Indirect bone resorption in orthodontic movement: when does periodontal reorganization begin and how does it occur?

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Tooth movement induced by orthodontic appliances is one of the most frequent therapeutic procedures in clinical dental practice. The search for esthetics and functionality, both oral and dental, demands orthodontic treatments, which are often associated with root resorptions that may, in extreme cases, lead to tooth loss, periodontal damage, or both.

The knowledge of induced tooth movement biology, based on tissue, cell and molecular phenomena that take place on each day during movement progression, enable us to act safely and consciously when using drugs, procedures and interventions to optimize orthodontic treatment and patient comfort, to reduce or avoid root resorptions and to treat systemically compromised patients.

The experimental model of induced tooth movement described by Heller and Nanda[5] has been widely adopted[3,10] because results can be extrapolated to orthodontic clinical practice (Fig 1). Standardization and detailed descriptions of this experimental model ensure greater applicability and easier result extrapolations. The improvement of this model may provide further knowledge about the biology of induced tooth movement.[3,10]

In general, experimental times were 5 to 7 days in the first studies.[7,8,9,13] However, it remains unclear what tissue phenomena take place in murine maxillary first molar roots that received intense forces and produce indirect bone resorption. Several questions raised in previous studies[4,6,10,11] using this model have not been answered to this date:

» Is the root resorption associated with experimental induced tooth movement more closely related with frontal or undermining bone resorption?
» How long does it take to eliminate the hyaline areas, and when does the periodontal ligament begin its reorganization?
» When and how is the reabsorbed cortical bone replaced to reinsert the periodontal ligament?
» Do the hyalinized areas of connective tissue undergo phagocytosis, resorption or circumscription?
» Where does root resorption occur, immediately next to or away from hyaline areas?
» When indirect bone resorption is suspected, do microscopic data suggest the adoption of a greater interval for the reactivation of the orthodontic appliance?

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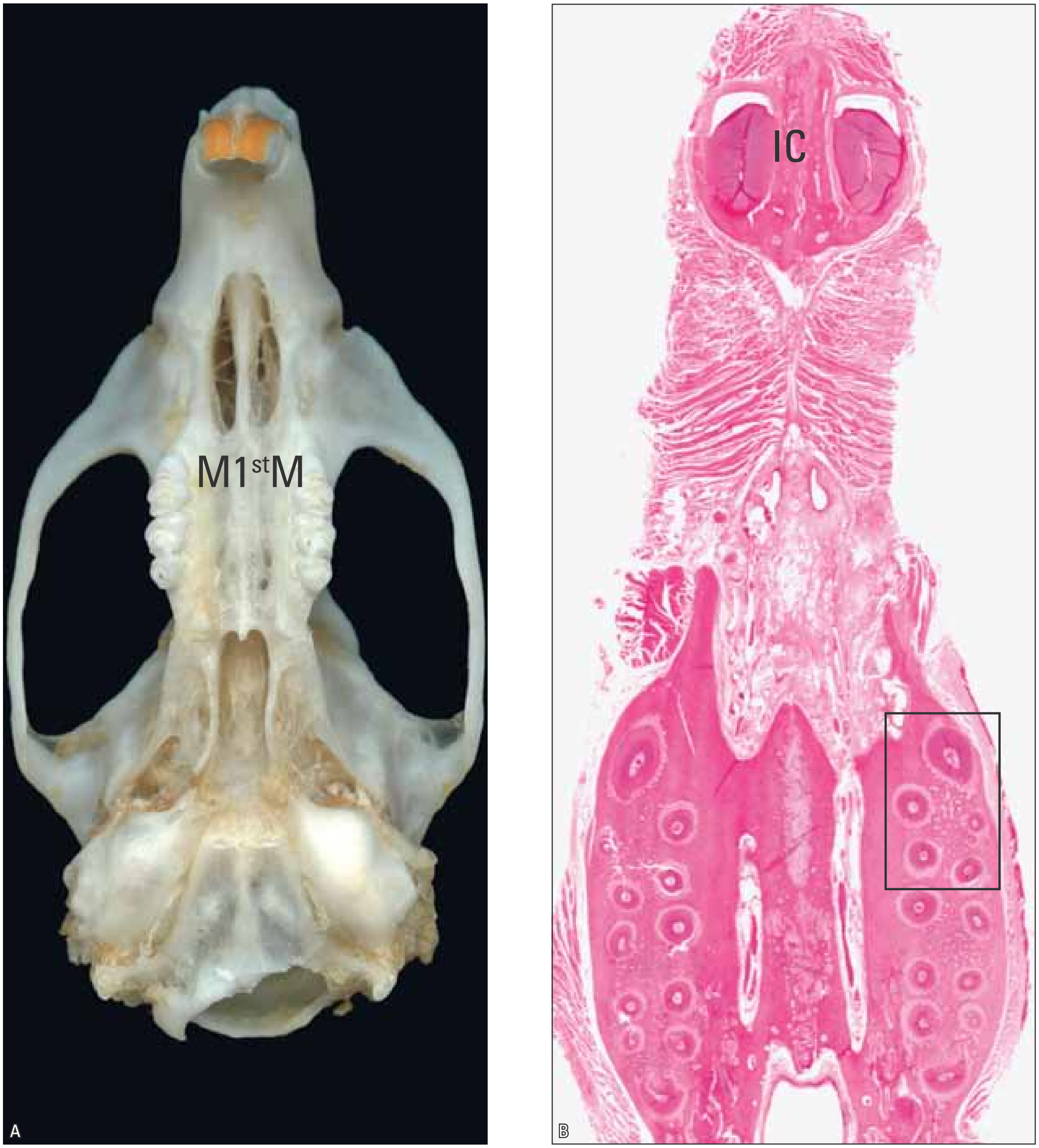

