Influence of One-Piece (Monoblock) Fibreglass Post Design on the Fracture Resistance of Extensively Damaged Teeth: An *Ex vivo* Study

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ZG and BE designed the study, wrote the protocol, made the experiments and the statistical analysis. Author DPS wrote the first draft of the manuscript, managed the literature searches and prepared for publication. All authors read and approved the final manuscript.

Original Research Article	

ABSTRACT

Aims: This study compared fracture resistances of roots restored with one-piece (monoblock) fibreglass post systems having different designs.
Study Design: Original Research Paper
Place and Duration of Study: Hacettepe University, Faculty of Dentistry, Department of Prosthodontics, between June 2013 and July 2014.
Methodology: Thirty natural teeth were endodontically treated and the canal walls were flared using a taper diamond bur. The roots were randomly assigned into three groups (n=10) as Mono Core Fibre Post (MFP), Fit Fibre Post (FFP), and Conventional Fibre Post (CFP), which served as control. All posts were luted with resin cement and zirconia substructures were fabricated. Each sample was subjected to thermal-cycling (6000 times between 5- 55°C) and then the samples were loaded in a universal testing machine until failure occured.

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Results: The mean of failure loads of MFP, CFP, and FFP were 315.8 N, 218.7 N and 146 N, respectively (P<0.05). 40% root fracture was observed in MFP group. Decementation was found in 90% of samples in FFP, and 40% in MFP and CFP.
Conclusion: This in vitro study showed that fiber post designs have an influence on fracture resistance and failure mode.

1. INTRODUCTION

Endodontically-treated teeth have greater risk of biomechanical complications compared to vital teeth [1-3]. The loss of structural integrity caused by trauma, caries, access hole preparations, loss of moisture content, and reduced thickness of dentine lead to decreased fracture resistance of such teeth [4-7]. Endodontic post and core systems have been commonly used to restore the missing part of the tooth structure to prevent fracture of the residual tooth and to improve retention of the final restoration [8]. Since cast metal or prefabricated posts materials affect the amplitude and distribution of stresses in root canal treated teeth, the biomechanical outcome is inevitably jeopardized [9-11]. Recent studies show that frequent episodes of vertical fractures in roots restored with metallic posts are strongly related to high elastic modulus yielding excessive stresses at the apical third level. Such fractures is one of the major reasons for tooth extraction following placement of endodontic posts [8,11-13]. Eventually, posts having elastic modulus similar to dentin, such as fibre-reinforced posts, gained high popularity compared to metallic post and core systems [9,11,12].

Fibre posts have flexural modulus similar to that of human dentin [12]. This promotes uniform stress distribution at the post-cement-dentin interface and avoids excessive stresses that risk longevity of the restoration [11-13]. It has been suggested that fibre posts luted with adhesive resin cements lead to higher fracture resistance of endodontically treated roots [11,13,14]. In addition, high survival rates of all ceramic crowns has increased patient demands for these restorative materials, particularly in the anterior region [15,16]. Consequently, there has been a substantial increase in the use of all-ceramic crowns as well as tooth-coloured endodontic post and core materials [17,18]. Among tooth-coloured post systems, glass-fibres have dominated clinical practice because of their comparable modulus of elasticity, high tensile strength, white colour and good transparency [19,20]. Glass-fibre posts can be removed and replaced easily without the risk of perforating the root [21]. Manocci et al. [22]. investigated the intermittent loading response of teeth restored with different tooth coloured post systems (quartz fibre, carbon quartz fibre, and zirconium posts) and found that fibre posts reduced the risk of root fractures. At present, posts are provided either in conventional or prefabricated monoblock types in the dental market. Dentists may prefer to use prefabricated one-piece glass-fibre post systems, because they are practical and less time-consuming. However, their effects on the fracture resistance of weakened roots still remain uncertain. This study, therefore, aimed to evaluate the effects of glass-fibre post design on the fracture resistance of extensively damaged endodontically-treated teeth.

