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Research Paper

Fatigue surviving, fracture resistance, shear stress and finite element analysis of glass fiber posts with different diameters

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ABSTRACT

This study evaluated the shear stress presented in glass fiber posts with parallel fiber (0°) and different coronal diameters under fatigue, fracture resistance and FEA. 160 glass-fiber posts (N=160) with eight different coronal diameters were used (DT=double tapered, number of the post=coronal diameter and W=Wider - fiber post with coronal diameter wider than the conventional): DT1.4; DT1.8 W; DT1.6; DT2W; DT1.8; DT2.2 W; DT2; DT2.2. Eighty posts were submitted to mechanical cycling (3×10^6 cycles; inclination: 45°; load: 50 N; frequency: 4 Hz; temperature: 37 °C) to assess the surviving under intermittent loading and other eighty posts were submitted to fracture resistance testing (resistance [N] and shear-stress [MPa] values were obtained). The eight posts types were 3D modeled (Rhinoceros 4.0) and the shear-stress (MPa) evaluated using FEA (Ansys 13.0). One-way ANOVA showed statistically differences to fracture resistance (DT2.2 W and DT2.2 showed higher values) and shear stress values (DT1.4 showed lower values). Only the DT1.4 fiber posts failed after mechanical cycling. FEA showed similar values of shear stress between the groups and these values were similar to those obtained by shear stress testing. The failure analysis showed that 95% of specimens failed by shear. Posts with parallel fiber (0°) may suffer fractures when an oblique shear load is applied on the structure; except the thinner group, greater coronal diameters promoted the same shear stresses.

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1. Introduction

Researchers have recently studied alternatives for improving the resistance of endodonticaly treated teeth. The amount of remaining coronal structure is used to determine if the use of fiber reinforced posts is necessary to retain the restoration material (Ferrari and Scotti, 2002). Teeth restored with pre-fabricated metallic posts or cast posts and cores have shown high values of fracture resistance (Silva et al., 2010; Silva et al., 2011). However, the mode of failure for these teeth is unfavorable, causing irreversible fractures and loss of the teeth. This mode of failure can be explained due the elastic modulus of these posts; with metallic posts presenting greater elastic moduli than fiber posts and generating elevated stress concentration on the remaining root structure (Silva et al., 2011; Akkayan and Gülmez, 2002; Ferrari et al., 2000, 2007; Giovani et al., 2009; Hayashi et al., 2006; Li et al., 2011; Padmanabhan, 2010).

The elastic modulus is representative of the flexibility of a material, where higher values indicate a hard material and lower values indicating a flexible material (Plotino et al., 2007). The diameter, the type of fiber and the resin material can influence the elastic limit of a pre-fabricated fiber reinforced post (Asmussen et al., 1999). The elastic modulus is related to the stress transmitted to the root, being one of the most important factors in the fracture mechanism (Coelho et al., 2009; Spazzin et al., 2009; Pegoretti et al., 2002).

In vitro (Akkayan and Gülmez, 2002; Coelho et al., 2009; Spazzin et al., 2009; Pegoretti et al., 2002) and clinical studies (Ferrari et al., 2000; Ferrari et al., 2007; Schmitter et al., 2007) have shown better or at least comparable performance for fiber reinforced composite posts when compared with cast post and cores and pre-fabricated metallic posts (reparable failures for fiber post approach, while irreparable fractures occur for metal post). Thus, adhesively cemented fiber posts have been indicated as a better option to restore endodonticaly treated teeth, especially in terms of minimal intervention and reducing the risk of root fracture (Ferrari and Scotti, 2002; Ferrari et al., 2000; Ferrari et al., 2007; Malferrari et al., 2003; Monticelli et al., 2003).

Static tests are important for assessing the maximum load required for rupture of a specimen. Most articles use the fracture resistance test (loaded at 45°) to assess the behavior of fiber posts (Silva et al., 2010, 2011; Akkayan and Gülmez, 2002; Asmussen et al., 1999). However, parallel fiber (0°) reinforced polymers usually fracture due to shear stress when submitted at oblique forces. Glass fiber posts are classified as a fiber reinforced polymeric material; where fiber arrangement is crucial in understanding their failure mode. The fiber posts usually present longitudinally organized fibers (parallel 0°), which can support high tensile stresses. On the other hand, the shear stresses destructively affect the polymer, indicating that the polymer matrix is important in the calculation of these fracture values (Shipley and Becker, 2002).

FEA is a numerical method that help to investigate stress and strain state and combined with experimental test allows obtaining a better understanding of failures, predicting where failure can occur. Hence, the use of both tests is important to obtain a better understanding regarding the mechanical behavior of a specimen during an event (Farah et al., 1973; Soares et al., 2008; Versluis et al., 2006).

Although there are studies showing that fiber reinforced post have good properties, there are some concerns regarding their use to restore weakened roots. Therefore, some techniques have been developed to guarantee better results when restoring weakened roots (anatomic post, accessory fiber post, glass fiber strips, composite resin) (Bonfante et al., 2007; Martelli et al., 2008; Gonçalves et al., 2006; Grandini et al., 2003; Island and White, 2005; Marchi et al., 2003; Miller, 1993). These techniques lead to decreasing the amount of resin cement around the fiber post and provide good fracture resistance to the weakened root. However, these techniques are not easy to perform and require more clinical time when compared to the use of conventional fiber post cementation.

Some tapered fiber posts present enlarged coronal/cervical diameters for restoring weakened roots by not requiring excess removal of the intracanal dental structure. Thus, these posts maintain a conservative dimension of the apical portion of a root canal and decrease the resin cement thickness around the post at the weakened portion of the root. These wider posts have a greater taper when compared with conventional posts; however, these posts keep the same fiber/matrix (80/20) ratio. However, there are no studies regarding the fracture resistance or the behavior of this type of post system during mechanical loading.

Consequently, this current study aimed to evaluate the fracture resistance, shear stress (in vitro and FEA test) and surviving after intermittent fatigue loading of fiber posts with different coronal wider diameters. The following conceptual hypotheses were tested: (1) fiber posts with increased coronal diameters would present higher rates of fracture resistance; (2) the finite element analysis would show similiar distribution for all groups without difference between real and virtual shear values calculated; (3) fiber posts with increased coronal diameters would present the best behavior during mechanical cycling.

2. Material and methods

2.1. *Specimen preparation and embedding procedures*

The posts used in the study are part of a system of fiber-reinforced polymers with double tapered (DT) shape. In this set of posts there are special retainers for larger root canals in which the coronary diameters are wider, but the apical is smaller relative to the other. So the groups was named according to factors: DT (double-tapered)+coronal diameter (for the wider posts the W letter was added in the name).

One hundred sixty fiber posts (White Post DC and White Post DCE systems, FGM, Joinvile, SC, Brazil) ($N=160$) were allocated into eight groups ($n=20$) (Fig. 1A). Each post was attached to a device, keeping its long axis perpendicular to the ground, and embedded with epoxy resin (Sikadur 55 SLV, Osasco, SP, Brazil) in plastic cylinders (height: 15 mm, Ø: 25 mm).

The fiber posts from the conventional system (White Post DC) were embedded to a depth of 14 mm, while the wider fiber posts of the special system (White Post DCE) were embedded to a depth of 12 mm. This difference in embedding length was