Finite element analysis of roots restored with metallic posts and ceramic crowns during occlusal movement

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Abstract: Oral rehabilitation of endodontically treated roots is inherently difficult, and the functional loads result in extremely complex structural responses of the oral tissues. The objective of this study was to evaluate, by finite element analysis, stresses induced in an endodontically treated maxillary central incisor that was restored with a cast metallic post and core system and a overlying ceramic crown during contacts with the antagonists. A 3D model of a central incisor was created: intact teeth, unrestored teeth with chamfer marginal preparation, the same tooth restored with a cast posta and core system and a full pressed ceramic overlying crown. The tooth preparation and the restorations were designed. Models were exported in Ansys finite element analysis software for structural simulations. Maximal equivalent stresses were recorded in the tooth structures and in the restorations for all contact areas. The values were higher in the crowns, and increase significant in the marginal segments of the contact areas. Regarding the stress distribution in the prepared teeth, the areas were larger around the marginal line. In the post and core system higher stress values were recorded.

Key-Words: ceramic crown, post and core system, root, oclusal movement, finite element analysis, stresses.

1 Introduction
Restoration of endodontically treated teeth is frequently a challenge for dentists. It results in loss of tooth structure and consequent reduction in tooth resistance to intraoral forces [1-4]. It is difficult to provide the valid index of stress distribution based on experimental and clinical observation. The finite element analysis (FEA) has recently become a powerful technique in dental biomechanics because its versatility to calculate stress distribution within complex structures, and it is most suitable for biological structures [5]. Some studies reported that the materials of the post and core affected the stress distribution of endodontically treated teeth restored with post-and-core system using three-dimensional FEA [6]. The cast post-core system is relatively time consuming and involves an intermediate laboratory phase to elaborate the retaining system, but is still frequent used in practice for its performance during years.

The post systems may include components of different rigidity. Because the more rigid component is able to resist forces without distortion, stress is expected to be transferred to the less rigid substrate. The difference between the elastic modulus of dentine and the post material may be a source of stress for root structures. [7] The use of post systems that have an elastic modulus similar to that of dentine and core result in the creation of a mechanically homogenous unit with better biomechanical performance. [8, 9]. Oral rehabilitation of endodontically treated roots is inherently difficult, and the functional loads result in extremely complex structural responses of the oral tissues. Considering changes in contacts with the antagonists teeth during the occlusal movements is also important. Determination of the resulting stresses can be accomplished only with appropriate stress analysis techniques and with sufficient information of the characteristics of the oral tissues and restorative materials. [7]

2 Purpose
The objective of this study was to evaluate, by finite element analysis, stresses induced in an endodontically treated maxillary central incisor that was restored with a cast metallic post and core system and a overlying ceramic crown during contacts with the antagonists.

3 Materials and Method
For the experimental analysis, a 3D model of a central incisor was created: intact teeth, unrestored teeth with chamfer marginal preparation, the same...
tooth restored with a cast posta and core system and a full pressed ceramic overlying crown.

The nonparametric modeling software (Blender 2.57b) was used to obtain the shape of the teeth structures.

The collected data were used to construct three dimensional models using Rhinoceros (McNeel North America) NURBS (Nonuniform Rational B-Splines) modeling program.

The tooth preparation and the restorations were designed (Fig. 1).

Models were exported in Ansys finite element analysis software for structural simulations. An occlusal load of 50 N was applied, according to the contact points with the antagonists during movements (Fig. 2).

The forces were applied perpendicular to the tooth surface in each point.

Stress analysis was performed on the restored incisor during protrusion.

The mesh structure of the solid 3D model was created using the computational simulation of Ansys finite element analysis software (Fig. 3).

Von Mises equivalent stresses were calculated and their distribution was plotted graphically.

3 Results and Discussions

Maximal equivalent stresses were recorded in the tooth structures and in the restorations for all contact areas. The values were higher in the crowns, and increase significant in the marginal segments of the contact areas (Table 1, Fig. 4).

<table>
<thead>
<tr>
<th>Contact area</th>
<th>Maximal Von Mises equivalent stress [Pa]</th>
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<tbody>
<tr>
<td></td>
<td>crown</td>
</tr>
<tr>
<td>1</td>
<td>7.09E+07</td>
</tr>
<tr>
<td>2</td>
<td>5.87E+07</td>
</tr>
<tr>
<td>3</td>
<td>4.71E+07</td>
</tr>
<tr>
<td>4</td>
<td>4.78E+07</td>
</tr>
<tr>
<td>5</td>
<td>5.29E+07</td>
</tr>
<tr>
<td>6</td>
<td>1.01E+08</td>
</tr>
</tbody>
</table>

Fig. 4. Distribution of the maximal Von Mises equivalent stress values in the prepared incisor and restorations.
In the dentin and post and core system the maximal values increase with the protrusion movement. They were higher in the prepared tooth than in the cast restoration.

In the crowns the stresses were distributed around the contact areas with the antagonists and in the cervical areas (Fig. 5, 6). In the middle of the protrusion trajectory the areas become greater in the oral part of the crown and cervical.

Fig. 5. Von Mises equivalent stress in the complete ceramic crown during cervical loading.

Fig. 6. Von Mises equivalent stress in the complete ceramic crown during protrusion.

Regarding the stress distribution in the prepared teeth, the areas were larger around the marginal line, especially under the line. The biggest disadvantage is that high stresses are present around the marginal areas (Fig. 7, 8).

Fig. 7. Total Von Mises equivalent stress in the restored tooth during cervical loading.

Fig. 8. Von Mises equivalent stress in the complete ceramic crown during protrusion.

In the post and core system higher stress values were recorded in the incisal parts of the post and core, oral (Fig. 9, 10).

Fig. 9. Von Mises equivalent stress in the post and core system during incisal loading.

Fig. 10. Von Mises equivalent stress in the post and core system during protrusion.

Some authors consider the design of the post to be an important factor influencing the radicular stress distribution in endodontically treated teeth restored with post systems [4]. Because in the FEA, assumptions related to the material properties of simulated structures (such as isotropy, homogeneity, and linear elasticity) are not usually absolute representations of the real structures, FEA must ideally be used as an initial
step and as an aid for planning further laboratory tests and clinical studies; this will reduce the inaccuracies inherent in FEA [5].

4 Conclusion
Within the limitations of the present study, the following conclusions can be drawn:
1. FEA can be the first step for the biomechanical study of roots restored metallic posts and ceramic crowns during occlusal movement.
2. The maximal stress values were higher in the crowns, and increase significant in the marginal segments of the contact areas.
3. Regarding the stress distribution in the prepared teeth, the areas were larger around the marginal line.
4. In the post and core system higher stress values were recorded oral.

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References: