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ORIGINAL RESEARCH

Comparative evaluation of the pushout bond strength of fibre reinforced composite resin post and PEEK (polyetheretherketone) post following surface treatments

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ABSTRACT

Background: There is a lack of literature in the scientific domain on the use of PEEK material as a radicular post for both anterior and posterior teeth.

Aim: To comparatively evaluate the push out bond strength of prefabricated glass fiber reinforced composite resin post and customized modified Polyetheretherketone (PEEK) post following surface treatments.

Materials and methods: Total of thirty mandibular first single rooted premolars were divided into two groups of fifteen each (n=15) named as fibre reinforced resin post and modified PEEK post. All the specimens were subjected to endodontic therapy, followed by post space preparation. The posts from both the groups were subjected to dual surface treatments (Al2O3 50µm air abrasion followed by silane coating) and were subsequently cemented with dual cure resin cement (Maxcem elite, Kerr). All the samples were sectioned into three regions of each 2mm thickness and were subjected to push out bond strength analysis, followed by the assessment of mode of failure. Bond strength was compared using oneway ANOVA and Independent T test.

Results: There were significant differences ($P < 0.05$) in the push out bond strength in the three regions of modified PEEK post. There were no significant differences ($P > 0.05$) in the three regions of prefabricated glass fiber reinforced composite resin post. There were highly significant differences in push out bond strength ($P < 0.05$) between glass fiber post and modified PEEK post in coronal and middle regions but not in the apical region.

Conclusions: Within the limitations of this study it was concluded that surface treated modified PEEK material can be used as an intra radicular post because there were significant differences in the mean push out bond strength in all the three regions and there was absolutely no cohesive failure (within the post).

Keywords: Glass fiber reinforced composite resin post, Modified PEEK post, Push-out bond strength, Mode of failure, Alumina air abrasion, Silane coating.

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1. Introduction

Root canal treatment is broadly performed on teeth evidently affected by deep caries, multiple repeat restorations and/or fracture. It involves the removal of necrotic and infected pulp tissue followed by a well condensed obturation to prevent further microbial proliferation within the canal system.[1]

However, the long term clinical success of root canal treatment relays on efficient post endodontic restoration which prevent bacterial recontamination of the root canal system from the oral fluids.[2]

Several researches had proposed that the dentin in root canal treated teeth is appreciably different than dentin in teeth with vital pulps, where a protective feedback mechanism is lost when the pulp is removed and roots are more prone to fracture.[3, 4]

A variety of materials have been used for posts ranging from wooden posts of the 18th-century to metallic posts made of precious or nonprecious casting alloys and, more recently, carbon fiber, glass fiber, poly ethylene fiber, ceramic and zirconia posts. Endodontic posts are available as active or passive posts, parallel or tapered, custom made or prefabricated.[5]

Generally active posts are threaded and are anticipated to engage the walls of the canal, whereas passive posts are retained firmly by the luting agent. Active posts are more retentive than passive posts, but they bring in more stress into the root dentin.[3, 6]

Customised cast posts were used which were extremely rigid, promote stress concentration in isolated points which increases the risk of root fracture and highly unesthetic.[7]In 1990, Duret et al introduced fiber post with modulus of elasticity approaching that of the root dentin that effectively transmit and distribute the stress uniformly throughout the dentinal walls.[1]

These fibre posts can be adhesively luted to the root canal dentine using polymerizable resin cements. The inherent chemical homogeneity between the fibre post and the resin cement enables them to function together as a homogenous biomechanical unit, known as tertiary monoblock that mechanically replaces the lost dentin.8 Bonding strategies are usually employed to achieve micromechanical retention between the resin cement and root dentin.[9]

An important aspect of adhesive procedure for fibre post cementation is that two interfaces are involved namely, resin cement/root dentin interface and resin cement/fibre post interface. The adhesion in both interfaces is crucial for the long term success of post endodontic restoration.[10]

With regard to dentin and resin cement interface wide range of investigation was done using surface treatment of root canal dentin to remove smear layer and increase surface energy followed by cementation with conventional and self-adhesive cements. In order to improve the adhesion between fibre post and resin cement interface, pre-treatment of the fibre post surface had been proposed.[11]

Glass fibre posts are composed of various types of glass fibres such as SiO2, CaO, B2O3, Al2O3, with inorganic fillers and a polymer matrix, commonly an epoxy resin or other resin polymers.[12]Different surface treatments have been applied for conditioning of the post surface namely silanization, hydrofluoric acid etching, hydrogen peroxide, airborne-particle abrasion, methylene chloride, and laser irradiation.[13]