FIGURE 1 - Murine skull where molars and incisors (IC) are seen, particularly maxillary first molar (M1stM) after movement by appliance designed by Heller and Nanda.[5] Microscopic cross-section (**B**) shows tooth roots, particularly M1stM, in cervical plane.

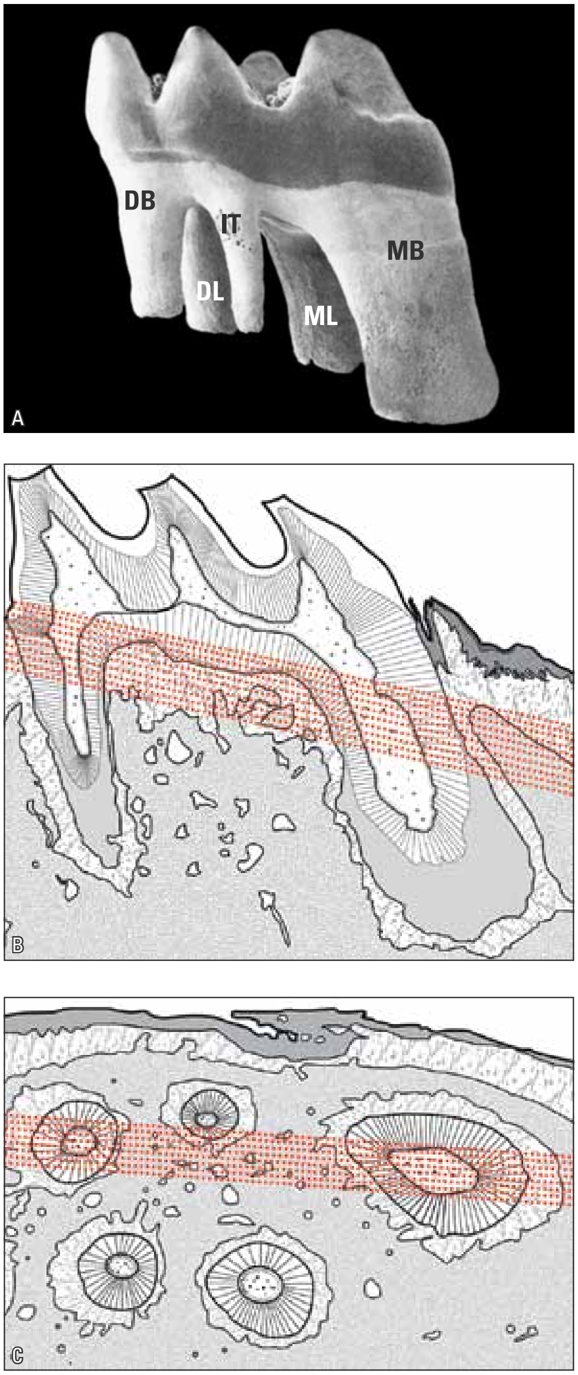

FIGURE 2 - In **A**, murine first molar and its five roots. In the mesiobuccal (MB) root, forces dissipate along its larger and longer structure. In other roots (distobuccal, intermediate, distolingual and mesiolingual), delicate structures clearly show effects of forces on periodontal tissues. In **B**, red lines show cross-sections at cervical level in schematic drawing of a longitudinal section of murine first molar. In **C**, red lines correspond to longitudinal views in cross-section of murine maxillary first molar (**A**: modified from Alatli-Kut et al.1; **B** and **C**: of Fracalossi[4]).

» When palatal expansion is used, appliance anchorage in maxillary premolars promotes hyalinization of the periodontal ligament on the buccal face. Forces dissipate and the process ends when the midpalatal suture is separated. Does indirect bone resorption begin long before that? When does it actually begin, at 3, 5, 7 or 9 days?

Few studies investigated the chronology and sequential events of indirect bone resorption and the consequent periodontal reorganization resulting from it. Microscopic analyses of the events induced by intense forces on teeth that undergo experimentally induced movement in murine models contributed to answer some of the questions raised, such as in the study conducted by Cardoso,[2] together with Consolaro, Kinoshita, Francischone, Santamaria Jr., Fracalossi and Maldonado. Their most interesting findings were the late results, when the periodontal ligament is reorganized and root resorptions are more active and intense (Figs 6, 7 and 8).

