

# Assessment of Fracture Resistance of PEEK and Fibre Posts of the Endodontically Treated Teeth

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**Abstract:** *This in vitro study aimed to compare the fracture resistance between pressed custom-made polyetheretherketone (PEEK) post and core and fibre reinforced post and composite core. A total of 40 single rooted extracted teeth were selected, endodontically treated, and prepared to receive the posts. Specimens were randomly divided into two main groups (n=20/group): group 1, (PEEK); group 2, fibre post. PEEK post was manufactured with a computer-aided design/computer-aided manufacturing system further divided into four sub groups (P7, P12, F7, F12) based on lengths 7 and 12 mm at which the posts were cemented. All posts were cemented with self-adhesive resin cement, and specimens were stored in 0.1% thymol solution during the experiment at all the times except during preparation and testing. A universal testing machine was used to measure the fracture resistance. The fracture resistance values (mean & SD, in newtons) were 1255N (P7), 1562N (P12), 1065N (F7), and 1384N (F12). Only P12 exhibited a significant difference (p,0.05). The turkey test showed an association between failure mode and post and- core material. In the remaining groups, most failures were nonrepairable and related to fracture. Customized post-and-cores of PEEK exhibited good mechanical performance. Their fracture resistance was comparable to that observed for fibre posts.*

**Keywords:** *glass fibre post, PEEK post, endodontically treated teeth, fracture load*

## 1.Introduction

When taking into account the restoration of non-vital teeth, different materials have to be able to restore this structure loss, to improve the functional and mechanical properties, preservation of coronal seal and esthetics [1]. A post-and-core might be essential to promote retention and resistance form for the tooth-restoration unit, when a full crown is the line of treatment needed to restore an endodontically treated tooth [2]. The material of post-and-core should have mechanical and physical properties close to those of dentin so as to better tolerate the occlusal loads, preventing tooth fracture or de-bonding of the post. Referencing to previous studies, using post and core material with a decrease elastic modulus, fiber glass for example, resulted in more favourable stress distribution [3]. However, as fiber glass posts are available as ready-made material, they have limited usage to the shape of the root canal. Furthermore, although fiber glass posts have reduced modulus of elasticity than those of different posts of metal alloy, these are still nearly three times the elastic moduli of dentin [4].

Newly, a new biocompatible good performance polymer, Polyetheretherketones (PEEKs), was introduced as new dental restorative materials. Because of their fracture resistance is acceptable, enhanced shock-absorbing ability and stress distribution, these increased performance materials are measured as substitute novel materials for metal and glass ceramics [5]. PEEK Young's modulus and tensile properties are similar to human bone, enamel and dentin. The material is available as either pellet or granulates for the pressing technology or as blanks for milling using the Computer Aided Design/Computer Aided Manufacturing technology (CAD/CAM). For the aforementioned characteristics of PEEK, this study was conducted to evaluate PEEK as a custom post material and study the effect of

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processing technique on fracture load of the produced restoration and compare it to the contemporary customized fiber post [6]. The null hypothesis was that no significant differences in fracture resistance in the two different systems.

PEEK has the most important characteristics is that it has low modulus of elastic that is close to cortical bone so that it can be used in dentistry for making different prosthesis [7]. The other benefit of PEEK is that it can be bonded with dental composites and resin cement and can be indirectly polymerized by light. In esthetic requirements, PEEK can be bonded with composite resin because it has low semi-opacity [8]. In addition, PEEK material can be produced by casting under heat and pressure with both the CAD-CAM systems and with the wax casting method. PEEK material was selected for use in this study due to these numerous positive advantages and in addition to being used as crown material, it was used as a dental post material, particularly because of the property of the low modulus of elasticity, near to that of dentin tissue [9].

In few studies [8, 10, 11] it was compared the fracture load of fibre with metal post and other different post material, they reported comparative performance of endodontic post made from newly introduced esthetic materials like PEEK which is inadequate and needs further analysis. Therefore current in-vitro study aimed to evaluate the fracture load of fibre reinforced and custom made PEEK posts.

