Intermittent Loading of Teeth Restored Using Quartz Fiber, Carbon-Quartz Fiber, and Zirconium Dioxide Ceramic Root Canal Posts

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**Purpose:** The purpose of the investigation was to compare the performances of teeth restored with quartz fiber, carbon-quartz fiber, and zirconium-dioxide posts covered with all-ceramic crowns when subjected to a cyclic loading test performed in a wet environment.

**Materials and Methods:** Forty single-rooted human lower premolars having similar dimensions were endodontically treated and mounted in acrylic resin blocks with a simulated periodontal ligament. The teeth were divided into three experimental groups and one control group. Post holes 8 mm long were prepared in the roots of the experimental groups in which quartz fiber, carbon-quartz fiber, and zirconium dioxide posts were cemented. In the control group, no posts were used. The crown buildup was made with composite resin. The teeth were covered with all-ceramic crowns and intermittently loaded at an angle of 45 degrees to the long axis of the tooth at a frequency of two loads per second.

**Results:** Only one failure (root fracture + post fracture) was observed in each of the fiber post groups, while in the zirconium dioxide post group, six failures were observed (one crown fracture and 5 root fractures + post fractures). The Kaplan-Meier analysis of the three experimental groups showed that the survival rate of zirconium dioxide posts was significantly lower than that of both types of fiber post. All the experimental groups showed a survival rate higher than that of the control group.

**Conclusion:** Fiber posts reduced to a minimum the risk of root fractures of teeth restored with composite cores and Empress crowns under the present experimental conditions (intermittent loading in a wet environment).

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**Post systems are used to restore endodontically treated teeth in many different clinical situations.**\textsuperscript{3,19} Clinical retrospective studies have shown that posts cannot strengthen teeth and that post-core restorations may result in root fractures or perforations, post fractures, and post dislodgement.\textsuperscript{20} Therefore, ideal posts should impart minimal stress to the tooth, provide adequate retention to the core, and be easily removable to permit endodontic retreatment.

Carbon fiber posts (Composiposts, RTD, St Egreve, France) were introduced on the market in order to fulfill these requirements.\textsuperscript{10} These posts are fabricated from continuous, unidirectional carbon fibers approximately 8 μm in diameter, embedded in an epoxy resin matrix. The flexural modulus of carbon fiber posts was found to be similar to that of metal posts in two different studies\textsuperscript{17,21} in which three-point bending tests were performed. In these studies, the load was applied with a direction of 90
manufacturers have explored the potential of developing metal-free all-ceramic restorations.\textsuperscript{1,14,16} All-ceramic crowns provide superior esthetic results compared to conventional porcelain-fused-to-metal restorations. Unfortunately, the esthetic results of all-ceramic restorations are influenced by several factors, such as post-core materials and luting cement color and shade.\textsuperscript{5} Light transmission is impeded by metallic posts; therefore, they may not be indicated for the crown buildup of endodontically treated teeth in need of an all-ceramic restoration. These teeth are often built up with white posts made of zirconium dioxide partially stabilized by the addition of yttrium oxide. The use of these white posts is intended to allow light transmission through the post structure.

A potential disadvantage of carbon fiber posts is that their black color might show through when all-ceramic crowns are employed, especially in anterior teeth. For this reason, white fiber posts (Aestheti-Plus, RTD) (“quartz fiber” posts, according to the manufacturer) and quartzfiber-coated carbon fiber posts (Aestheti-Post, RTD) with a design very similar to that of carbon fiber posts (Fig 1) were recently introduced on the market. The epoxy resin matrix is the same for both the new fiber and carbon fiber posts.

After luting the all-ceramic restoration, the crown and the post transmit occlusal loading to the root; in this manner, the fracture resistance of the root might be related to the type of post used.

The aim of the present investigation was to compare the fracture resistance of teeth restored using quartz fiber, carbon-quartz fiber, and zirconium dioxide posts covered with all-ceramic crowns when subjected to cyclic loading in a wet environment.

\textbf{MATERIALS AND METHODS}

Forty extracted single-rooted human lower premolars were selected for this study. The teeth were kept moist with saline solution during all procedures.

The roots were divided into four groups of ten teeth each. The crowns of the teeth were cut off with a carbide bur mounted on a turbine handpiece, so that the length of the roots was 14 mm.

The root canals were prepared chemomechanically and filled by lateral condensation of gutta-percha and an epoxy-resin–based root canal sealer (AH 26, De Trey, Konstanz, Germany). Using Largo drills
Twenty-four hours after the crown buildup, the teeth were prepared for a crown. The finishing line used was a 90-degree shoulder. The height of the preparations was 5 mm; the width of the shoulder was 1.5 mm. The impressions were taken with Permadyne (ESPE, Seefeld, Germany).

Empress crowns (Ivoclar, Schaan, Liechtenstein) were prepared by the same technician.