In patients, delayed events and periodontal reorganization occur at each activation time, between 15 and 21 days. At the end of six to twelve years, the resulting sum of the several orthodontic appliance activation times may be demonstrated by radiographic and CT images of periodontal tissues and tooth roots. Knowing each activation time and its beginning, middle and end substantially increases our chances of acting to reduce unwanted consequences.

Some of the interventions that orthodontic specialists may choose, based on results of experimental studies, are:

1) Defining plans to prevent root resorption and bone loss.

2) Distributing the application of forces on tooth structure to reduce patient pain and discomfort.

Ligament hyalinization reduces or blocks tooth movement and may also be associated with root resorption. Knowledge about tissue,

FIGURE 3 - Normal periodontal structures on the mesial face of murine M1stM distobuccal root, which received intense forces in the experimental model designed by Heller and Nanda.[5] B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; P = tooth pulp; V = vessels; Cb = cementoblasts; Ob = osteoblasts; ECM = extracellular matrix. (HE;10X).

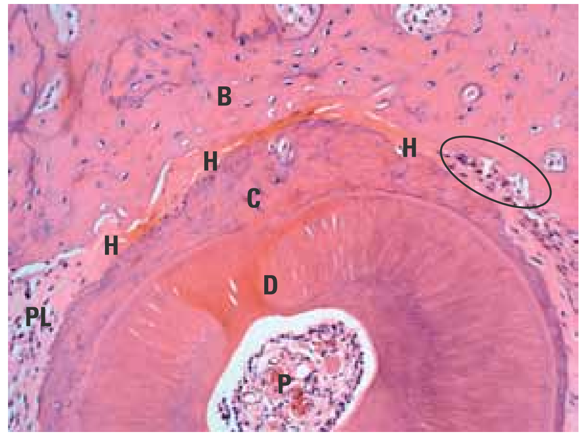

FIGURE 4 - Incipient indirect bone resorption on mesial face of murine M1stM distobuccal root after application of intense forces for 3 days. Hyalinized periodontal ligament (H) and initial clastic activity (circle) surround it. B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; P = tooth pulp. (HE; 10X).

