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Original Research Article

The stress evaluation of root posts using the finite element analysis

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Abstract

Introduction and objective: The aim of this investigation was to evaluate through Finite Element Analysis (FEA) the displacement and stress distribution of prefabricated serrated and tapered dental root posts of different compositions: carbon fiber, glass fiber and titanium. **Material and methods:** Through this biomechanical analysis a carbon fiber post (CF), a glass fiber post (GF) and a titanium post (TI) were compared according to their design (tapered [T]) and serrated [S]) and under a load of 250 N, at 45º, in order to simulate an occlusal load of a canine tooth. **Results:** FEA demonstrated the following maximum displacement (MXD) in millimeters: T.CF (tapered carbon fiber post) = 2.48 mm; T.GF = 1.58 mm; T.TI = 0.50 mm; S.CF = 7.66 mm; S.GF = 4.87mm. **Conclusion:** These results showed that the carbon fiber post demonstrated the greatest displacement, followed by the glass fiber and the titanium posts. The tapered design presented detachment values much lower than the serrated design.

Introduction

Endodontic treatment may be necessary due to deep decay, wide restorations, and dental fractures. Endodontically treated teeth are known to present a higher risk of biomechanical failure due to both lack of pulp tissue [4] and loss of dental structure [23].

Root posts have been used to retain coronary restorations [1, 20, 23] and to improve the distribution of stress through dental structure [10]. There are several types of root posts commercially available in the market, among which, glass fiber posts have been extensively studied [2, 15, 16, 26] because of their physical properties, such as elastic modulus (more similar to dentin) [21], which in turn determines a stress field comparable to a natural tooth structure [8].

Biomechanical analysis is important to dental research, since it involves all rehabilitation treatments. Finite Element Analysis (FEA) has been of great value to conducted generated stress studies, and studies regarding the material behavior on dental structures during the use of root posts while these receive a certain amount of force [5, 13, 19, 22, 24, 25]. The technique was developed to create mathematic models, in which the behavior of a physical system can be reproduced, i.e., a physical prototype can be studied through the creation of a mathematical model. In this method, a computer system is used to simulate the physical properties of the structures in analysis, and through a great number of mathematical equations it determines the generated tension resulted from an applied force [6].

Little is known about the behavior of different designs of fiber posts. Therefore, the aim of this investigation was to evaluate, through FEA, the displacement and stress distribution of prefabricated serrated and tapered root posts of different compositions: carbon fiber, glass fiber, and titanium.

Material and methods

Five different posts of medium size were selected (titanium, carbon fiber, glass fiber - either serrated or tapered) (table I) and modeled in two bi-dimensional models, in order that all elements were created on the X and Y axis, allowing the study of the generated tension in two levels.

Table I – Study design

Group	Types of posts
T.CF	Tapered carbon fiber post
T.GF	Tapered glass fiber post
T.TI	Tapered titanium post
S.CF	Serrated carbon fiber post
S.GF	Serrated glass fiber post

The tapered posts presented low values at the apical region; medium to high values, at middle and coronal region, respectively. The serrated posts presented a uniform diameter. The serrated post is not commercially available in titanium, but only in carbon and glass fiber.

For tapered posts geometry definition, the models were made directly in an ANSYS™ 7.0 (Swanson Analysis Systems, Houston, Texas, USA), at the Center for Civil Engineering Studies (CESEC), Federal University of Parana, Brazil. Computer aided design software (AutoCAD V14, Autodesk, San Rafael, California, USA) was used to create the serrated posts models, later transferred to the ANSYS™ 7.0. The post models shapes were standardized with 20 mm in length. In this case, the created triangular elements produced the following values:

–Prefabricated tapered posts – 4,193 nodes and 1,976 elements.

– Prefabricated serrated posts – 4,065 nodes and 1,882 elements.

All nodes at the 2/3 total external posts surfaces were constrained in all directions, keeping the upper 1/3 free for load application. To simulate a canine loading stress during mastication, a 250 N, at a 45° angle, was applied [19]. Five models with different configurations were simulated.

Subsequently, the posts' mechanical properties were considered isotropic, elastic and continual. Then, the Young's modulus and the Poisson's coefficient were determined according to literature data.

Table II presents the parameters used as mechanical properties of the posts. Tensions were plotted by von Mises criterion, generating graphics, while maximum displacements were also assessed.

Table II – Mechanical properties of the materials

Materials	Young's Modulus (GPa)	Poisson's Coefficient	References
Dentin	18.6	0.31	18
Carbon Fiber Bis-GMA	21	0.33	19
Glass Fiber Bis-GMA	33	0.33	7
Titanium	103.4	0.33	8

Results

By von Mises criterion, a stress concentration was observed at the interface between the anchorage surfaces and the free surfaces (figure 1). The stress concentration for the tapered titanium post showed a higher value than carbon and glass fiber posts.

Maximum displacement values (MXD) obtained were T.CF = 2.48 mm, T.GF = 1.58 mm, T.TI = 0.50 mm, S.CF = 7.66 mm, S.GF = 4.87 mm.

