SHORT COMMUNICATION

Importance of periodontal ligament thickness

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Abstract: This study evaluated whether periodontal ligament (PL) thickness varied with root size and examined the possible influence of this variation on orthodontic mechanics. Measurements were taken of the maxillary left first molar in 54 male Wistar rats. Mean mesial and distal PL thicknesses were compared between the intermediate buccal and mesiobuccal roots using paired Student's *t*-tests with a 5% significance level. Mean values differed significantly between roots ($p < 2.2 \times 10^{-16}$). PL thickness in rats is directly proportional to root dimensions.

Descriptors: Periodontal Ligament; Rats; Tooth Movement; Tooth Root.

Introduction

In experimental studies in humans and animals, periodontal ligament (PL) thickness is reported by giving mean values and ranges. For example, mean PL thickness in rats is 0.130 (range, 0.100–0.160) mm across the molar region.[1-3]

The maxillary first molars of Wistar rats have an average of five roots of different sizes and diameters. Tooth movement studies[4,5] in which force was applied to these molars found that responses differed between the larger mesiobuccal (MB) root and the smaller intermediate buccal (IB) and distopalatal roots (Figures 1 and 2). These findings raise the question of whether different responses to force application can be explained by differences in root size. Alternatively, because roots are single, solid structures fixed to a tooth that dissipate pressure into the PL along the entire length of the radicular surface, different responses may be explained instead by variation in PL thickness.

This study assessed whether PL thickness varied with root size and whether this variation influenced the biological response to orthodontic force.

Methodology

Immobile maxillary left first molars of 54 male white Wistar rats (*Rattus norvegicus*; ~90 days old, 300 g each) were measured in this study. For histologic examination, 6-µm-thick transverse sections were taken from the cervical regions to the separation points of all first molar roots and stained with hematoxylin and eosin. Images were captured using an AxioCam MRc5 microscopic camera and optical microscope (Carl Zeiss, Göttingen, Germany). Measurements were taken using Im-

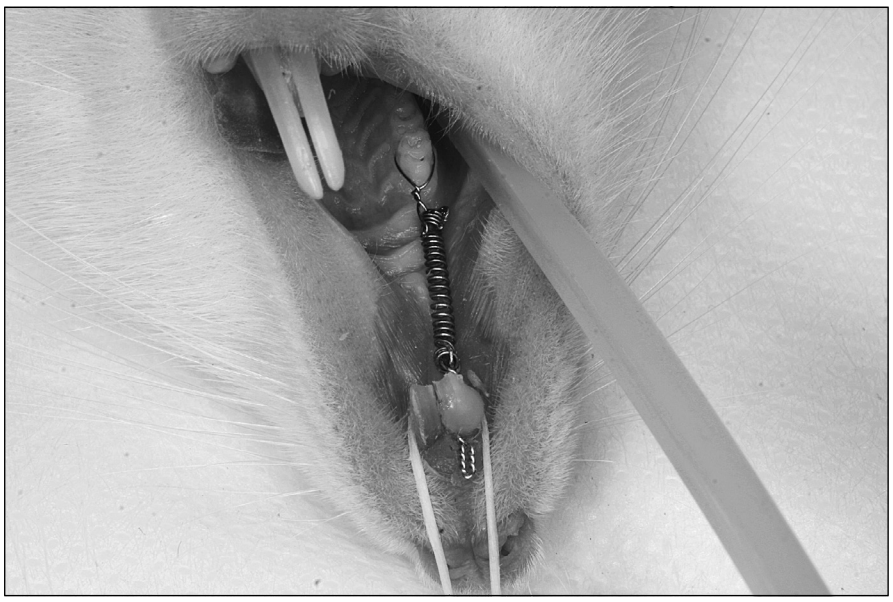

Figure 1 - Orthodontic tooth movement device on the maxillary right molar, anchored to the incisor.