In recent times PEEK had evolved as a material of choice in various medical and dental applications. PEEK is a linear polyaromatic and semi-crystalline thermoplastic polymer with a suitable combination of high strength, stiffness, fatigue, and wear resistance. In addition, it is easy to process, non-toxic while possessing natural radiolucency as well as excellent thermal and chemical stability.[14]

PEEK based implants were used in (1).In the form of maxilla, facial and cranial implants. (2) For spine surgery – spinal cages. (3) For orthopedic surgery: In bone and hip- replacement surgeries, fixation plates, screws. (4) In cardiac surgery as intracardiac pump; heart valves. In dental applications for tooth replacement – dental implants from CFR-PEEK, dental prosthesis, intra-radicular posts.[15]

It has a melting point around 335.80C. PEEK can be modified either by the addition of functionalized monomers (pre-polymerization) or post polymerization modifications by chemical processes such as sulphonation, amination and nitration. The major beneficial property is its lower Young's elastic modulus (3–4GPa) being close to human bone, enamel, and dentin.[16]

To obtain better adhesion, PEEK surface requires treatment since it has low surface energy. Sand blasting is an efficient method for modifying surface morphology and to increase the surface area other methods are tribochemical silica coating and chemical attack.[17]

BioHPP (High Performance polymer) is a PEEK variant that has been specially optimized for dental field. It has been strengthened with special ceramic

filler, and optimized mechanical properties have been created for dental technical and/or dental medical use. This ceramic filler has a grain size of 0.3 to 0.5µm. Due to this very small grain size, constant homogeneity can be produced. The Elastic modulus of BioHPP lies in the range of 4000MPa, which is resemblance of human bone, makes it a more natural material. The aesthetic white shade supports its use in field of prosthetic and post and cores. Its insolubility in water makes it a biocompatible material, which is ideal for patients with metal allergies.[18]

Extensive search on the use of PEEK material as a post in medline/pubmed/cochrane databases didn't yield positive results. Therefore there was a need to explore the use of PEEK as a post material from a research point of view and then to identify its clinical feasibility. Glass fiber reinforced composite resin post had been widely used clinically and therefore it was chosen for comparative evaluation of push-out bond strength against modified PEEK in the current study

The null hypothesis for this study was that there would be no significant differences in the push-out bond strength between customized modified polyetheretherketone (PEEK) post and prefabricated glass fiber reinforced composite resin post.

Materials and Methods

Thirty single rooted human mandibular first premolars extracted as part of orthodontic therapeutic extractions and following severe periodontal problems were selected. After extraction, the teeth were cleaned and stored in 0.9% saline (Paradental drugs, India) at room temperature.[19] Each tooth was examined radiographically for presence of single root canal, a closed apex and with no evidence of a caries lesion or restoration. Each tooth was sectioned 15mm coronally from the root apex at CEJ using diamond disc (Mani Inc, Japan). All the teeth were embedded in a tooth colored self-curing acrylic resin (Dental products of India,Ltd, India), using a putty index made out of addition silicone impression material (Aquasil – putty index, Dentsply Sirona, Germany).

Access cavities were prepared and the working length was established by placing a size 20 K-file (Mani Inc, Japan) into the canal with 1mm short of apex. The root canals were prepared by Crown down technique using 6% rotary protaper file system (S1, S2, F1, F2, and F3) (Diadent, Korea). The root canals were irrigated with 3% NaOCl solution (Prime Dental Products PVT, India) at 37ºC and finally irrigated with normal saline (0.9%). The canals were dried with multiple sterile paper points (Diadent, Korea). Master cone size 30 of 6% taper was selected. All teeth were obturated by Warm vertical compaction method using 6% taper gutta percha cones of size 30 (Diadent, Korea) with Root canal sealer (Rc-seal, Prime dental, India). The decoronated and filled roots were stored for 24 hours in distilled water at 37ºC.[20]

Fig. 1 Pre fabricated glass fiber post and drill

The gutta percha was removed with the help of micromotor and handpiece (Marathon-3,Saeyang microtech, Korea) by using peeso reamers size1, 2, 3, 4 and 5 (Mani Inc, Japan), and Reforpost space drill (Angelus,Brazil) leaving a minimum 5mm apical seal and creating a standard post space of 9mm from the coronal surface corresponding to the tapered glass fiber post size #3 (1.5mm diameter, Reforpost, Angelus, Brazil) Following the preparation, the post spaces were rinsed with 3% sodium hypochlorite. A final irrigation was accomplished with distilled water (Emplura ®, Mumbai), and then the post spaces were dried with paper points. 30 mandibular first premolar root samples were divided into 2 groups according to the type of post material used, Group I: Prefabricated glass fiber reinforced composite resin post (REFORPOST- Size #3,Angelus,Brazil) (15 Nos,1.1mm apicaldiameter,1.5mm coronals) (Figure. 1), Group II: Customized modified Polyetheretherketone (PEEK) post (BioHPP, Bredent , Germany) (15 Nos) (Figure. 2).

