Finite Element Study on Corono-Radicular Restored Teeth

Sandu Liliana, Topală Florin, and Porojan Sorin

***Abstract*—Two parameters strongly influences the mechanical behavior of endodontically treated teeth restored with posts: the design and the rigidity of the materials. The aim of the present study was to evaluate the influence of the root preparation taper and crown materials on dowel and core restored upper central incisor. In order to obtain relevant FEA results, particular attention was given to an accurate computer reconstruction of a tooth. Round canal shapes with different tapers were modeled for the dowel, to allow the design of the cast metallic dowel-and- core 3D models. All the restorations were simulated to be covered by all-ceramic and metal-ceramic crowns. A three-dimensional finite element analysis was performed. Von Mises equivalent stresses were calculated. Areas vulnerable to damage were located in the cervical parts of the restorations. Within the limitations of the present study, it was found that the crown material is important for the stress values.**

***Index Terms*—Crown, dowel/core, finite element, restored teeth.**

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 incisal 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 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].

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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].

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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 softwares. 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 assessing 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 root preparation taper and crown materials on dowel and core restored upper central incisor.

III. Materials and Methods

The external shape of the maxillary central incisor was obtained by 3D modeling, using literature data (Fig. 1, 2). In order to obtain relevant FEA results, particular attention was given to an accurate computer reconstruction of a tooth.

The collected data were used to construct three-dimensional models using Rhinoceros (McNeel North America) NURBS (Nonuniform Rational B-Splines) modeling program. Nonuniform rational B-spline (NURBS) is a mathematical model commonly used in computer aided design, manufacturing and engineering. It was introduced in dentistry through CAD/CAM systems. The solid model of the tooth was generated at this stage (Fig. 3).

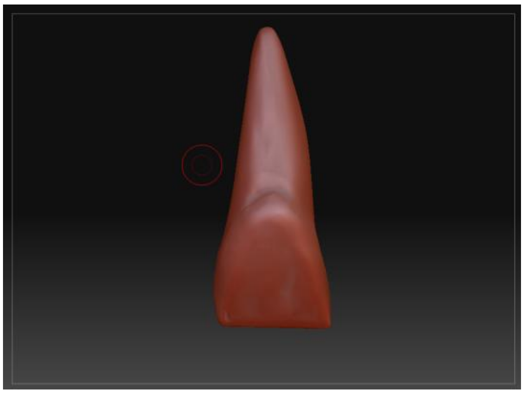

Fig. 1. External shape of the maxillary central incisor – buccal view.

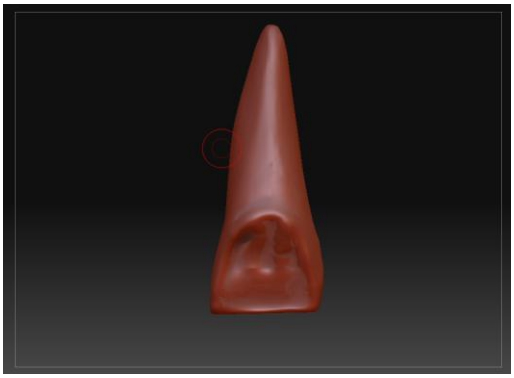

Fig. 2. External shape of the maxillary central incisor – oral view.

Round canal shapes with different tapers were modeled for the dowel, to allow the design of the cast metallic dowel-and- core 3D models.

The taper varied from 0 to 8 degree, while the base diameter 1.0 mm, and insertion depth of 10 mm (about 2/3 of the root length) were maintained constant. All the restorations were simulated to be covered by all-ceramic and metallo-ceramic crowns (Fig. 4, 5).

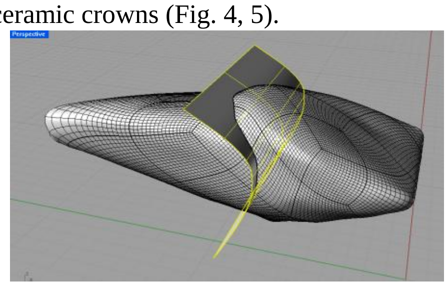

Fig. 3. Solid model of the maxillary central incisor.

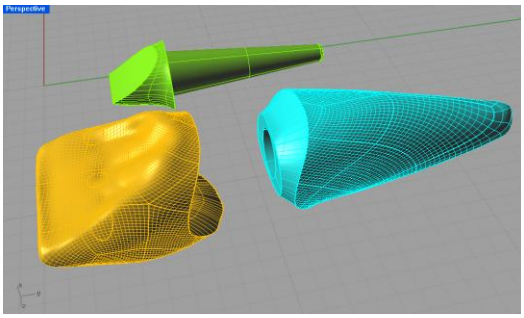

Fig. 4. 3D model of a prosthetic restored maxillary central incisor – prepared root, dowel and core restoration, and crown.