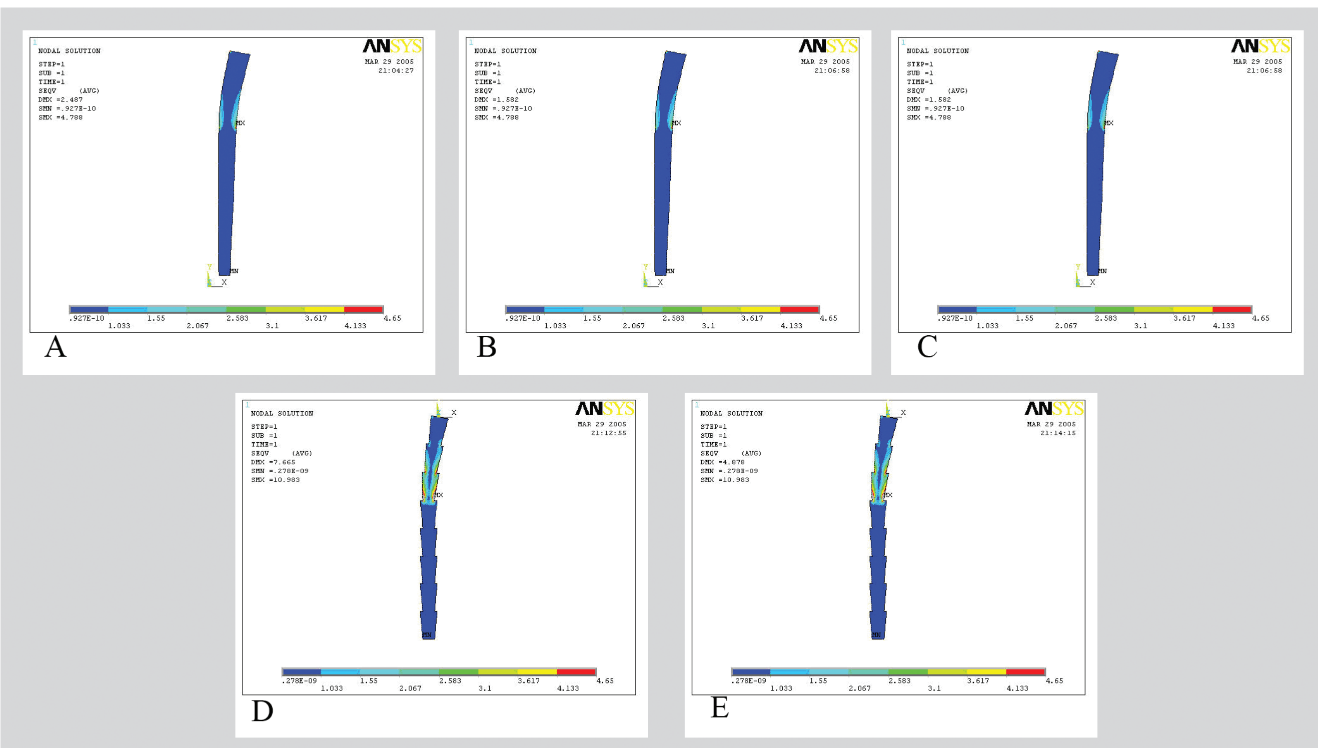

Figure 1 – Finite Elements Analysis representation of all posts. (A) Tapered Carbon Fiber Post (T.CF); (B) Tapered Glass Fiber Post (T.GF); (C) Tapered Titanium Post (T.TI); (D) Serrated Carbon Fiber Post (S.CF); (E) Serrated Glass Fiber Post (S.GF)

Discussion

The results of this study demonstrated that the posts' materials and designs influenced on both stress distribution and maximum displacements.

The metal root post does not present all the mechanical requirements for an endodontically treated tooth [9]. The metallic post shows a higher Young's modulus than the tooth structure and may generate root fracture. To achieve optimum results, the materials that are used to restore endodontically treated teeth should have physical and mechanical properties that are similar to those of dentin, be able to bond to tooth structure, and be biocompatible in the oral environment [3]. Based on the theory that prefabricated posts should have the same Young's modulus as dental tissue, carbon fibers prefabricated posts are presented as a new alternative [11]. Fiber-reinforced composite have also been introduced as an alternative to conventional materials [10]. The biomechanical properties of fiber posts have been reported to be similar to those of dentin [11, 17]. Clinical prospective and retrospective studies on the use of fiber posts have reported encouraging results [7, 18].

Duret *et al*. [10] and Glazer [12] stated that metallic posts are very resistant, but, present a Young's modulus ten times superior to that of dentin, which can lead to a high risk of root fracture, fact that is confirmed by literature.

In the case of the serrated posts, their shape seems to help to be retained into the root due to higher lapping contact when compared to other posts. Thus, it was possible to verify high stress concentrations, at the strangulated areas.

However, when the posts were analyzed separately, it could be observed that the serrated posts bended more when compared to tapered posts, implying that they may be less resistant to the applied (angled) load due to a higher stress transfer to the dental structure. Again, since the serrated titanium post is not commercially available, it was not analyzed.

It has been very known that carbon and glass fiber posts are more efficient in preventing root fracture as their deformation reaches the pattern of both the root and the luting cement [10, 24].

Conclusion

Thus, it can be concluded through Finite Element Analysis that all posts detached, despite of the material. The carbon fiber posts presented the greatest detachment values, followed by glass fiber posts, regardless of the shape. Considering the shape, the maximum detachment values of the tapered posts were much lower than the serrated posts. When comparing tapered and serrated designs of the same material, the tapered presented the lowest displacement values, while the serrated presented the highest values.

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