Fig. 2 Customized modified peek post

Fig. 3 BioHPP peek granules

After post space dried with paper points and air dry, Canal space was applied with Isolating Liquid (Yeti Lube, Yetti Dental, Germany). Dental Inlay casting wax (GC Corporation, Tokyo, Japan) was used to obtain the intra canal wax patterns by using direct technique. The post patterns which were fabricated by using direct technique were sprued and invested in size 9 casting ring, according to manufacturer's instructions. 210 gms of powder with 35 ml of liquid (75% Deguvest liquid, 25% water) (Degudent GmbH, Germany) was used. After the investment set, burn out procedure was carried out in furnace (VULCAN 3-130, Dentsply, JAPAN) along with plunger for pressing. The procedure duration was 3hours and temperature was raised from 0oc to 840oc. After two and half hours the investment was taken out and BioHPP PEEK granules (BioHPP ds2 , Bredent , Germany) (Figure. 3) were inserted and then it was put back in the furnace for not more than half an hour at 400oc. After the burn out procedure was complete, the investments along with its plunger were subjected to pressing in its respective pressing unit (for 2 press, Bredent) (Figure. 4) at 60 psi for half an hour.[21] All the sprues were trimmed with diamond disks .All the posts were then fitted into their respective root samples.

Fig. 4 Bio HPP vaccum press

Surface of the post specimens were sandblasted with 50µm Al2O3 particles (Alminox 50µm ,Delta labs, India)for 10s. The air pressure for sandblasting was maintained at 2.8 bars at a distance of approximately 10mm between the surface of the specimen and the blasting tip in the sand blasting unit.22Then, the specimens were rinsed under running water and then dried with oil-free compressed air to remove the remnants for 10s. Silane coupling agent (Silano, Angelus, Brazil) was applied on the surface of each specimen and very gently air dried before cementation of the post into the post space of the each tooth sample.[23, 24, 25, 26] All the posts from both the groups were luted with dual-cure resin (Maxcem elite, kerr, New south wales, Australia) cement according to manufacturer's instructions. The cement was applied into the root canal with intra-canal tips and small amount was applied on the fiber post, to ensure adequate cementation.[27] The post was fixed under finger pressure, the excess cement was removed carefully and light cured for 20secs with LED curing light device (3M ESPE, Germany)

Thirty samples were luted with glass fiber post and modified PEEK post were transversely sectioned perpendicular to the post starting at 6mm from the apex of the specimen using a hard tissue microtome (LEICA SP 1600,Germany), along with continuous water irrigation to prevent overheating . In this manner, 3 slices of 2.0mm thickness were obtained in coronal, middle and apical region of each root specimen resulting in 45 slices/ group.[28] The push-out bond strength (MPa) was determined using Universal testing machine (Instron3369, Massachusett, USA). A custom made stainless steel platform (Figure. 5) was fabricated with a punch hole in the center of the platform. The diameter of this punch hole is made 0.2mm greater than the greatest diameter of post.

Fig. 5 Custom made platform for PBS

The specimens were positioned on the jig in an apico-coronal direction to avoid interferences due to root canal taper. The post segments were loaded with a cylindrical plunger of 1 mm in diameter

centered on the post segment; without contacting the surrounding dentin surface. Loading (Figure. 6) was performed at a cross head speed of 1.0mm/min until the post was completely extruded from the specimen.[25,27] The peak force of post extrusion was considered as bond failure and recorded in Newton (N), and this was divided by the bonded area (A) which was calculated by the formula:

$$A= \pi (R1+R2)*\sqrt{(R1-R2)2+h2}$$

Where R1 and R2 were the largest and the smallest radius, respectively of the cross sectioned tapered post, and h is the thickness of the root section.[20, 29]

Fig. 6 Load application in UTM

After the assessment of push out bond strength all the thirty test samples from both the groups were observed under optical microscope (OIAL/MET/01-A Dewinter Technologies, Maharastra, INDIA) with a magnification of 50X to assess the five modes of failures (Figure. 7), (Figure. 8).

Fig. 7 Optical image of resin post

Fig. 8 Optical image of PEEK post

1. Results

Oneway Anova test revealed that there was statistically insignificant difference in the both strengths of glass fiber posts in three regions. Whereas there was statistically significant difference in bond strengths of modified PEEK post in three regions (Table 1). Independent T test revealed there was statistically significant difference in bond strengths between glass fiber post and modified PEEK post at coronal and middle region. There was no statistically significant difference at the apical region.

Chi square test (Table 4) revealed that there was a statistically significant difference between glass fiber post and modified PEEK post at coronal region with regard to mode of failure.

Discussion:

Since teeth are always in contact with saliva in oral conditions, it is generally recommended that they are stored in a solution and kept wet. 30 In the present study, the extracted teeth were stored in saline solution (0.9%) at room temperature, according to the method described by Goracci et al.[25,31] Subsequently teeth were subjected for ultrasonic scaling and cleaned with water to remove calculus and soft tissue Teeth were sectioned with the cemento-enamel junction as reference point with root length of 15 mm to standardize the working length.

In the present study, 3% sodium hypochlorite was used as an irrigating solution because it is an effective antimicrobial agent, serves as a lubricant and also, it has effective tissue dissolving properties.[32] Warm vertical compaction method was performed for obturation of all the thirty samples. Abramovitz suggested that 3-6mm of gutta percha to be left to maintain apical seal.33 but in many other later studies, authors recommend 4-5mm of remaining gutta percha after post space preparation. It allows for proper apical seal. So the level of 4-5mm was chosen for this study.[34]

Surface of the post specimens were sandblasted with 50µm Al2O3 particles for 10s. The air pressure for sandblasting was maintained at 2.8 bars at a distance of 10mm between the surface of the specimen and the blasting tip in the sand blasting unit .Then, the specimens were rinsed under running water and then dried with oil-free compressed air to remove the remnants for 10s. Silane coupling agent was applied on the surface of each specimen and dried before cementation of the post into the post space of each tooth sample. In this study dual cure resin cement Maxcem Elite (Kerr) along with intra-canal tips was used because it reduces the clinical steps of etching, bonding and application of conventional resin luting cement.

Table 1: Materials used in the present study

S No	Material name	Manufacture name	Chemical composition	Commercial Name	Lot Number
1	Glass fiber reinforced composite resin post	ANGELUS	Glass fiber(80%),pigmented resin(19%),stainless steel filament(1%)	Reforpost	42430
2	PEEK post (BioHPP)	BREDENT	BioHPP ds 2 granules	BioHPP granules	458616
3	Silane coupling agent	ANGELUS	Silane and ethanol	Silano	44626
4	Alumina particles	DELTA	Al_{2O3} particles - 50µm size	Alminox	10104
5	Dual cure resin cement	KERR	1,6-hexanediyl bismethacrylate (5-10%) 2-hydroxy-1,3-propanediyl bismethacrylate-(5-10%) 7,7,9(or 7,9,9)-trimethyl-4, 13-dioxo-3,14-dioxa-5, 12-diazahexadecane-1, 16-diyl bismethacrylate-(1-5%) 3-trimethoxysilylpropyl Methacrylate-(1-5%) 1,1,3,3-tetramethylbutyl Hydroperoxide-(0.1-1%)	Maxcem Elite	6785838

TABLE 2: Overall comparison of mean push out bond strength (MPA) of prefabricated glass fiber reinforced composite resin post and customized modified peek post

		CORONAL	MIDDLE	APICAL	P – VALUE
FIBER POST	MEAN	10.173	8.404	8.846	.061
	S.D	±2.127	±1.803	±2.231	
PEEK POST	MEAN	6.178	6.279	7.593	**.003****
	S.D	±1.048	±1.088	±1.422	
P - VALUE		**.000***	**.001***	.077	

Table 3: Mode of failure for prefabricated glass fiber reinforced composite resin post

REGIONS	1 Adhesive (b/w post & cement)	2 Adhesive (b/w cement& dentin)	3 Cohesive (with in post)	4 Cohesive (with in cement)	5 Mixed
CORONAL	5 (33.3%)	4 (26.7%)	5 (33.3%)	-	1 (6.7%)
MIDDLE	5 (33.3%)	8 (53.3%)	2 (13.3%)	-	-
APICAL	1 (6.7%)	5 (33.3%)	2 (13.3%)	-	7 (46.7%)

Table 4 : **Mode of failure for customized modified peek post**

REGIONS	1 Adhesive (b/w post & cement)	2 Adhesive (b/w cement & dentin)	3 Cohesive (with in post)	4 Cohesive (with in cement)	5 Mixed
CORONAL	2 (13.3%)	13 (86.7%)	-	-	-
MIDDLE	6 (40%)	4 (26.7%)	-	4 (26.7%)	1 (6.7%)
APICAL	1 (6.7%0	8 (53.3%)	-	1 (6.7%)	5 (33.3%)

