Continuous vs. discontinuous force application and root resorption

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Abstract: The aim of this study was to compare the effects on root resorption of continuous and discontinuous force application. The experimental material consisted of 22 first premolars that were to be extracted as part of orthodontic treatment. Prior to extraction, a 100 g tipping force was applied to the experimental teeth by means of elastics. One side was randomly selected to be the continuous force side, and the contralateral side became the discontinuous force side. Elastics were worn 24 hours per day on the continuous force side and 12 hours per day on the discontinuous side. The experimental procedure lasted 9 weeks. Composite electron micrographs of the buccal surface of each specimen were digitized and areas affected by resorption were determined. The degree of root blunting was assessed by visual scoring. Mean percentage of resorption-affected areas was smaller and apical blunting was less severe on the discontinuous force side. The results of this study show that the application of discontinuous force results in less root resorption than does the application of continuous force.

Key Words: Continuous force , Discontinuous force, Root resorption

Root resorption is an undesirable side-effect of orthodontic treatment. As indicated in a recent extensive review by Brezniak and Wasserstein,[1,2] it is a multifactorial problem associated with patient characteristics such as age, sex, systemic conditions, type of malocclusion, and tooth structure, as well as with treatment factors such as type of appliance, duration of treatment, orthodontic force magnitude, and type of tooth movement. The associations between magnitude and duration of orthodontic force and root resorption have been investigated from a variety of aspects over the past several decades,[3-9] and controversial views have been reported. According to Dellinger[3] and Reitan,[10] root resorption was aggravated by increasing force magnitudes, while Owman-Moll et. al[11] claimed that root resorption was not very force-sensitive. Harry and Sims[7] suggested that duration of force was a more critical factor than magnitude. On the other hand, Dermaut and DeMunck[8] concluded that there was no significant relationship between the duration of the force and root resorption.

Apart from magnitude and duration, the type of force should also be considered when evaluating root resorption. Differences may exist in tissue responses to continuous and discontinuous forces. Owman-Moll et al.[11] compared the effects of continuous (24 hours per day) and interrupted continuous (interrupted one week every fourth week) forces in adolescents and reported that there was no difference in the amount or severity of root resorption. In a recent animal study, Maltha and Dijkman[12] compared the amount of root resorption after continuous (24 hours per day) and discontinuous (16 hours per day) force applications. They showed that discontinuous forces caused less extensive root resorption.

The aim of the present study was to compare the effects of continuous and discontinuous force application on root resorption.

Materials and methods

The test material consisted of 22 first premolars that would be extracted as part of planned orthodontic treatment. The teeth were obtained from eight patients who ranged in age from 15 to 23 years. In three patients, four first premolars

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were extracted; in another three patients, the mandibular first premolars were extracted; in the remaining two patients, the maxillary first premolars were extracted. Informed consent for an experimental procedure on the premolars was obtained prior to extraction. Approximal contacts of the experimental premolars were eliminated by means of a diamond bur in order to prevent dissipation of the applied force. Buttons were bonded to the buccal surfaces of the experimental teeth. Maxillary and/or mandibular incisors were bonded, and 0.017" x 0.025" stainless steel utility arches were inserted. Elastics that delivered a tipping force of 100 g were applied from the premolar buttons to the lateral arms of the utility arches (Figure 1). One side was randomly selected to be the continuous force side; the contralateral side was the discontinuous force side. An elastic band was worn 24 hours per day on the continuous force side, with no rest period. Every 24 hours, the patient would apply a new elastic band. On the discontinuous force side, an elastic band was worn for 12 out of 24 hours daily. After 12 hours, the patients would remove the band and allow a rest period of 12 hours, after which a new elastic band would be applied. This experimental protocol was followed for 9 weeks. During this 9-week period, the patients were called weekly to be sure that the initial force applied by each new elastic was 100 g. When the initial force generated by the elastics decreased as a result of tooth movement, the patient was given a new pack of elastics with a smaller diameter (generating a force of 100 g on initial application).