FIGURE 5 - Indirect bone resorption on mesial face of murine M1stM distobuccal root after application of intense forces for 5 days. Hyalinized periodontal ligament (H) and clastic activity (circle) surround it. B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; P = tooth pulp; MS = marrow space. (HE; 10X).

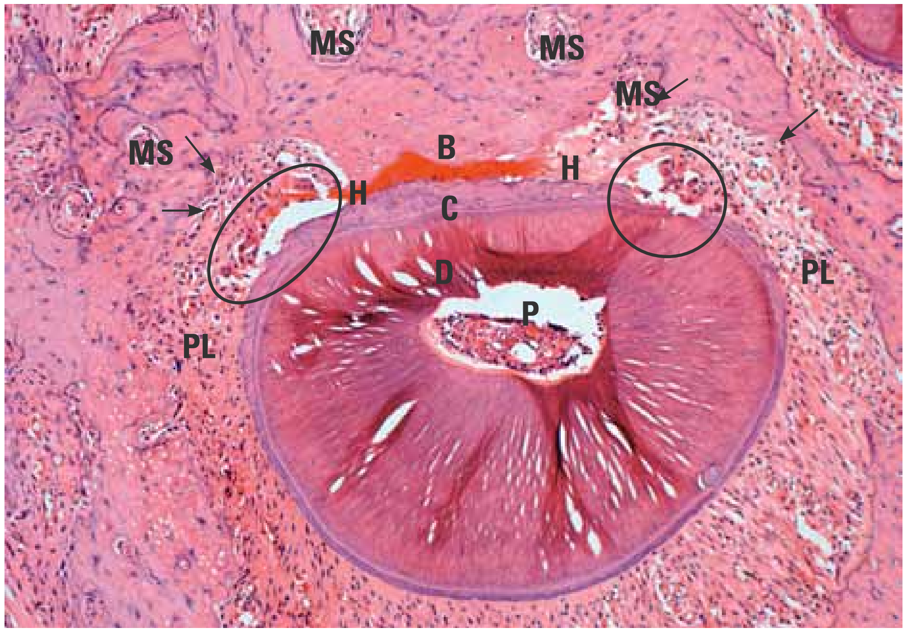

FIGURE 6 - Indirect bone resorption (arrows) on mesial face of murine M1stM distobuccal root after application of intense forces for 7 days. Hyalinized periodontal ligament (H) and clastic interaction with hyalinized areas surround it. Root surface exposure due to root resorption induced by death of cementoblasts; several associated bone remodeling units (circles). B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; P = tooth pulp; MS = marrow space. (HE; 10X).

