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Research Paper

A novel anatomical short glass fiber reinforced post in an endodontically treated premolar mechanical resistance evaluation using acoustic emission under fatigue testing

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ABSTRACT

This study evaluates the fracture resistance in an endodontically treated tooth using circular fiber-reinforced composite (FRC) and innovated anatomical short glass fiber reinforced (SGFR) posts under fatigue testing, monitored using the acoustic emission (AE) technique. An anatomical SGFR fiber post with an oval shape and slot/notch design was manufactured using an injection-molding machine. Crown/core maxillary second premolar restorations were executed using the anatomical SGFR and commercial cylindrical fiber posts under fatigue test to understand the mechanical resistances. The load versus AE signals in the fracture and fatigue tests were recorded to evaluate the restored tooth failure resistance. The static fracture resistance results showed that teeth restored using the anatomical SGFR post presented higher resistance than teeth restored using the commercial FRC post. The fatigue test endurance limitation (1.2×10^6 cycles) was 207.1 N for the anatomical SGFR fiber post, higher than the 185.3 N found with the commercial FRC post. The average accumulated number of AE signals and corresponding micro cracks for the anatomical SGFR fiber post (153.0 hits and 2.44 cracks) were significantly lower than those for the commercial FRC post (194.7 hits and 4.78 cracks) under 40% of the static maximum resistance fatigue test load (pass 1.2×10^6 cycles). This study concluded that the anatomical SGFR fiber post with surface slot/notch design made using precise injection molding presented superior static fracture resistance and fatigue endurance limitation than those for the commercial FRC post in an endodontically treated premolar.

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1. Introduction

Fiber-reinforced composite (FRC) posts were introduced as an alternative to more conventional materials because their elastic properties are similar to those of dentin. This characteristics makes tooth fractures restorable (Chuang et al., 2010; Chieruzzi et al., 2012; Santos-Filho et al., 2014; Martinho et al., 2015; Uzun et al., 2015). Clinical studies have reported that using a fiber post could reduce the incidence of root fractures and the most common cause of failure becomes debonding (Monticelli et al., 2003; Bitter and Kielbassa, 2007; Ferrari et al., 2007; Dietschi et al., 2008; Ozkurt et al., 2010; Wang et al., 2016). Debonding is more likely to occur in the presence of an excessively thick layer of cement, which has a negative impact on post retention (Ferrari et al., 2000, 2007; Cagidiaco et al., 2007; Muñoz et al., 2011) because of worse adaptation to the oval shaped canal walls and circular FRC posts. Effective bonding can contribute to reducing the stress generated on the root canal walls, thereby strengthening the remaining tooth structure and decreasing the risk of fracture (Cagidiaco et al., 2007; Muñoz et al., 2011; Manicardi et al., 2011).

Although new posts with a uniform ovoid cross section have been marketed for oval cross section canals to improve post adaptation (Muñoz et al., 2011). A controversy still remains as to whether oval posts adapt better than circular posts to the oval canal morphology. Muñoz et al. implied that oval posts do not adapt better than circular posts to the oval canal morphology (Weiger et al. 2002; Muñoz et al., 2011). Uzun et al. (2015) addressed that oval posts did not provide a higher fracture resistance to endodontically treated roots with oval canals compared with circular posts. However, Gomes et al. (2014) indicated a lower resin cement thickness resulting in better bond strength and less gap formation.

Cylindrical/oval (conical) FRC posts usually contain a high volume of continuous (long) reinforced glass fibers embedded in a polymer matrix produced by extrusion molding (Cagidiaco et al., 2008). However, simplified profiles do not improve adaption to the oval canal morphology and fracture resistance to endodontically treated teeth. An anatomical post using short glass fibers reinforced (SGFR) with reinforcing structure to enhance retention was proposed using precise injection molding (Wang et al., 2016). Pilot mechanical performances indicated that the anatomical SGFR presented acceptable flexural strength and modulus values compared with the current market circular FRC post. However, fracture resistance was doubted in an artificial endodontically treated premolar even though better fit adaption was found in the root canal to resist torque.

The aim of this study was to evaluate the fracture resistance in an endodontically treated tooth using the circular FRC and anatomical SGFR posts under fatigue testing. The non-destructive acoustic emission (AE) technique was applied to monitor the resistance under cyclic loads. AE signal results at different cyclic load stages and treatment tooth fracture modes were recorded to understand the biomechanical response of an endodontically treated tooth.

2. Materials and methods

2.1. *Endodontically treated premolar preparation*

Thirty four freshly extracted intact maxillary second premolars were stripped of ligaments and stored at 18 °C in normal saline and randomly assigned to two groups of 17 teeth each. Teeth with similar size and shape were selected using root length and crown dimensions after measuring the buccolingual and mesiodistal widths at the cement-enamel junction (CEJ) in millimeters, allowing for a maximum deviation of 20% from the mean. The artificial PDL of each premolar was replicated with approximated 0.3 mm thickness around the tooth from 1.5 mm below the CEJ to the root using silicon (Gingifast Elastic, Zhermack SpA, Badia Polesine, Italy) and embedded into an epoxy resin block.

The anatomical SGFR post used with “GRIVORY GVX-7H natural” (EMS-CHEMIE Holding AG, Herrliberg, Switzerland) based on semi-crystalline polyamides and manufactured using an injection-molding machine (Polypax, Green Point Enterprise Co., Ltd., Taichung, Taiwan) were proposed in a previous study (Wang et al., 2016). The anatomical SGFR post is a 70% glass-fiber reinforced engineering thermoplastic material with 0.8–1.0 mm length based on a combination of semi-crystalline polyamide matrix with partially aromatic copolyamide. Different cross-sections were designed with a circular shape (radius: $r1$ is 1.0 mm) at the tip region to fit well with the tooth root apical, circular-oval shape (radius from r1 changed to $r2$, $r2$ is 1.6 mm) at the middle region and oval shape (major axis: $a=2r2$; minor axis: $b=r2$) at the coronal region to fit well the tooth anatomical oval shape (Fig. 1). Surface slots with 0.25 mm radius surrounding the post and four transverse notches with 0.7 mm pitch were designed to increase the contact areas between the post and cement to enhance the post, cement and core retention (Fig. 1(a)).

The total length of the anatomical SGFR and commercial FRC posts (X-Post Radix Fiber Post No. 1, Dentsply Maillefer, Ballaigues, Switzerland) was 13 mm (1.3 mm in diameter). These posts were inserted into the root canal according to clinical treatment procedures (Fig. 1(b)). A self-etching bonding agent was used in combination with a dual-cured composite resin material (Dentsply Core-X flow, Dentsply Caulk, Milford, DE, USA) indicated for post cementation and the luting procedure. A custom cast Ni-Cr alloy crown and composite core (Core-x-flow, Dentsply Maillefer, Ballaigues, Switzerland) were then luted using RelyX U200 cement (3M ESPE, Seefeld, Germany).

2.2. *Static and fatigue fracture resistance tests*

Five samples in each group were arranged to perform a static resistance test that was designed to drive a 45° oblique load onto the functional cusp of each restored tooth at a crosshead speed of 0.05 mm/s with a universal testing machine (Instron, Canton, MA, USA) until fracture (Fig. 2(a)).

Fatigue tests were performed by applying a maximum load calculated as a percentage with respect to the maximum static resistance and a minimum load of 10% as stipulated by the ISO14801 standard to evaluate the restoration mechanical