Proximal alveolar bone level after orthodontic treatment with magnets, superelastic coils and straight-wire appliances

Lars Bondemark, DDS, Odont dr; Jüri Kurol, DDS, Odont dr

The purpose of orthodontic treatment is to move teeth as efficiently as possible with minimal adverse effects on teeth and supporting tissues. Intentionally moving a tooth presupposes resorption of supporting tissues on the pressure side and apposition of tissues on the tension side. Orthodontic movement thus depends on the physiological processes of cell activity in the periodontal connective tissue and osteoblast-osteoclast activity in the alveolar bone.[1,2]

Considerable attention has been focused on the relationship between orthodontic therapy and periodontal changes. For evaluating changes of periodontal support of teeth, radiographic quantification of crestal alveolar bone level is a valuable aid.[3,4] Currently information about the effect of orthodontic treatment on crestal alveolar bone level is contradictory: lack of effects,[5-8] detrimental effects[9-11] and transient effects[12] have been reported.

It has recently been shown that effective and rapid orthodontic tooth movements, up to 6 mm in 6 months, can be achieved with new force systems, such as magnets[13,14] and superelstic coils, i.e., Japanese nickel-titanium alloys.[15-17] Rapid tooth movement demands fast reorganization and adaptation of soft tissue and alveolar bone

Abstract

Proximal alveolar bone level changes were radiographically determined in 20 subjects (mean age 14.3 years, SD 2.00) a short time after rapid orthodontic treatment with magnets and superelastic nickel-titanium coils succeeded by straight-wire appliances. The findings were compared with a matched control group of 20 individuals (mean age 14.3 years, SD 1.99) who had no history of orthodontic treatment. Proximal alveolar bone level changes were determined on bitewing radiographs as the distance between the cementoenamel junction (CEJ) and the alveolar bone crest (AC). The observation period was 2.7 years (SD 0.65) for the treatment group and 2.8 years (SD 0.65) for the control group. In the treatment group, a small mean increase of 0.2 mm (SD 0.29) in the CEJ-AC distance was found a short time after treatment. In the control group the increase in CEJ-AC distance was 0.1 mm. The difference between the groups was significant ($P<0.001$). In the treatment group, sites in the maxilla showed significantly greater CEJ-AC distances than in the mandible ($P<0.001$), 0.3 mm (SD 0.33) versus 0.1 mm (SD 0.24). The mesial sites of the maxillary first molars in the treatment group showed the highest average increase in distance between CEJ and AC, mean 0.5 mm (SD 0.33). Neither group had any sites with bone loss, i.e., CEJ-AC distance exceeding 2 mm. No significant difference was found in CEJ-AC distance between teeth moved with magnets succeeded by straight-wire appliances and teeth moved with superelastic coils succeeded by straight-wire appliances.

Key Words

Alveolar bone level • Magnets • Orthodontic appliance • Radiography • Superelastic coils

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Table 1
Age (years), sex, decayed, missing, and filled teeth (DMFT), and decayed, missing, and filled surfaces proximally (DMFS-p) of two groups at the first examination.

	Treatment group n = 20	Control group n = 20
Age		
Mean	14.3	14.3
SD	2.00	1.99
Range	11.3-19.2	11.5-19.0
Sex		
Male	5	5
Female	15	15
DMFT		
Mean	3.8	3.3
SD	3.07	3.43
Range	0-8	0-12
DMFS-p		
Mean	0.5	0.7
SD	1.15	1.30
Range	0-4	0-4

both initially and throughout the treatment period. Until now no studies have evaluated the influence of magnet and superelastic force systems in combination with straight-wire appliances on the proximal alveolar bone level.

The aim of this investigation was to radiographically determine and compare proximal alveolar bone level changes in individuals who had completed rapid orthodontic tooth movement with magnets and superelastic coils succeeded by straight-wire appliances, and to relate the findings to individuals who had no history of orthodontic treatment.

