Finite Element Study on Corono-Radicular Restored Premolars

Sandu L., Topală F., and Porojan S.

Abstract—Restoration of endodontically treated teeth is a common problem in dentistry, related to the fractures occurring in such teeth and to concentration of forces little information regarding variation of basic preparation guidelines in stress distribution has been available. To date, there is still no agreement in the literature about which material or technique can optimally restore endodontically treated teeth. The aim of the present study was to evaluate the influence of the core height and restoration materials on corono-radicular restored upper first premolar. The first step of the study was to achieve 3D models in order to analyze teeth, dowel and core restorations and overlying full ceramic crowns. The FEM model was obtained by importing the solid model into ANSYS finite element analysis software. An occlusal load of 100 N was conducted, and stresses occurring in the restorations, and teeth structures were calculated. Numerical simulations provide a biomechanical explanation for stress distribution in prosthetic restored teeth. Within the limitations of the present study, it was found that the core height has no important influence on the stress generated in corono-radicular restored premolars. It can be drawn that the cervical regions of the teeth and restorations were subjected to the highest stress concentrations.

Keywords—3D models, finite element analysis, dowel and core restoration, full ceramic crown, premolars, structural simulations.

I. INTRODUCTION

RESTORATION of endodontically treated teeth is a common problem in dentistry, related to the fractures occurring in such teeth and to concentration of forces [1]. Particularly, the magnitude and the angle of the load greatly influence the long-term success of restorative systems involving central incisors [2]. Post restorations are complex systems where the stress distribution within the structure is multiaxial, non-uniform and depending on the magnitude and direction of the applied external loads [3].

Little information regarding variation of basic preparation guidelines in stress distribution has been available. To date, there is still no agreement in the literature about which material or technique can optimally restore endodontically treated teeth.

The degree of stress generated in the endodontically treated and restored tooth can be influenced by the composition and configuration of the dowels used for the restoration. Two

Sandu L. is with the "V. Babeş" University of Medicine and Pharmacy Timişoara, Romania (e-mail: lilianasandu@gmail.com).

Topală F. is with the "V. Babeş" University of Medicine and Pharmacy Timişoara, Romania (e-mail: florin.topala@gmail.com).

Porojan S. is with the "V. Babeş" University of Medicine and Pharmacy Timişoara, Romania (e-mail: sorin_poro@yahoo.com).

parameters strongly influences the mechanical behavior of endodontically treated teeth restored with posts: the design and the rigidity of the materials. In order to assess all the eventual variables, also the types of materials used for core build-up and crown restoration have to be carefully evaluated [4].

To date, there is still no agreement in the literature about which material or technique can optimally restore endodontically treated teeth [5].

The simultaneous interaction of the many variables affecting a restorative system can be studied by means of a simulation in a computerized model [6].

The continuing evolution of numerical analysis methods and their increased reliability and accuracy have made them indispensable in solving biomechanical problems. Finite element method (FEM) has proven itself as an extremely powerful tool in addressing a wide range of biomedical problems that have proven challenging for more conventional methods because of structural and material complexity. The FEM can predict failure by fracture [7].

The simultaneous interaction of the many variables affecting a restorative system can be studied by means of a simulation in a computerized model. The finite element analysis (FEA) consists in dividing a geometric model into a finite number of elements, each with specific physical properties. The variables of interest are approximated with some mathematical functions. Stress distributions in response to different loading conditions can be simulated with the aid of computers provided with dedicated software. As a consequence, detailed evaluations of the mechanical behavior of biologic and/or restorative systems are achievable [4,8]. The FEA could be useful in optimizing restorative design criteria and material choice and in predicting fracture potential under given circumstances [4,9].

The first papers based on FE modeling and stress distribution in post and crown restored teeth are based on two-dimensional (2D) models. Two-dimensional meshing procedures do not allow to correctly assess the spatial distribution of stresses. In order to overcome such a problem, three-dimensional FEA was introduced to obtain more realistic models [3, 4, 9].

II. OBJECTIVE

The aim of the present study was to evaluate the influence of the core height and restoration materials on corono-radicular restored upper first premolar.

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III. MATERIALS AND METHODS

The first step of the study was to achieve 3D models in order to analyze teeth, dowel and core restorations and overlying full ceramic crowns. The geometry of the intact tooth was obtained by 3D scanning using a manufactured device. The collected data were used to construct three dimensional models using Rhinoceros (McNeel North America) NURBS (Nonuniform Rational B-Splines) modeling program. These points were used to extrapolate the shape of the object, a process called reconstruction. Reconstruction involves finding and connecting adjacent points in order to create continuous surfaces. Nonuniform rational B-spline (NURBS) is a mathematical model commonly used in computer aided design, manufacturing and engineering. With Rhinoceros modeling program the preparations and the appropriately prosthetic restorations were designed.