## Materials and methods

### Preparation of specimens

In this in-vitro study custom-made and customized post and core were made by two different materials; PEEK granules for pressing (PEEK granule (Dalian Bona Biological Technology Co., Ltd. China), fibre post (Tenax fibre post, Coltène/Whaledent, Cuyahoga Falls, OH, USA) To determine the number of specimens required for this study, the research hypothesis that there is no difference between the fracture resistances of posts made with different materials. A total of 40 human single rooted teeth averaging cervico-occlusal length of the crown about  $8\pm 0.5$  mm and  $14.5\pm 0.5$  mm for root length were collected for this study. All specimens revealed fully developed apices and had no caries, cracks, restorations, erosion, abrasion, or fractures. Teeth were extracted for orthodontic or periodontal reasons, before teeth extraction all patients approved and gave consent for the teeth to be used for this study. Teeth were carefully cleaned and stored in distilled water at room temperature until used. The crowns were decapitated 2mm above the level of the cement-enamel junction (CEJ) with a low-speed disc (Dental Fix, Canada). Each root was embedded in acrylic resin (diamond dental acrylic, National Keystone, Cherry Hill, NJ), up to 2.0 mm short of the CEJ, using a circular polyvinyl chloride cylinder (25 mm in diameter 20 mm high). The set (tooth, matrix, and resin) remained stable for 72 hours to ensure setting of the resin. Endodontic treatment was then done on all 50 teeth. Root canals were prepared by one operator. Preparation of the post space was done using size #2 and #3 peeso reamer (Largo, Dentsply Maillefer) to remove 12 mm of gutta-percha from each root canal. This process was implemented without irrigation because the heat generated by the drill enhanced gutta-percha removal. Any residual gutta-percha on the post space walls was discovered with radiographic imaging. In order to standardize the post space, the corresponding blue drill (relyx fiber post, 3M ESPE, Germany) was utilized to finish and enlarge the preparation of the root canal (12 mm in length) (1 mm width apically) and the canal was enlarged leaving 2mm thickness dentin wall circumferentially, and the drilling for all specimens. After the preparation of each root, the corresponding teeth were allocated randomly to two groups (n=20/group) according to the type of material and fabrication technique used to generate the post-and-core: group 1; PEEK, group 2; fiberglass. These groups further divided into subgroups according to length of the post PEEK (P7 and P12) and fibre (F7 and F12)

For group 1 the designs were prepared by making impression of intracanal and poured by hard stone than wax pattern is prepared. The wax patterns were invested using special phosphate-bound investment material: powder (Gilvest HS, SRL Dental GmbH, Germany) and liquid (Gilvest liquid G high expanding, SRL Dental GmbH, Germany). The pressing procedure was completed fully automatically within 35 minutes after wax elimination, the restorations were then deinvested. A short water bath was

used to guarantee freedom from dust and make the devesting process easier. The fine investment material residues were removed using a fine blasting device (Easyblast, BEGO, Germany), fine cross-toothed carbide mills were used for cutting sprues and fine adjustments. The final restorations were then checked on their corresponding teeth. Prior to cementation, the root canals were flushed with 2mL of distilled water to remove the residues of water soluble gel. The canals were dried using triple syringe with oil free air, to ensure complete drying absorbent paper cones (Dentsply Maillefer) were used.

In both groups, cementation regulations were followed according to the manufacturer instructions; sandblasting was done first, the posts were blasted with 110  $\mu\text{m}$  aluminium oxide and 2-3 bar pressure. The blasting distance was 3 cm. Self-adhesive resin cement G-CEM dual cure capsules (GC America) were used according to manufacturer's directions and injected into the root canal. Afterwards, posts were inserted into root canals and seated first by finger pressure then a seating device with 250 gm weight was used to standardize the seating pressure, soft curing was done for 5 s to allow proper excess cement removal and this was followed by complete curing for further 40 s in the cervical portion of the root, with a light cure (3M ESPE, USA)

### Statistical analysis

The prepared samples were fixed in metal jig at 135-degree angulation to simulate the direction of forces in the oral cavity and were subjected to compressive load at the demarcated area on the lingual surfaces of the specimen under universal testing machine (Model No. SSUTM1025 PSI Sales, Pvt. Limited, New Delhi). Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. One-way ANOVA followed by Tukey's post hoc test was used for intergroup comparison. The significance level was set at  $p \leq 0.05$  for all tests. Statistical analysis was performed with IBM (IBM Corporation, NY, USA.) SPSS (SPSS, Inc., an IBM Company) Statistics Version 26 for Windows.

### 3. Results and discussions

The failure load values were obtained for both PEEK and fibre posts at 7 and 12 mm of post space length were calculated, which shows that less value for PEEK post (527N) was lesser than that of fibre post (473N) as shown in Table 1.

