Effect of Post Length and Material on the Fracture Resistance of Endodontically Treated Maxillary Central Incisors: An in Vitro Study

Mohamed Abdel- Aziz [1], Heba Badra [2] and Hanaa Nassar [3]*

ABSTRACT:

Aim: This study aimed to assess and compare the effect of two different post and core materials at two different post lengths on the fracture resistance of endodontically treated maxillary central incisors. **Materials and Methods:** Twenty maxillary central incisors were selected, root canal treated and randomly divided into four groups (n=5/group): A.7mm glass fiber post and composite core. B.10mm glass fiber post and composite core. C. 7mm PEEK post and core. D. 10mm PEEK post and core. After Post spaces preparation, fiber posts were bonded to the teeth followed by composite core build-up while, PEEK post/cores were CAD/CAM fabricated. Finally, lithium disilicate crowns were fabricated and bonded to all teeth. Fracture resistance test was done using universal testing machine until failure occurred. Statistical analysis was performed using one-way ANOVA, and Tukey's post-hoc tests to detect significance between groups. **Results:** Regarding post length, no statistically significant difference was found between groups (A), (B) of glass fiber post (P = 0.64) or between groups (C), (D) of PEEK post (P =0.95). While, significant difference between the two different materials of the same length was observed in (A) & (C) and (B) & (D) (P = 0.0001). Groups of glass fiber & composite core were had significantly higher fracture resistance than groups of PEEK post & core.

Conclusions: Glass fiber post and composite core exhibited higher fracture resistance compared with that made of PEEK material. Post length equal to clinical crown length provided high fracture resistance with less invasive post hole preparation.

KEYWORDS: Endodontically treated teeth, CAD/CAM, Polyetheretherketone, glass fiber post, fracture resistance

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[1]Professor, Fixed Prosthodontics, Faculty of Oral and Dental Medicine, Ahram Canadian University
[2]Assistant professor, Department of Endodontics, Ahram Canadian University, Cairo, Egypt
[3*]Assistant professor, Fixed Prosthodontics, Faculty of Oral and Dental Medicine, Ahram Canadian University

INTRODUCTION:

Following endodontic treatment, significant coronal tooth structure occurs to endodontically treated teeth that had been already weakened due to caries, trauma, and access cavities preparation [(1)]. For years, radicular posts in combination with core and full coverage crowns were used to improve the mechanical characteristics of endodontically treated teeth. Posts are known to disperse the active pressure along the tooth's long axis thereby, improving the load-bearing ability and the fracture strength of severely weakened tooth [(2)].

Based on the amount of coronal tooth structure still present, the tooth's anatomic position, the functional stress placed on it, and aesthetic considerations, post type and material are chosen [(3)]. The post material ought to adhere to the dentin, be biocompatible, meet aesthetic requirements, and share many of the same physical and mechanical properties as dentin [(4)].

Glass fiber posts are frequently used nowadays due to their elastic modulus that closely resembles that of dentine [(5)]. Made of unidirectional glass fiber embedded in epoxy resin matrix, which reinforces the dowels without affecting their modulus of elasticity, and help the posts to retain their shape [(6)]. In addition, glass fiber posts have the capacity to form a bond with resin luting cements, which allows for the construction of a monoblack structure, where the tooth, post, core, and crown function as one cohesive unit [(7)]. This may lessen the chance of root fracture by more efficiently transmitting and distributing functional loads throughout the tooth [(8,9)].

Glass fiber posts, however, are regarded as prefabricated posts and may only have a few applications in the restoration of teeth that have undergone endodontic treatment. The decision to use a custom-made post or a prefabricated one depends on a variety of criteria, including the design of the canal, the amount of surviving tooth structure, and the restorative approach [(10,11)]. Metal, zirconia, heat-pressed ceramics, and most recently Polyetheretherketone (PEEK) [(12,13)] can all be used to create unique custom posts.

PEEK is a biocompatible material with low modulus of elasticity that is comparable to dentin tissue, according to numerous studies. It has high shock absorption capabilities and good fracture resistance with adequate stress distribution to the reconstructed tooth. Therefore, a tooth replaced with PEEK post and core material may have higher fracture resistance in theory [14,15]. Moreover, PEEK material is supplied as blanks for CAD/CAM milling. Digital design planning and milling using the digital workflow makes it easier and more dependable to produce custom-made post and core while also saving time [11,12].