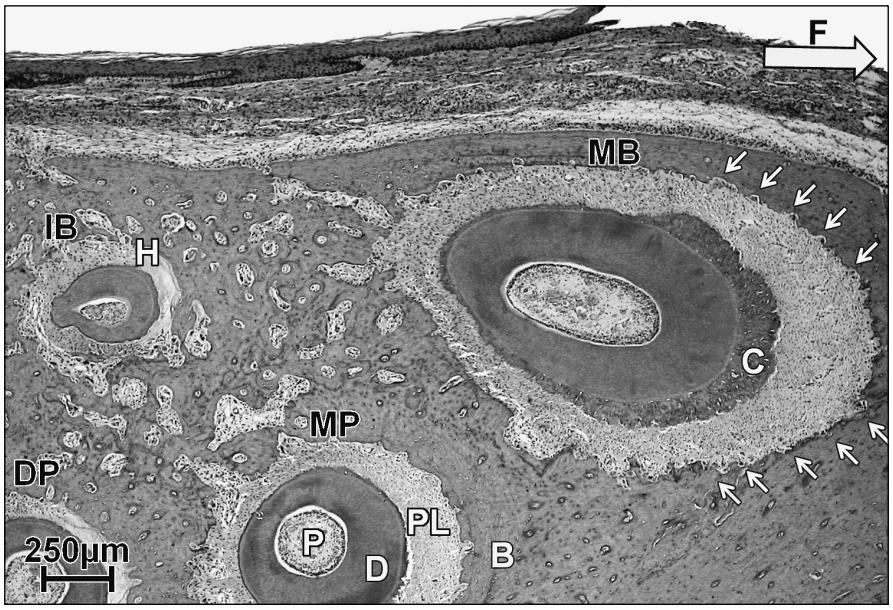

Figure 2 - Hyalinization (H) adjacent to the mesial surface of the intermediate buccal (IB) root, showing intense compression of the periodontal ligament (PL). Mesiobuccal (MB) root with normal appearance of the PL, lacking hyaline formation and direct or frontal resorption of bone (arrows). F, force; P, pulp; D, dentin; C, cementum; B, bone; DP, distopalatal root; MP, mesiopalatal root. Hematoxylin and eosin, ×25.

ageLab 98 software (Diracom Bio Informatics Ltda, Vargem Grande do Sul, Brazil) after the following series of lines were drawn on the images (Figure 3):

1. A line joining the centers of the IB and MB roots and continuing to the cementum;
2. A line dividing each root into mesial and distal sections, perpendicular to line 1 and passing through the center of the root; and
3. A line bisecting lines 1 and 2 and continuing to the cementum.

Analyses were made perpendicular to the radicular surfaces extending to the cortical bone at lines 1 and 3, i.e., three measurements each were taken on the mesial and distal root surfaces. The mean of these three measurements was used to determine PL thickness on the mesial and distal sides, respectively, of each root. Mesial and distal thicknesses were then compared between the IB and MB roots using paired Student's t-tests with a 5% significance level.

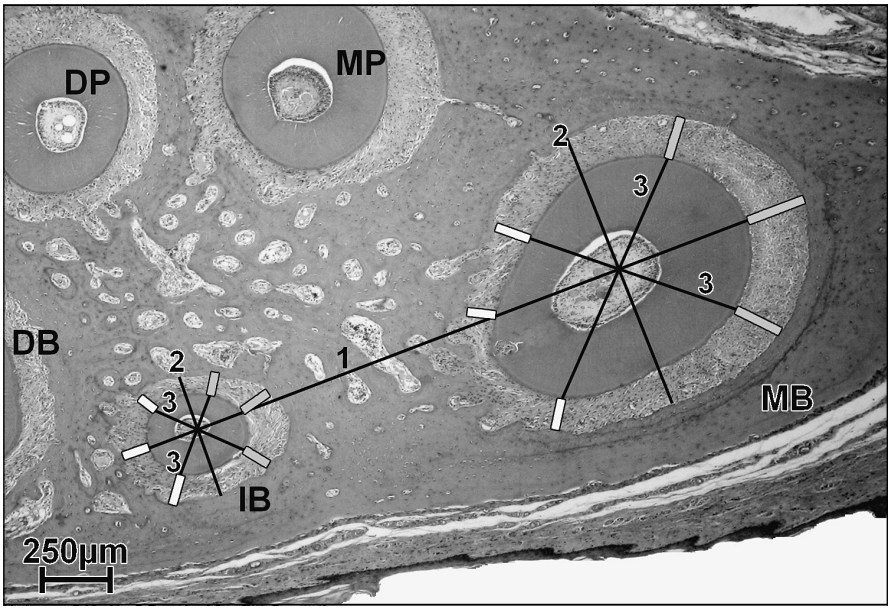

Figure 3 - Measurements taken on the maxillary left first molar roots in rats. Line 1 joins the centers of the intermediate buccal (IB) and mesiobuccal (MB) roots. Each line 2, perpendicular to line 1, passes through the center of the root and continues to the alveolar margin, separating the root into mesial and distal portions. Each line 3 bisects lines 1 and 2 and continues to the cementum. The white and gray lines indicate periodontal ligament (PL) thicknesses at lines 1 and 3. DB, distobuccal root; DP, distopalatal root; MP, mesiopalatal root. Hematoxylin and eosin, ×25.

Results

Mean distal and mesial PL thicknesses were 0.091 mm and 0.099 mm, respectively, on the IB root, and 0.117 mm and 0.171 mm, respectively, on the MB root (Figures 4 and 5). Mean values differed significantly between roots ($p < 2.2 \times 10^{-16}$).