Table 2 showed that the mean value between the groups of failure load (N) for PEEK and fibre subgroups at 7mm post lengths showed a significant difference with the highest failure load of PEEK was (801N) and fibre post was (753N). The mean value of failure load (N) for fibre subgroups was in 12mm group (1071N), and in PEEK group (1179N) ( $P$  value = 0.05).

Table 3 showed that failure load of PEEK versus fibre posts. The PEEK failure load (N) was more (654N) than the fibre post (623N). Further Tukey B test revealed in Table 3 that failure load properties were comparable in 12mm but were different from 7mm posts. The comparison of failure load (N) for fibre post groups at 7 and 12 mm post lengths showed a significant difference with the highest failure load in 12mm (1179N) and 7mm (753N) ( $P$  value < 0.005) as shown in Figure 1.

**Table 1.** Failure load values (N) for fracture resistance of PEEK and fibre posts at 7 and 12mm length

Sample no.	Failure load (N)			
	(P7)	(P12)	(F7)	(F12)
1	732	972	527	840
2	657	1037	734	904
3	591	807	621	1007
4	630	1103	542	721
5	594	869	612	802
6	801	906	753	921

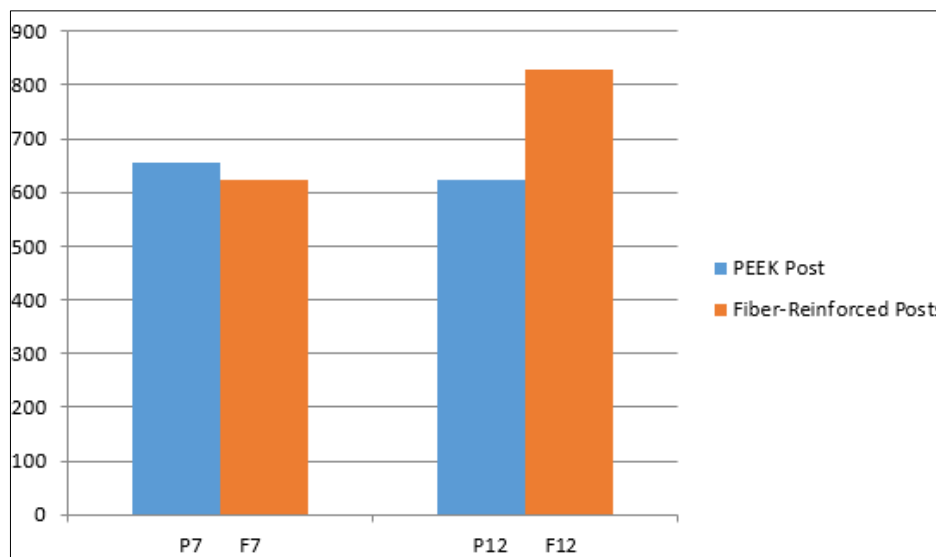
7	713	874	592	731
8	671	895	721	589
9	624	1179	622	1071
10	527	1032	507	701

**Table 2.** Comparison of failure load (N) between different experimental groups of posts.

S.No.	Comparison	Mean	Std. Deviation	t-value	P-value
1.	Group P7 VS Group F7	638	176	3.1	0.617
2.	Group P12 VS Group F12	897	243	4.6	

**Table 3.** Comparison of failure load (N) for PEEK and fiber posts

Group	Mean	Std. Deviation	F-value	P-value	Tukey B
P7	654	174	5.238	0.05	A
P12	967	283			B
F7	623	191	3.219		B
F12	828	260			B



**Figure 1.** Mean values for failure load for PEEK and fibre posts (N)

The present study tested the performance of PEEK generated by pressing technique as a possible endodontic post material by comparing it with the standard contemporary fiber post. In this study natural teeth were used to best simulate the actual canal space and allow endodontic treatment for the teeth, single rooted teeth were selected as they have mostly a uniform root shape for the purpose of standardization and to minimize the effect of different post geometries on the results of fracture resistance [12, 13]. The current study used the Universal testing machine for fracture resistance testing; a vertical load was applied as it seems to check the cohesive properties of the tested posts and to spread the stress more consistently between the restorative material and the dental tissues reproducing a normal occlusion.

