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A Study of Fracture Resistance on Strengthening of Endodontically Treated Premolar Teeth Restored with Different Posts Cemented with Composite Material: An *in vitro* Study

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Abstract: *Comparing and evaluating the fracture load of different posts and composite core of root canal-treated teeth is the aim of this study. Endodontically treated teeth were restored with zirconia (ZP), prefabricated glass fiber (GFP), and carbon (CP) post systems. Single root eighty maxillary 2^nd^ premolars were chosen, and they received endodontic therapy. Depending on the kind of length used, the teeth were randomly assigned to four groups (n = 20), each of which was then divided into two subgroups: subgroup 1/2 removed the one-half sealing material, and subgroup 2/3 removed two-thirds of the sealing material. Prefabricated glass fiber posts were used in Group I, zirconia posts were used in Group II, carbon posts were used in Group III, and direct composite resin restoration without a post was used in Group IV (control). Samples were loaded into a universal testing machine, and statistical interpretations were made. Fracture resistance was noted. The results of the fracture one-way ANOVA were used to examine the load, and then multiple comparisons with the Bonferroni test with a threshold significant value (α=0.05). The prefabricated glass fiber post group, the carbon post, the zirconia post, and the control group all had lower fracture loads than the zirconia post.*

Keywords: *Zirconia post, fracture strength, post length, dental composite, fiber post*

1. Introduction

Successfully treating teeth with endodontic treatment is always tricky, as the tooth's strength decreases when the roof is gone. The tooth weakens due to extensive caries, access opening, and bio-mechanical preparation [1]. Pereira et al. reported that the primary factor contributing to endodontically treated teeth breaking is the loss of tooth structure. On the other hand, some have claimed that teeth with lower moisture content may become more brittle. Complete crown restorations are sometimes required because of concerns about function and appearance. Post and core are advised to improve the fracture resistance and retention of crowns. To improve crown retention, post, and core recommendations are frequently made [2]. Treatment challenges arise when teeth have severe caries, or coronal walls are absent. In these circumstances, the best treatment option for maintaining coronal restoration is to use intraradicular posts. Following the placement of a crown on the tooth, post-retention becomes crucial to the restoration's effectiveness [3].

Several variables affect the repaired tooth's prognosis, including the luting cement, post material, design, length, and diameter [4]. Prefabricated posts, however, need one appointment and are quicker and less costly to manufacture. They are more flexible because of their less exact fit, and the energy absorption and stress distribution improve since there is more cement in the interfacial area. The length of the post, in addition to its kind, is a significant component that influences the mechanical stability of root canal-preserved teeth [4, 5]. While some research indicates that longer posts enhance retention, longer posts may potentially cause more stress in the apical regions [6]. To offer the core a robust restoration that can withstand occlusal and masticatory stresses, crown preparation is completed after the core is built on post. For fixed restorations to succeed over the long term, crown preparations must be resistant and retentive [7 - 9]. The retention form will stop the casting from being dislodged along a path parallel to the restoration's insertion path, while any other direction of dislodgment will be pro -

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hibited by the resistance form [9]. Numerous research on the impact of different posts on the mechanical behaviour of teeth are documented in the literature, although the findings are inconclusive [1, 6, 10].

Nowadays, aesthetically pleasing good posts such as zirconia, fibre-reinforced, carbon, and other glass fiber posts are used [5, 11]. Physiochemically homogenous materials of posts and metal-free make their similar physical properties to that of dentin. The zirconia post had a decreased tendency to root fracture and a considerably superior prognosis compared to other types of posts. The literature provides evidence of several investigations on the impact of different posts about the mechanical behaviour of teeth; however, the findings are inconclusive [6 - 8].

The present investigation's goal was to assess the relative impact of various post configurations and post lengths on the fracture load while endodontically treating teeth. In this study, the fracture resistance (FR) of three distinct post and core systems recovered severely damaged primary anterior teeth was compared. This was carried out because there was a dearth of knowledge on the use of post systems in teeth and inconsistent findings about the FR of various post and core systems for the restoration of severely damaged premolar teeth. According to the null hypothesis, there would be no appreciable change in FR when five distinct post and core systems were used to replace severely damaged primary anterior teeth.