The retention of the post, core, and crown are all affected by the post length. The preservation of the restoration increases with increasing apical length of the post inside the root canal [16]. The length of the post and the ability of endodontically treated teeth to withstand fracture were frequently reported to be interlinked [16,17]. If the post is too short or too lengthy, the root may be at risk of breaking. Conversely, shortening the post's length was argued that it could help preserve tooth structure thanks to advancements in the adhesive systems used to bind posts inside root canals [18].

The objective of this study was to assess and compare the effect of two different post and core materials (glass fiber post with composite core and PEEK post and core), at two different post lengths (7 mm and 10 mm) on the fracture resistance of endodontically treated maxillary central incisors. The null hypothesis was that there would be no difference in the fracture resistance of the teeth restored with either post materials or lengths.

MATERIALS and METHODS:

This study has been registered and exempted by Institutional Review Board Organization IORG0010868, Faculty of Oral & Dental Medicine, Ahram Canadian University. Research Number: IRB00012891#61. The materials used in fabrication of post, core and crown manufacturers, types, and their compositions are listed in **Table (1)**.

Preparation of teeth samples:

Twenty maxillary central incisors that had been extracted due to periodontal disease were chosen and examined for decay or cracks. The chosen teeth had average lengths of 16mm + 1.0 mm and similar diameters at the cemento-enamel junction. All teeth surfaces were ultrasonically cleaned to eliminate exterior debris and calculus and then teeth were stored at room temperature in distilled water. To ensure proper handling of the teeth samples and to create periodontal ligament simulation, the root of each tooth was dipped into melted pink modelling wax (CAVEX, CAVEX dental, Netherland), 2mm apical to the cemento-enamel junction to approximate bone level to generate a 0.2-0.4mm thick artificial periodontal ligament around the teeth. The resulting thin coating of wax closely resembles the normal thickness of periodontal ligaments. Each tooth was placed into a plastic mold filled with auto-polymerizing resin (Acrostone; Acrostone dental plant, Industrial zone, Cairo, Egypt) until the cemento-enamel junction was 2mm above the surface.

Table (1): The materials used in fabrication of post, core, and crown.

Material	Manufacturer	Composition
breCAM. BioHPP	**Bredent. UK**	**80% PEEK with 20% nanoceramic filler**
Glass fiber post	**Ena, MICERIUM S.p.A. Italy**	**The fibers made of carbon, glass/silica, and quartz, within Epoxy and bis-GMA resin bases.**
Core material	**Build-It FR, Penetron, USA**	**Fiber Reinforced composite Core Material**
IPS e.max CAD	**IvoclarVivadent Inc., New York, USA**	**Lithium disilicate-based glass-ceramic having two phases: Partially crystallized phase consists of 40% lithium metasilicate crystals embedded in a glassy phase. Fully crystallized phase consists of approximately 70% fine-grain lithium disilicate crystals embedded in a glassy matrix.**
Self-adhesive resin cement	**G-Cem, USA**	**Methacrylated phosphoric acid ester, dimethacrylate, acetates, initiator, stabilizers, glass fillers, silica, calcium hydroxide**

After the initial indications of polymerization, the tooth was taken out of the resin, and the wax spacer was washed away with hot water. A light body silicon impression material (Speedex, Coltene Whaledent, Switzerland) was injected into the acrylic socket, and the tooth was subsequently placed back into the socket creating a thin silicon layer that resemble the periodontal ligament and retain the tooth into the acrylic socket undercuts. [(19)]. After all excess silicon was removed with scalpel, teeth were left immobile for 72 hours to ensure complete resin setting before proceeding with preparation steps.

Under constant water cooling, the coronal portion of each incisor was removed at the cemento-enamel junction using diamond disc in a low-speed straight handpiece, leaving a uniform 15mm of the root length.

All specimens' preparation, endodontic procedures, and restoration steps were all carried out by the same operator in the same precise order to assure procedure standardization.