2. MATERIALS AND METHODS

Thirty freshly extracted, caries free human maxillary central incisors extracted for periodontal reasons having minimum 21 mm root length and single straight root canals were used in this study. The teeth were ultrasonically cleaned and the coronal parts were removed 2-3 mm from the cemento-enamel junction (CEJ) using a high-speed sawing machine (IsoMet 1000, Buehler, IL, USA) under copious water-cooling. The roots were coated with 0.2-0.3 mm thick wax (Dipping Wax, Bego Bremen, Germany) 2 mm below the CEJ, to partly allow physiological tooth movement during the experiments. Each tooth was embedded into acrylic resin (Vertex, Vertex Dental, Netherlands) blocks 2 mm above CEJ to simulate the clinical bone level. Upon polymerization, the teeth were removed and wax was replaced with polyvinylsiloxane (Elite HD+ Light Body Normal Setting, Polesine, Italy) to simulate periodontal ligament. The roots were cleaned in distilled water and stored in formaldehyde solution.

The root canals were enlarged using ProTaper rotary instruments (Maillefer, Dentsply, Tulsa, OK, USA) with Glyde File Prep lubrication (Denstply, Maillefer, Ballaigus, Switzerland) until
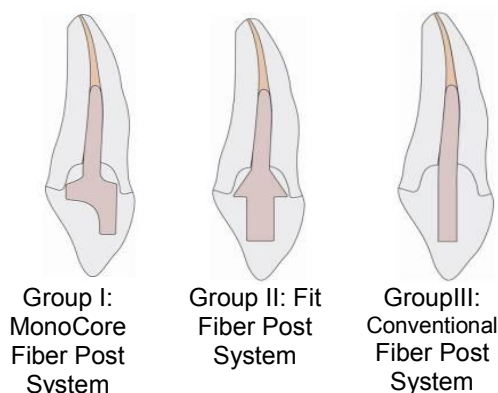
the file F5 reached the working length (1 mm from the apical foramen). The root canals were irrigated with 2 mL 5.25% sodium hypochlorite (NaOCl) between each file size. To remove the smear layer, the root canals received a final rinse of 5 mL 17% ethylenediaminetetraacetic acid (EDTA). Finally, roots were irrigated with 10 ml distilled water to avoid prolonged affect of EDTA and NaOCl solutions. The canals were subsequently dried with paper points. All the samples were filled with ProTaper F5 gutta-percha and AH 26 sealer (AH 26, Dentsply, Detrey, Konstanz, Germany) in strict adherence to the recommendations of the manufacturers.

The post space preparation of each sample was carried out using Peeso-reamer size #1 and followed by dowel space drills of Ø 1.4 mm and Ø 1.7 mm, respectively to a depth of 10 mm provided in the kit from the manufacturer. In order not to deteriorate the apical seal, the post length was set to 10 mm in all samples by giving respect to 4-5 mm apical seal. Finally, walls of the roots were flared using an occlusal reduction diamond bur (905.313, Komet Dental, Germany) to a dentin thickness of 1 mm at the coronal portion to simulate a weakened tooth structure.

The samples were randomly divided into three groups for post placement: Monoblock Monocore fibre post group (MFP) (Monocore, Bioloren Metal Free Dental System, Soronna, Italy); Monoblock Fit fibre post group (FFP) (Bioloren Metal Free Dental System, Soronna, Italy); and Conventional fibre post group (CFP) (Avant Bioloren Metal Free Dental System, Soronna, Italy). Monocore and Fit post systems are fiberglass posts made of an upper part (abutment side) and a lower conical part(post side).The upper part is easily shapeable with a diamond bur for a quick reconstruction. The lower part can be inserted in a root canal and is self-threading. They both have microrough surface. They differ in designs. Monocore fiber post has a shape similar to a prepared central incisor; Fit fiber post system has a cylindrical design (Figs. 1 and 2).