2. Materials and methods

Eighty recently removed, human maxillary second premolar teeth free of caries with similar anatomical features and root lengths between 16 and 18 mm were chosen for this in vitro investigation from the hospital's tooth bank. Until they were tested, the teeth were kept in a solution of 0.1 percent thymol and water. The study protocol was approved by the Ethics Review Committee of the Department of Research at King Khalid University's College of Dentistry under registration number ECM#2025-109.

A sectioning disk and continuous water cooling were used to section the crowns at the cemento-enamel junction (CEJ). Using manual instrumentation and the traditional step-back approach, the canals were prepared up to an ISO K-file size 40 maximum size (MANI, INC. Utsunomiya, Japan). The canals were irrigated with 2 milliliters of a sodium hypochlorite solution with a 5.25 percent solution and then dried with absorbent paper points. The gutta-percha cones were obturated using a zinc oxide eugenol sealer. Test specimens were divided into four categories, each with twenty samples, at random. The sealing material was further divided into two subgroups: subgroup 1/2 removed half of the material, while subgroup 2/3 removed two-thirds. Group I was restored with prefabricated glass fiber posts (RelyX™ Fiber Post), group II was restored with zirconia post (Zirix trademark by Harald Nordin SA in CH-1817 Brent/Montrreux), group III was restored with carbon post (J.Morita Japan), group IV repaired with a post-free direct composite resin restoration (control).

Each sample had its identity labeled based on the group that it belonged to. Subsequently, using a size #2 Peeso reamer (MANI, INC. Utsunomiya, Japan), endodontic filling material was removed at the appropriate length determined by the research group; that is, ½ of the endodontic material was removed for one grouping and 2/3 for the other. To get rid of any remaining gutta-percha and dentin, post space was made using peeso reamers and irrigated with saline and 2.5% sodium hypochlorite solution. After a 4 mm expansion in the crown, the corresponding in order to ascertain if they had reached the required length, posts were placed into the canal space. The post was finally positioned by removing the surplus with a diamond disc while it was submerged in water and cooled. After that, absorbent paper points were used to help dry the canals. After cleaning with 70% ethanol and water, the posts were allowed to air dry. The seventh generation (3M ESPE) single-bond universal adhesive was used in the canals. Prefabricated fiber posts and other posts were cemented at the proper lengths in each subgroup using self-adhesive resin cement. Auto-polymerizing acrylic resin was used to secure the roots in hollow 20 x 20 mm cylindrical tubes with a 2 mm space between the acrylic resin and the CEJ, oriented parallel to the long axis of the cylinder. After that, the core build-up material was applied to each specimen, and the specimens were light-cured. Similar-sized cores were assembled using a core-forming matrix. Using an air motor handpiece and diamond burs, the teeth were ready for all-metal crown restorations once the core build-up was finished. A chamfer finish line with a consistent reduction of 1 mm was produced on each specimen. The sample was then imprinted using polyvinyl siloxane impression material and placed into a specially designed self-cure resin tray. The impression was created using die stone (die stone, snow rock, Korea), and then die preparation was done. To produce their dies, the identical procedure was used on every specimen, as seen in Figure 1. The dies were waxed using blue inlay wax. On the lingual surface of the wax patterns, an area was marked off where the compressive force for the universal testing equipment would be applied at a specific distance from the finish line. Nickel-chromium wax designs were invested in and cast. Following the try-in, crowns were fixed using self-adhesive resin cement on all samples (Universal, 3M ESPE, USA).

