 ≠ T3
ANS-Me, vertical growth (mm)																	
Treatment group	30	64.8	6.20		23	68.8	6.95		19	71.8	8.07		21	74.8	6.60		All groups different
Control group	31	63.9	3.87		19	70.8	5.89		29	78.6	6.35	**	23	78.6	6.45		T1 ≠ T2, T3, T4; T2 ≠ T1, T3, T4; T3 ≠ T1, T2
Ar-B, horizontal growth (mm)																	
Treatment group	30	94.0	4.27		23	100.0	5.98		19	103.8	6.07		21	107.8	6.00		All groups different
Control group	31	91.2	4.11	**	19	101.2	5.94		26	111.8	6.34	***	23	110.9	6.05		T1 ≠ T2, T3, T4; T2 ≠ T1, T3, T4; T3 ≠ T1, T2

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

treated subjects, however, increased by 0.8 mm from 14.8 to 26.1 years of age, indicating a minor relapse after treatment.

The mean maxillary and mandibular intermolar width decreased after treatment when measured from both the central fossa and the gingival crest. This appears to be the same for the control group. Uhde *et al.* (1983) found similar results, as did Bishara *et al.* (1997), who observed, in an untreated sample, a decrease in maxillary and mandibular intermolar width in females but not in males between 13 and 26 years of age.

Mandibular intercanine distance was found to decrease beyond the original intercanine dimension at T4 for both the treatment and control groups. The mandibular intercanine distance increased during treatment by 0.2 mm. At T4, the intercanine width had decreased by 1.0 mm. Sixteen of the 30 treated patients had no retention in the mandible while 14 who had had retention in the mandible had been out of retention for 7 years (Table 1). A review by Burke *et al.* (1998) demonstrated that the mandibular intercanine width tended to expand during treatment by 0.8–2.0 mm regardless of pre-treatment classification or whether treatment was extraction or non-extraction but tended to constrict post-retention by 1.2–1.9 mm. In the present study, these values were smaller than those of Burke *et al.* (1998).

The maxillary intercanine distance was almost the same for both the treatment and control groups at all registrations. The only difference that was significant was measured at T1 because the children in the control group were younger at this registration (3.4 years younger) than in the treatment group. Kahl-Nieke *et al.* (1996) found post-retention arch width relapse to occur more frequently in the mandibular (23.9 per cent) than in the maxillary (13.8 per cent) intercanine region.

There was a highly significant difference between the treatment and control groups in mandibular lateral arch length at T1, with the largest values in the control group. The difference in age between the treatment (12.2 years) and the control (8.8 years) groups explains this difference. Bishara *et al.* (1998) found that mandibular arch length continued to increase until 8 years, and between 8 and 13 years began to significantly decrease.

The mandibular plane angle and the intermaxillary angle decreased in both groups from T1 to T3 and then increased at T4. This is in agreement with Forsberg (1979) who found that the mandibular plane angle in an untreated sample increased in both genders from 24 to 34 years of age.

There was less vertical and horizontal growth in the treatment group compared with the control group. Between T3 and T4, however, more vertical and horizontal growth was observed in the treatment group than in the control group. In both groups, the subjects were nearly 20 years of age at T3. In the treatment group, vertical growth as well as horizontal growth continued. This may be a delayed effect caused by the treatment and the retainers.

While the maxillary incisors became more proclined in the control group from T1 to T4, their position remained unchanged in the treatment group. Despite proclination of the incisors, the mandibular anterior teeth in control group were more crowded than in the treatment group.

The mandibular incisors to APg also had a larger value in the control than in the treatment group at T4. The mandibular incisors to ML were more proclined in the treatment group only from T1 to T3. This is in agreement with Parker *et al.* (1995), who found that treatment of overbite primarily affected the proclination of the incisors. At T4, the position of the mandibular incisors was observed to be in a normal position and more upright. This could be one explanation for the increased overbite seen at T4, a phenomenon that was also observed by Riedel (1960), Ludwig (1967), and Kim and Little (1999). Fidler *et al.* (1995) found an overbite relapse of 0.9 mm in a successfully treated Class II division 1 sample 14 years post-retention. In their study, the mandibular incisors were not proclined during treatment and they did not change in mean inclination post-retention. That study included extraction as well as non-extraction cases, which probably explains the unchanged group mean in mandibular incisor inclination (Fidler *et al.,* 1995).

In the present study, no differences between the four registrations was observed regarding the interincisal angle in the treatment group. This could be one reason why the long-term results were favourable. Riedel (1960), Ludwig (1967), and Berg (1983) considered a larger interincisal angle to be more prone to overbite relapse.

Even though the treatment group had a larger overbite, mandibular anterior crowding was less than in the control group.

Conclusions

The long-term stability of the corrected deep bite and the corrected space deficiency in the mandibular anterior segment was good both 5 years as well as 11 years after treatment. Although the overbite tended to exhibit a relapse of 0.8 mm at T4 in the treatment group, it was still within the normal range, mean 3.6 mm (SD 0.92). The overbite in the control group underwent a bite opening of 0.7 mm during the same period.