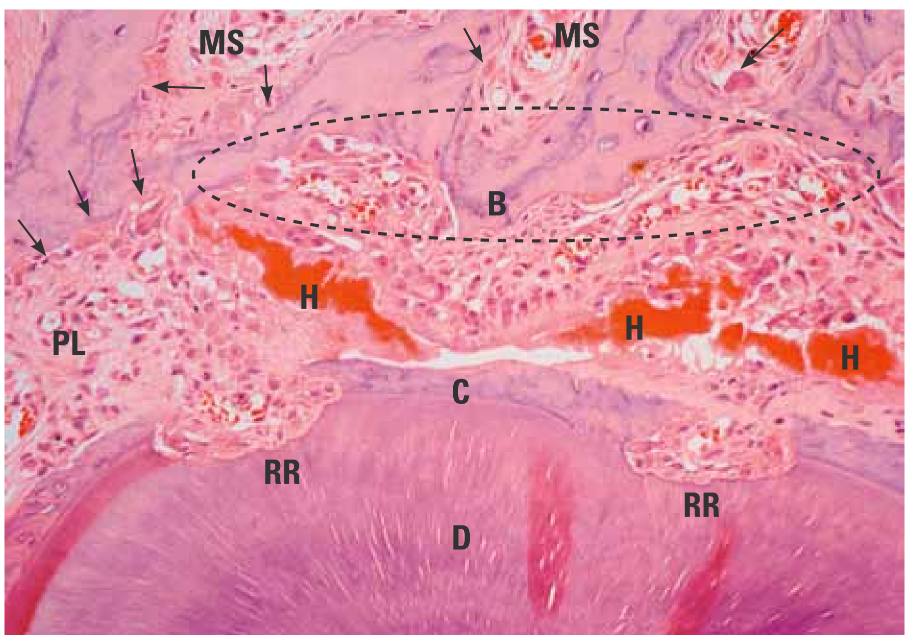

FIGURE 7 - Indirect bone resorption (arrows) on mesial face of murine M1stM distobuccal root after application of intense forces for 9 days. Ligament is reorganizing and frontal bone resorption is already visible on periodontal surface of cortical plate (circle). Hyaline areas remaining from previously hyalinized periodontal segment (H) are associated with clastic activity. Root resorption (RR) is seen in cement and dentine, together with active bone remodeling units. B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; MS = marrow space. (HE;10X).

cell and molecular phenomena involved in induced tooth movement may provide a basis for clinical procedures.

Murine molars have 5 roots,[3,5,12] and the experimental orthodontic appliance (Fig 1) designed by Heller and Nanda[5] applies intense forces on four roots: distobuccal, intermediate, distolingual and mesiolingual (Fig 2). In the mesial or mesiobuccal root, the forces applied by the appliance dissipate along larger and longer root structures, which affect periodontal tissues similarly to the application of slight or moderate forces. Because of these characteristics, in the experimental model the effects of two types of forces may be analyzed at the same time according to their intensity: mild/moderate or intense.

The distolingual root, according to the study by Cardoso,[2] may show morphological changes associated with indirect buccolingual bone resorption in cross-sections of the cervical region of the root and the alveolar bone process, as illustrated in Figures 3, 4, 5, 6, 7 and 8.

FIGURE 8 - Indirect or undermining bone resorption (arrows) on mesial face of murine M1stM distobuccal root after application of intense forces for 9 days, and more advanced reorganization than in Figure 7. Periodontal ligament is reorganizing together with remnants of cortical bone. Hyaline areas remaining from previously hyalinized periodontal segment (H) are associated with clastic activity. B = alveolar bone; PL = periodontal ligament; C = cement; D = dentine; P = tooth pulp; MS = marrow space. (HE;10X).

Final considerations

The conclusions of the study discussed here showed that:

1. At 3 days of tooth movement induced by intense forces, indirect bone resorption had not begun in most of the specimens analyzed, but some showed discrete points of bone remodeled units (Fig 4).
2. Only at 5 days were osteoclasts from bone remodeled units seen on adjacent bone surfaces and around hyaline areas. At this time, root resorption was still incipient and limited to cement (Fig 5).
3. At 7 days, there was clear indirect bone resorption on trabecular bone and cortical surfaces, but is far from the cortical bone associated with the segment of hyalinized periodontal ligament (Fig 6). Bone resorption in orthodontic movement, when induced by mild to moderate forces, occurs on the surface of cortical bone in front of the area of periodontal ligament compression and is, therefore, called frontal bone resorption. In indirect bone resorption, the connections of cortical bone with adjacent and underlying bone are undermined by numerous bone remodeling units. Root resorptions are active, occur in a larger extension and affect dentine more deeply.
4. At 9 days of tooth movement induced by intense forces, the hyaline areas are under partial resorption (Figs 7 and 8). The periodontal ligament is under reorganization. Only isolated signs of the previous undermined cortical plate remain because it is undergoing complete remodeling. Root resorptions are still actively occurring.

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