Materials and methods

Subjects and orthodontic appliances

Two groups, one treated and one untreated control, each with 20 adolescents, participated in the study (Table 1). The treatment group had completed simultaneous distal movement of the maxillary first and second molars using repelling samarium-cobalt magnets (Modular Magnetics Inc, New York, NY) on one side and superelastic nickel-titanium open coils (GAC International Inc, Central Islip, NY) on the contralateral side (Figure 1). The forces of each magnet pair and each open coil were were calibrated to 225 g at the start of treatment and when reactivation was performed every fourth week. The magnets and coils, which were attached to the headgear tube of the maxillary first molar band, were inserted alternately in the right and left sides to avoid possible right or left side biases. For bite opening and anchorage reinforcement, a palatal bar was soldered onto the second premolar bands and was connected to an anterior acrylic bite plane. (For details, see Bondemark et al.[17]) Then, after 6 months of distal molar movement and bite opening, the magnets and coils were removed and straight-wire appliances ("A"-Company Inc, San Diego, Calif) were inserted in the upper and lower arches for leveling and retraction of the anterior teeth (Figure 1). The straight-wire appliances were used for a mean period of 1.5 years (SD 0.13, range 1.2-1.7 years). Hence, in the maxilla the treatment group was divided into two subgroups, magnets succeeded by straight-wire appliances (M) and superelastic coils succeeded by straight-wire appliances (S). In the mandible, treatment was completed using a straight-wire appliance only.

The control group, which had not received any form of orthodontic treatment, was selected to match the treatment group as closely as possible with respect to age, sex, residential area, decayed, missing and filled teeth (DMFT) and decayed, missing, and filled surfaces proximally (DMFS-p) (Table 1). The adolescents in both groups had received free annual dental care from 3 years of age under the Swedish public dental health system. The good oral health status of the subjects was evident: at the first examination appointment, 80% of the treatment group and 70% of the control group had no caries or fillings on proximal surfaces.

Individuals in both groups were instructed to clean their teeth properly twice daily using rotating movements of the toothbrush. Subjects in the treatment group were also told to use a single tufted toothbrush (Interspace® Lactona) for better access to the orthodontic appliance, and to the tooth surfaces and gingival margins adjacent to the appliance. Furthermore, subjects in the treatment group were recalled every third month for plaque staining and tooth polishing with a fluoride-containing polishing paste.

Radiographic examination

Two radiographic examinations were performed. The time between the two examinations was 2.7 years (SD 0.55, range 1.8-3.6 years) for the treatment group (including the treatment period) and 2.8 years (SD 0.65, range 1.6-3.7 years) for the control group. The radiographic examination included two posterior bitewing radiographs. Projections were standardized with a vertical angle of 10 degrees and the central beam was directed to the mesial surface of the maxillary first molars. Radiographs were taken with a dental x-ray unit (Philips Oralix, 65 kV)

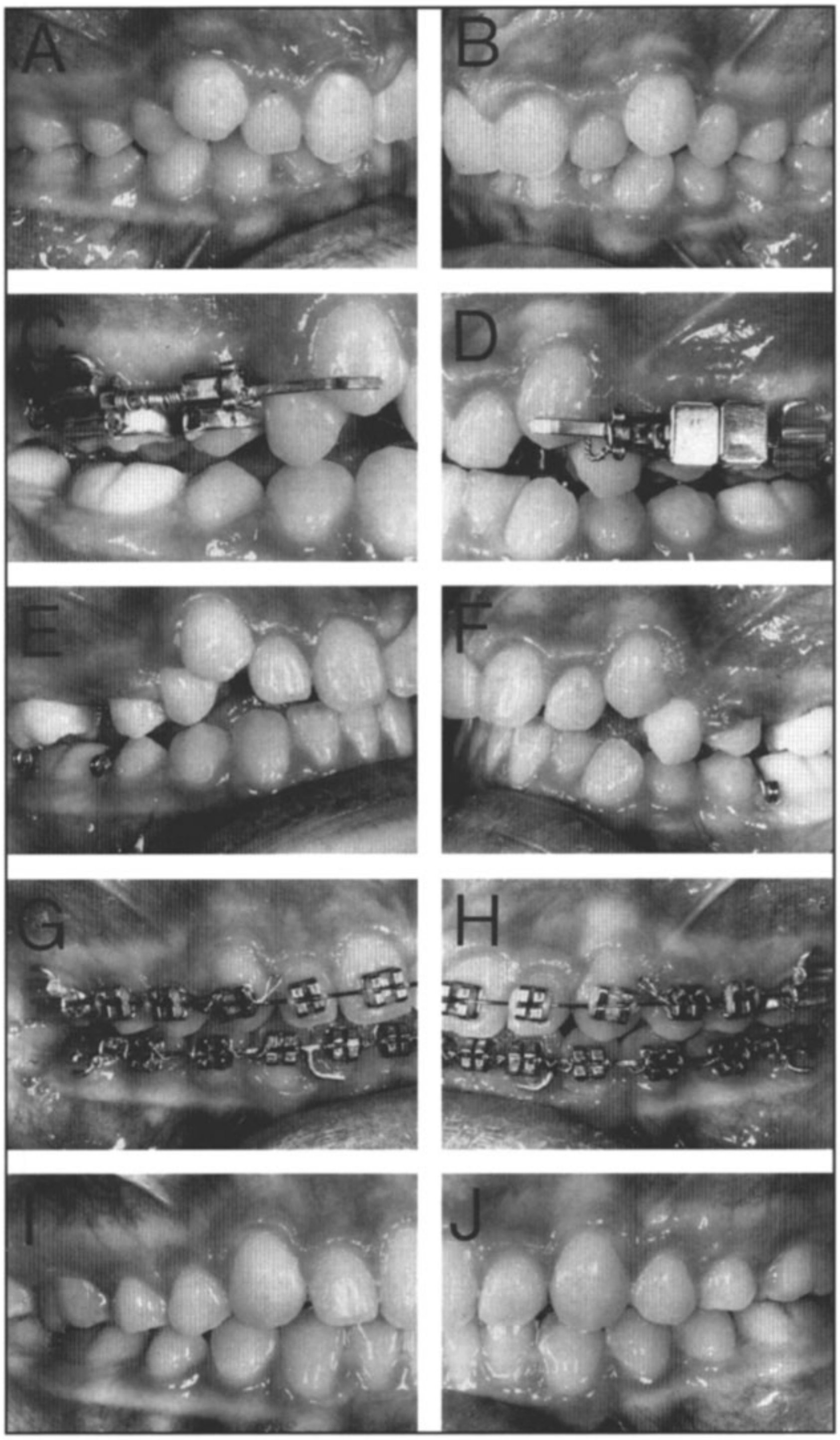

Figure 1

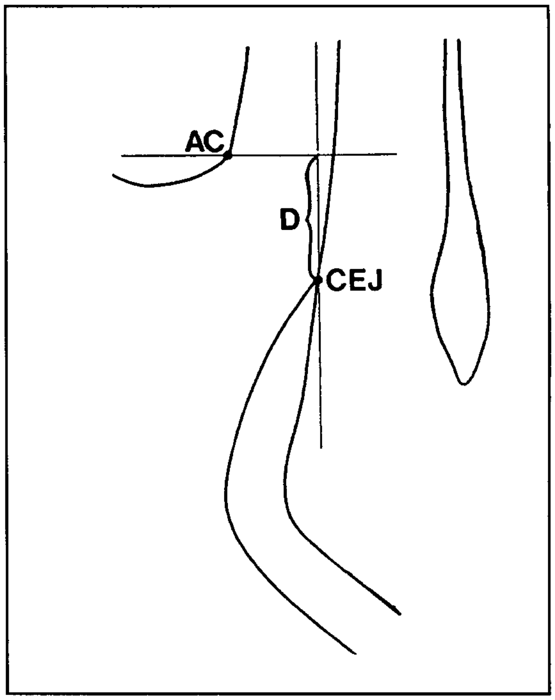

Figure 2

Figure 1A-J
A girl from the treatment group with Class II malocclusion, deep bite, and space deficiency in the maxilla, treated with a superelastic coil on the right side and repelling magnets on the left for distal movement of maxillary molars. Following distal movement of the molars, a straight-wire appliance was used for leveling and retraction of the anterior teeth.
A-B: Before treatment;
C-D: Following insertion of supercoil and magnets. After 6 months a Class I molar relationship was achieved;
E-F: Separation springs were inserted in the lower arch to prepare for the straight-wire appliance;
G-H: Subsequent straight-wire appliance in the upper and lower arches;
I-J: The final result after a total treatment period of 2.1 years.

Figure 2
Schematic illustration of the measured distance between the cementoenamel junction (CEJ) and alveolar bone crest (AC). Modified from Zachrisson and Alnaes, 1974.

using a long rectangular cone (20 cm/8.5 inch). Ekta-speed film (Kodak EP-22) was used and developed as recommended by the manufacturer.

All radiographs were mounted identically and coded by an independent person. Radiographs from the treatment and control groups were intermixed in order to facilitate blind examination between groups and between the first and second examinations.

The radiographs were examined by one examiner (LB) in a darkroom using a bright-light lamp that was framed to avoid stray light. A PEAK scale magnifier (magnification x7) with a scale allowing measurements to the nearest 0.1 mm was used for the analysis of the radiographs.

To measure the proximal alveolar bone level, interproximal measurements were made of the distance along a line parallel to the long axis of the tooth between the cementoenamel junction (CEJ) and the alveolar bone crest (AC). The CEJ

Table 2
Changes in distance (mm) between the cementoenamel junction (CEJ) and alveolar bone crest (AC) in the maxillary arch during the observation period. Two treatment groups were assessed—magnets succeeded by straight-wire appliances (M) and supercoils succeeded by straight-wire appliances (S)—and one control group (C).

Tooth surface and group	n	X	Maxillary arch SD	X_{min}	X_{max}	Probability
Second molar mesial						
M	18	0.3	0.31	0.0	1.0	M-S : NS
S	19	0.3	0.37	0.0	1.0	M-C : **
C	38	0.1	0.21	0.0	0.5	S-C : **
First molar distal						
M	20	0.2	0.25	0.0	0.5	M-S : NS
S	20	0.2	0.26	0.0	0.5	M-C : NS
C	40	0.2	0.34	0.0	1.5	S-C : NS
First molar mesial						
M	20	0.5	0.34	0.0	1.0	M-S : NS
S	20	0.5	0.33	0.0	1.0	M-C : ***
C	40	0.1	0.19	0.0	0.5	S-C : ***
Second premolar distal						
M	18	0.2	0.39	0.0	1.0	M-S : NS
S	20	0.2	0.24	0.0	0.5	M-C : **
C	40	0.1	0.20	0.0	0.5	S-C : NS
Second premolar mesial						
M	18	0.2	0.25	0.0	0.5	M-S : NS
S	20	0.2	0.30	0.0	0.5	M-C : NS
C	40	0.2	0.26	0.0	1.0	S-C : NS
First premolar distal						
M	19	0.2	0.35	0.0	1.0	M-S : NS
S	19	0.1	0.28	0.0	1.0	M-C : NS
C	40	0.1	0.23	0.0	0.5	S-C . NS

Significance of differences between the groups.
NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001.

was defined as the connection between root surface and crown enamel, and the AC as the most coronal level where the periodontal membrane retained its normal width[3,4,9,18] (Figure 2).

A widening of the cervical part of the periodontal membrane space was considered to be bone loss only if it was accompanied by evidence of oblique resorption.[3,4,9,10] A site was scored as unreadable if at least one of the reference points needed to measure the alveolar bone level could not be identified.

The proximal distance between CEJ and AC was measured to the nearest 0.5 mm[3,4,9]and in 24 sites of each subject, viz., the mesial surfaces of maxillary and mandibular second molars, the mesial and distal surfaces of the maxillary and mandibular first molars and second premolars, and on the distal surfaces of maxillary and mandibular first premolars. Hence, altogether 1,920 sites were measured. Radiographs from not more than 10 patients at a time were evaluated in order to minimize the risk of doubtful assessments due to fatigue.

Furthermore, presence or absence of proximal subgingival calculus, decayed, missing and filled teeth (DMFT), and values of decayed, missing and filled surfaces proximally (DMFS-p) were recorded at the two examinations.

To measure intraexaminer reproducibility, randomly selected radiographs of 10 subjects (240 sites) were re-read 2 weeks after the main measurement.

Statistical analysis of differences between paired data was performed using Student's *t*-test. Differences with probabilities of less than 5% (P<0.05) were considered to be statistically significant.

Results

Twenty-one (1.1%) of the examined 1,920 sites were excluded because the cementoenamel junction (CEJ) or alveolar bone crest (AC) could not be identified. The mean distance between the CEJ and AC at each tooth surface was calculated for the remaining 1,899 sites.

No significant differences in mean values were found between contralateral tooth surfaces or between males and females. Therefore, sites from contralateral surfaces as well as from males and females were pooled and analyzed together.

Proximal alveolar bone level changes obtained from the measurements of bitewing radiographs are shown in Tables 2 and 3.

In the treatment group, the overall average increase in CEJ-AC distance was 0.2 mm (SD 0.29, range 0.0-1.0 mm) (P<0.001) and in the control group 0.1 mm (SD 0.22, range 0.0-1.5 mm) (P<0.001). The difference between the groups was significant, P <0.001.

The mean increase in CEJ-AC distance for the separately recorded maxillary surfaces amounted to 0.3 mm in the treatment group (SD 0.33, range 0.0-1.0 mm) (P<0.001) and 0.1 mm in the control group (SD 0.25, range 0.0-1.5 mm) (P<0.001). The corresponding mean values for the mandible were 0.1 mm in the treatment group (SD 0.24, range 0.0-1.0 mm) (P<0.001) and 0.1 mm in the control group (SD 0.19, range 0.0-1.0 mm) (P<0.001). The difference between the treatment and control groups was significant at the 0.1 percent level for the maxilla but not significant for the mandible.

The mesial sites of the maxillary first molars in the treatment group showed the highest change of CEJ-AC difference, mean 0.5 mm (SD 0.33), followed by an average of 0.3 mm (SD 0.34) for the mesial sites of the maxillary second molars in the treatment group (Table 2). For all other sites the mean differences ranged between 0.1 and 0.2 mm (Tables 2 and 3).

In the treatment group, no significant difference in proximal bone level was found between the two subgroups, magnets succeeded by straight-wire appliances and supercoils succeeded by straight-wire appliances (Table 2). Tooth movements ranged from 2.0 mm to 6.0 mm and no relationship was found between the amount of tooth movement and the amount of decreased bone level.

In neither group were any proximal surfaces with CEJ-AC distance exceeding 2.0 mm found, and only 1.4 percent of all sites showed a distance of 2 mm. Nineteen of 26 sites with a CEJ-AC distance of 2 mm were found in the orthodontically treated group and the majority of the sites were found mesially on the maxillary first molars (Table 4).

None of the radiographically examined sites showed any proximal subgingival calculus. The mean increase of values of decayed, missing, and filled surfaces proximally (DMFS-p) was 0.3 (SD 0.72) for the treatment group and 0.2 (SD 0.52) for the control group. The increase in each group was not significant. Neither was the difference in increase of DMFS-p between the groups significant, and no verified dependence between changes in CEJ-AC distance and DMFS-p was found.

The intraexaminer reproducibility test showed that the reliability was high (Table 5). The second reading was consistent with the first for 91.3% of the sites.

Table 3
Changes in distances (mm) between the cementoenamel junction (CEJ) and alveolar bone crest (AC) in the mandibular arch during the observation period in treatment (T) and control (C) groups. Treatment in the mandible involved a straight-wire appliance only.

Tooth surface and group	Mandibular arch					
	n	X	SD	X_{min}	X_{max}	Probability
Second molar mesial						
T	39	0.2	0.21	0.0	0.5	T-C : *
C	40	0.1	0.22	0.0	0.5	
First molar distal						
T	40	0.1	0.18	0.0	0.5	T-C : NS
C	40	0.1	0.30	0.0	0.5	
First molar mesial						
T	40	0.2	0.32	0.0	1.0	T-C : NS
C	40	0.1	0.17	0.0	0.5	
Second premolar distal						
T	39	0.2	0.23	0.0	0.5	T-C : *
C	38	0.1	0.18	0.0	0.5	
Second premolar mesial						
T	39	0.1	0.23	0.0	0.5	T-C : NS
C	38	0.1	0.17	0.0	0.5	
First premolar distal						
T	40	0.1	0.21	0.0	0.5	T-C : NS
C	40	0.1	0.15	0.0	0.5	

Significance of differences between the groups.
NS = not significant., * = P<0.05, ** = P<0.01, *** = P<0.001.

