Finite Element Analysis of Molars Restored with Complete Cast Crowns

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Abstract: Complete cast crowns are good alternatives for the restoration of damaged posterior teeth. They have the best longevity of all fixed restorations. Their incomplete fit remains a critical problem for dentists, leading many researchers to study this problem. Gold alloys complete crowns can prove to be extremely long-lived restorations because of the excellent properties of these alloys. 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. Three margin designs may be used for complete cast crowns: shoulderless, chamfer, and shoulder. The objective of this study was to evaluate, by finite element analysis, the influence of different marginal geometries (shoulderless, chamfer, shoulder) on the stress distribution in teeth prepared for cast metal crowns and in the gold alloy restorations. A 3D model of a molar was created: intact teeth, unrestored teeth different marginal geometries: shoulderless, with chamfer, with shoulder preparations; the same tooth restored full cast metal 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 types. In all cases the values were higher in the crowns. Chamfer preparation is the recommended preparation tooth design for cast gold alloy crowns, from biomechanical point of view. It is followed by the shoulder preparation. Consideration should be given to the designs also from prophylactic and biological points of view. Chamfer margins are also favorable from this point of view.

Key-Words: molar, complete cast crown, gold alloy, finite element analysis, accuracy, preparation design.

1 Introduction

Even if the esthetic factors may limit their applications, complete cast crowns are good alternatives for the restoration of damaged posterior teeth. They have the best longevity of all fixed restorations [1, 2]. The incomplete fit of full cast 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 [3]. Gold alloys complete crowns can prove to be extremely long-lived restorations because of the excellent properties of these alloys. 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 [1, 4]. 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 [2, 5]. Three margin designs may be used for complete cast crowns: shoulderless, chamfer, and shoulder. Although they are conservative for tooth structure, shoulderless crown preparations should be avoided because they fail to provide adequate bulk at the margins. Overcontoured restorations often result from shoulderless preparations. Under most circumstances, these kinds of margins are unacceptable. A chamfer margin is particularly suitable for cast metal crowns. It is distinct and easily identified, provides space for adequate bulk of material, although care is needed to avoid leaving a ledge of unsupported enamel. Shoulder margins always offer space for the crown material. It should form a 90 degree angle with the unprepared tooth surface [3].
Traditional tooth preparation margin designs are still advised by most manufacturers for indirect restorations [6-10]. The shoulder preparation emerged as the recommended preparation design from both mechanical and periodontal points of view. As for a less invasive preparation design, the slight chamfer preparation would be the recommended option [11].

2 Purpose
The objective of this study was to evaluate, by finite element analysis, the influence of different marginal geometries (shoulderless, chamfer, shoulder) on the stress distribution in teeth prepared for cast metal crowns and in the gold alloy restorations.

3 Materials and Method
For the experimental analysis, a 3D model of a molar was created: intact teeth, unrestored teeth with different marginal geometries: shoulderless, with chamfer, with shoulder preparations; the same tooth restored with full cast metal crowns. The geometry of the intact tooth were obtained by 3D scanning using a manufactured device (Fig. 1). The nonparametric modeling software (Blender 2.57b) was used to obtain the shape of the teeth structures (Fig. 2).

The collected data were used to construct three dimensional models using Rhinoceros (McNeel North America) NURBS (Nonuniform Rational B-Splines) modeling program (Fig. 3).

The tooth preparations: shoulderless, chamfer, shoulder were designed (Fig. 4).
Complete cast crowns were designed for all preparation types. Models were exported in Ansys finite element analysis software for structural simulations. An occlusal load of 200 N was applied in 10 points, according to the contact points with the antagonists (Fig. 5).

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. 5. Points selected for loading on the restored molar.

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 restoration for all preparation types. In all cases the values were higher in the crowns.

The stresses are distributed around the contact areas with the antagonists (Fig. 6). The stress distribution areas are larger for shoulderless preparation, followed by shoulder and chamfer.

The values of the maximal equivalent stress in the tooth structures were higher for the shoulder preparations, but distributed on the occlusal surface. Regarding the stress distribution for the other two preparation designs, the areas are larger (Table 1, Fig. 7).

For the last two a disadvantage is that more stresses are present around the marginal area.

Margin design is a determining factor in establishing the extent of the minimal preparation for a cast metal crowns.

Table 1. Maximal Von Mises equivalent stress values in the cast crowns and in the restored molars.

<table>
<thead>
<tr>
<th>Preparation type</th>
<th>Maximal Von Mises equivalent stress [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
</tr>
<tr>
<td>chamfer</td>
<td>1.21E+08</td>
</tr>
<tr>
<td>shoulder</td>
<td>1.12E+08</td>
</tr>
<tr>
<td>shoulderless</td>
<td>1.35E+08</td>
</tr>
</tbody>
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Fig. 7. Von Mises equivalent stress in the complete cast crown for different marginal designs: a. chamfer, b. shoulder, c. shoulderless.
Fig. 7. Von Mises equivalent stress in the restored teeth with different marginal designs:
a. chamfer, b. shoulder, c. shoulderless.

4 Conclusion
Within the limitations of the present study, the following conclusions can be drawn:
1. In all cases the maximal equivalent stress values were higher in the crowns. The stresses are distributed around the contact areas with the antagonists and are smaller for the chamfer preparation.
2. Chamfer preparation is the recommended preparation tooth design for cast gold alloy crowns, from biomechanical point of view. It is followed by the shoulder preparation.
3. In light of these results, consideration should be given to the designs also from prophylactic and biological points of view, with emphasis on conserving tooth structure and preventing preparation trauma. Chamfer margins are also favorable from this point of view.

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References: