ORIGINAL RESEARCH ARTICLE

STRESS IN THE PERIODONTAL LIGAMENT DURING ORTHODONTIC RETRACTION OF POSTERIOR TOOTH: A FINITE ELEMENT ANALYSIS

Authors:

Dr. Arif Ismail[1]
Dr. Asif Ismail[2]
Dr. Hariprasad[3]
Dr. Shaji A P[4]
Dr. Vaishak R[5]
Dr. Sonu Thomson P[6]

Assistant Professor[1]
Department of Orthodontics and Dentofacial Orthopedics, Royal Dental College, Palakkad, Kerala

Reader[2]
Department of Pedodontics and Preventive Dentistry, Annoor Dental College and Hospital Muvattupuzha, Kerala

Professor[3]
Department of Orthodontics and DentofacialOrthopedics, Royal Dental College, Palakkad, Kerala

Professor[4]
Department of Orthodontics and DentofacialOrthopedics, Royal Dental College, Palakkad, Kerala

Assistant Professor[5]
Department of Orthodontics and DentofacialOrthopedics, Royal Dental College, Palakkad, Kerala

Assistant Professor[6]
Department of Orthodontics and Dentofacial Orthopedics, Royal Dental College, Palakkad, Kerala

Address for correspondence:
Dr. Arif Ismail
Assistant Professor
Department of Orthodontics and Dentofacial Orthopedics, Royal Dental College, Iron Hills, Chalissery, Palakkad, Kerala 679536
E mail: dr.arif89@yahoo.in

ABSTRACT

The purpose of the study was to use the finite element method to investigate the stress related changes in periodontal ligament of the posterior segment under orthodontic force application. The three dimensional finite element models of the maxillary first molar, maxillary first premolar, bracket, arch wire and molar tube are constructed. The models of the tooth were made from CT scans of the upper dentition. Uneven distributions of the compressive and tensile stresses were seen in the PDL. This was due to the tendency of the teeth to rotate and tip instead of undergoing bodily movement.

Keywords: Orthodontic, Dentoalveolar, Archwire, FEM

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INTRODUCTION

The study of orthodontic biomechanics requires the understanding of the nature of stresses and strain in the periodontium induced by orthodontic forces. Periodontal ligament tooth and alveolar bone are deformable entities under loads. Stress in the periodontal ligament is believed to be the initiating factor in tooth movement and a range of stresses are transmitted through alveolar bone through periodontal ligament.

Experimental techniques are limited in measuring the internal stress levels of the periodontal ligament. The major challenge comes from constructing complicated three dimensional shapes of tissues with different biomechanical properties. These characteristics of the periodontium make the finite element method (FEM) the most suitable means of analysis because of its ability to handle various shapes and material in homogeneity[1].

Finite element analysis (FEA) was introduced by R.Courant in 1943. It is a powerful computer stimulation tool in solving stress strain problems in the mechanics of solids and structures in engineering. FEM is an approximation method that divides the entire region of the structure into a set of elements the are connected by points called nodes. Element types are decided, and each element is assigned material properties to represent the physical properties of the model. The forces and boundary are defined to stimulate applied loads and constraint of the structure. The structural response is computed and presented for display.[2]

It is very important to keep in mind that the FEM will give results based upon the nature of the modeling systems and for that reason, the procedure for modeling is most important.

This study involves analyzing the stress related changes occurring in the periodontal ligament of the posterior segment during orthodontic force application. The direction of forces used in this study is mesial and distal. A model of 0.019 x 0.025 stainless steel arch wire was also made.

MATERIALS AND METHOD

A CT-Scan of the upper dentition and maxilla was taken of a patient in the axial direction at a distance of 1mm. The scanned images were converted into soft copy and were viewed with dental software and images were copied to modeling software.