The surfaces of the preparations were etched with a semi-gel of 32% phosphoric acid (Bisco) for 20 seconds, rinsed, and gently dried with compressed air. The Empress crowns were etched for 2 minutes with an 8% hydrofluoric acid gel (Bisco); silane was then applied to the Empress crowns for 4 minutes and gently air dried. The crowns were then cemented with All Bond 2 dental adhesive (Bisco) and C&B cement (Bisco) according to manufacturer's instructions. The cement was allowed to set, and then the crowns were kept in water for 4 weeks. The experimental model used was that described by Isidor with some modifications: a small ball of composite (Z100, 3M, St Paul, MN, USA) was placed on the root tip and a thin layer of siliccone was applied along the root surface to simulate a periodontal ligament.

The roots were mounted in acrylic resin blocks, with 6 mm of tooth extending beyond them. The specimens were then loaded intermittently at a frequency of 2 cycles per second, with a peak load of 250 N. The load was applied by a custom-made machine to the buccal surface of the premolars (45 degrees to the long axis of the tooth). Loading was automatically discontinued upon indication that the restorative system had failed. Root fractures, ceramic crown fractures, post fractures, and post and crown decementation were considered causes of failure.

The location of post-root fracture (above or below the resin block margin) was also evaluated. The machine was stopped after 400,000 impacts if no failure had occurred. During the loading procedure, the teeth were submerged in water.

The survival rates of the three groups were statistically compared with a Kaplan-Meier analysis.

RESULTS

The results obtained are shown in Table 1. All the root fractures observed both in the experimental groups and in the control group were located above the resin block margin. Only one failure (root frac-
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The survival rate of the teeth of the control group was found to be significantly lower than that of the experimental groups (P < 0.05). No statistically significant difference (P > 0.05) was found between the Kaplan-Meier curves for groups 1 and 2, neither was any difference found between the different types of failures of the two groups.

Both quartz fiber and carbon-quartz fiber posts had statistically significantly (P < 0.05) higher survival rates than zirconium dioxide posts (group 3). The comparison of the survival curves of the experimental groups and of the control groups is shown in Fig 2.

**DISCUSSION**

The results of the present investigation show that quartz fiber and carbon-quartz fiber posts were able to reduce to a minimum the risk of root fractures of teeth restored with composite cores and Empress crowns under these experimental conditions (cyclic loading in a wet environment). All the root fractures observed were located above the resin blocks. In the experimental model used, the resin block simulated the level of the gingival margin. The locations of the fractures were thus considered favorable because, in a clinical situation, they would have simplified the re-preparation of the tooth.

The load applied (250 N) exceeded normal biting forces. It was used in order to allow a comparison with a previous study\(^{13}\) in which carbon fiber posts were tested with cyclic loading.
Fig 2: Kaplan-Meier curves of the experimental groups and of the control group: 1-quartz fiber posts, 2-carbon-quartz fiber posts, 3-zirconium dioxide posts, 4-no-post group (control).

Findings by Dietschi et al. may help explain the results of the present investigation. Those authors found poor adaptation of experimental zirconium oxide posts (Ceramtec, prototype, Dentsply-Maillefer) to the root canal walls after cyclic loading, while good adaptation of carbon fiber posts was found.

The difference between the elastic modulus of zirconium dioxide and dentin might explain the higher fracture rate observed in the zirconium dioxide post group. Carbon fiber compounds have been found to be biocompatible and mechanically satisfactory in many dental and surgical applications.4, 6, 7, 8

Unfortunately, an aqueous environment might induce corrosion effects in the surface of the fibers resulting from water diffusing through the polymer matrix. In a recent study, a wet storage period of 4 months and wet thermocycling produced a significant reduction of the flexural strength values of carbon fiber posts.21 The same flexural strength test was performed comparing carbon fiber posts in bovine teeth submerged in water for 4 months with carbon fiber posts stored under dry conditions: no significant difference of the flexural strength values was reported.15 It can be speculated that, when a post is cemented into the root canal and covered with dental adhesive, the composite cement, the composite core, and the ceramic crown, little or no contact of the post with tissue fluids can occur, thus eliminating the risk of weakening the epoxy resin matrix.

The mechanical behavior of the quartz fiber and quartz-carbon fiber posts was found to be similar to that of carbon fiber posts in a recent investigation.15

The no-post control group exhibited more fractures than the experimental groups, thus proving the need for a radicular support for the core materials when the entire coronal structure of endodontically treated teeth has been lost.

The esthetic advantage of white posts should be evident when all-ceramic crowns are employed, but recent spectrophotometrical studies have clearly shown that when the thickness of the ceramic crowns is adequate to resist chewing forces, carbon fiber posts are not detectable.22 However, the use of tooth-colored materials for post construction might be useful when buildups of endodontically treated anterior teeth are performed with composite resins without crown coverage.

Regrettably, no prospective clinical studies regarding post and core behavior have as yet been reported, and caution must be exercised when extrapolating clinical recommendations from a work of a purely in vitro nature. However, since the results of the in vitro studies are promising, controlled clinical studies comparing these new fiber posts to metal ones are indicated.
REFERENCES