Round canal shapes were modeled for the dowel, for both roots, to allow the design of the dowel-and- core 3D models. The base diameter and insertion depth of about 2/3 of the root length were maintained constant. The height of the core was decreased with every 0.2 mm for each case. All the restorations were simulated to be covered by all-ceramic crowns (Fig. 1).
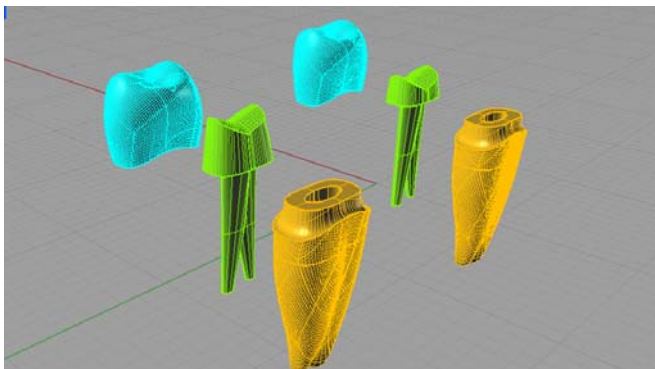

Fig. 1 3D model of a prosthetic restored maxillary first premolar – prepared root, dowel and core restoration, and crown

The FEM model was obtained by importing the solid model into ANSYS finite element analysis software (Ansys Inc., Philadelphia, USA) (Fig. 2, 3).

A three-dimensional finite element analysis was performed. All the nodes on the external surface of the root were constrained in all directions. The finite element model was obtained by dividing in 3833 solid elements connected in 7563 nodes (Fig. 4).
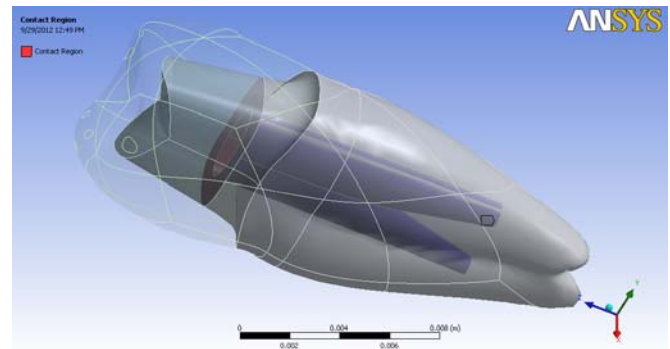

Fig. 2 Geometry of the dowel-and-core prosthetic restored maxillary first premolar imported in ANSYS
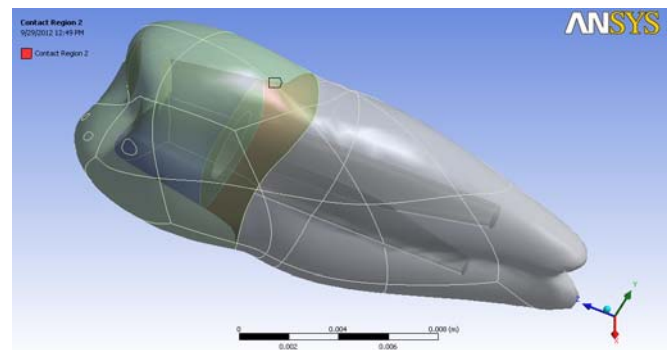

Fig. 3 Geometry of the complete prosthetic restored maxillary first premolar imported in ANSYS
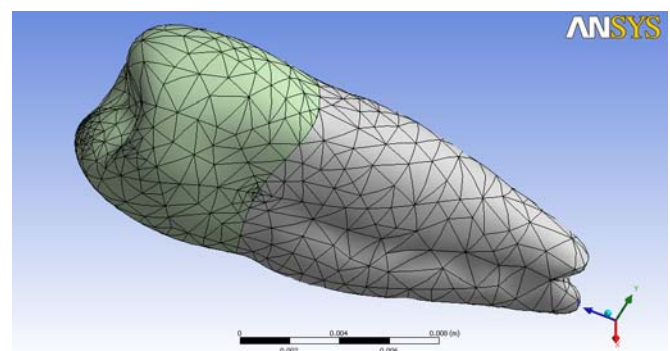