Discussion

Orthodontic tooth movement (OTM) experiments in rats are performed to evaluate the effects on supporting tissues and the amount of tooth movement.[3-5] For example, the maxillary right first molar can be subjected to OTM by means of a closed coil spring anchored to the maxillary right incisor (Figure 1). The spring produces a force that moves the molar anteromesially. Microscopic analysis can then be performed to evaluate the effects of the force on tissues surrounding the roots.

An OTM study in rats using intense force observed no hyalinization around the MB roots,[4] but direct bone resorption on the compressed side. Such resorption is often associated with the slight application of force to the PL,[2] suggesting that force is better distributed in the PL of the larger MB root of the first molar compared with the PLs of smaller roots, reducing hyaline formation and root resorption. However, in our observations of OTM, the IB root seemed to experience intense pressure, resulting in hyaline formation that covered up to half of the compressed PL (Figure 2). In this study, we evaluated whether this difference could be explained by variations in PL thickness.

Kondo[6] reported that blood circulation in the PL persists when its thickness is compressed by 1/3. In view of this finding, Kogure and Noda[7] applied forces that compressed 1/3 and 2/3 of the PL. They observed hyaline formation and severe root resorption in PLs that had been compressed by 2/3, but not in those that had been compressed by 1/3.

In this study, we found wide variation in PL thickness between transverse sections of the IB and MB roots of immobile molars that were associated with root size and shape. Mean mesial and distal PL thicknesses differed significantly between the MB and IB roots; the mesial PL thickness of the MB root was almost twice that of the IB root. Thus, PL thickness is clearly related directly to root dimensions, increasing with root size.

These findings suggest that the application of intense force that completely compressed the PL of the IB root would compress the PL of the MB root to only half of its thickness. Thus, greater PL thickness in the MB root leads to better dissipation of force, whereas stress is more concentrated in the thinner PL of the IB root, with a greater potential for hyaline formation and root resorption.

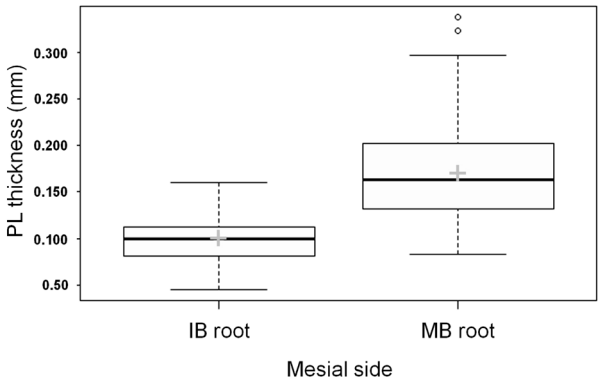

Figure 4 - Mesial periodontal ligament thicknesses on the intermediate buccal (IB) and mesiobuccal (MB) roots. +, mean; °, outlier.

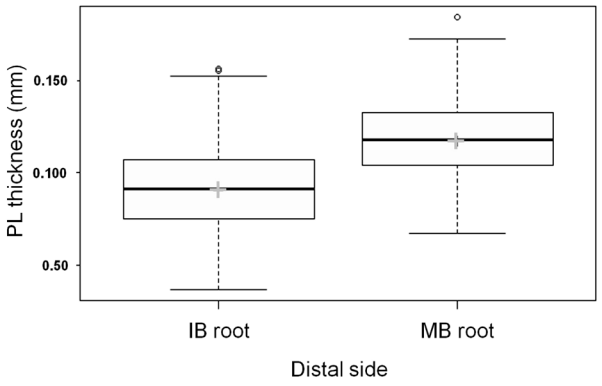

Figure 5 - Distal periodontal ligament thicknesses on the intermediate buccal (IB) and mesiobuccal (MB) roots. +, mean; °, outlier.

Bone and root surfaces are not uniform, and stress or strain can be concentrated in areas other than the PL, as demonstrated by Cataneo *et al.*[8] By analogy with experimental studies in rats, PL thickness is also likely to vary in the roots of human teeth, which also have varying shapes and sizes. Smaller roots may show more severe effects, such as resorption and hyalinization, which are not results of their smaller size, but of reduced PL thickness, which compromises pressure dissipation.

PL thickness (mean in rats, 0.130 mm) can be reduced by lack of function to around 0.055–0.114 mm.[1] Age-related variation in prostaglandin E_2 levels in the PL can explain differences in the rate of orthodontic treatment.[9] Thus, PL thickness is a determining factor in the effect of force application; a thinner PL will result in an increased local effect.

Conclusion

The results of this study indicate that PL thickness in rats is directly proportional to root dimensions, and that the biological response to force application varies with PL thickness. Thus, care should be taken in interpreting the results of research involving roots of different dimensions.

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