Endodontic procedure:

Root canal therapy was carried out using crown-down technique utilizing rotary M-Pro nickel-titanium instruments (IMD Company) according to the manufacturer's instructions up to #35 instrument.The M-Pro system was connected to an endodontic micro-motor (Wismy). Each canal was irrigated with 2 ml of 5.25% sodium hypochlorite (NaOCl) at each file size by means of a 27-gauge needle. After completion of root canal preparation, each canal was irrigated with 5ml of 17% ethylenediaminetetraacetic acid (EDTA) for 60 seconds and then it was obturated with gutta-percha and root canal sealer (MetaBiomed resin sealer) using lateral condensation technique. With the use of a temporary filling (MD Temp, MetaBiomed, Korea), the access cavities were sealed.

Samples grouping:

Teeth samples were randomly divided into four equal groups of five specimens each (n=5) according to the post material and length used. The post/crown ratio determined that the lengths of the posts were either 7 mm, which resembles 1:1 ratio to the crown length, or 10 mm, that resembles 2/3 of the root length. Samples grouping were done as follows:

- *Group A*: 7 mm post length preparation and restored with glass fiber post & composite core material.
- *Group B*: 10 mm post length preparation and restored with glass fiber post & composite core material.
- *Group C*: 7 mm post length preparation and restored with custom PEEK post & core material.
- *Group D*: 10 mm post length preparation and restored with custom PEEK post & core material.

Post-space& ferrule preparation:

Using a Gates Glidden drill size 3 (Dentsply Sirona), 7mm of gutta percha filling was removed from each root of the ten tooth samples from groups (A) and (C), while the root canal filling was removed to 10mm from the other ten samples for groups (B) and (D). Using the same sizes and shapes of post drill provided by the manufacturer (Ena, MICERIUM S.p.A., Italy) for all teeth samples, post spaces were prepared with size 1 followed by size 2 post drills with 2% taper following the pre-determined lengths for each group. After flushing each prepared post space with sodium hypochlorite solution followed by saline solution, paper points were used to dry it completely. Using a round end tapered diamond stone; a 2mm ferrule with a deep chamfer finish line was created on each tooth cervically.

Glass fiber post placement and core build up:

The prefabricated tapered glass fiber posts (Ena, MICERIUM S.p.A., Italy) were tested in each corresponding post space to verify internal adaptation, then the root canal was filled with dual cure, self-adhesive resin cement (G-Cem, USA). Fiber post was inserted into the root canal and held under light finger pressure for 10 seconds to ensure proper seating and uniform displacement of the excess cement. After excess cement was completely removed, light polymerization was done for 40 seconds with 600mW/cm^2 light curing unit (Elipar™, 3MESPE, USA). To standardize the core shape and size, a transparent matrix was used for all core build-up. A 4mm cervico-incisal height core was built using fiber-reinforced composite core material (Build-It FR, Penetron, USA) and light-cured for 40 seconds on each surface.

Fabrication of PEEK post & core:

For standardization, a full digital approach was employed for fabrication of all custom-made PEEK posts and cores. All ten prepared post spaces of groups C and D were digitally scanned using CEREC Primescan intraoral scanner (Dentsply Sirona. Germany). Images were obtained on CEREC 3D software (version 5.0, Sirona Dental Systems GmbH, Germany) **(Figure 1)**, then STL file was exported to CEREC inlab software SW18.0 for designing and milling all of custom-made PEEK posts and cores **(Figure 2)**. 4mm occluso-incisal height of PEEK cores was maintained for all samples to resemble the same height done for glass fiber post samples. All PEEK posts were finally milled using 5-axis milling machine CEREC in lab MCX5 (Dentsply Sirona, Germany) from PEEK blank of diameter 98.5mm and 12mm thickness. Five posts of 7mm length for group C and another five posts of 10mm length for group D were milled.

PEEK specimens were subjected to airborne-particle abrasion with 50 mm

Al2O3 particles at 0.2MPa pressure from a10mm working distance, and 10 seconds of exposure time. Finally, the identical procedures used for cementing glass fiber posts were used to cement all PEEK posts and cores in their post spaces.