Fig. 4 Finite element model of the maxillary first premolar

An occlusal load of 100 N was conducted, and stresses occurring in the restorations, and teeth structures were calculated. The load was applied in 5 points, according to the contact points with the antagonists at 90° angle with tooth surface in that point (Fig. 5). Von Mises equivalent stresses was calculated.
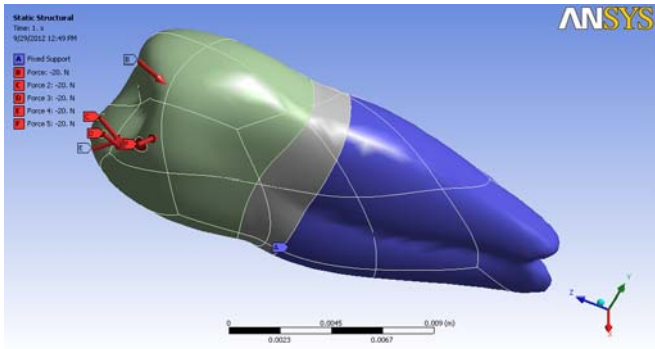
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Fig. 5 Loading of the restored premolar

IV. RESULTS AND DISCUSSIONS

For all designs (sample 1-11), stresses in the restoration, and tooth were evaluated separately (Table I, Fig. 6).

TABLE I
VON MISES EQUIVALENT STRESS VALUES IN THE RESTORATIONS AND IN THE PREMOLARS FOR ALL SAMPLES

Sample	Core height [mm]	Von Mises equivalent stress [Pa]		
		Dentin	Crown	Dowel and core restoration
1	x	1.32E+07	1.06E+08	1.71E+07
2	x-0.2	9.60E+06	9.39E+07	1.71E+07
3	x-0.4	9.58E+06	1.00E+08	1.71E+07
4	x-0.6	9.59E+06	9.58E+07	1.70E+07
5	x-0.8	9.60E+06	9.77E+07	1.71E+07
6	x-1	9.59E+06	1.03E+00	1.70E+07
7	x-1.2	9.59E+06	8.85E+07	1.70E+07
8	x-1.4	9.64E+06	9.75E+07	1.70E+07
9	x-1.6	9.64E+06	9.63E+07	1.70E+07

Fig. 6 Von Mises equivalent stress values in the restored premolar

In the prepared teeth stresses were generated around the marginal preparation line, in the palatal area of the ferrule (Fig. 7).

In the crown stress values were recorded around the occlusal contact areas (Fig. 8).

In all the models the stress values recorded at the cervical part of the dowel, on palatal surface. In the core stress concentrates at regions located on the palatal half (Fig. 9). They suggest the areas vulnerable to damage.

For the studied cases, the stress values were not significant

influenced by the height of the core.
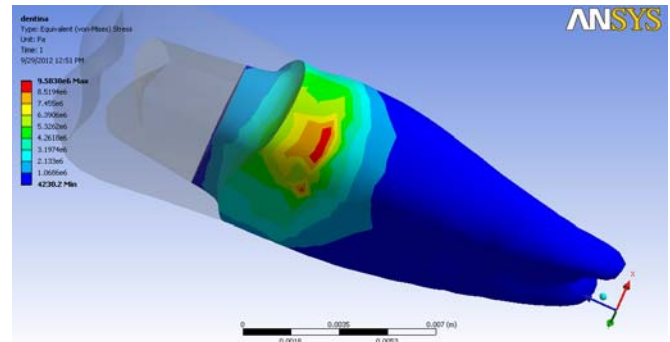
Fig. 7 Stress distribution in the prepared tooth

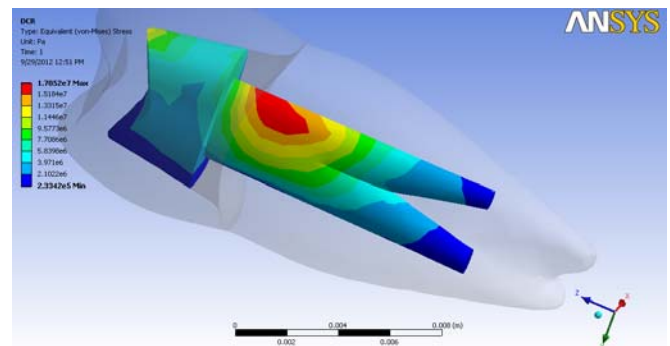Fig. 8 Stress distribution in the overlying crown

Fig. 9 Stress distribution in the dowel and core restoration

A number of factors influence the functional life span of a restoration on a root filled tooth; these include the amount of remaining enamel and dentine, the properties of restorative materials and the design of the tooth preparation [10].

V. CONCLUSION

Numerical simulations provide a biomechanical explanation for stress distribution in prosthetic restored teeth. Within the limitations of the present study, it was found that the core height has no important influence on the stress generated in corono-radicular restored premolars. It can be drawn that the cervical regions of the teeth and restorations were subjected to the highest stress concentrations.

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