Adhesive luting agent Panavia F 2.0 (Kuraray Co., Japan) has been shown to increase the fracture resistance of excessively damaged root canal treated teeth significantly. Therefore, all posts were luted to root samples using this cement. The cement was applied to the post and root canal wall using a lentulo spiral, and light cured with dental light-curing unit (Elipar Free Light 2, 3M ESPE, Seefeld, Germany) for 10 seconds after inserting the post with finger pressure. The conventional post samples were

restored with composite material (3M ESPE, Filtek Z250, Seefeld, Germany) using a silicon matrix to standardize the core length and shape. Composite was used for the FFP group, where necessary. 0.5 mm- thick zirconia copings (Cercon, Degussa, Hanau, Germany) were fabricated. After the adjustment of fit, zirconia copings were luted to the samples using the resin cement. Each sample then received thermal cycling (6000 cycles 5-55°C) with a dwell time of 20 seconds in each water bath. (Water Bath, Nuve Sanayi Malzemeleri Imalat ve Ticaret A.S., Ankara, Turkey). Specimens were loaded at 45 degree in a universal testing machine (Lloyd LRX; Lloyd Instruments Ltd, Fareham, UK) at a crosshead speed of 1 mm/min until fracture occurred. Fig. 3 data were statistically analyzed with SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Kruskal Wallis variance analysis was used to reveal difference in fracture resistances among groups. Pairwise comparisons were made using Mann Whitney U test. Confidence level was set to 95% for all statistical assessments. The mode of failure of each specimen was also recorded descriptively.

Group I: MonoCore Fiber Post System

Group II: Fit Fiber Post System

GroupIII: Conventional Fiber Post System

Fig. 1. Schematic illustration of the study groups

3. RESULTS AND DISCUSSION

The mean failure loads (N) of MFP, CFP, and FFP were 315.8 N, 218.7 N and 146 N respectively (Table 1 and Fig. 4). Fracture resistances varied among designs and the differences between the groups were significant ($P<0.05$) (Table 2). Pairwise comparisons showed significant differences among the groups ($P<0.05$). The modes of failure for each group are presented in Table 3. In MFP group, 40% root fracture, 20% crown fracture, and 40% decementation were observed. In the FFP group, 90% decementation was observed.

Fig. 2. MonoCore Fiber Postsand Fit Fiber Posts (Bioloren Metal FreeDentalSystem, Soronna, Italy)

Fig. 3. Specimens were loaded at a universal testing machine until fracture occurred.

**Table 1. Mean and standard deviations of the tested groups
(MFP, MonoCore Fiber Post; FFP, Fit Fiber Post; CFP, Conventional Fiber Post)**

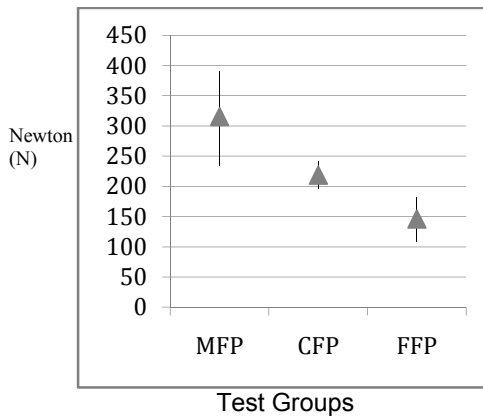| Groups	Number of samples	Mean	Standard deviation	Max.	Min.
MFP	10	315,8	47,43	390	234
FFP	10	146	25,56	281	108
CFP	10	218,7	15,21	241	196

In this study, fracture resistances of endodontically treated teeth with different fibre post designs were evaluated. To prevent early loss and improve fracture resistance of weakened endodontically treated roots in the oral cavity, different techniques and materials have been tested [15]. Marchi et al. [23] used different types of cements in order to achieve higher fracture strength. Similarly, Mendoza et al. [24] compared different types of resin cements and found that Panavia F significantly increased the fracture resistance of excessively damaged root canal treated teeth [24]. In another study, cast Cr-Ni posts were found to increase the fracture strength of weakened roots twice when compared to glass-fibres. However, failures in fibre posts were re-treatable [25]. Rundquist et al. [26] stated that canal angulations create higher stresses under functional forces. Recent clinical investigations indicated that fibre posts could protect the root against fracture [27]. Prospective clinical studies revealed that root canal treated teeth restored with adhesively luted fiber-reinforced posts have survival rates between 3 to 7 years [28-31]. Using fiber post system combined with composite resin, resin cement and core material form a homogenous structure by decreasing the risk of root fracture [32,33]. Hence, using chemically compatible adhesive restorative materials coupled with mechanical properties close to that of dentin improves preservation of the root integrity [15,34-36].

