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Load-bearing capacity of human incisor restored with various fiber-reinforced composite posts

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ABSTRACT

Objectives. The aim of this study was to evaluate the load-bearing capacity and microstrain of incisors restored with posts of various kinds. Both prefabricated titanium posts and different fiber-reinforced composite posts were tested.

Methods. The crowns of human incisors were cut and post preparation was carried out. The roots were divided into groups: (1) prefabricated serrated titanium posts, (2) prefabricated carbon fiber-reinforced composite posts, (3) individually formed glass fiber-reinforced composite posts with the canal full of fibers, and (4) individually formed "split" glass fiber-reinforced composite posts. The posts were cemented and composite crowns were made. Intact human incisors were used as reference. All roots were embedded in acrylic resin cylinders and stored at room temperature in water. Static load was applied under a loading angle of 45° using a universal testing machine. On half of the specimens microstrain was measured with strain gages and an acoustic emission analysis was carried out. Failure mode assessment was also made.

Results. The group with titanium posts showed highest number of unfavorable failures compared to the groups with fiber-reinforced composite posts.

Significance. With fiber-reinforced composite posts the failures may more often be favorable compared to titanium posts, which clinically means repairable failures.

1. Introduction

Various constructions for restoring a root canal treated tooth have been suggested. However, there is still no consensus upon what would be the optimal post system or construction for restoring a root-treated tooth in order to obtain a long-lasting result. The lifetime of a restored root-treated tooth depends on many factors, e.g. how badly the tooth is damaged, the thickness of remaining dentin, which materials are used for the restoration and how they are positioned, how the different materials distribute the masticatory forces in the root, and of course on the occlusion of the patient [1]. Only a few well designed clinical studies have been conducted and most of the investigations are made in vitro in the laboratory where it is difficult to simulate a clinical situation. Today, our knowledge of post-restored teeth is very contradictory. Many studies indicate that materials having a modulus of elasticity similar to that of dentin, e.g. fiber-reinforced glass fiber posts, divide the stresses better in the root than traditional metallic posts,

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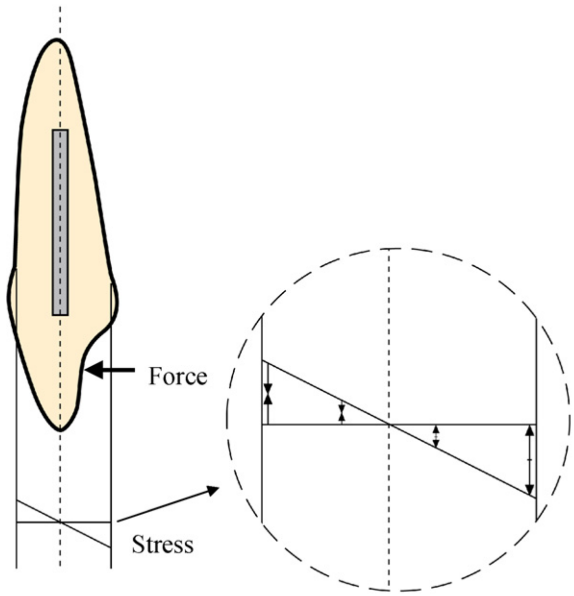

Fig. 1 – Stress distribution in a post treated tooth. A post situated in the most central part of the tooth, where stresses are minimal, does not reinforce the root. The figure is modified from Guzy and Nicholls [17] and Torbjörner [18].

resulting in fewer root fractures [2–6]. Other studies claim that if a severely damaged tooth is restored with a metal crown with a ferrule (collar) around the root, the post material does not play a big role in terms of fracture resistance [7,8]. On the other hand, there are also studies showing that higher fracture resistance and fewer catastrophic failures are observed in teeth restored without a post [9–15].

