EFFECT OF CROWN MATERIAL ON TEETH RESTORED WITH PREFABRICATED GLASS FIBRE POSTS: STRESS DISTRIBUTION

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ABSTRACT
Nowadays, it is recognized that the main purpose for using prefabricated posts is the connection of the replacement for the missing coronal portion of the tooth to the remaining root structure, thereby providing retention for the crown. Prefabricated posts allow fast, cheap, and easy techniques.

The aim of the present work is to ascertain the influence of crown material, using a previously validated 3D finite element model, on teeth restored with prefabricated glass fibre posts. Porcelain and enamel-like crowns were compared studying the case of a 300 N load applied on the palatal side at an angle of 30º to the radicular axis, in the vestibular direction. The model predicted similar stress distributions in both post systems. Moreover, the stresses predicted when using the porcelain crown were smaller than the ones predicted without the final crown in a previous work, thus acting as a protection. Within the limitations of this study, it can be stated that using porcelain for restoring crowns will produce an alike success rate as when using a material with properties similar to those of enamel.

KEY WORDS
Finite element methods, dental biomechanics, stress distribution, prefabricated glass fibre post.

1. Introduction

Post-and-core restorations are widely used for building-up endodontically treated teeth with extensive loss of hard tooth tissue. Traditionally, the custom-made cast post and core was the restoration of choice, but today, prefabricated metal and non-metal posts combined with resin composite cores are considered viable alternatives. Post-and-core systems should provide sufficient retention for the final crown restoration, show acceptable fracture resistance, and add to the protection for the remaining tooth [1]. In a recent work [2], it was suggested that posts are not necessarily required for restoring teeth. Such a claim was based on the comparison of the fracture resistance of two different groups of severely damaged maxillary premolars restored with different techniques: one group was restored with direct resin composite crowns without posts and the other one used fibre reinforced composite posts. Both restoration systems presented similar fracture resistances and failure modes. Nevertheless, this study did not test the retention of both groups of restored teeth and, as mentioned previously, the main purpose of using prefabricated posts is to retain the crown.

From the literature as well as from clinical experiences, it is known that fracture of the root of a post and core reconstructed tooth is the most frequent and dramatic consequence of failure. These fractures are rarely repairable; in the majority of cases, they are considered catastrophic for the tooth, especially in the case of vertical root fractures. Root fracture is considered the most severe failure of restoration because it leads to the need of tooth extraction. For this reason, not only the fracture resistance but also the topic of reparability is an increasing important feature in evaluating post systems for clinical use. From the literature it can be found comparable proportions of vertical root fractures for custom-cast post and cores and prefabricated metal post systems [3, 4], whereas dramatic vertical root fractures have been reported less frequently for fibre-reinforced composite (FRC) post systems [3, 5].

Several studies have been performed in order to compare the retention and the stress distribution of different post systems as a function of post dimensions [6, 7, 8] or post material [9, 10] but studies about the influence of crown material are lacking. The purpose of the present work is, using a previously validated model [10], to ascertain the influence of crown material on the stress distribution on teeth restored with prefabricated glass fibre posts.
2. Material and Methods

The purpose of this work was to study how the crown material affects the biomechanical performance (fracture strength and stress distribution) of teeth restored with a post-and-core system using prefabricated glass fibre posts. Those teeth needed a restoration due to the loss of dental substance because of caries or previous restorations. For such purpose, a theoretical method was used based on a 3D finite element model of the restored tooth. This model was properly validated in previous works performed by the authors: for the study of the influence of post material [10] and for the study of the influence of post dimensions [11], both on restored teeth.

The ParaPost Fiber White (Coltène/Whaledent Inc., Mahwah, NJ, USA) was used for the study. The 3D finite element model described in a previous work [10] was used to study the stress distribution pattern of the restored tooth under external loads, for different crown materials in glass fibre post systems. In the previous work, the inclusion of a crown with a ferrule in the experimental set-up was deliberately omitted to exclude any external strengthening influence on the post and core system. The configuration used was believed to be worse than any other with regard to resistance of the restored tooth [12, 13]. Thus, the element crown was added to the 3D finite element for accomplished the present work. Figure 1 shows a longitudinal section of the geometrical model considered, with all the components that were modeled: bone (cortical and trabecular components), periodontal ligament, root/dentine, gutta-percha, post, cement, core and crown.

![Figure 1. Section of the geometrical model generated. Modeled components.](image)

Solid tetrahedral elements were used for the mesh, with sizes that varied depending on the different geometries considered, so that the final mesh represented the original geometry in an accurate manner. The model had close to 300 000 elements defined by approximately 55 000 nodes.