Table 5: Overall comparsion of mode of failure for prefabricated glass fiber reinforced composite resin post and customized modified peek post

REGION	P- VALUE
CORONAL	**.007***
MIDDLE	.077
APICAL	.403

The push out bond strength was employed to measure the bond strength in MPa between the root dentin, the resin luting cement and fibre post at three different levels categorized as coronal, middle and apical third. Goracci et al have highlighted the parameters that influence the bond strength tests and they include the geometry of the specimen, the size of the bonded surface area, the loading configuration and the type of the resin luting cement to be tested.[35] The push out tests proved to be more effective as it provided measurements with limited data variability. These push out tests had the ability to record low levels of the bond strength which was inherent in all the post- cement-root dentin bonds. The premature failure rates of the specimens were also less when push out bond strength was employed. Monticelli F et al demonstrated that push out bond strength were superior to micro tensile stresses using finite element analysis.[36, 37] Bitter et al stated that push out tests produces shear stresses comparable to the shear stress developed during the clinical conditions at the post-cement-dentin interface.[38]

However the limitations of push out tests include the following: Push out test when performed on thick root sections or on whole post causes non uniform shear stress distribution. The specimen position, the angle at which the load is applied influences the push out bond strength results.[39]To overcome these limitations the specimens were modified in our study to obtain 2mm thick dentin slices. The mean push out bond strength of customized modified PEEK post (Group –II) showed significant differences in all the three regions, with the highest bond strength observed at the apical region followed by middle and least in the coronal region. This could be due to the dentin depth and tubule density in the apical region. This results was consistent with the previous study on glass fiber post.[40, 41] The push out bond strength results in all the three regions of our present study for customized modified peek post were comparatively higher than those of previous studies on glass fiber reinforced composite resin post.[30,42,43] This could be attributed due to the silanization of the post surface following air abrasion with alumina particles.

The mean push out bond strength of prefabricated glass fiber reinforced composite resin post (Group – I) in comparison with customized modified PEEK post (Group –II) showed high significant differences at coronal and middle regions. There was no significant difference in the apical region. The push out bond strength for prefabricated glass fiber reinforced composite resin post was highest in the coronal region.

LIMITATIONS

The use of one type of diameter of the posts for the both the groups. mode of fabrication of modified PEEK post was done by Hot pressing technique, whereas CAD-CAM method can also be applied in future studies. Other modes of surface treatments for modified PEEK post should be explored. Future studies should include the use one piece customized modified PEEK post & core. Only one type of self-adhesive dual cure resin cement was used. It is unclear from the scientific literature with regard to the choice of cement to be used for luting of modified PEEK post. Therefore on an experimental basis self-adhesive dual cure resin cement was used. Future studies should include on GIC and resin modified GICs.

Relationship between radicular dentin surface conditioning and modified PEEK post should also be explored. In the current study specimens were not subjected to thermal and cycling loading before evaluation of push out bond strength. The relationship between these loading factors and post adhesion should be carried out in future studies for modified PEEK post. Future studies on modified PEEK post could include single rooted anterior teeth. Studies on flexural and fracture strength of modified PEEK post should also be explored.

Conclusions

Based on the findings of the present study it was concluded that surface treated modified PEEK material can be used as an intra radicular post because there was significant differences in the mean push out bond strength in all the three regions and there was absolutely no cohesive failure (with in the post)seen. However glass fiber post provided superior mean push out bond strength than the modified PEEK post and this was significant in coronal and middle regions only.

Clinical significance

Surface treated modied PEEK material can be used as an intraradicular post in clinical situations.But this material should not be considered as a replacement material for customized metal posts or prefabricated fiber reinforced resin posts. More future studies are required to enhance the results of this study.hese results are in accordance with previous glass fiber post studies.[20,25,26,29,44]

The most frequent type of failure in modified PEEK post (Table 3) was adhesive (between cement and dentin). This could be attributed due to

the remaining dentin debris on the canal walls after instrumentation and the absence of intra canal dentin surface treatment. Upon comparison these results were in line with the previous studies on mode of failure of glass fiber post.[29,43] The most frequent mode of failure in prefabricated glass fiber reinforced composite resin post (Table 2)was adhesive (between cement and dentine). This could be due to lack of intra radicular dentin surface treatment. These results were in line with previous studies.[44, 45] Based on the results of the present study, the null hypothesis was rejected because there was significant difference ($P < 0.05$) in the push out bond strength between customized modified PEEK post and prefabricated glass fiber reinforced composite resin post in the coronal and middle regions.

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