

An Overview of Basic Concepts of Finite Element Analysis and Its Applications in Orthodontics

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Abstract. *Purpose:* The aim of this article is to acquaint the readers with the aims and goals of the finite element method and how to use it in dentistry and especially in orthodontics.

Methods: The finite element method (FEM) has shown to be a beneficial research tool that has assisted scientists in various analyses such as stress-strain, heat transfer, dynamic, collision, and deformation analyses. The FEM is responsible for predicting the behavior of objects under different working conditions. It is a computational procedure to measure the stress in an element, which performs a model solution to solve a problem; the FEM subdivides a large system into smaller, simpler parts called finite elements. This is achieved by a particular space discretization in the space dimensions, which is implemented by the construction of a mesh of the object. The technique of FEA lies in the development of a suitable mesh arrangement.

Conclusions: The FEM can be effective in understanding the behavior of teeth, both jaws, craniofacial structures, and other hard tissue structures of humans under various working conditions, as the technique allows for evaluating tooth movement and the stress distribution within the surrounding alveolar bone, the periodontal ligament (PDL). This technique is exceptionally valuable for evaluating mechanical aspects of biomaterials and human tissues that can hardly be measured *in vivo*. This review article presents the FEM, its methodology, and its application in the orthodontic domain.

Keywords: Finite element analysis, Finite element method, Orthodontics.

INTRODUCTION

Experimental, analytical, and numerical methods are well-known techniques used to solve problems [1]. Each method has some advantages and disadvantages making them practical or impractical in different problems. For instance, although experimental technique can lead to trustable outcomes, it has some drawbacks such as being time consuming, can be influenced from human error, being high-cost technique, all variables cannot be controlled, and its result can be applied to only one situation [2]. Furthermore, employing analytical methods would be really challenging and, in some cases, inapplicable for complex problems (like alveolar structures). Therefore, the numerical method can be a good choice in terms of time, cost, eliminating human error, managing the variables, repeating the analyses, and solving complex problems. The Finite Element Method (FEM) is

regarded as a numerical method that can be employed to model physical or physiological phenomena. Computers using the FEM, simulate different physical and geometrical characteristics of any structures. This method can assist in the prediction of behavior of any object under differing situations, and can help with the design and manufacturing process [3].

Finite element analysis (FEA) evaluates physical phenomena using a numerical technique, the FEM. It is a powerful computerized method that can analyze the behavior of complex geometry with heterogeneous material properties. FEA is employed in orthodontics by evaluating the interactions between the teeth and the surrounding tissues. The method allows orthodontists to understand better the physiological reactions that are likely to occur within the dento-alveolar complex, resulting from thermal stress created by hot and cold drinks [4].

FEA was first developed by R. Courant [5] in 1943 using the Ritz method in numerical analysis. A few years later, in 1956, Turner MJ et al. [6] published a paper focusing on the "stiffness and deflection of

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