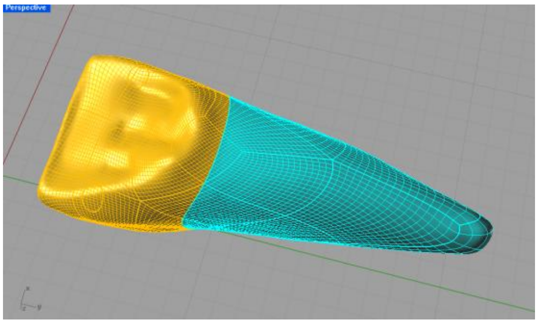

Fig. 5. 3D model of a dowel-and-core prosthetic restored maxillary central incisor.

The FEM model was obtained by importing the solid model into ANSYS finite element analysis software (Ansys Inc., Philadelphia, USA) (Fig. 6).

A three-dimensional finite element analysis was performed. All the nodes on the external surface of the root were constrained in all directions.

Experimental models with different dowel tapers were simulated. The finite element model was obtained by dividing in solid elements (Fig. 7).

An arbitrary load of 10 N was applied at 90° angle with tooth longitudinal axis on the palatal surface of the crown (Fig. 8). Von Mises equivalent stresses was calculated.

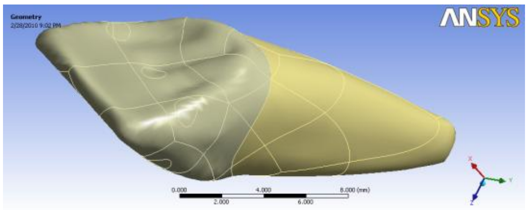

Fig. 6. Geometry of the dowel-and-core prosthetic restored maxillary central incisor imported in ANSYS.

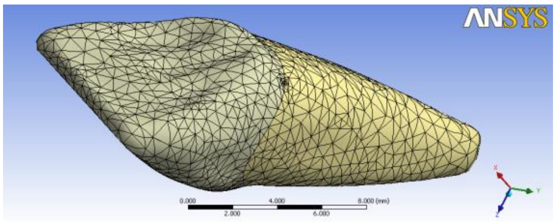

Fig. 7. Finite element model of the maxillary central incisor.

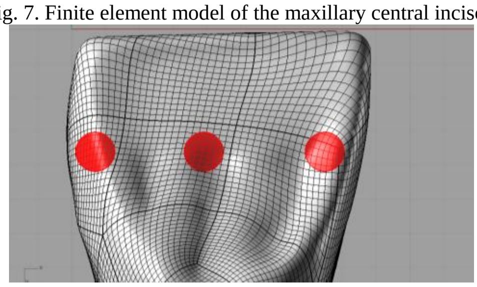

Fig. 8[redacted]. Areas selected for load application.

IV. Results and Discussions

In all the models the stress areas were recorded at the cervical half of the dowel, on buccal and palatal surface. In the core stress concentrates at regions located on the incisal half of the palatal surface, and near the crown margins, also oral (Fig. 9-12).

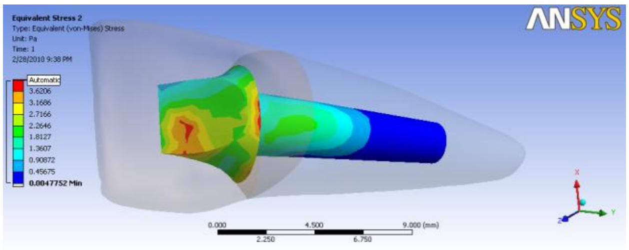

Fig. 9. Stress distribution in the dowel-and-core restoration covered with a metal-ceramic crown (taper of 3 degree).

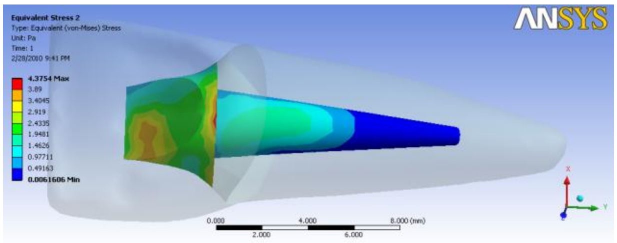

Fig. 10. Stress distribution in the dowel-and-core restoration covered with a metal-ceramic crown (taper of 6 degree).

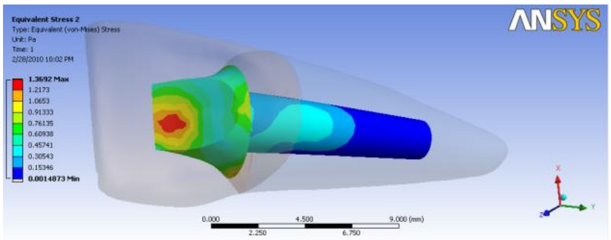

Fig. 11. Stress distribution in the dowel-and-core restoration covered with an all-ceramic crown (taper of 3 degree).