Figure (1): Digital scanning of the prepared post space using intraoral scanner CEREC Prime scan and image viewing on CEREC software SW5.0

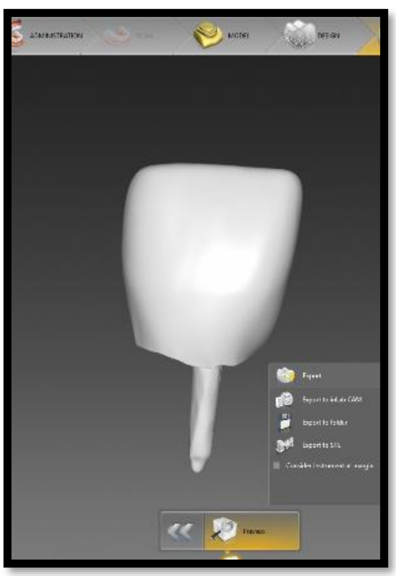

Figure (2): Digital 3D model of final PEEK post and core design on CEREC in lab SW18.0

Fabrication and bonding of lithium disilicate full coverage crowns:

Coronal portion of all teeth samples were finished with fine-grit 30-40µm tapered diamond bur (4137F-856-025 Microdont, USA) to ensure smoothening and rounding of any sharp line angles and the presence of smooth and uniform heavy chamfer finish line for the final full coverage restoration **(Figure 3 a & b).** Prime scan intraoral scanner was used to scan all prepared teeth, then full coverage restorations designing was done on CEREC 3D software (Version 5.0, Sirona Dental Systems GmbH, Germany) utilizing Copy-mirror tool to guarantee a standardized restoration design with comparable size and anatomy for all crowns.

Twenty lithium disilicate, IPS e-max CAD (IvoclarVivadent Inc., New York, USA) crowns were milled using the MCXL 4-axis wet milling and grinding machine (Dentsply Sirona, Germany). Crowns were checked after milling for uniform margins, occluso-incisal height of 7mm was confirmed with digital caliper (Mitutoyo IP 65, Kawasaki, Japan), then restorations were inspected on their corresponding teeth for proper seating and marginal adaptation. All crowns were crystallized and glazed in Programat P310 ceramic furnace (IvoclarVivadent Inc., New

York, USA) following the manufacture recommendation, then, crowns were cleaned for three minutes in ultrasonic cleaner containing distilled water.

Each crown's intaglio surface was etched with a 9.5% hydrofluoric acid gel (Porcelain Etchant 9.5%, BISCO, USA) for 20 seconds before being completely cleaned and dried with oil-free compressed air. A silane coupling agent (Porcelain Primer Bis-silane, BISCO - USA) was used prior to cementation and allowed to air dry for 60 seconds.

All of the previously prepared coronal surfaces were covered with bonding agent (All-Bond Universal, BISCO, USA), thinned with air syringe, and exposed to light for 20 seconds. Following that, all crowns were bonded to their corresponding teeth using dual-cured, self-adhesive resin cement (G-Cem, USA) under 1kg load with a custom-made loading device. After removal of excess cement, light-curing for 40 seconds was performed on all crown surfaces and finally the samples were kept in distilled water at 37°C for 24 hours prior to testing. **(Figure 4)**

a b

Figure (3): Finished Preparation of teeth samples, a. Glass fiber post & composite core, b. PEEK custom-made post & core

Figure (4): Tooth sample after bonding of lithium disilicate crown.

Fracture resistance test:

A universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) was used to perform the fracture resistance test of all four sets of samples, and results were recorded using software (Instron® Bluehill Lite Software). Each specimen with the acrylic resin block was fixed to the lowest fixed compartment of the testing apparatus at a 135-degree angle to its long axis [3] **(Figure 5).** Each tooth specimen was subjected to a controlled loading force at a cross head speed of 1mm per minute using a stainless-steel rod until failure by audible crack or fracture of either the restoration or the tooth, or both, occurred. Each sample's loading force necessary to cause failure was measured in Newtons(N).