The mechanical properties of the different components of the model were obtained from the literature [14, 15, 16] and from the manufacturer of the posts (Coltène/Whaledent Inc., Mahwah, NJ, USA). The aforementioned properties are presented in Table 1. All the model components/materials are assumed to be isotropic, except the post/glass fibre that is considered to be transversally isotropic. As boundary conditions, the displacements of all nodes on the lateral surface and base of the cylinder representing the bone were constrained.

<table>
<thead>
<tr>
<th>Component/Material</th>
<th>Elastic modulus, $E$ (GPa)</th>
<th>Poisson coefficient, $\nu$</th>
</tr>
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<tbody>
<tr>
<td>Root/Dentine*</td>
<td>18.6</td>
<td>0.31</td>
</tr>
<tr>
<td>Gutta-percha**</td>
<td>0.00069</td>
<td>0.45</td>
</tr>
<tr>
<td>Periodontal ligament*</td>
<td>0.0689</td>
<td>0.45</td>
</tr>
<tr>
<td>Cortical bone*</td>
<td>13.7</td>
<td>0.30</td>
</tr>
<tr>
<td>Trabecular bone*</td>
<td>1.37</td>
<td>0.30</td>
</tr>
<tr>
<td>Cement**</td>
<td>18.6</td>
<td>0.30</td>
</tr>
<tr>
<td>Core**</td>
<td>20</td>
<td>0.30</td>
</tr>
<tr>
<td>Porcelain crown***</td>
<td>120</td>
<td>0.28</td>
</tr>
<tr>
<td>Enamel****</td>
<td>41</td>
<td>0.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$E_1$, $E_2 = E_3$, $\nu_{21} = \nu_{31}$, $\nu_{32}$</th>
</tr>
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<tbody>
<tr>
<td>E1 E2 = E3</td>
</tr>
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</table>

* From Eskitascioglu et al. [14]
** From the manufacturer Coltène/Whaledent Inc, Mahwah, NJ, USA
*** From Genovese et al. [15]
**** From Ko et al. [16]

Table 1. Mechanical properties of the materials used in the finite element model.

A 300 N load was applied on the palatal side of the tooth at an angle of 30° to the radicular axis, in the vestibular direction, to simulate real biting force, as already discussed in the previous work [10]. Under this load, the stress distribution pattern of the restored tooth was studied for two different crown materials: porcelain and enamel-like. The stress distribution pattern provided information about the fracture mechanism of the restored tooth: for the same external load, higher stresses indicated a higher probability of reaching the failure load. The structural analyses were performed using the finite element analysis software MSC-PATRAN-NASTRAN (MSC.Software Corporation, Santa Ana, California, USA). Moreover, the stresses predicted when using the porcelain crown were compared with the ones predicted without the final crown in the previous work, for evaluating the protection effect of the crown.

2. Results

The von Mises stress distribution estimated by the model on the central longitudinal section of the fibre post system for the two crown materials considered is shown in Figure 2, using a colour scale (warmer colours represent higher stresses). Both systems present stress concentrations in
the vestibular side (right side in the figures). Though stress concentration is less spread in the system restored with porcelain crown, globally the stress distributions are very similar.

In order to compare the protective effect of the crown, the stress distribution along the central longitudinal section of the restored tooth was obtained without the final crown restoration made (Figure 3). It can be observed the considerably higher level of stress concentration when none crown was using comparing to using crown (Figure 2). Higher stresses are concentrated on the vestibular side too, but they are about two times higher than when non using crown.

3. Discussion

Several studies have been performed in order to compare the retention and the stress distribution of different post systems as a function of post dimensions [6, 7, 8] or post material [9, 10] but studies about the influence of crown material are lacking. The purpose of the present work is, using a previously validated model [10, 11], to ascertain the influence of two crown materials on the stress distribution on teeth restored with prefabricated glass fibre posts.

A previously validated 3D finite element model of the restored tooth [10] was used to analyze the stresses originated with the different crown materials (enamel-like and porcelain), simulating the real direction of loads during biting.

The developed model predicted a stress distribution pattern with slightly higher values of stress concentration when using an enamel-like crown. This result supports the versatility of prefabricated glass fibre posts versus metallic posts. Considerable differences have been found in stress concentrations values depending on crown material when restoring with stainless steel posts [17].

Moreover, the protective effect of the crown was analyzed by comparing the stress distributions predicted with and without the final crown restoration made.

4. Conclusion

Within the limitations of this study, it can be stated that using porcelain for restoring crowns will produce a similar success rate than using a material with properties similar to those of enamel. In addition, it has been revealed the protective effect of the crown. This result confirms that, when studying prefabricated post systems,
non considering the crown is the most unfavourable situation.

References