At the end of the 9th week, the teeth were extracted and prepared for scanning electron microscopic (SEM) study. The roots were separated from the crowns at the cementoenamel junction by a rotary carbon disc under water spray. In order to remove the soft tissue remnants on the root surfaces, the specimens were immersed in 5% sodium hypochlorite solution for 2 hours. Following this, they were rinsed and thoroughly air dried at room temperature. The roots were vacuum coated with palladium and gold.

Six unoperated first premolars that were extracted for orthodontic purposes served as control material. They were obtained from six patients whose ages ranged between 14 and 20. Control teeth underwent the same preparation procedure for SEM as the experimental teeth.

Topographic investigation of the specimens was performed according to a method previously described by Barber and Sims.[13] Composite low magnification (X16) electron micrographs of the entire buccal surface of each specimen were obtained. A MOP videoplan digitizer (Kontron Bildanalyse GMBH) was used to determine the total area of the buccal surface of each root and to calculate the resorption-affected areas on the surface. The resorbed root area was calculated as a percentage of the total root area seen in each composite. The error of the measuring method was assessed from double determinations of 30 randomly selected resorbed areas. Significant agreement was seen between the two measurements ($r^2=1.00$, $p<0.001$).

Visual assessment of apical morphology of experimental roots was performed by three independent observers. The degree of root blunting was categorized into one of the following ordinal stages:

0-No root resorption
1-Apical blunting
2-Moderate resorption
3-Severe resorption

Two roots were excluded because their apices could not be wholly viewed on the composites.

Intraoperator error in scoring

Twenty composites were reevaluated 2 weeks later by observer A. Nineteen of 20 determinations were

Figure 1

Appliance used for force delivery. 0.017"x 0.025" stainless steel utility arch and elastics, which were applied from premolar buttons to lateral arms of utility arch

Figure 2

Left: Buccal aspect of a root that had received continuous force
Right: Buccal aspect of the contralateral root, which received discontinuous force. Arrows show areas of root resorption (X16)

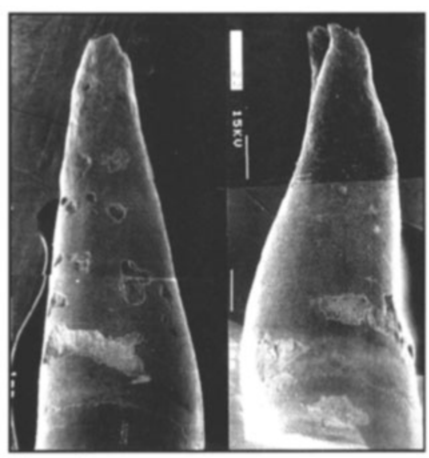

Figure 3

Left: Continuous force side
Right: Discontinuous force side (X16)

the same in the second evaluation as they were in the first (r^2=0.89, p<0.001).

Interoperator error in scoring

Observer B agreed with observer A on 17 of 20 determinations (r^2=0.71, p<0.001), and observer C agreed on 19 (r^2=0.89, p<0.001). Observer B's scoring coincided with observer C's 18 out of 20 times (r^2=0.75, p<0.001).

Results

On both continuous and discontinuous force sides, resorption cavities with varying diameters were observed on the buccal root surfaces (Figures 2 and 3). Resorption cavities tended to widen in the middle and cervical portions of the root surface compared with the apical region. In the apical one-third, resorption was characterized by small cavities with diameters between 50 and 500 µm. In the middle and cervical regions, resorption cavities displayed irregular shapes, and some were as wide as 2 mm (Figure 4). These wide resorption bays seemed to occur by the merging of smaller cavities. Dentine was involved in the majority of the lesions, as marked by the presence of openings in the dentinal tubules.