Discussion

In this study it was demonstrated radiographically that a group of young individuals showed a statistically significant greater mean decrease in proximal alveolar bone support a short time after orthodontic treatment compared with matched individuals in a control group. However, the difference was small (0.2 mm for the treatment group versus 0.1 mm for the control group) and was considered clinically insignificant. The observations agree with previous studies reporting that orthodontic treatment causes a statistically significant but small increase in the distance between the cementoenamel junction (CEJ) and the alveolar bone crest (AC).[9-11] The fact that untreated subjects showed a small but statistically significant increase of CEJ-AC distance is also in accordance with previous studies.[12,19,20]

The results show that the CEJ-AC distance was 1.5 mm or less in the majority of sites (Figure 3). Only in 1.4% of the sites was the distance 2 mm, and no site had a higher value. A distance of ⊕2 mm between CEJ and AC has recently been suggested to represent a significant loss of marginal bone support.[3,4,20] Thus, the data from this study confirmed that the majority of teeth with rapid orthodontic movement sustained little or no damage to the proximal alveolar bone support.

The data also revealed that 19 of 26 sites with a CEJ-AC distance of 2 mm were found in the treatment group and the majority were found mesially on the maxillary first molars (Table 4). The maxillary first molar mesial sites in the treatment group were also the sites that showed the highest average bone level change, 0.5 mm, followed by the maxillary second molar mesial sites, 0.3 mm (Table 2). The fact that the maxillary first molar mesial site showed the greatest CEJ-AC distances is in agreement with the findings of Aass and Gjermo.[12] During treatment the distal tipping of the molars was small (range 0

Table 4
Number and distribution of bilaterally pooled proximal surfaces with 2 mm between the cementoenamel junction (CEJ) and alveolar bone crest (AC). In the maxilla, the treatment group was divided into two subgroups--magnets succeeded by straight-wire appliances and supercoils succeeded by straight-wire appliances. In the mandible the treatment involved a straight-wire appliance only.

	Treatment				Control	
Group	Magnets		Supercoils			
Examination	1	2	1	2	1	2
Maxillary arch						
Second molar mesial	-	1	-	2	-	-
First molar distal	-	1	-	1	-	1
First molar mesial	-	6	-	5	-	1
Second premolar distal	-	-	-	-	-	1
Second premolar mesial	-	-	-	-	-	1
First premolar distal	-	-	-	1	1	1

	Treatment		Control	
Examination	1	2	1	2
Mandibular arch				
Second molar mesial	-	-	-	-
First molar distal	-	-	-	1
First molar mesial	-	2	-	-
Second premoalr distal	-	-	-	-
Second premolar mesial	-	-	-	-
First premolar distal	-	-	-	-

Table 5
Intraexaminer reproducibility of the measurement of distances between the cementoenamel junction (CEJ) and the alveolar crest (AC). In 10 random subjects (240 sites) the distances were read on two different occasions with at least 2 weeks' interval.

Difference in measuring CEJ-AC distance (mm) on two occasions	n	percent
-0,5	7	2.9
0	219	91.3
+0,5	14	5.8

to 4 degrees[17]). The small tipping movement was considered to be insignificant for the geometrical relationship of the distance between the distal tipped tooth and the alveolar bone crest. Instead, it may be speculated that the subgingival placement of bands could have traumatized the periodontal tissue, resulting in loss of marginal bone,[21] and/or that maxillary first molars have a mesial concavity at the cementoenamel junction that can predispose to subgingival plaque accumulation.

This investigation also confirmed that there was no statistically significant difference in CEJ-AC distance between teeth moved rapidly by magnets succeeded by straight-wire appliances and teeth moved rapidly by superelastic coils succeeded by straight-wire appliances (Table 2). Thus, with respect to the influence on proximal alveolar bone level, there was no difference between an interrupted continuous force system produced by the magnets[17,23] and a more pronounced continuous force system produced by the superelastic nickel-titanium coils.[17,24]

Radiographic quantification of marginal bone level is a well accepted technique for assessing periodontal bone support.[3,4,9-12,19,25,26] Assessing loss of support from measurements on bitewing radiographs may be superior to clinical methods when comparing the periodontal bone level on different occasions.[3,4] With clinical methods, it may be difficult to keep diagnostic criteria stable over time, while radiographic evaluation can be performed on a single occasion and can be done in a blinded fashion. In this study, alveolar bone level was assessed as the distance between two well-defined reference points, the cementoenamel junction (CEJ) and the alveolar bone crest (AC) (Figure 2). It has been previously shown by Albander and Abbas[3] that using such an absolute measuring technique is superior in reproducibility to relative methods using the distance between AC and the crown tip of the tooth related to the total length of the tooth (method described by Björn et al.[18]) or measuring the alveolar bone level in relation to root length (method described by Schei et al.[22]).