The mandibular incisors proclined significantly in relation to ML during treatment but had normalized at T4. Despite this, the available mandibular incisor space was less, −1.8 mm, in the control group compared with the treatment group, −0.9 mm.

The findings of the study showed no differences in the interincisal angle between the four registrations in the treatment group. Both groups developed anterior rotation of the mandible between T1 and T3. SN/ML angle as well as the NL/ML angle decreased. After the patients reached 20 years of age, between T3 and T4, these angles further increased.

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References

Årtun J, Garol J D, Little R M 1996 Long-term stability of mandibular incisors following successful treatment of Class II, division 1, malocclusions. The Angle Orthodontist 66: 229–238

Berg R 1983 Stability of deep overbite correction. European Journal of Orthodontics 5: 75–83

Bergersen E 1988 A longitudinal study of anterior vertical overbite from eight to twenty years of age. The Angle Orthodontist 58: 237–256

Bishara S E, Jakobsen J R, Treder J, Nowak A 1997 Arch width changes from 6 weeks to 45 years of age. American Journal of Orthodontics and Dentofacial Orthopedics 111: 401–409

Bishara S E, Jakobsen J R, Treder J, Nowak A 1998 Arch length changes from 6 weeks to 45 years. The Angle Orthodontist 68: 69–94

Björk A 1947 The face in profile. Svensk Tandläkare Tidskrift 40 (Supplement 1)

Björk A 1953 Variability and age changes in overbite and overjet. American Journal of Orthodontics 39: 779–801

Björk A, Skieller V 1972 Facial development and tooth eruption: an implant study at the age of puberty. American Journal of Orthodontics 62: 339–383

Blake M, Bibby K 1998 Retention and stability: a review of the literature. American Journal of Orthodontics and Dentofacial Orthopedics 114: 299–306

Burke S P, Silveira A M, Goldsmith L J, Yancey J M, Van Stewart A, Scarfe W C 1998 A meta-analysis of mandibular intercanine width in treatment and postretention. The Angle Orthodontist 68: 53–60

Canut J A, Arias S 1999 A long-term evaluation of treated Class II, division 2, malocclusions: a retrospective study model analysis. European Journal of Orthodontics 21: 377–386

Feldmann I, Lundström F, Peck S 1999 Occlusal changes from adolescence to adulthood in untreated patients with Class II, division 1, deepbite malocclusion. The Angle Orthodontist 69: 33–38

Fidler B C, Årtun J, Joondeph D R, Little R M 1995 Long-term stability of Angle Class II, division 1, malocclusions with successful occlusal results at end of active treatment. American Journal of Orthodontics and Dentofacial Orthopedics 107: 276–285

Forsberg C M 1979 Facial morphology and ageing: a longitudinal cephalometric investigation of young adults. European Journal of Orthodontics 1: 15–23

Kahl-Nieke B, Fischbach H, Schwarze C W 1996 Treatment and postretention changes in dental arch width dimensions a long-term evaluation of influencing cofactors. American Journal of Orthodontics and Dentofacial Orthopedics 109: 368–378

Kim T-W, Little R M 1999 Postretention assessment of deep overbite correction in Class II, division 2, malocclusion. The Angle Orthodontist 69: 175–186

Little R M, Riedel R A, Stein A 1990 A mandibular arch length increase during the mixed dentition. Postretention evaluation of stability and relapse. American Journal of Orthodontics and Dentofacial Orthopedics 97: 393–404

Little R M, Wallen T R, Riedel R A 1981 Stability and relapse of mandibular anterior alignment first premolar extraction cases treated by traditional edgewise orthodontics. American Journal of Orthodontics 80: 349–365

Ludwig M 1967 A cephalometric analysis of the relationship between facial pattern, interincisal angulation and anterior overbite changes. The Angle Orthodontist 37: 194–204

Nie N H, Hull C H, Jenkins J G, Steinbrenner K, Bent D H 1975 SPSS statistical package social sciences, 2nd edn. McGraw-Hill, New York

Parker C D, Nanda R S, Currier G F 1995 Skeletal and dental changes associated with the treatment of deep bite malocclusion. American Journal of Orthodontics and Dentofacial Orthopedics 107: 382–393

Riedel R A 1960 A review of the retention problem. The Angle Orthodontist 30: 179–199

Rönnerman A, Larsson E 1981 Overjet, overbite, intercanine distance and root resorption in orthodontically treated patients. Swedish Dental Journal 5: 21–27

Shields T E, Little R M, Chapko M K 1985 Stability and relapse of mandibular anterior alignment: a cephalometric appraisal of first premolar extraction cases treated by traditional edgewise orthodontics. American Journal of Orthodontics 87: 27–38

Simons M E, Joondeph D R 1973 Change in overbite: a ten-year postretention study. American Journal of Orthodontics 64: 349–366

Solow B 1966 The pattern of craniofacial associations. Acta Odontologica Scandinavica 24 (Supplement 46)

Uhde M D, Sadowsky C, BeGole E A 1983 Long-term stability of dental relationships after orthodontic treatment. The Angle Orthodontist 53: 240–252

Zachrisson B U 1997 Important aspects of longterm stability. Journal of Clinical Orthodontics 31: 562–583