Mean percentages of resorbed buccal root area on the continuous and discontinuous force sides were 11±5% and 6±3%, respectively (Figure 5). The differences in percentages of resorbed root area between the continuous and discontinuous force sides are shown in Table 1.

Distribution of roots according to the scorings of apical morphology is seen in Figure 6. In continuous force application, 40% of the roots showed blunting and 60% showed moderate apical resorption. In discontinuous force application, 20% of the roots showed no apparent apical resorption, 40% showed blunting, and 40% showed moderate resorption.

Of six untreated control teeth, two showed regular cementum surfaces with no visible resorption. In the remaining four teeth, superficial resorption cavities located in the apical and middle one-thirds were observed (Figure 7). The percentage area of resorption in these four teeth varied between 0.1% and 1.8%.

Resorption cavities were noted on the palatal-apical aspect of the experimental roots, which was also a pressure zone. Similar to observations on the buccal root surface, the

Table 1
Differences in percentages of resorbed root area in the continuous and discontinuous force sides

	Percentage area of resorption		
Tooth pair	Continuous force	Discontinuous force	Difference
1	7	4	3
2	15	9	6
3	15	8	7
4	16	9	7
5	17	10	7
6	2	0	2
7	3	2	1
8	9	6	3
9	14	6	8
10	9	5	4
11	14	7	7

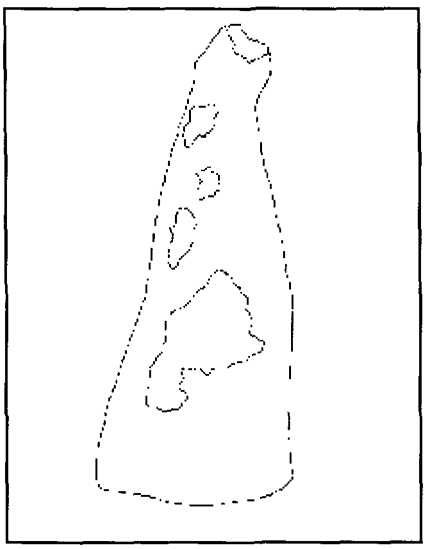

Figure 4
Schematic drawing of resorption areas on the buccal root surface of experimental teeth. Resorptive lesions tend to get wider toward the middle and cervical regions.

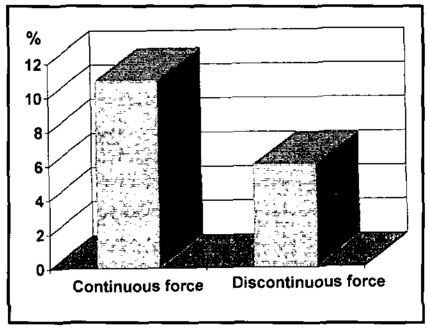

Figure 5
Comparison of mean percentages of resorbed root area in continuous and discontinuous force sides

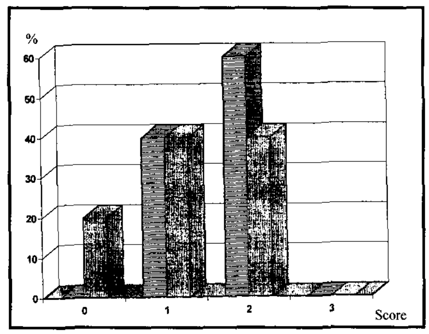

Figure 6
Distribution of tooth roots according to scorings of apical morphology. Score 0: No root resorption; 1: Apical blunting; 2: Moderate resorption; 3: Severe resorption

Figure 7
Control tooth with superficial resorption (shown by the arrows) in the apical and middle thirds (X35)

severity of palatal-apical resorption on the continuous force side was greater than that on the discontinuous force side (Figure 8).

Another finding of this study was that severity of root resorption showed individual variation. Although all individuals received the same treatment, corresponding experimental teeth of different individuals showed varying degrees of root resorption (Figures 9 and 10).