The data gained from present study approves the refusal of the null-hypothesis, since the fracture resistance of differently produced restorations was statistically diverse, PEEK group showed the highest mean value ( $1179 \pm 283\text{N}$ ) while fiber post group ( $1070 \pm 260\text{N}$ ) showed the lowest mean value. Pair wise comparisons showed that fiber post group had a significantly lower mean value compared to the PEEK groups ( $p < 0.005$ ).

These findings were found to be in harmony with the outcomes of one study who evaluated the influence of various fabrication procedures of fixed partial denture of PEEK on fracture resistance [14]. PEEK milling blanks are industrially pre-pressed, the granular pressed restorations revealed slightly



higher fracture resistance values than those from milled PEEK [15, 16]. For that reason it is concluded that the industrial pre-pressing technique for the CAD/CAM blanks improve the mechanical characteristics as the industrial manufacture under optimal circumstances a decreased risk of porosities in the restorations [17]. On the contrary, the mechanical characteristics of pressed PEEK restorations are more operator-dependent; the preheating process, the vacuum pressing equipment and other elements may affect the overall quality of the produced object [18].

The mean fracture resistance recorded in the current study of pressed PEEK ( $810 \pm 1281$ N) and showed relatively higher values compared to the fibre post. In addition, results of the previously mentioned study showed mean fracture loads of pressed PEEK (2,354 N) and fibre post (1,738 N) between the groups. This can be explained as different types of restorations were used, as 3 units FPDs have higher fracture resistance values than custom-made post and core [19 20]. Another study investigated the fracture resistance of CAD/CAM milled non-veneered three-unit PEEK fixed prosthesis frameworks with a connector area of  $7.36 \text{ mm}^2$  revealed a restoration fracture resistance of 1,383 N with a deformation at approx. 1,200 N, these values are similar to those in the current study [6].

For the customized fiber post with composite core group, the mean fracture resistance value obtained from the current study ( $725 \pm 98$ N) was higher than those obtained from another study who evaluated the fracture load and failure type of custom-made post-and-cores made with various esthetic materials, the mean fracture resistance value for the fiber post with composite core group was ( $925.6 \pm 179$ N) [21]. This may be due to different angulation of the applied load to the long axis of the tooth, as the samples were placed in the universal testing machine with the load directed  $135^\circ$  to the buccal edge of the core [11, 17].

The highest fracture resistance of fibre post at 12mm subgroup can be explained by the concept of monobloc formation by the fibre posts, which means the achievement of a single biomechanical complex by adhesion between the tooth structure and reconstruction material capable of resisting greater forces. As the post length was reduced in 7mm subgroup, the reinforcing effect of both posts diminished. Also, comparatively unfavourable crown to post ratio probably led to concentration of high stresses in the tooth [22]. The present study also evaluated the effect of various posts lengths on the two types of posts i.e. fibre posts and PEEK posts. It was found that the PEEK post at length 12mm had best fracture resistance as compared to 7mm.

It should be affirmed that the values of fracture load seen in this study were more than those corresponding to a normal adult forces of occlusion, which differ from 190-290 N (in the anterior teeth) to 200-360 N (in the posterior region) [23]. Finally, the results of this study might be directly related to the materials/ methodology utilized and might not reflect what could happen under different circumstances. The resin cement used was left to complete its setting at room temperature, which are few degrees less than body temperature [2, 4]. As known with other adhesive cements, the polymerization shrinkage, degree of polymerization, timing and reaction kinetics may have been influenced by the conditions of the study. The failure loading protocol included aging-induced degradation of the adhesive interfaces (water storage of samples and thermocycling) but it did not involve a dynamic process that could simulate the oral conditions more accurately, also crowns were not used in order to prevent external impacts over force distribution, as the scope of this study was radicular events, but clinically results are expected to be higher as crowns act as protective factors preventing catastrophic failure involving the root [9, 15, 24]. Future studies should perform the comparison between groups of teeth with variable levels of idealistic tooth structure.

#### 4. Conclusions

On the basis of the results and conditions of this study, the following conclusions can be drawn: PEEK post and core made pressed granules techniques have surpassed the fracture resistance values of fiber reinforced post. Moreover, the fracture resistance of these post-and-cores was comparable to that of fiber posts customized with a nanohybrid resin composite and lower than that of PEEK posts. The greatest number of repairable fractures was observed with fibre posts at the junction of root and core.

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