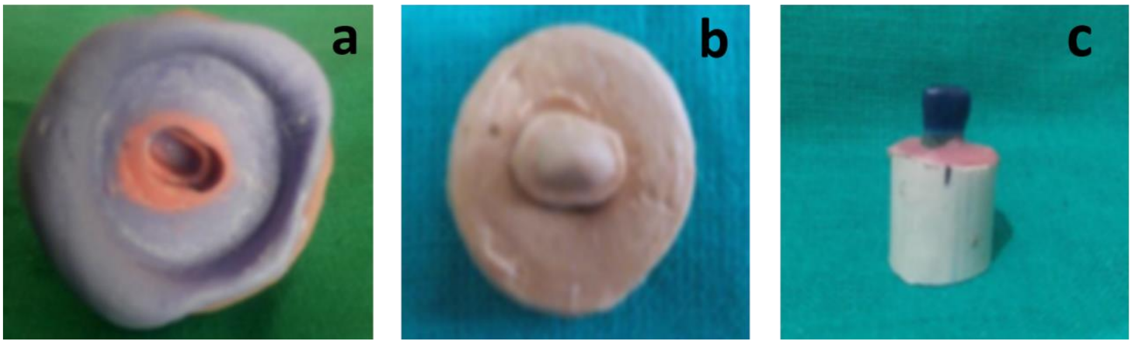

Figure 1. a. Impression of sample, b. Die, c. Wax up of die

2.1. Sample test

The specimens were placed in a metal jig at a 135-degree angle to replicate the mode of loads in the mouth. The specimens were then compressed at a specific region on their lingual surfaces in a universal testing machine. Following the fracture, the load was delivered to the crown at a crosshead speed of 1mm/min. The measured values were recorded and tallied for additional examination.

2.2. Statistical analysis

SPSS software was used to examine data (SPSS version 23.0 for Windows). For each of the four groups, the fracture resistance loads in Newton were calculated as mean and standard deviation. Comparison of mean fracture load was analyzed using one-way ANOVA followed by multiple comparisons with the Bonferroni test with threshold significant value (α=0.05).

3. Results and discussions

A total of 80 human maxillary premolar teeth were selected and divided into four groups. The mean and standard deviation of fracture loads in Newton (N) according to groups are presented in Table 1. Fracture resistance was statistically significant among the groups (P=0.0005) for removing one-half and two-thirds of the sealing material, as shown in Figure 1. Zirconia Post had significantly higher fracture resistance than all other groups in removing one-half and two-thirds of the sealing material. Zirconia endodontic post had good fracture resistance in for removal of one-half of the sealing material (635.5±71.46N) when compared with carbon post (227±29.24N) and glass fiber-reinforced post (465.5±34.02N) and also control groups (P <0.0001) as shown in Figure 2. Glass Fiber Post has lesser fracture resistance compared to Zirconia post; however, it was significantly higher fracture resistance with Carbon posts and also control group in removal of one-half and two-thirds of the sealing material. Similar Glass Fiber Post has significantly lesser fracture resistance than Zirconia Post and significantly higher fracture resistance with Carbon posts and the control group (Figure 2 and Table 2).

Table 1. Comparison of mean readings for fracture strength (Newton)

Groups	n	1/2 strength	2/3 strength
		Mean ±SD	Mean ±SD
Glass Fiber Post	20	465.50±34.02	550.40±65.31
Zirconia Post		635.50±71.46	804.90±26.36
Carbon Post		227.00±29.24	334.30±34.32
Control Group		116.70±28.87	

