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The early reparative process of orthodontically induced root resorption in adolescents—location and type of tissue

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SUMMARY The aim of this investigation was to determine the pattern of repair of root resorption regarding the location and type of tissue in adolescents after application of a well-controlled force magnitude. In 16 adolescents (mean age 13.8 years), the maxillary first premolars were buccally moved with a weekly reactivated force of 50 cN (≈50 g) for 6 weeks following which the appliance was made passive for 2, 3, 6, and 7 weeks. The subjects were divided into two groups of eight individuals for which the retention periods were 2 and 6 weeks (Group I), or 3 and 7 weeks (Group II), implying intra-individual differences of 4 weeks.

Reparative cementum in the resorption cavities was seen in all test teeth, significantly more often after 6 and 7 weeks of retention (82 per cent) compared with 2 and 3 weeks (35 and 44 per cent, respectively). The reparative process appeared to commence in the bottom of the resorption cavity, frequently covered by a thin layer of acellular cementum. However, most of the reparative cementum was of the cellular type and always covered the initially formed acellular cementum. There were great individual variations regarding the occurrence of healing of orthodontically-induced root resorption.

Introduction

Root resorption is a common feature during orthodontic tooth movement (e.g. Massler and Malone, 1954; Kurol *et al.*, 1996). When the applied force is discontinued or reduced below a certain level the reparative process starts (Rygh, 1977; Reitan, 1985) and has been recorded as early as during the first week of retention (Owman-Moll *et al.*, 1995). The healing process seems to increase over time (Barber and Sims, 1981; Langford and Sims, 1982), and especially during the first 4 weeks of retention (Owman-Moll *et al.*, 1995). After 5–6 weeks of retention, the repair of root resorption seems to slow down and reach a steady phase (Vardimon *et al.*, 1993; Owman-Moll *et al.*, 1995).

Different spatial repair patterns have been reported, proceeding either from the periphery of the resorption cavity (Lindskog *et al.*, 1987; Brudvik and Rygh, 1995a,b) or from the centre of the patches outward (Barber and Sims, 1981). Sismanidou and Lindskog (1995) observed both types of repair pattern in adolescents.

In the early 1950s Henry and Weinmann (1951) observed in autopsy material of 15 human dentitions that the repaired resorption areas exhibited many combinations of cellular and acellular cementum. Vardimon *et al.* (1993) distinguished between two types of repair pattern after rapid maxillary expansion in adolescent monkeys: functional rapid cellular repair and non-functional retarded acellular repair. The latter type was mainly seen at the onset of the reparative phase. Clinical investigations of the healing process after rapid maxillary expansion in young individuals exclusively, revealed reparative cementum of a cellular type in the resorption lacuna (Barber and Sims, 1981; Langford and Sims, 1982).

Several different experimental designs have been used to elucidate the repair pattern. Very often, the repair process has been investigated after rapid maxillary expansion with a force magnitude much higher than during treatment with a full fixed appliance. Such a rapid expansion model will probably create a higher relapse force magnitude in the tissues, which may affect the healing process. Moreover, the cementum in animal and man is different (Boyde and Jones, 1968; Jones and Boyde, 1972). Therefore, it seems important to further investigate the repair pattern in adolescents after discontinuation of a relevant orthodontic force magnitude.

The aim of this study was therefore to histologically analyse the pattern of the reparative process of orthodontically induced root resorption regarding the location and type of tissue in adolescents following application of a well-controlled force magnitude.

Subjects and methods

The subjects were 16 adolescents, 10 girls and six boys (mean age 13.8 years), who had been referred for orthodontic specialist treatment, which included extraction of maxillary first premolars on both sides. The extractions were postponed in order to utilize the teeth for the experiment.

The maxillary first premolars were moved buccally with a fixed orthodontic appliance with a frontal bite block to reduce the occlusal forces (Lundgren *et al.*, 1996). A force of 50 cN (≈50 g), checked and reactivated once a week, was applied for 6 weeks in order to induce root resorption, following which the appliance was made passive for 2, 3, 6, and 7 weeks to retain the test teeth and to prevent any relapse which might induce new resorption and repair. The subjects were divided into two groups of eight individuals for which the retention periods were 2 and 6 weeks (Group I), or 3 and 7 weeks (Group II) with 4 weeks intra-individual difference. The treatment procedures have been described earlier (Owman-Moll *et al.*, 1995).