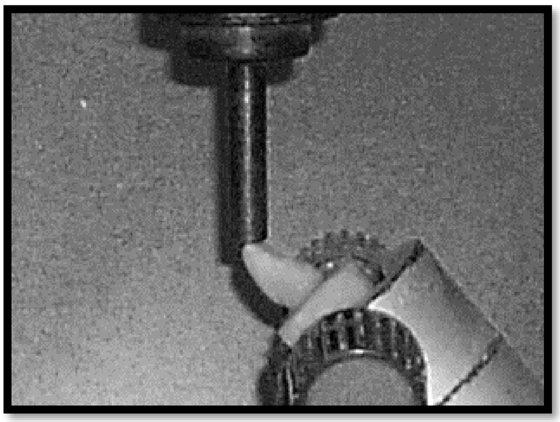

Figure (5): Fracture resistance testing using universal testing machine.

Statistical analysis:

Data analysis was performed using one-way analysis of variance (ANOVA), followed by pair-wise Tukey's post-hoc tests which were performed to detect significance between groups. P values ≤0.05 are statistically significant in all tests.

RESULTS

Mean fracture resistance and standard deviations (SD) of the tested groups for post-cores made from glass fiber and PEEK and prepared in two different lengths are recorded and shown in **Table (2)** and graphically drawn in **Figure (6).**

Regarding the post length, there was no statistically significant difference between groups (A), (B) of glass fiber & composite core material (P = 0.64) or between groups (C), (D) of PEEK post & core (p =0.95). When the two different materials of the same length were compared, a significant difference was observed between (A) & (C) and between (B) & (D) (P = 0.0001). Groups of glass fiber & composite core were significantly having higher fracture resistance than groups of PEEK post & core.

Table (2): Fracture resistance results (Mean values ± Standard Deviations) of all groups in Newton (N)

G.p	*Material*	*Length*	*No.*	*Mean*	*SD*	*Range*	
						Mini.	*Maxi.*
A	GF post & comp core	7 mm	5	584[a]	21.89	561	610
B	GF post & comp core	10 mm	5	602[a]	6.79	594	609
C	PEEK post & core	7 mm	5	373[d]	18.65	341	388
D	PEEK post & core	10 mm	5	383[d]	14.43	379	391

Different small letters within the column indicate the statistically significant differences ($P < .05$). Similar small letters indicate no statistical differences between the groups ($p>0.05$) according to one-way ANOVA and Tukey post hoc tests

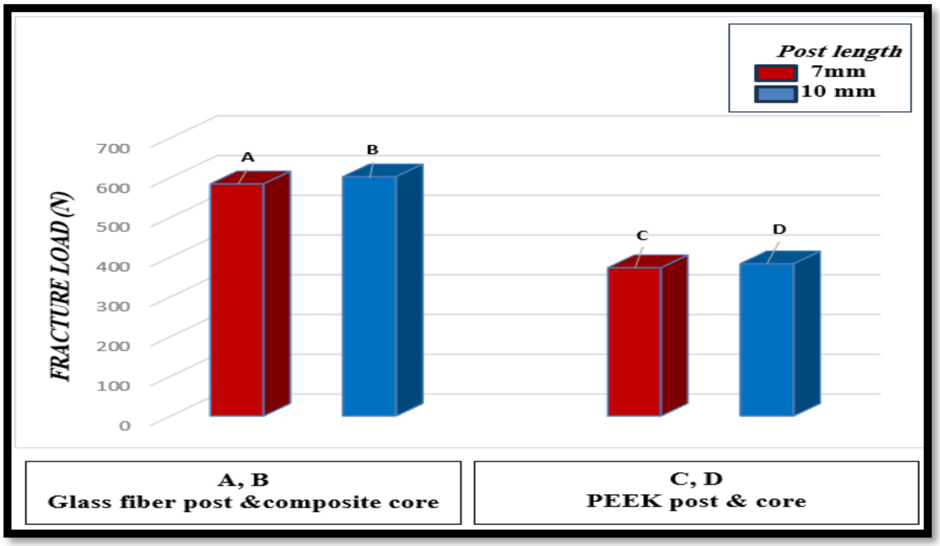

Figure (6): Column chart showing the mean values of fracture resistance for both material groups.

DISCUSSION:

This in vitro study investigated the fracture resistance of maxillary central incisors teeth that had undergone endodontic treatment and been restored with lithium disilicate ceramic crowns constructed over glass fiber with composite core build-up or PEEK custom-made post and core systems. Although many studies previously investigated CAD/CAM fabricated post and core systems, very few studies investigated PEEK post and core and fewer studies that compared PEEK posts to fiber-reinforced posts at two different intra-radicular lengths. Fiber-reinforced posts were employed in this study due to their close similarity to the elastic modulus of dentin which may have an impact on the fracture resistance of the restored teeth [14,20].

To imitate the contact with an opposing tooth in Angle's class I occlusion, all specimens were inserted in the universal testing machine in a position to ensure that the compressive force was applied at a 135° angle to the long axis of their roots [17]. Moreover, in order to replicate the periodontal ligaments which can influence the fracture resistance results, a thin layer of light body silicone-based impression material was created around each root [19,20].

It has been previously suggested that when the post is too short or too lengthy, the root is susceptible to breaking. Therefore, the post length should ideally be two-thirds of the root length or at least equal to its clinical crown [21]. In this investigation, the chosen post lengths for teeth with a root length of about 15 mm were 7 and 10 mm, and the optimum crown length for all specimens was 7 mm. Lithium disilicate crowns were chosen as final coronal restoration for all prepared teeth samples as they were regarded as suitable aesthetic restorations for maxillary central incisors.

In either the PEEK post & core groups or the glass fiber post groups, there were no statistically significant differences detected between the two post lengths. These findings were in agreement with those of Özarslan M *et al*[22] who discovered no discernible variation in fracture resistance between the short and long posts in the glass fiber or PEEK post groups. They came to the conclusion that adding length to the post did not increase its resistance to fracture. Although the retention of the post is increased by its longer length in the canal, root fracture or perforation is still a possibility. Additionally, Hatta M *et al*[23] noted that short glass-fiber posts had much higher fracture resistance. Thanks to the posts' cementation with adhesive resin. Furthermore, Nissan J *et al*[24] observed that even with a shorter post length, the adhesive resin cement increased post retention and optimized fracture patterns.

PEEK applications in prosthodontics field have recently expanded due to its good mechanical attributes [25]. Owed to its high biocompatibility, acceptable aesthetic quality, and low Young's modulus, modified PEEK (BioHPP) with 20% ceramic fillers was chosen for this investigation [26]. In order to ensure high accuracy, precision, and elimination of lab mistakes originating from conventional casting procedures in this study, PEEK posts and cores were manufactured by scanning post spaces with a recently introduced intraoral scanner Prime scan IOS and milling was achieved by 5-axis milling machine[27]. In non-circular canals, where prefabricated posts are ineffective, and difficult to prepare without the risk of perforation, PEEK material can be used as a custom-made post and core,

Between the two tested materials, the results for fracture resistance were noticeably different. Comparing PEEK post/cores to glass-fiber posts & composite cores, statistically significant difference was found. Higher mean fracture resistance values were recorded in both glass fiber post and composite core groups than their corresponding PEEK post/core groups of the same lengths. This may be explained as the close resemblance of glass-fiber posts to root canal dentin in terms of modulus of elasticity [24]**.** And that despite their low Young's modulus, PEEK material comes in a second place when matching the dentine elasticity. Habibzadeh*et al*. [29], also explained that the great fracture resistance of glass fiber posts comes from their ability to bond adhesively to dentin, which enhances the overall homogenous monoblock structure that's formed from fiber post, composite core and bonded glass-ceramic crown to self-adhesive resin cement. While, Lee KS *et al*[30], explained that despite the many benefits of CAD/CAM PEEK post and core material, attaching PEEK to resin cement is still difficult due to its low surface energy and resistance to surface modification.

However, the averages of each group's maximal fracture resistance still exceeded the maximum force values listed in the literature for the anterior region (286 N) [28].

Based on the results of this study, the null hypothesis was partially rejected as there was no significant difference between the two tested post lengths in terms of fracture resistance mean values, while statistically significant difference was found between the two tested post and core materials.

CONCLUSIONS:

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

- Glass fiber and composite core exhibited higher fracture resistance compared with that made of PEEK material.
- Regardless of the type of the construction material, post length equal to the tooth clinical crown length provided high fracture resistance with less invasive post preparation.
- Further investigations are needed to use the PEEK material in restoring endodontically treated teeth as it has many acceptable properties.

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