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Fracture Resistance of Anterior Teeth Restored by PEEK Post and Core: (In-Vitro Study)

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ABSTRACT

Objective: The aim of the study is to assess the fracture resistance of anterior teeth restored with PEEK custom made post and core versus traditional post and core. **Materials and Methods:** In this in-vitro investigation, 20 sound upper central incisor teeth extracted due to periodontal disease were endodontically treated and randomly divided into two groups (n = 10), group I restored with prefabricated fiberglass post and composite core, and group II restored with PEEK post and core. Zirconia crowns have been used to restore teeth. The Instron Universal Testing Machine was used to perform the fracture-resistant test. The Kruskal Wallis test was utilized to assess the fracture resistance data, and the t-test was used for comparison. **Results:** It was found that the teeth restored by fiber posts had considerably higher fracture resistance and are statistically significant different from teeth restored by PEEK posts. **Conclusion:** Fiber posts strengthen teeth than PEEK posts and are more suited for high-stress dental restorations. Although PEEK material has potential, further improvements are needed to enhance its mechanical properties. Further research is needed to assess its long-term viability.

Keywords: fracture resistance, anterior teeth, PEEK post and core, fiber post, CAD-CAM post and core

1. Introduction

The structural integrity of severely damaged teeth is frequently impaired, necessitating foundation restorations to provide sufficient support and retention for subsequent restorations. Post and core foundation is a crucial technique used to restore such teeth. Studies assessing the survival rates of extensively damaged endodontically treated incisors restored with various post-and-core materials shed light on their clinical efficacy over time. The assessment considers parameters including failure rates, longevity, and fracture resistance. Traditional prefabricated metal posts, made from materials like stainless steel or titanium, have long been used due to their strength (Heydecke *et al.*, 2001). On the other hand, the cast metal posts were custom made according to the root canal morphology with the advantages of better adaptation and no excessive root canal shaping is required to accommodate the post. The major disadvantages of the cast post are its predisposition for catastrophic root fracture, unretrievable and its unesthetic color (Torbjörner and Fransson, 2004).

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Concerning esthetics and potential root fractures have led to exploring alternative materials. Fiber-reinforced composite posts offer advantages such as flexibility, its modulus of elasticity close to that of dentin, less cost, quick technique and improved esthetics (Jurema *et al.,* 2020). The main disadvantage is that its shape does not conform to the root canal anatomy, as in prefabricated metallic posts. Hence, they are supplied with specialized calibrated drills to reshape the root canal. This leads to increased removal of radicular dentin and thicker luting cement.

Zirconia and ceramic post-and-core systems have gained popularity due to their excellent esthetics and biocompatibility. Customized ceramic post and core using CAD-CAM technology was uniquely designed and fabricated to precisely fit the anatomical features of an endodontically treated tooth (Awad and Marghalani, 2007). Three-dimensional finite element analysis (FEA) has shown the ability of this restoration to perform homogeneous distribution of stress and improve the structural integrity of endodontically treated teeth (Marghalani *et al.,* 2012). However, this zirconium post and core had the same difficulty as custom-made metallic posts and cores in that they are unretrievable.

Polyetheretherketone (PEEK) is a novel substance that has gradually gained prominence in dental restoration practice (Pourkhalili and Maleki, 2022). It is a linear, aromatic, semi-crystalline thermoplastic, high performance polymer used in dentistry as a framework material for metal-free fixed dental prostheses (Zoidis *et al.,* 2023). In vitro investigations found that PEEK-based endodontic post systems have excellent mechanical properties such as flexural strength, modulus of elasticity, fatigue and corrosion resistance. Furthermore, their flexibility and retention capabilities make them a valuable choice for endodontic restorations (Ahmad *et al.,* 2023). Some researchers used sophisticated approaches such as in vitro testing and finite element analysis to investigate how PEEK posts interact with the anatomy of dental roots (Yu *et al.,*2022 and Lima *et al.,* 2023). Yu *et al.* (2022) used FEA to demonstrate and compare the stress and strain of PEEK reinforced by 30% carbon fiber and pure PEEK with traditional fiber and metal posts. They found that both pure PEEK and reinforced PEEK could reduce the risk of debonding and vertical root fracture, whether they were used as prefabricated posts or customized posts better than the other posts. Also, the biomechanical behaviour of reinforced PEEK restorations was the closest to dentin. Therefore, could be more suitable to restore massive tooth defects. Furthermore, PEEK's radiolucency allows for a reliable assessment of post-placement problems during follow-up assessments (Kasem *et al.,* 2022). One important factor in assessing the clinical feasibility of custom-made post-and-cores is their fracture resistance.

Studies have evaluated the resistance of PEEK and nano-ceramic composite post-and-cores to occlusal forces by applying controlled loads to clinically simulated scenarios using experimental setups. Studies contrasting PEEK and nano-ceramic composite post-and-cores revealed variations in how they failed under different loading scenarios. While PEEK exhibited good resistance to fracture and deformation, nano-ceramic composites demonstrated distinct failure modes, such as cohesive or adhesive failures, depending on the applied stress (Teixeira *et al., 2020*). One-piece post and core systems integrate the post and core into a single component. While these systems can simplify the repair process and save chair time, they may have limitations in adaptability to complicated canal morphologies and customization when compared to two-piece systems. When compared to conventional one-piece systems, clinical investigations assessing the success rates and survival of restorations using the two-piece post and core procedure have shown encouraging outcomes in terms of durability and decreased incidences of debonding or fracture. Furthermore, the option to adjust the post and core individually allows versatility in obtaining optimal appearance and function (Bailey *et al.,* 1989). Three aesthetic cast post-core systems—zirconia posts, fiber-reinforced composite posts, and metal-ceramic posts—were compared in another study. Each has unique qualities and bonding traits. The performance of several aesthetic cast post-core systems composed of zirconia, alumina, and composite resin has been studied. When utilized with all-ceramic crowns, various materials showed varying bonding properties, retention, and fracture resistance. Certain materials showed higher adherence to dentin, while others showed superior fracture resistance under various stress situations (Safari *et al.*, 2023).

The mechanical characteristics of PEEK in relation to other metal-free polymers in dental post applications have been examined in a few research. Research frequently assesses factors such as flexural strength, fracture resistance, elastic modulus, and bond strength. In vitro research comparing PEEK posts to carbon fiber posts, zirconia, and fiber-reinforced composite. Their findings indicated

that PEEK had equivalent or greater mechanical capabilities in certain aspects, such as flexural strength, when compared to the other materials evaluated. Rakotoaridina *et al*. (2017) demonstrated that although PEEK displayed desirable qualities in terms of elasticity, its fracture resistance was lower than that of zirconia-based posts in certain stress circumstances. This emphasizes using a variety of mechanical factors under diverse stress situations. The use of a composite resin core, noted for its versatility and attractiveness. Sugano *et al.* (2020) comprehend the relationship between flared root canals and composite resin. Their study provides a potential strategy for fortifying damaged dental structures.

Based on what has been demonstrated, restoring flared root canals using a composite resin core and a prefabricated PEEK post has great promise. Papathanasiou *et al.* (2020), examined PEEK in digital prosthodontics to determine how the material can be utilized with cutting-edge CAD-CAM technology and the phases from the first digital impressions to the last restorative fabrication. This narrative assessment demonstrated a potential synergy that occurs when modern technology meets a material with PEEK's capabilities. This research promises to revolutionize the precision and efficiency of prosthodontic practice. An additional study made by Yildiz *et al.* (2023), compared and assessed the stress of several materials to find the optimal post system for maxillary incisors. The study concluded that custom-made PEEK dental posts and cores warrant additional consideration in clinical practice. Their capacity to provide better stress distribution than standard post-core systems may contribute to enhanced longevity and clinical outcomes in incisor restorations. However, they realized that more in vitro and clinical investigations are required to show and analyze these findings and establish PEEK as a trustworthy option in post-core restorations.

Several studies have been conducted to evaluate the influence of various surface treatments on the bond strength of milled PEEK posts. These studies investigated the important rules of treatments in terms of enhancing surface roughness, providing chemical interaction, and establishing micromechanical retention for adhesives. These treatments can involve procedures such as chemical etching, sandblasting, air abrasion, and the application of adhesive agents. The purpose is to modify and improve the surface qualities of the material to better its interaction with adhesives or cement. However, it is crucial to note that the efficiency of surface treatments can or cannot be done based on aspects such as the specific chemical properties of the PEEK material, the type of adhesive utilized, and the clinical consideration in which the post is attached (Attia *et al.,* 2022).