material. Two one-piece glass-fibre post systems with different designs were compared with conventional fibre post system. Regarding fracture strength properties, a significantly higher maximum fracture load was recorded for monoblock MFP group, while the lowest fracture load value was achieved in the monoblock FFP group. This might be due to the design of the FFP, which is cylindrical in shape and that does not correspond with the anatomical form of a central incisor. Besides, additional composite filling material was used to fill the gaps and to form a "prepared central incisor design" during core preparations of FFP samples. The base portion of FFP design has a 45 degree angulation and that may also lead to weak retention and resistance behavior" of FFP under occlusal efforts. In contrast to FFP, MFP, which has a similar design like a prepared central incisor and did not require application of a composite filling material, showed the highest fracture resistance value. The conventional post group showed mean fracture force of 218.7 N. However, a direct comparison of the monoblock systems cannot be done in the literature, since these materials are new and no data could be found regarding monoblock fibre post systems.

Table 2. Kruskal Wallis variance analysis. MFP, MonoCore Fiber Post; FFP, Fit Fiber Post; CFP, Conventional Fiber Post

Groups	n	Mean rank	Sd	X^2	p
MFP	10	25.30			
FFP	10	5.50	2	25.318	.000
CFP	10	15.70			

In this study, monoblock fibre post systems, those newly introduced to the dental market, were used in combination with an adhesive luting

Fig. 4. Graphical analysis of the mean and standard deviation values of tested groups (MFP, MonoCore Fiber Post; FFP, Fit Fiber Post; CFP, Conventional Fiber Post)

Table 3. Mode of failure of the tested groups (MFP, MonoCore Fiber Post; FFP, Fit Fiber Post; CFP, Conventional Fiber Post)

Groups	Post fracture	Core fracture	Crown fracture	Root fracture	Decementation
MFP	0	0	2	4	4
FFP	0	0	1	0	9
CFP	1	3	2	0	4

All post groups exhibited fracture strength values that are in the same range or higher than the maximum functional forces in the anterior region. The functional forces in the anterior area varies according to age, gender and have been found to be between 100-200 N [37]. Another study reported maximum functional forces for males as 146±44 N [38]. Both MFP and CFP groups showed higher fracture force values than the maximum functional forces in the masticatory system. A fracture force value of 146 N achieved in the FFP group is close to the maximum functional forces. According to the findings of this study, FFP cannot be recommended for clinical applications or should be used with caution.

The major causes for post failure are debonding of post and crowns and root fracture. Infrequent causes of failure are post distortion and post fracture [21,27]. While the use of metal post often leads to root fractures, the most common type of failure with conventional fibre reinforced posts is post debonding [27]. This statement is in agreement with the findings of this study, as debonding was found 90% in the FFP group, and 40% in MFP and CFP groups. On the other hand, MFP group also showed 40% root fracture, while no root fractures occurred in the FFP and CFP groups. As root fracture necessitates the extraction of the tooth, MFP could not be recommended for a tooth restoration.

The post-core systems can be evaluated in in vitro, in vivo or ex vivo studies. Clinical studies seem to be more predictable, but difficult to perform due to patient standardization protocols and patient related variables. However, restorative materials, teeth, testing methods and devices also affect the results of a study [33]. In this study, a common testing method was used to compare the fracture resistance values of different fiberglass post designs [39]. In order to simulate the clinical situation, human maxillary central incisors extracted for periodontal problems were used [40,41]. Because some studies expressed the importance of a crown for the results of post-core studies, a zirconia core was also used during tests [42,43]. All samples restored with zirconia substructures were adhesively bonded with a special luting agent Panavia F 2.0 as referred in the literature [36].

4. CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The highest fracture resistance values were achieved in MFP, followed by CFP FFP groups.
2. The highest root fractures were observed in the MFP group. No fracture occurred in FFP samples.
3. For FFP group, the fracture load is close to the functional masticatory forces in the anterior region. Further clinical investigations are needed.
4. MFP could not be recommended for a tooth restoration, because this will lead to more fractures and more loss of teeth than the use of other tested post systems. Further clinical studies are needed.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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