The bitewing radiographs in this investigation were taken with a standardized technique. Unmeasurable sites were therefore few, 1.1%, lower than in reports using a comparable technique.[4,9,11] The results of the intraexaminer duplicate determinations of CEJ-AC distances also showed high reliability (Table 5).

In this study, a control group was chosen to match the orthodontically treated group regarding dental habits, age, sex, and DMFT/DMFS-p values, and the two groups were followed longitudinally and compared. Hence, there was a slight but statistically insignificant possibility that the difference in proximal alveolar bone level between the treated and untreated groups could have been established prior to the treatment. Because a significant number of sites with increased CEJ-AC distances was found in the treatment group compared with the control group, the question arises whether treatment per se or oral hygiene was the factor of decisive importance. According to the dental records, subjects in both groups had low caries activity and good oral hygiene and all individuals had received free annual dental care since they were 3 years old. Furthermore, the subjects in the two groups came from socioeconomically similar residental areas. The good oral health status of the subjects was also evident from the fact that at the first examination appointment 80% in the treatment group and 70% in the control group had no caries or fillings on proximal surfaces of the teeth. Moreover, none of the subjects in either group had any proximal subgingival calculus. Given these facts regarding oral health status and because individual variation in bone level changes was small, it seems justified to assume that the significant increase in CEJ-AC distance found in the orthodontic treatment group was due to the orthodontic treatment. The difference in bone level between the test and control groups was statistically significant but clinically insignificant and does not qualify for the diagnosis of early loss of periodontal bone support. It has been shown that early loss of periodontal bone support in orthodontically treated and untreated young subjects could be of a transient nature,[12] and long-term results may show a continued progression or a return to normal bone levels. Therefore, the results in this study should be interpreted with caution, and it is important to follow up on the results several years after the orthodontic treatment. Such a complementary study is in progress.

Conclusions

1. A short time after treatment in the orthodontic group, a small overall mean increase amounting to 0.2 mm was found in the distance between the cementoenamel junction (CEJ) and the alveolar bone crest (AC). For the untreated control group the increase in CEJ-AC distance was 0.1 mm. The difference between the groups was significant at the 0.1% level.

2. In the treatment group, the sites in the maxilla showed greater CEJ-AC distances than those in the mandible, mean 0.3 mm versus 0.1 mm ($P<0.001$).

3. The mesial proximal sites of the maxillary first molars in the treatment group showed the highest average increased distance between CEJ and AC, mean 0.5 mm.

4. No sites with bone loss, i.e., CEJ-AC distance exceeding 2 mm, were found in either the treatment or control group.

5. No significant difference in CEJ-AC distance was found between teeth that were moved rapidly with magnets succeeded by straight-wire appliances and teeth moved rapidly with superelastic coils succeeded by straight-wire appliances.

Figure 3A

Figure 3B

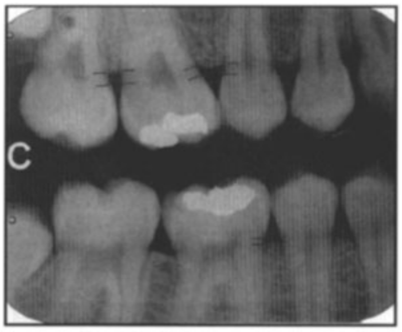

Figure 3C

Figure 3D

Figure 3A-D
Bitewing radiographs of a girl from the treatment group.
A-B: Before treatment; C-D: A short time after treatment. The time interval between A-B and C-D was 2.7 years. Horizontal lines indicate examples of bone support and CEJ-AC distances. The film holder is more visible in A-B than in C-D.