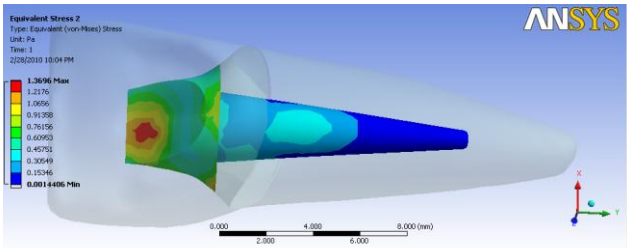

Fig. 12. Stress distribution in the dowel-and-core restoration covered with an all-ceramic crown (taper of 6 degree).

Stress patterns suggest the areas vulnerable to damage. In the crown stress values were recorded on the palatal cervical margin both for the metal-ceramic and all-ceramic crowns (Fig. 13-16).

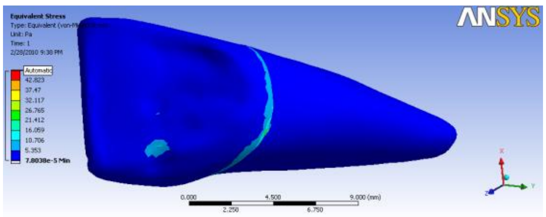

Fig. 13. Stress distribution in the metal-ceramic crown (taper of 3 degree).

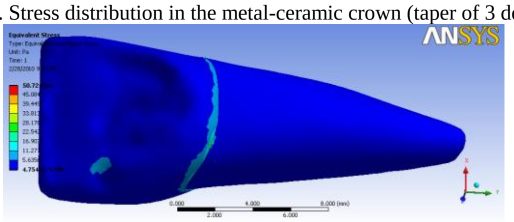

Fig. 14. Stress distribution in the metal-ceramic crown (taper of 6 degree).

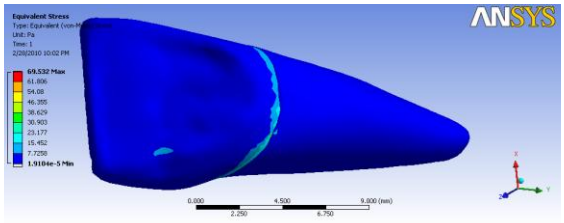

Fig. 15. Stress distribution in the all-ceramic crown (taper of 3 degree).

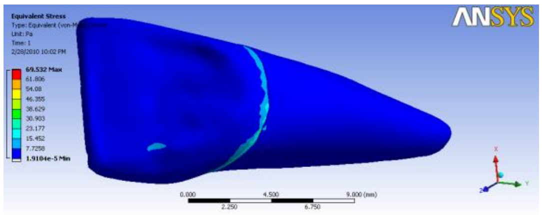

Fig. 16. Stress distribution in the all-ceramic crown (taper of 6 degree).

The taper of the root preparation has no significant effect on the stress distribution areas between the restorations with the same crowns. Regarding the crown material, it was observed that the stress areas are larger in the core for the metal-ceramic crowns and this is associated with higher stress values. For the crowns larger stress areas were found in the all ceramic crowns. It means that higher stress values are associated with higher stress values for the studied samples.

Stresses were higher in the dowel and core restoration with the use of metal-ceramic crowns and higher in the crown when using all-ceramic crowns. The stress distribution was similar in all cases (Table I and II).

TABLE I: MAXIMAL EQUIVALENT STRESS IN THE TEETH RESTORED WITH DOWEL/CORE/METAL-CERAMIC CROWN.

Taper	Equivalent stress max in the crown [Pa]	Equivalent stress max in the dowel and core restoration [Pa]
0	48.422	4.0334
1	48.423	4.1866
2	49.032	4.1042
3	48.176	4.0725
4	49.367	4.1726
5	49.825	4.2240
6	50.720	4.3754
7	50.581	4.1775

TABLE II: MAXIMAL EQUIVALENT STRESS IN THE TEETH RESTORED WITH DOWEL/CORE/ALL-CERAMIC CROWN.

Taper	Equivalent stress max in the crown [Pa]	Equivalent stress max in the dowel and core restoration [Pa]
0	70.793	1.3784
1	70.414	1.3655
2	70.452	1.3562
3	69.500	1.3692
4	70.750	1.3203
5	71.499	1.3809
6	71.914	1.3696
7	71.487	1.3864

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]. More rigid materials may transfer less stress to the margins [11].

V. Conclusions

Within the limitations of the present study. it was found that the dowel taper has no important influence on stresses generated in dowel-and-core restored teeth. The crown material is important for the stress values and stress distribution both in the dowel and core restoration and in the crown. Regarding the location of the stresses it can be drawn that the cervical regions of the restorations were subjected to the highest stress concentrations. More rigid crown materials induce higher stresses in the crowns and more elastic crown materials induce higher stresses in the dowel and core restorations.

Acknowledgment

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