Discussion

The relationship between variables of orthodontic force, such as magnitude and duration, and root resorption have been investigated in a number of studies in an effort to establish an optimal force regimen in which tissue damage would be minimized.[3-5,7-9] However, the relationship between the type of force application and root resorption has not been adequately verified. According to Reitan,[8] light, interrupted forces would help prevent excessive resorption. Rest periods during continuous tooth movement would enhance repair of resorbed lacunae.

The purposes of this study were to evaluate root resorption in continuous and discontinuous force applications and to find out whether a difference in the amount and severity of resorption exists between teeth treated with two different force regimens.

As it was impossible for the present investigators to make the daily adjustments necessary for discontinuous force application, i.e., to see the patients every 12 hours, force was delivered by elastics that the patients themselves changed. Force delivery by elastics has its own disadvantages, such as demand for strict patient cooperation and rapid decay of initially applied force. Latex elastics are known to lose 20% to 30% of their initial force during the first two days.[14-16] This problem of rapid force decay was partly overcome by generating a relatively high initial force (100 g) each time the elastics were renewed.

The presence of resorptive areas on some of the untreated control teeth was in agreement with earlier reports on root resorption.[5,7,17] Although quantitative comparisons could not be made, the extent of root resorption in the control teeth in the present study seemed to be less than that reported in previous studies.

The difference in resorbed root area between the two types of force administration indicates that a smaller portion of the buccal root surface was affected by resorption in the discontinuous type of force application. With discontinuous force, apical involvement was also less severe in comparison with continuous force application. The observations in this study were in agreement with the findings of Maltha and Dijkman.[12] Reducing the hours per day of force administration seemed to delay the resorptive activity to some extent. The repair of a resorption cavity is known to start when orthodontic force is terminated or even just reduced below a certain level.[18-19] Though 12-hour rest periods are too short for any perceptible sign of repair to take place on root surfaces, they may be useful in retarding the resorptive activity on a cellular level. Further studies are needed in order to shed light on these processes.

It is well established that extraoral force and functional appliances produce tooth movement without requiring full-time wear. Rest periods are thought to improve circulation in the supporting tissues and enhance cell proliferation.[10] The rates of tooth movement in continuous and discontinuous force regimens were not evaluated in the present study. However, there is evidence that discontinuous forces are able to produce tooth movement equivalent to that obtained by continuous forces. In a study of rabbits, Proffit and Sellers[20] showed that light intrusive forces applied 50% of the time produced the same amount of intrusive movement

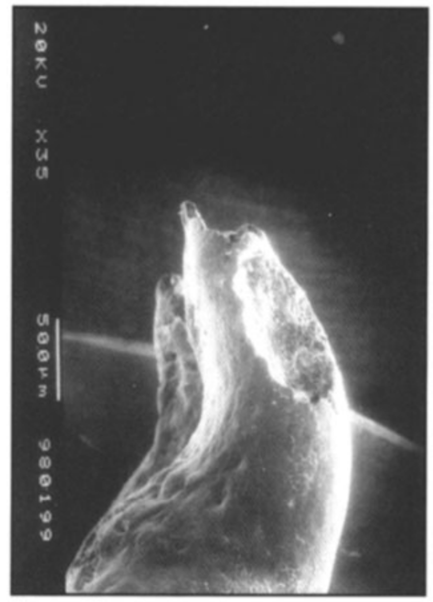

Figure 8A

Palatal-apical aspect of a root that had received continuous force. Severe apical resorption is noted.