The materials used for restoring a root-filled damaged tooth should protect the remaining tooth structure at the particular areas which are under the highest stress. The materials should be placed to allow even stress distribution. With the prefabricated glass fiber-reinforced composite (FRC) posts, which have a modulus of elasticity in the same range as dentin, the construction in the root becomes more "dentin-like" compared to those made with the traditional metallic posts. Therefore, the risk of root fracture may be decreased, as has been shown in several studies [2,3,16]. On the other hand, the post-insertion procedure leads to removal of dentin, and thus the remaining dentin wall becomes thinner. Since the prefabricated FRC post is placed in the most central part of the post space (neutral axis), the post is not optimally placed in terms of mechanics if the intention is to produce a reinforcing effect by means of the post. A more correct place mechanically for the reinforcement might be on the outer surfaces of the post canal close to the dentin wall where the highest tensile stresses occur [17,18] (Fig. 1). Therefore, the hypothesis was that whether positioning of fibers close to the dentin rather than in the center of the root canal would influence the load-bearing capacity of the restored tooth. As testing material, a FRC material consisting of a semi-interpenetrating polymer network (IPN) polymer matrix was selected [19,20]. This material has shown good bonding between the post, the cement and the dentin compared to the bonding of prefabricated FRC posts with a cross-linked polymer matrix [21–24].

The aim of this study was to evaluate the fracture load, i.e. the load-bearing capacity of upper central incisors restored with four different post groups and composite crown, and to compare them with intact teeth. Additionally, the stiffness of the crown was evaluated by measuring the microstrain using the strain gage technique.

2. Materials and methods

Fifty extracted caries-free human incisors were stored in chloramine (0.5%) for one month. The crowns of the incisors were cut (ground) at the cemento-enamel junction (grinding machine, grit 180 FEPA = Federation of European Producers of Abrasives) and some of the incisors were left intact for the reference group. The buccal and palatal sides of the roots were marked, the root thicknesses were measured at the cemento-enamel junction from two sides (the thinnest and the thickest), and the mean root diameter was calculated (6.17 ± 0.28 mm). The mean root diameter value did not differ between the groups ($p > 0.05$). Post preparation of up to 9 mm was carried out in a parallellometer (where axial drilling can be standardized) with Parapost drills (diameter 1.5 mm), and coronal opening (canal entrance) was standardized with two different drills under water cooling. The canal entrance was 3 mm in diameter with a conical form (flared opening) toward the apical end. The preparation simulated a relatively damaged tooth. The remaining dentin was measured from two sides (the thinnest and thickest) and a mean value of remaining dentin was calculated (1.80 ± 0.14 mm). The root thicknesses of the intact roots used as reference were measured in the same way as in the other groups, and the remaining dentin thicknesses of that group were measured after testing the specimens. Six roots had to be excluded because of large dimensional differences or preparation failure. Due to the small amount of natural human incisors available the final specimen number (n) in each group was varying. The roots were divided into groups, according to the type of post used: (1) prefabricated serrated titanium posts (Parapost XP, Colténe/Whaledent, Inc., Mahwah, USA) ($n = 9$), (2) prefabricated carbon/graphite FRC posts (C-Post, Bisco Inc., Schaumburg, USA) ($n = 9$), (3) individually formed glass FRC posts with a semi-IPN polymer matrix (everStick Post; Stick Tech Ltd, Turku, Finland) ("everStick Post A") ($n = 10$) with the hole post space filled up with fibers (Fig. 2a), and (4) individually formed glass FRC posts with a semi-IPN polymer matrix (everStick Post; Stick Tech Ltd, Turku, Finland) ("everStick Post B") ($n = 9$) with the fibers formed into a split tube (Fig. 2b). The remaining intact roots, which were not restored with posts, served as reference ($n = 7$). The individually formed FRC posts in groups 3 and 4 were formed by hand following the manufacturer's instructions. In group 3 (everStick Post A), the individually formed post was formed from one fiber bundle with a diameter of 1.5 mm and two fiber bundles with a diameter of 1.2 mm. First the 1.5 mm bundle was fitted into the canal, both ends were cut for a perfect fit (the apical end diagonally and the coronal end leaving 4 mm of fiber bundle above the coronal opening) and then light-polymerized