Effect of preparation height on stress distribution in premolars restored with pressed ceramic crowns

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Abstract: Little information regarding variation of basic preparation guidelines in stress distribution of teeth covered with ceramic crowns has been available. The incomplete fit of full crown restorations remains a critical problem for dentists, leading many researchers to study this problem. Finite element analyses have been used for many investigations, because they can reproduce structures of various shapes of teeth with many elements defined with specific Young’s modulus and Poisson’s ratio values. In this manner, the distribution and magnitude of stress at any point can be precisely analyzed. The geometry of tooth preparation has been the subject of many debates without clear evidence that one type of tooth preparation or method of fabrication provides consistently superior marginal fit. The objective of this study was to evaluate, by finite element analysis, the influence of preparation height on the stress distribution in teeth prepared for full ceramic crowns and in the restorations. A 3D model of a premolar was created: intact teeth, unrestored teeth; the same teeth restored with full ceramic crowns. These were exported in Ansys finite element analysis software for structural simulations. Maximal equivalent stresses were recorded in the tooth structures and in the restoration for all preparation heights. In all cases the values were higher in the crowns. In all cases the maximal equivalent stress values were higher in the crowns. The stresses are distributed around the contact areas with the antagonists. The preparation height is not significant for stress distribution.

Key-Words: premolar, complete ceramic crown, preparation height, finite element analysis, stresses.

1 Introduction
Mechanical analyses of teeth covered with crowns through finite element analysis (FEA) have provided valuable insight concerning design parameters and materials that favor lower stress patterns. However, little information regarding variation of basic preparation guidelines in stress distribution has been available [1]. Owing to improved material properties of ceramics, jacket crowns have become popular as esthetic restorations. However, in order to function for a long term, it is necessary to ensure that they possess high mechanical strength. Therefore, in choosing a material for the definitive restorations, it should be one where stress will not concentrate at the cervical area [2]. With improvement in material properties of ceramic restorative materials, these materials have been used as the definitive restoration material instead of the dental alloy, even in the posterior region [3].

The incomplete fit of full crown restorations remains a critical problem for dentists, leading many researchers to study this problem. Marginal and internal accuracy of fit is valued as one of the most important criteria for the clinical quality and success of complete crowns. The geometry of tooth preparation has been the subject of many debates without clear evidence that one type of tooth preparation or method of fabrication provides consistently superior marginal fit [4].

A well-designed preparation has a smooth and even margin. Rough, irregular margins substantially reduce the adaptation of the restoration. The cross-section configuration of the margin has been the subject of much analysis and debate. The minimization of crown marginal gaps is an important goal in prosthodontics [5, 6].

Finite element analyses have been used for many investigations, because they can reproduce structures of various shapes of teeth with many elements defined with specific Young’s modulus and Poisson’s ratio values. In this manner, the distribution and magnitude of stress at any point can be precisely analyzed [3].

With finite element analysis, finite element modeling is a complex and difficult task. However, this method can analyze the distributions and
magnitudes of internal stress by changing the characteristics of materials. This also means that the results of finite element analysis depend on its modeling methods and the given values of material properties [2]. Traditional tooth preparation margin designs are still advised by most manufacturers for indirect restorations [7-9].

2 Purpose
The objective of this study was to evaluate, by finite element analysis, the influence of preparation height on the stress distribution in teeth prepared for full ceramic crowns and in the restorations.

3 Materials and Method
For the experimental analysis, a 3D model of a premolar was created: intact teeth, unrestored teeth with chamfer marginal preparation, the same tooth restored with full pressed ceramic crowns. The geometry of the intact tooth were obtained by 3D scanning using a manufactured device. 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 preparations with different heights (between 2 and 3.6 mm) were designed (Fig. 1).

Complete ceramic crowns were designed for all preparations. Models were exported in Ansys finite element analysis software for structural simulations. An occlusal load of 100 N was applied in 5 points, according to the contact points with the antagonists (Fig. 2).

Fig. 1. Tooth preparations for pressed ceramic crown.

Fig. 2. Points selected for loading on the restored premolar.

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

Fig. 3. Mesh structure of the restored premolar.

3 Results and Discussions
Maximal equivalent stresses were recorded in the tooth structures and in the restoration for all preparation heights. In all cases the values were higher in the crowns (about five times) (Table 1, Fig. 4). The stresses were distributed around the contact areas with the antagonists (Fig. 5, 7).

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. 6).
Table 1. Maximal Von Mises equivalent stress values in the crowns for chamfer prepared teeth and in the restored premolars.

<table>
<thead>
<tr>
<th>Preparation height [mm]</th>
<th>Maximal Von Mises equivalent stress [Pa]</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>total</td>
</tr>
<tr>
<td>2</td>
<td>1.05E+08</td>
</tr>
<tr>
<td>2.2</td>
<td>9.34E+07</td>
</tr>
<tr>
<td>2.4</td>
<td>1.00E+08</td>
</tr>
<tr>
<td>2.6</td>
<td>9.54E+07</td>
</tr>
<tr>
<td>2.8</td>
<td>9.74E+07</td>
</tr>
<tr>
<td>3</td>
<td>1.03E+08</td>
</tr>
<tr>
<td>3.2</td>
<td>8.83E+07</td>
</tr>
<tr>
<td>3.4</td>
<td>9.73E+07</td>
</tr>
<tr>
<td>3.6</td>
<td>9.62E+07</td>
</tr>
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</table>

For a less invasive preparation design, the chamfer preparation would be the recommended option for tooth preparations and the influence of the preparation height on stress distribution is not significant.

4 Conclusion

Within the limitations of the present study, the following conclusions can be drawn:

1. Numerical simulations provide a biomechanical explanation for stress distribution in prepared teeth and overlying crowns.
2. In all cases the maximal equivalent stress values were higher in the crowns. The stresses are distributed around the contact areas with the antagonists.
3. The preparation height is not significant for stress distribution.

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References:


