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Flexural strength of fiber reinforced posts after mechanical aging by simulated chewing forces

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ABSTRACT

This study evaluated the effect of simulated chewing forces on the flexural strength of fiber reinforced posts (FRPs). Four different brands of FRPs were selected as main group for the study: RelyX Fiber Post (RX), IceLight (ICE), Unicore Posts (UC), FlouroPost (FP). Ten posts in each main group didn't receive any aging process and tested as baseline (BL), other ten posts were subjected to simulated chewing forces/mechanical aging (MA) as follows:

Post spaces were prepared in acrylic with drill. Depth of preparation was adjusted to leave 4-mm coronal part of posts protruding from canals. Coronal parts were incrementally restored with resin-composite (Clearfil Majesty Posterior A2, Kuraray, Osaka, Japan). Prepared samples were subjected to chewing cycles in a chewing simulator (Chewing Simulator CS-4, Mechatronik, Germany). Flexural strengths of all groups were measured with three-point bending test. Data were analyzed by two-way ANOVA and Tukey's test ($\alpha = 0.05$). After MA, flexural strengths of all posts were significantly decreased when compared with BL for all FRPs tested ($p < 0.05$). At BL, highest flexural strength values were obtained for ICE. After MA, similar to BL, highest flexural strength values were obtained for ICE. Only RX showed statistically significant difference when compared with ICE ($p < 0.05$). UC and FP showed similar flexural strength values with ICE ($p > 0.05$). It may be concluded that chewing forces on post-core systems may reduce the flexural strengths of FRPs.

1. Introduction

Endodontically treated teeth with severely compromised crowns are often reinforced with posts. For this purpose, materials such as metal, zirconia, ceramic or fiber reinforced composites can be used (Cheung, 2005). Different types of post materials cause stresses within the root and surrounding tissues at varying levels (Asmussen et al., 2005; Lanza et al., 2005; Pegoretti et al., 2002). These stresses can cause root or post fractures (Barjau-Escribano et al., 2006; Li et al., 2006; Maceri et al., 2007; Pegoretti et al., 2002) therefore may lead to failure of the restoration. Among the post materials, modulus of elasticity of fiber reinforced posts (FRPs) are closest to that of root dentin (Asmussen et al., 1999). Using such low modulus posts help to reduce stresses along the root therefore may improve the prognosis of post-endodontic restoration and tooth (Forberger and Gohring, 2008; Gu et al., 2007). Moreover, esthetic requirements are fulfilled with FRPs, thus make them a solid alternative to rigid posts (Drummond et al., 1999).

Structural integrity of FRPs depend on their matrix and fiber combinations as well as interfacial strength and alignment of fibers (Goldberg et al., 1994; Parry and Wronski, 1981). Masticatory forces are transferred from crown to root through the post, therefore may affect the physical properties of the post used. There are many laboratory studies that assess the physical properties of FRPs such as elastic limit, stiffness, flexural strength and flexural modulus (Asmussen et al., 1999; Novais et al., 2011; Plotino et al., 2007; Sazak-Öveçoğlu et al., 2004). Among those properties, flexural strength is one of the main indicators for clinical performance of FRPs (Lassila et al., 2004; Mannocci et al., 2001; Plotino et al., 2007). Three-point bending test is a method to determine the flexural strengths of materials. The applied load is plotted against the number of cycles to failure. The resulting data is used to calculate the flexural strength in the case of brittle materials.

Abbreviations: MA, Mechanical aging; BL, Baseline; FRP, Fiber reinforced post; RX, RelyX Fiber Post; ICE, IceLight; UC, Unicore Posts; FP, FlouroPost

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Mechanical properties such as fracture resistance, rigidity and flexural strength of FRPs were extensively reviewed in the literature (Bateman et al., 2003; Cheleux and Sharrock, 2009; Zicari et al., 2013). In vitro flexural strengths of FRPs were mostly evaluated without any aging protocol and only few studies investigated the effect of thermal aging and water sorption of FRPs (Drummond, 2000; Drummond et al., 1999; Mannocci et al., 2001). However, in vitro flexural strength measurement as well as the fewer number of in vivo studies still make it difficult for the practitioner to judge the clinical behavior of FRPs (Bitter and Kielbassa, 2007; Cheung, 2005). To obtain clinically relevant results from in vitro studies one should design a study which mimics the clinical situation as close as possible. In the literature, there are no in vitro studies which assess the effect of mechanical aging (chewing forces) on the flexural strength of FRPs. The present study aimed to evaluate the effect of simulated chewing forces on the flexural strength of some contemporary FRPs. The null hypothesis tested was mechanical aging would have no effect on the flexural strength of FRPs.

2. Material and methods

2.1. Experimental modeling and groups

Four different brands of FRPs were selected as main group for the study: RelyX Fiber Post (RX), IceLight (ICE), Unicore Posts (UC), FlouroPost (FP) (Table 1). Each main group consisted of 20 randomly selected posts with similar diameters. Ten posts in each main group didn't receive any aging process and tested as baseline (BL), other ten posts were subjected to simulated chewing forces/mechanical aging (MA).

2.2. Specimen preparation for chewing simulation

Specimen preparation procedures for chewing simulation are given in Fig. 1. To resemble the roots of human teeth, self-cure acrylic resins were set in 0.5 mL Eppendorf tubes. Set acrylic models were removed from the tubes. Initially, a pilot hole was prepared with a #2 Peeso reamer (Peeso Enlarger, VDW GmbH, Munich, Germany) on the acrylic models. Post spaces were the prepared in acrylic models with drills of the corresponding size of the post of each brand. A new drill was used for each specimen. Depth of preparation was adjusted to leave the coronal part of posts protruding 4 mm from canals. Post spaces were rinsed with distilled water for 1 min and dried with paper points. Following the post-space preparation, posts in each group were inserted into post spaces without any bonding agent or resin cement. A one-step self-etch adhesive (Prelude SE, Danville Materials, USA) was scrubbed to top surfaces of acrylic models and protruding sections of the posts for 20 s, air dried for 5 s, circumferentially polymerized for a total of 80 s.

Coronal parts around the FRPs were initially restored with 2-mm increments of resin-composite (Clearfil Majesty Posterior A2, Kuraray, Osaka, Japan) and circumferentially polymerized for a total of 80 s. Afterwards, a strip crown (Adult premolar), which was filled with the same resin composite, was placed on the coronal portion of the post and circumferentially polymerized for a total of 80 s. This procedure ensured that similar cores were fabricated for all specimens.

Each increment of the composite was light cured for 20 s. A core of conical shape was modelled for each specimen. A LED curing unit (Elipar Freelight II, 3 M ESPE, St Paul, MN, USA) with an output intensity of 900 mW/cm^2 was used for all light polymerization processes. Single operator performed the specimen preparation procedures.

2.3. Chewing simulation

Artificial root portions of the post-core models were covered with wax (Feitosa et al., 2010). Thickness of the wax adjusted to 0.2 mm to simulate the average thickness of the human periodontal ligament (Nanci and Bosshardt, 2006). Samples were then embedded into a self-cure acrylic resin inside the lower sample holder of the simulator. While embedding, samples were aligned at 45° angle with the long axis of the post-core restoration. After cure of the acrylic resin, samples were removed from the mold, wax around the roots was scraped off and wax inside the mold was removed with hot water. Space in the mold was filled with a polyvinyl siloxane impression material (Aquasil Ultra Extra; Caulk-Dentsply) followed by re-insertion of the post-core samples. Excess impression material was removed using a scalpel.

A dual axis weight-controlled chewing simulator (Chewing Simulator CS-4, Mechatronik, Germany) was used for this study. A rounded conical shaped zirconia balls were used as antagonist. The diameter of the antagonist tip was 1 mm at a height of 2.5 mm from the cuspal tip to the base. Antagonists were fixed to the upper sample holders with a cyanoacrylate adhesive. A cyclic load of 108 N was applied to each specimen with 2.4-mm vertical movement at 60-mm/s, and 0.7-mm lateral movement at 40-mm/s. Totally 120,000 cycles were applied to each specimen for chewing simulation.

2.4. Flexural strength test

After MA, posts with cores were removed from the acrylic models. Core was sectioned with a diamond disc to obtain a post without core. Four mm portion of the coronal parts of the BL specimens were also sectioned to match the length of the MA specimens. All specimens (BL and after MA) were then subjected to three-point bending test for flexural strength measurement in a universal testing machine (Instron Corp., Norwood, MA, USA). To eliminate the influence of the taper of the posts, a short span length (9.7 mm) was used to get support for the post within the cylindrical part of the post in the testing machine. The load cell was applied perpendicular to the post long axis with a crosshead speed of 0.5 mm/min until fracture.

Flexural strengths [MPa] of all groups were measured with three-point bending test (9.7-mm span, full-scale load of 250 N at 1 V, 25 N for each specimen). Flexural strength (σ) was calculated using the following equation: $\sigma = 8F_{max} L/\pi d^3$, where, F_{max} is the applied load in Newtons (N), L is the distance between the support points in mm (standardized to 9.7 mm) and d is the average post diameter in mm measured by a digital caliper (Mitutoyo, Tokyo, Japan) at three different points (Mannocci et al., 2001).

2.5. Statistical analysis

Mean flexural strength were calculated for each test group. Statistical analysis was performed using a commercially available statistical analysis software (GraphPad Prism, 6.0 h; GraphPad Software Inc; La Jolla, CA, USA). Data were analyzed by two-way ANOVA and

Table 1
FRPs used in the study.

Fiber post brand	Diameter (mm)	Fibers	Taper	Manufacturer	Lot number
Fluoropost (FP)	1.6	Zirconia enriched, glass fibers embedded in epoxy resin	Not disclosed	Dentsply Caulk, Milford, DE, USA	MT-F21567
ICE Light (ICE)	1.6	Zirconia enriched, parallel glass fibers	Not disclosed	Danville Materials, San Ramon, CA, USA	23141
RelyX (RX)	1.6	Pre-tensioned parallel glass fibers embedded in a composite matrix	8%	3 M Espe, St. Paul, MN, USA	216791304
UniCore (UC)	1.5	Quartz glass fiber	Not disclosed	Ultradent, South Jordan, UT, USA	B92PC