The aim of this study is to assess the fracture resistance of endodotically treated badly destructed maxillary central incisors restored with PEEK custom made post and core versus traditional fiber reinforced post and composite core.

2. Materials and Methods

This in-vitro study was undertaken at King Abdulaziz University's Faculty of Dentistry. It was approved (196-11-23) by the Institutional Review Board (Ethical Committee) at King Abdulaziz University, Faculty of Dentistry.

2.1. Sample preparation

Twenty extracted human maxillary central incisors were selected according to inclusion criteria which are: (1) extracted for periodontal reasons; (2) intact (3) with single, straight root canal; (4) closed apex; and (5) similar in size and shape with the root diameter almost equal at cemento-enamel junction. The exclusion criteria were fractured, decayed, cracked, restored teeth, amelogenesis imperfecta. The teeth selected were cleaned from blood, calculus or debris and preserved in distilled water with a few thymol crystals at 37 ºC.

2.2. Preparation of the roots:

All the preparation steps were performed by one investigator to avoid inter operators' errors. The crowns of the teeth were removed 2 mm. above the cemento-enamel junction using tapered diamond stone and root canal treatment was done. The working length was determined, and canals were cleaned and formed with F1, F2, and F3 ProTaper Universal files. After each instrument change, irrigation was performed using 2 mL of 2.5% NaOCl solution and 30-gauge side-vented irrigation needles. The roots were dried using paper points and 96% alcohol. The root canals were filled using a

single cone obturation procedure that included an F3 gutta-percha master cone and sealer. Teeth was preserved in distilled water in a laboratory incubator at 37 °C.

2.3. Post and core restorations:

The post space of the teeth was prepared by removing gutta percha with no. 2, 3, and 4 Gates Glidden burs and leaving 4-5 mm of the apical area. To ensure consistent dentine removal during canal preparation, post drill no. 3 was utilized for all teeth. Radiography was used to ensure that the root canal filling was fully removed from the post area. The specimens were divided into two groups I and II (n = 10).

Group I (Control group): the teeth were restored by blue glass fiber post with diameter: 1.5 mm (3M RelyX™ Fiber Post 3D Glass Fiber Post, Neuss, Germany). For group II, the teeth were restored with PEEK post and core constructed from PEEK disc (Fig 1) composition: (Natural ≥ *99.99*) (Dental Direkt GmbH Industriezentrum 106–108 32139 Spenge, Germany). Each post and core was constructed from duralay material (Reliance Dental Mfg, LLC Alsip, IL 60803) (Fig 2) according to the following: The post was made by applying duralay material to a plastic post, and fitted inside the canals with passive pressure. Extended plastic post was cut 2 mm above the root canal opening. The core was constructed attached to the extended part of plastic post by adding duralay to the coronal portion of the plastic post. To standardize the core buildup with shape and size of a prepared maxillary central incisor, maxillary central incisor preformed mold (Build-It kit, Jeneric/Pentron, Wallingford, CT 06492, USA) was used. The duralay post and core was copied into PEEK posts and cores (Fig 3) using computer-aided design/computer-aided manufacturing (CAD/CAM) technique. Prior to cementation, the posts were cleaned with alcohol and air-dried. Following that, the root canals were rinsed with distilled water and dried with paper points. For group I, each fiber post was cemented into their post space by using dual-polymerizing self-adhesive resin cement according to the manufacturer's instructions and composite core build up was done using maxillary central incisor performed mold as mentioned before. For group II, PEEK post and core was cemented using same cement of group I. Ferrule was prepared using a conventional high speed handpiece with coolant (Kavo Ltd, Amersham, UK) and a tapered diamond bur with flat end which had a plastic tube around the shank up to a point 2 mm from the cutting end to limit the depth of the ferrule preparation to 2 mm.

All cemented specimens were embedded in acrylic resin blocks just below the cementoenamel junction. Final impression was taken, and zirconium crown was constructed to each tooth and cemented using the same cement. All restored teeth were preserved in distilled water with a few thymol crystals in a laboratory incubator at 37 ºC for 7 days.

Fig. 1: PEEK Disc used for milling PEEK post and core

Fig. 2: Buildup of duralay post and core

Fig. 3: Milled PEEK post and core

2.4. Fracture resistance test

The samples were attached to the universal testing machine with a jig that was inclined 45 degrees to simulate the position of the central incisor in the patient's mouth with 135-degree angle, making the force angled at the tooth. The force was applied on the crowned specimens at a 45º angle to the horizontal plane on the middle middle third of the palatal surface at a speed of 1 mm/min, until fracture.

2.5. Statistical analysis

Statistical analysis was done using SPSS version 20.0. A sample size of 10 each group had 80% power to detect a difference in fracture resistance means of 143 MPa (the difference between a Group A mean, μ_1, of 811 MPa and a Group B mean, μ_2, of 668 MPa; based on Pourkhalili and Maleki, 2022) assuming that the common standard deviation is 100 MPa using a two-group t-test with a 5% two-sided significance level.

3. Results

An independent samples t-test was conducted to compare the fracture resistance between fiber posts and PEEK posts. There was a significant difference in fracture resistance between fiber posts (M = 1108.48, SD = 185.22) and PEEK posts (M = 868.02, SD = 178.22), p = 0.002. These results suggest that fiber posts exhibit significantly higher fracture resistance compared to PEEK posts

Table 1: Comparison of fracture resistance between Fiber post and PEEK

Mean ± SD	Fiber post (n=10)	PEEK (n=10)	p-value
Fracture resistance	1108.48 ± 185.22	868.02 ± 178.22	0.002 *

Independent sample t-test

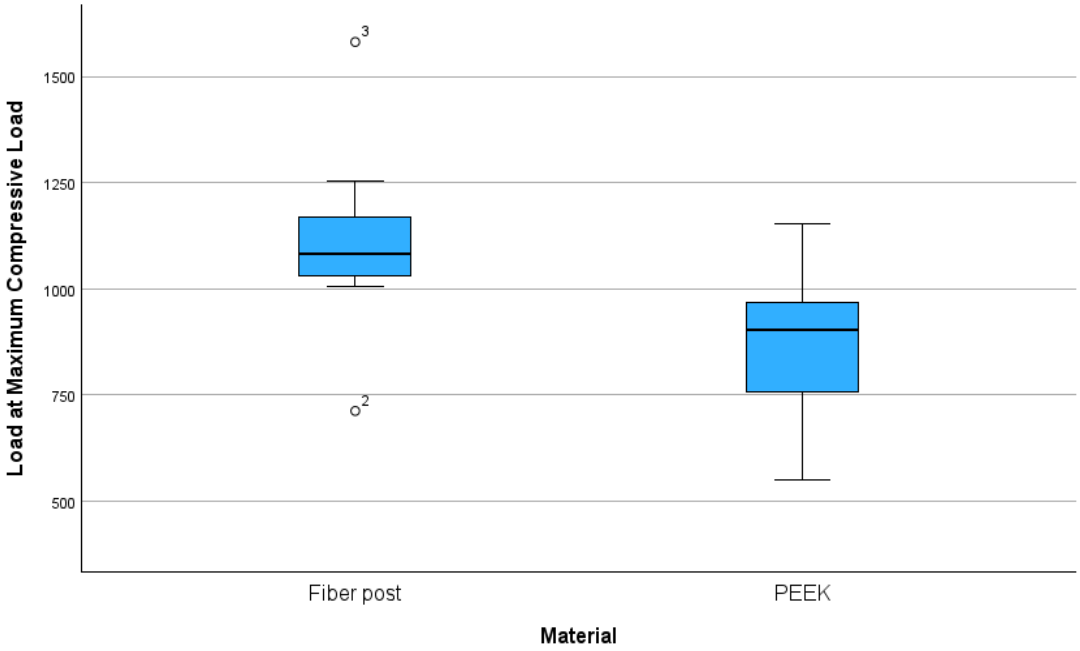

Fig. 4: Maximum load applied to teeth restored by both fiber post, composite core and PEEK post and core before failure