The design of the study was approved by the Ethics Committee of the Medical Faculty, Göteborg University, Göteborg, Sweden.

At the end of the experiment the test teeth were extracted and subjected to routine histological preparation; serially sectioned parallel to the long axis in a bucco-palatal direction from the mesial surface. Sections were collected from the stage when most of the root length was seen until the middle of the root was reached (three levels, 0.3 mm apart). The sections were stained with haematoxylin and eosin. A light microscope was used to record root resorptions and repair on one randomly chosen histological section from three different section levels in the experimental teeth (Kurol *et al.*, 1996).

The following recordings of repair were made:

1. No repair or repair related to the time factor.
2. Extent of repair:
   - no repair (Figure 1A);
   - partial repair: part of the surface of the resorption lacuna was covered with reparative cementum (Figure 1B);
   - functional repair: the total surface of the resorption lacuna was covered with reparative cementum without re-establishment of the original root contour (Figure 1C);
   - anatomical repair: the total surface of the resorption lacuna was covered with reparative cementum and the original root contour had been re-established (Figure 1D).
3. Location of early repair; starting centrally or peripherally in the resorption cavity (Figure 2A–D).
4. Type of repair tissue; cellular (Figure 1C) or acellular cementum (Figure 1B).

All recordings on histological sections were performed by one of the authors (P.O.M).

Statistical analyses

The statistical analyses were performed using the Statview 4.0 statistical computer program (Abacus Concepts, Inc., Berkeley, CA, USA, 1992). The intra-individual variations of reparative potential were investigated using a paired *t*-test.

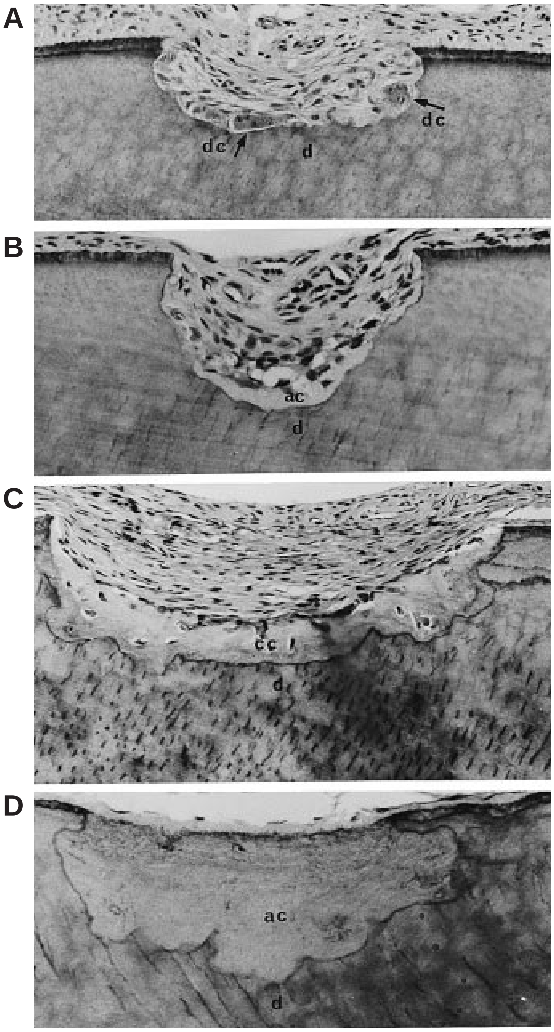

Figure 1 Histological illustration showing varying degrees of repair in orthodontically-induced root resorption in maxillary premolars after 2, 3, 6, and 7 weeks of retention; (A) no repair. Dentinoclasts (dc; haematoxylin and eosin; ×70); (B) partial repair with acellular cementum (ac), dentine (d; haematoxylin and eosin; ×112); (C) functional repair with cellular cementum (cc), dentine (d; haematoxylin and eosin; ×70); (D) anatomic repair with almost cell-free, acellular cementum (ac), dentine (d; haematoxylin and eosin; ×112).

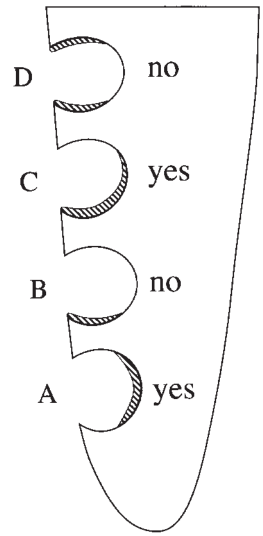

Figure 2 Schematic illustration of the findings (Yes or No) regarding the location of healing cementum in partially repaired root resorptions; (A) central in the bottom of the cavity—Yes; (B) peripheral on one of the lateral walls of the cavity—Yes; (C) central-peripheral on one of the lateral walls of the cavity—Yes; (D) only peripheral on both lateral walls of the cavity—No.

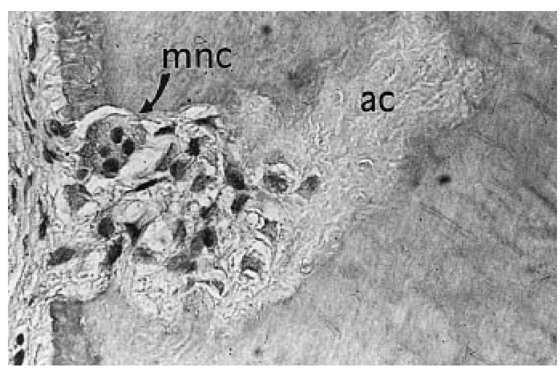

Figure 3 Root resorption in the pressure zone of the palatal-apical third of a buccally moved maxillary premolar. Repair with acellular cementum (ac) and active root resorption with a multinucleated cell (mnc) are seen in the same resorption lacuna (haematoxylin and eosin; ×252).

Results

Active root resorption and the repair process were sometimes observed close together (Figure 3).

The healing process was recorded after 2, 3, 6, and 7 weeks of retention. The percentage of root resorptions with repair was 38 per cent after 2 weeks, 44 per cent after 3 weeks, and 82 per cent after 6, as well as 7 weeks of retention. There was significantly more root resorption with varying degrees of repair after a retention period of 6 weeks compared with 2 weeks, and after 7 weeks compared with 3 weeks ($P < 0.0001$; Figure 4).

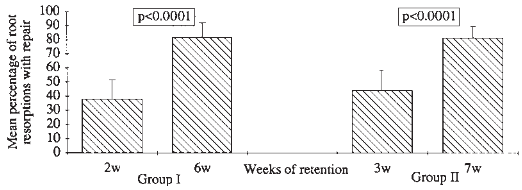

Figure 4 Orthodontically-induced root resorption with repair (mean percentage) and standard deviation in the two groups (I and II) with an intra-individual difference of 4 weeks of retention between the two sides of the maxilla. Probability values between the two sides in each group.

In cases with partial repair of the resorption, the healing cementum was seen more often in the central part of the resorption lacuna (Figure 2A) than in the central-peripheral areas of the cavity (Figure 2C). Reparative tissue was never observed on the lateral walls alone (Figure 2B,D).

The type of repair tissue found was more frequently cellular (Figure 1C) than acellular (Figure 1B) in all experimental groups (Figure 5). In cases when acellular cementum was seen, it occurred more often in the early stage of repair, i.e. in the resorption lacunaes with partial repair compared with those revealing functional repair, or when anatomical repair with re-establishment of the root contour was seen. Thus, when acellular cementum was found it was seen in the bottom of the resorption cavity, and with time it was frequently covered by cellular cementum. In no instance was cellular cementum seen covered with acellular cementum.

The repair process did not vary with the location or type of tissue, neither on the buccal or lingual side of the tooth nor in the cervical or apical parts of the root.

