ONLINE ARTICLE*

Study of tension in the periodontal ligament using the finite elements method

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Abstract

Orthodontic movement is process of transformation of a physical stimulation into a force applied to a tooth, with a biological response identified as bone remodelling. Although it is possible to measure the force applied on a tooth, its distribution around the root is irregular forming areas of higher concentration of tensions, which do not correspond to the force initially applied. To evaluate the behavior of the periodontal ligament after the application of an external action and to prove which would be the areas of higher tension generated in the periodontium, the Finite Elements Method (FEM) was used in comparison to the results obtained *in vivo* on experimental models in rat. To test the error susceptibility of the technique used in the experimental model, the force application was simulated in three different heights on the mesial surface of the molar. The resulting histological analysis was compared with the result obtained for the computational code and disclosed that the greater focus of osteoclasts in activity had coincided with the compressed areas of the periodontal ligament. The alteration of points of force application generated areas of more extensive deformations in the periodontal ligament, as the point of application was more distant of the initial point, the horizontal force vector became bigger. These results demonstrate that the FEM is an adequate tool to study the distribution of orthodontic forces. The sensitivity of the experimental model used was also observed in relation to the installation of the dental movement device, which should be considered depending on the objective of the research.

Keywords: Finite Elements Method. Orthodontics. Tensions.

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Editor's abstract

Orthodontic tooth movement is achieved when forces are applied to teeth and transmitted to the supporting periodontium, which triggers the remodeling of the alveolar bone by means of bone deposition in the traction area and bone resorption in the area under pressure. Studies to define parameters to guide orthodontic practices are conducted considering two aspects: Experiments with human beings or animals; and numerical analyses conducted using the finite element method (FEM). FEM analysis is an excellent computational resource for the evaluation of tooth structures in the several areas of dentistry and a low-cost and practical alternative to test materials and techniques. The purpose of the present study was to evaluate, using numerical experiments, the results of *in vivo* trials and to test the sensitivity of the technique used for tooth movement. Experimental model and finite element analyses were conducted. For the experimental analysis, tooth movement was induced in the maxillary left first molars of rats (n=6) using a nickel-titanium closed coil spring at a force of 0.25 N. Seven days after coil spring activation, the animals were killed and histological slides were prepared. To analyze the tooth structure using FEM analysis, tooth geometry was defined and the rat's maxillary molar was extracted and photographed using a stereomicroscope. The photograph was printed on graph paper, and the coordinates of interest were obtained. Nine-node tetrahedral finite elements for plane stress of the ADINA 8.3 computational code were used to create the discretization mesh (Fig 1). The forces were applied to sites located at 0.38 mm, 0.64 mm and 0.83 mm (Fig 2) while the same anchorage point was kept for the three situations. The purpose was to evaluate the effect of height on the application of force and error susceptibility of the technique applied to the experimental model of tooth movement and to small deviations in the spring position in relation to the occlusal surface of the tooth. Histological analysis was compared with the result obtained using the computational code and revealed that the greater foci of active osteoclasts were found in areas compressed by

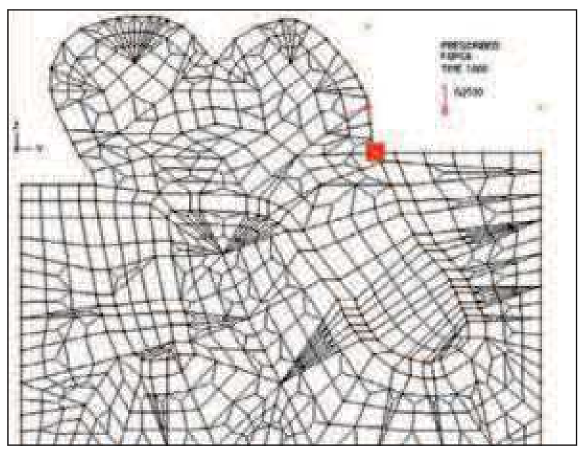

FIGURE 1 - Finite element mesh; square indicates reference site for application of forces (cervical margin of tooth).

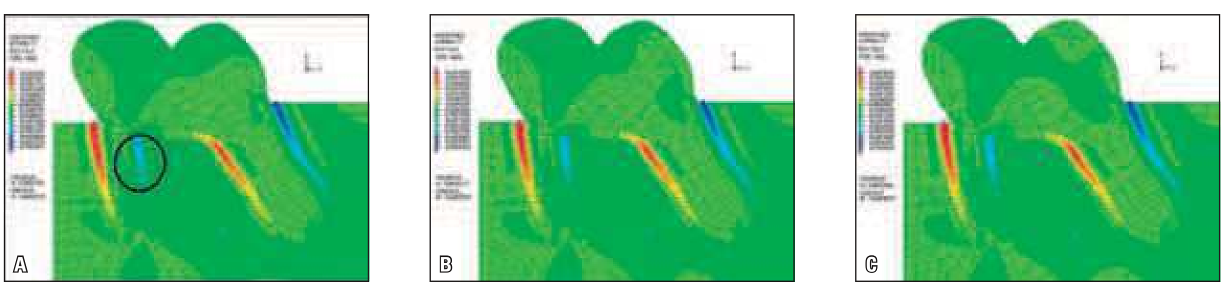

FIGURE 2 -Deformations due to forces applied to sites at 0.38 mm, 0.64 mm and 0.83 mm from the cervical margin.

the periodontal ligament. The change in force application sites generated larger deformation areas in the periodontal ligaments as the application was more distant from the initial site and the horizontal force vector was greater.

The authors concluded that FEM analysis is an adequate tool to study the distribution of orthodontic forces. Additionally, the sensitivity of the experimental model in relation to the placement of a device to promote tooth movement should be considered depending on the objective of the study to be conducted.

Questions for the authors

1) Do the authors believe that orthodontists will have access to finite element methods (FEM) in the future to plan their cases using computational modeling?

Finite element analysis is not the application of some commercial software. It is an approximation method for the study of complex structures and, therefore, requires knowledge of engineering to be applied. For an orthodontist to be capable of using it, it is necessary to obtain qualifications by thoroughly studying this application method, which has been well established in engineering, and to acquire basic knowledge in this area. We believe that it can be directly applied to research to evaluate orthodontic techniques, appliances and new mechanical resources. Case planning will benefit from the results of these studies.

2) What are the limitations of using FEM analysis when working with biological responses?

The greater difficulty is the mechanical representation of the actual behavior of biological tissues in the mathematical models that are to be analyzed using FEM. However, in studies conducted in recent years, efforts have been made to ensure that simulations come increasingly closer to reality. Another limitation of this study is the simulation of masticatory movements, whose representation is limited when compared with actual mastication.

3) Is FEM analysis useful only for isolated evaluations, or is it also used for complex systems, such as a full maxillary arch with a fixed appliance associated with an extraoral appliance and intermaxillary elastics?

FEM analysis may be used for planning and testing complex mechanical systems, such as designing aircrafts, bridges and buildings. Therefore, it can also evaluate the behavior of the stomatognathic system in general, such as mastication, or the composition of both arches. Materials with different behaviors, such as human tissues, appliances or elastic bands, may also be evaluated simultaneously. However, as the system becomes more complex, the number of variables, such as muscles and ligaments, is high, and this requires that the researcher should have extensive experience in bioengineering and master FEM analysis.

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