4. Discussion

This investigation studied the fracture resistance of PEEK posts and cores covered with zirconia crowns in anterior upper central incisors. Since all studies employed the PEEK post and core on molars and premolars, we elected to use it in upper central incisors. The results of this in vitro study will help researchers better grasp the advantages and applications of PEEK post and cores material. The outcomes of this study shed light on the fracture resistance of fiber posts versus Polyetheretherketone (PEEK) posts in the restoration of endodontically treated anterior teeth. The findings showed that the two materials' fracture resistances differed statistically significantly, with fiber posts showing noticeably greater fracture resistance than PEEK posts. This outcome underscores the importance of material selection in the restoration of structurally compromised teeth, especially those that are subjected to high masticatory forces. PEEK posts have various advantages, including biocompatibility and a modulus of elasticity equivalent to dentin; however, their poorer fracture resistance may limit their use in situations where large occlusal forces are expected.

Our result agrees with Yu *et al.* (2022), which concluded that pure PEEK needs filler reinforcement to be used for post retained restorations. They reinforced PEEK by 30 % carbon fiber and found that this reinforcement is more suitable to restore massive tooth defects. The outcomes of this study show that PEEK posts may be more appropriate for situations where cosmetic considerations are crucial and functional demands on the repaired tooth are relatively minimal. Because of its superior biocompatibility and positive interaction with surrounding tissues, PEEK may be especially useful in certain situations. Ahmad *et al.* (2023) investigated fracture resistance using two types of PEEK post and core systems: two-piece PEEK post and composite core and one-piece custom-made PEEK post and core. They found that the two-piece system had more fracture resistance than the custom made one. Also, the predominant type of failure using two-piece was a core fracture, while in the one-piece PEEK post-core, most types of failures were either in the crown or in the post. This may explain the low failure rate of our PEEK group.

According to current literature, there were no appreciable differences between PEEK and fiberglass posts. Both materials showed dentin-like moduli of elasticity, which improved load distribution and decreased catastrophic failures. Customization is made possible by CAD/CAM or relining techniques enhanced performance and post adaptability. However, more debonding occurred in the PEEK group, indicating that its application has to be further optimized (Teixeira *et al.,* 2020).

Despite the limitations identified by this study, PEEK remains a material of major interest in restorative dentistry because it is chemically stable in the oral environment and does not cause harmful tissue reactions, also its biocompatibility is especially remarkable. PEEK's qualities make it an ideal choice for long-term restorations, particularly in patients who are allergic to metals or other materials frequently used in dental posts. One of the primary benefits of PEEK is its ability to be precisely manufactured utilizing CAD CAM technologies. This enables the fabrication of custom-made posts that can be adjusted to the individual anatomy of the patient's root canal, potentially improving the fitness and retention of the post. However, the mechanical constraints revealed in this study indicate that additional research and development are required to enhance PEEK's characteristics for application in high-stress locations of the mouth. The results of this study, together with current research into materials like PEEK, lead to a future in restorative dentistry where physicians have a broader selection of materials and techniques at their disposal, each tailored to the unique needs of the patient. As our understanding of the mechanical and biological features of dental materials advances, we can anticipate more tailored and long-lasting restorative treatments that not only restore function but also conserve the original dentition for as long as possible. Despite the difficulties found in this study, PEEK still has tremendous potential. As research into its features and applications continues, it is probable that new approaches and modifications may develop to overcome its current limits, making it a more feasible option for a wider range of clinical situations.

In conclusion, Fiber posts had substantially higher fracture resistance than PEEK. PEEK post and core is a promising restoration that may have a role in improvement of restorative dentistry, giving a potential alternative to existing materials. Their superior mechanical qualities, biocompatibility, and radiolucency all contribute to their long-term viability in endodontically treated teeth. As research and clinical experience with PEEK continue to expand, it is expected that this material will become a fundamental component of modern restorative dentistry, leading to better patient outcomes and the preservation of native dentition. To ensure that these findings are accurate, more studies are required, particularly long-term clinical trials. Understanding the impact of certain clinical protocols and adhesive systems on PEEK restorations is also quite essential.

Limitations

Getting sound anterior upper central incisors with our inclusion and exclusion criteria limits the sample size and variation needed.

5. Conclusion

The comparative analysis of fracture resistance between fiber posts and PEEK posts illustrates the merits and limits of both materials in restorative dentistry. While fiber posts provide stronger fracture resistance and are better suited for high-stress restorations, PEEK posts offer significant biocompatibility benefits.

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