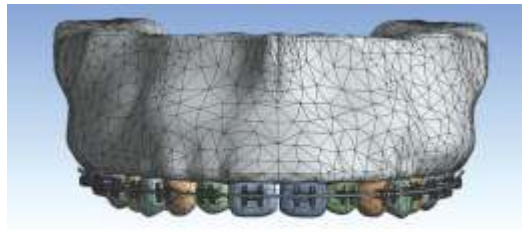

Fig 1. FEM Model of Maxilla with brackets and archwire

Different volumes were created for all the teeth, bone, wire and PDL to study the movement of individual teeth in the alveolar bone sockets. The bracket considered for this study was of MBT, 0.022 x 0.025 inch slot with molar tubes. A complete scan 3D image replicating the exact shape and size of the brackets with tip and torque values incorporated.

Fig 2. FEM Model of Periodontal Ligament

The different structures such as alveolar bone, dentition, periodontal ligament and various wires used in the finite element model of human maxilla were assigned their respective material properties. The material data used in this study were taken from finite element studies conducted previously by Tanne K et al[1] (Table 1).

Next phase was to study the stress distribution in the periodontal ligament of the posterior

Material	Young's modulus(N/mm2)	Poissons ratio
Tooth	20300	0.30
Periodontal Ligament	0.68000	0.49
Bone	140000	0.30
Stainless Steel	201000	0.31

Table 1. Material Properties

segment using FEA in response to Mesialising force and Distalising force.

RESULTS

The resulting stress patterns generated in the periodontal ligament were represented by different colours, from blue to red. Different colours represented different stress levels in the deformed state and expressed in Newton/mm^2. Positive values with red colour indicate maximum tensile stress and negative values with blue colour indicates maximum compressive stress.

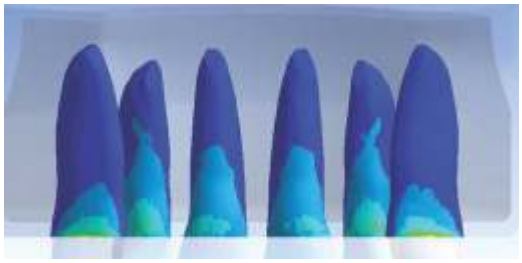

Fig 3. Stress Patterns in PDL

DISCUSSION

In the present study FEM was used to analyse the stress related changes in the posterior segment, simultaneously for two teeth during application of various orthodontic forces. The two different forces, the stress related changes were represented as color-coded bands, from blue to red. Results of similar studies on maxillary first molar by Peter D. Jeon this small difference could be due to difference in the number of teeth. showed that when a distalising force of 300gm was applied a maximum compressive stress of -0.0079 and a maximum tensile stress of 0.00501 was obtained in the present study 300gm of distalising force there was a maximum of -0.077188 and a maximum tensile stress of 0.071371. During the application of mesialising and distalising forces of varying amount the PDL of the posterior segment showed an uneven distribution of compressive and tensile stresses. This suggests that the teeth were undergoing rotation and tipping instead of bodily movement.

FORCE	COMPRESSIVE STRESS (N/mm2)	TENSILE STRESS (N/mm2)
250 gm	- 0.045064	0.088155
300 gm	-0.054076	0.105784
350 gm	-0.06309	0.12347
400 gm	-0.072715	0.128749
450 gm	-0.08116	0.158679

Table 2
Compressive And Tensile Stress Values Seen On PDL At Different Mesial Forces

CONCLUSION

FEM has been widely used in engineering .The results of the study were obtained from a simulated model. When mesial and distal forces in the range of 250 gm to 450 gm were applied tipping and rotation movements were observed instead of bodily movement.

The limitation of our model are:

Approximation in the material behavior and shape of the tissues the PDL was modeled as a layer of uniform thickness and was treated as linear, elastic and isotropic, eventhough the PDL exhibits anisotropy and non linear viscoelastic behavior because of tissue fluid.

The shape of the teeth described in this study represents most common morphologic features of a maxillary first premolar and maxillary second premolar; there may be wide variations in morphologic conditions among normal individuals, which may affect the applicability of the analysis.

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