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Author Address

Dr. Lars Bondemark
Tandregleringskliniken
Esplanadgatan 15
S-281 38 Hässleholm
SWEDEN

References

1. Davidovitch Z. Tooth movement. Crit Rev Oral Biol Med 1991;2:411-50.
2. Owman-Moll P. Orthodontic tooth movement and root resorption with special reference to force magnitude and duration. Swed Dent J 1995 (suppl 105):7-45.
3. Albander JM, Abbas DK. Radiographic quantification of alveolar bone level changes. Comparison of three currently used methods. J Clin Periodontol 1986;13:810-3.
4. Källestål C, Matsson L. Criteria for assessment of interproximal bone loss on bite-wing radiographs in adolescents. J Clin Periodontol 1989;16:300-4.
5. Baxter DH. The effect of orthodontic treatment on alveolar bone adjacent to the cemento-enamel junction. Angle Orthod 1967;37:35-47.
6. Kloehn JS, Pfeifer JS. The effect of orthodontic treatment on the periodontium. Angle Orthod 1974; 44:127-34.
7. Eliasson L, Hugoson A, Kurol J, Siwe H. The effects of orthodontic treatment on periodontal tissues in patients with reduced periodontal support. Eur J Orthod 1982;4:1-9.
8. Polson AM, Reed BE. Long-term effect of orthodontic treatment on crestal alveolar bone levels. J Periodontol 1984;55:28-34.
9. Zachrisson BU, Alnaes L. Periodontal condition in orthodontically treated and untreated individuals. II. Alveolar bone loss: Radiographic findings. Angle Orthod 1974;44:48-55.
10. Hollender L, Rönnerman A, Thilander B. Root resorption, marginal bone support and clinical crown length in orthodontically treated patients. Eur J Orthod 1980;2:197-205.
11. Ögaard B. Marginal bone support and tooth lengths in 19-year-olds following orthodontic treatment. Eur J Orthod 1988;10:180-6.
12. Aass AM, Gjermo P. Changes in radiographic bone level in orthodontically treated teenagers over a 4-year period. Community Dent Oral Epidemiol 1992;20:90-3.
13. Gianelly AA, Vaitas AS, Thomas WM. The use of magnets to move molars distally. Am J Orthod Dentofac Orthop 1989;96:161-7.
14. Bondemark L, Kurol J. Distalization of maxillary first and second molars simultaneously with repelling magnets. Eur J Orthod 1992;14:264-72.
15. Gianelly AA, Bednar J, Dietz VS. Japanese NiTi coils used to move molars distally. Am J Orthod Dentofac Orthop 1991;99:564-6.
16. Jones RD, White MJ. Rapid Class II molar correction with an open-coil jig. J Clin Orthod 1992;26:661-4.
17. Bondemark L, Kurol J, Bernhold M. Repelling magnets versus superelastic nickel-titanium coils in simultaneous distal movement of maxillary first and second molars. Angle Orthod 1994;64:189-98.
18. Björn H, Halling A, Thyberg H. Radiographic assessment of marginal bone loss. Odont Revy 1969;20:165-79.
19. Albandar JM, Rise J, Gjermo P, Johansen JR. Radigraphic quantification of alveolar bone level changes. A 2-year longitudinal study in man. J Clin Periodontol 1986;13:195-200.
20. Källestål C, Matsson L. Marginal bone loss in 16-year-old Swedish adolescents in 1975 and 1988. J Clin Periodontol 1991;18:740-3.
21. Hamp S, Lundström F, Nyman S. Periodontal conditions in adolescents subjected to multiband orthodontic treatment with controlled oral hygiene. Eur J Orthod 1982;4:77-86.
22. Schei O, Waerhaug J, Lovdal A, Arno A. Alveolar bone loss as related to oral hygiene and age. J Periodontol 1959;30:7-16.
23. Vardimon A, Graber TM, Drescher D, Bourauel C. Rare earth magnets and impaction. Am J Orthod Dentofac Orthop 1991;100:494-512.
24. Miura F, Mogi M, Ohura Y, Karibe M. The superelastic Japanese NiTi alloy wire for use in orthodontics. Part III: Studies on the Japanese NiTi alloy coil springs. Am J Orthod Dentofac Orthop 1988;94:89-96.
25. Benn DK. A review of the reliability of radiographic measurements in estimating alveolar bone changes. J Clin Periodontol 1990;17:14-21.
26. Shrout MK, Hildebolt CF, Vannier MW. The effect of alignment errors on bitewing-based bone loss measurements. J Clin Periodontol 1991;18:708-12.