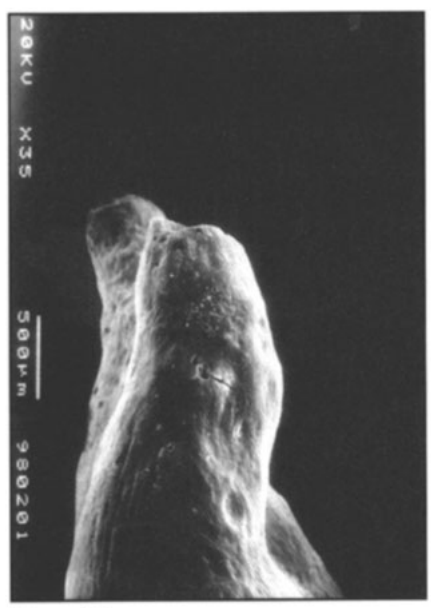

Figure 8B

Palatal-apical aspect of the contralateral tooth root, which had received discontinuous force, showing only a few small resorption pits (X35).

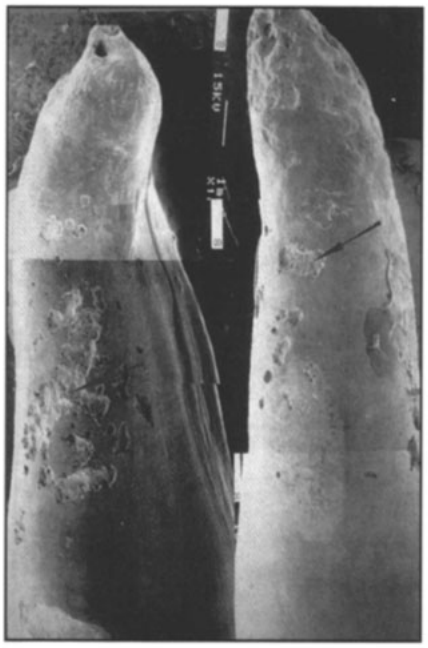

Figure 9

Left: Continuous force side
Right: Discontinuous force side. Arrows show extensive resorptive lesions on both sides (X16)

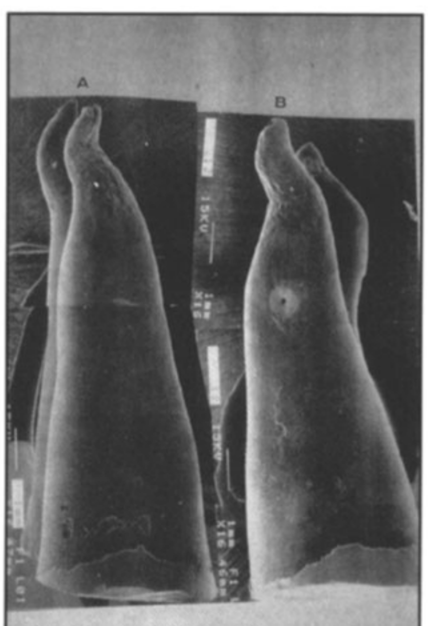

Figure 10

Left: Continuous force side
Right: Discontinuous force side. Although this individual received the same treatment as the others, root surfaces and apices seemed unaffected with the exception of a few superficial lesions on the cervical regions (X16)

as a continuous force. Further experiments are necessary to show whether this effect can be achieved in humans, too. In that event, it would be tempting to think that discontinuous forces, producing the same amount of movement as a continuous force and causing less root resorption, would be a better choice during orthodontic treatment.

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Commentary: Continuous vs. discontinuous force application and root resorption

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This study compares the extent of root resorption occurring in response to continuous and discontinuous force application and concludes that discontinuous force causes less root resorption. This issue is of some clinical significance to orthodontists because orthodontic treatment places patients at risk for root resorption. Clearly, the causes and mechanisms of root resorption are multifactorial, and orthodontic treatment is only one part of the picture. Some have argued that, despite its prevalence in patients, most orthodontic root resorption is minimal and has few clinical consequences. However, some patients (about 10%) seem to be highly susceptible to extensive root resorption. Factors other than orthodontic biomechanics may come into play because susceptible patients often show pre-existing root loss and root anomalies. Developing a means to identify these unusually suscep-