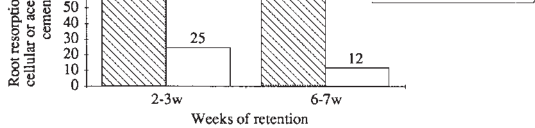

Figure 5 Distribution of root resorption with repair (mean percentage) according to type of repair tissue, cellular and acellular, respectively, related to 2, 3, 6, and 7 weeks retention.

The individual variations were great regarding the occurrence of repair of root resorption after elimination of the applied force.

Discussion

Orthodontically-induced root resorption is not uncommon in the clinical experimental model used. However, after release of the applied force and when retention was started after allowing a rest period, substantial repair was observed within a few weeks.

As early as 2 weeks after the start of retention 38 per cent of the root resorptions showed some type of healing, and this increased to 82 per cent after 6 and 7 weeks. A similar relationship with increased healing with time is in agreement with other clinical investigations (Timms and Moss, 1971; Barber and Sims, 1981; Langford and Sims, 1982; Odenrick *et al.*, 1991). In a recent experimental study in adolescents, reparative cementum was observed after 1 week of retention (Owman-Moll *et al.*, 1995). Sismanidou and Lindskog (1995) also reported an early onset of the healing process within 2 weeks after maxillary expansion using a Quad-Helix appliance in humans.

It has been claimed from studies in animals that early repair starts in the periphery of the resorption lacuna (Lindskog *et al.*, 1987; Vardimon *et al.*, 1993; Brudvik and Rygh, 1995a,b) in association with the invasion of fibroblast-like cells from the surrounding periodontal ligament (Brudvik and Rygh, 1995a,b). In the present investigation in adolescents, early repair was recorded initially on the bottom of the resorption cavity only. Sometimes the reparative cementum had extended to one of the lateral walls (Figure 2C), but was never recorded on the lateral walls alone (Figure 2B,D). Our findings are in agreement with a previous clinical study by Barber and Sims (1981), who reported that the healing process started in the central part of the resorption cavity. The difference in cementum deposition between humans and animals may be explained by certain morphological differences between human cementum and the cementum of various mammals, such as rats and dogs as indicated by observations in the scanning electron microscope (Boyde and Jones, 1968; Jones and Boyde, 1972).

Theoretically, when deep resorptions are found, the squeezing of tissue between the tooth and bone surface is less pronounced on the bottom of the resorption cavity than in the periphery due to the resilience of the tissue. This should promote cell proliferation and regeneration of tissue in the deep central part of the resorption lacuna and might explain the centrifugal deposition of repair cementum in this study.

The present investigation revealed that the repair process of root resorption was achieved by deposition of mainly cellular cementum. However, in the initial phase of healing, acellular cementum was recorded.

It may be hypothesized that cellular cementum is formed when the repair process is fast and cells are captured in the repair tissue. Acellular cementum would then be associated with slow repair. The distinction between slow and fast deposition of repair cementum has been discussed by Vardimon *et al.* (1993) in a report on monkeys, i.e. functional rapid cellular repair and non-functional retarded acellular repair. This has later been confirmed by Bosshardt (1994), who suggests that the initial reparative cementum is often of an acellular type, but that the continued repair process of the resorption cavity occurs with rapidly formed cellular cementum. However, repair has been claimed to be always of a cellular type (Barber and Sims, 1981; Langford and Sims, 1982) and in some instances even with osteoid tissue (Timms and Moss, 1971).

Besides the mechanism that rapid deposition encapsulates more cells, the cells responsible for producing acellular cementum may be phenotypically different to those producing cellular cementum. Previous publications indicate that this is possible in rodents (Zhang *et al.*, 1992; Tenorio *et al.*, 1993; Tenorio and Hughes, 1996). Such a mechanism responsible for switching over from acellular to cellular healing remains to be further elucidated. Moreover, there are differences in cementogenesis in animals and humans due to variations in growth rates and tooth sizes (for review see Bosshardt and Schroeder, 1996).

The experimental periods in this clinical study in adolescents were short (2–7 weeks), and the reparative process with long-term retention in humans remains to be further elucidated. However, such studies are difficult to perform for practical and ethical reasons and careful analysis of findings from experiments in both animals and humans is therefore necessary, since they may supplement each other.

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