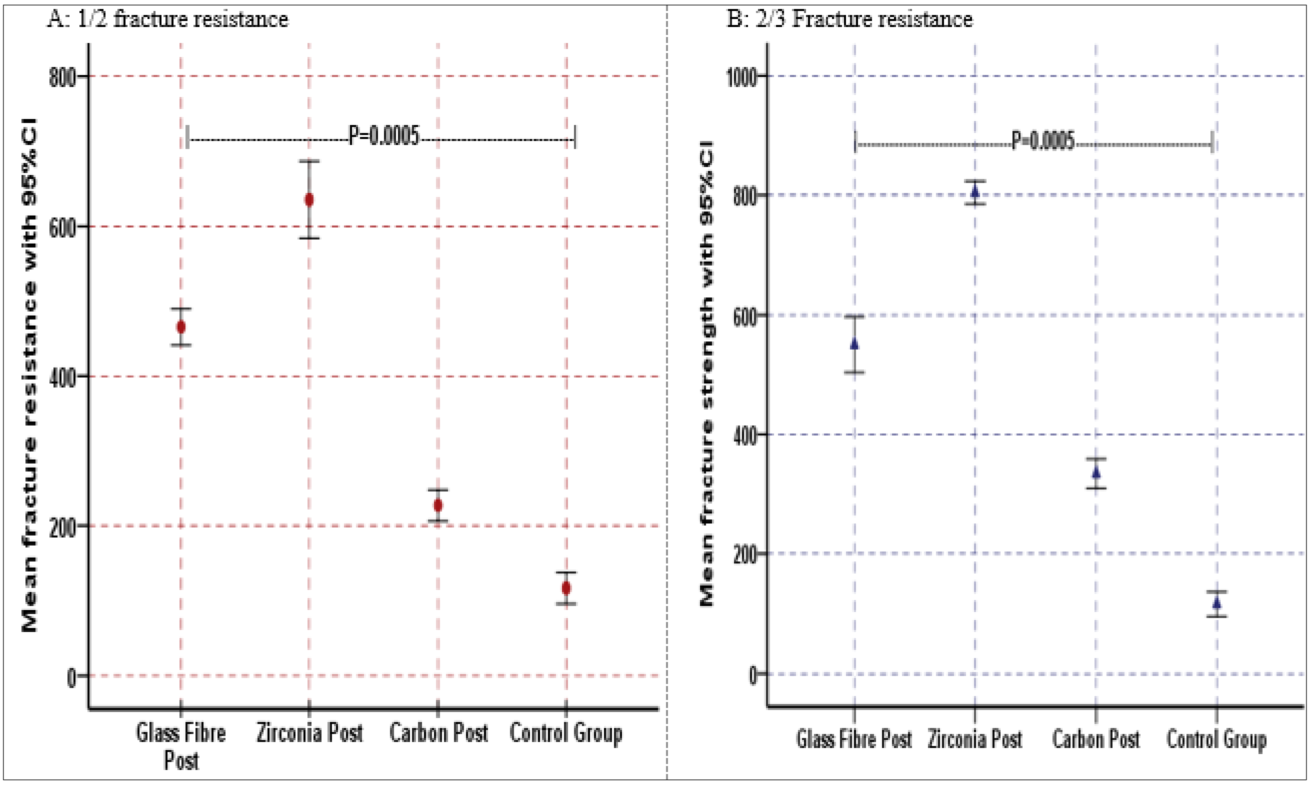

Figure 2. Comparison of mean 1/2 and 2/3 fracture resistance

Table 2. Intragroup comparison for 1/2 and 2/3 fracture resistance

(I) Groups	(J) Groups	Fracture resistance: 1/2 group Mean Difference (I-J)	Sig.	Fracture resistance: 2/3 Group Mean Difference (I-J)	Sig.
Glass Fiber Post	Zirconia Post	-170.0	0.0005	-254.5	0.0005
	Carbon Post	238.5		216.1	
	Control Group	348.8		433.7	
Zirconia Post	Glass Fiber Post	170.0		254.5	
	Carbon Post	408.5		470.6	
	Control Group	518.8		688.2	
Carbon Post	Glass Fiber Post	-238.5		-216.1	
	Zirconia Post	-408.5		-470.6	
	Control Group	110.3		217.6	
Control Group	Glass Fiber Post	-348.8		-433.7	
	Zirconia Post	-518.8		-688.2	
	Carbon Post	-110.3		-217.60	

post hoc Bonferroni, *P*=Significant (p=0.0005)

3.1. Discussions

Post-core systems are used in radial restorations to compensate for the lack of coronal structure necessary for sufficient crown retention. Radicular restorations make up for inadequate coronal structure by using a post-core system [12, 13]. Using zirconia, fiber, and carbon posts to fabricate posts, the present study examines the fracture resistance effects [14]. Despite the partial acceptance of According to the first hypothesis, there was a substantial difference between the various post types at all lengths, except the digitally produced posts' maximum post length of 10 mm. To create samples for this investigation, human teeth were removed., which is accepted as the second hypothesis that fracture strength does not differ significantly at different post lengths. All teeth in the current study got endodontic therapy. Teeth treated with endodontics typically necessitate the installation of a post and core, a partial loss of normal tooth structure. Most clinical investigations show that zirconia, fiber, and carbon posts are prefabricated posts most often utilized [15 - 17]. Three different types of prefabricated posts were employed in this investigation. Aside from that, the requirements mentioned above cannot be reached in some clinical settings, such as lengthy clinical crowns or short roots with a shallow taper [18 - 20].

Composite resin was used in the construction of the core (Bis core build-up material). Cecchin et al literature's review [9] produced recommendations for the post and core restoration of teeth that have undergone endodontic treatment. Their findings validate the superiority of composite resin as a building material for cores. These findings were consistent with the results of Singh et al. [16], who determined that digitally generated glass was related to fiber posts; this material has the highest mean fracture strength. Jindal et al. [17] discovered similar results, concluding that cylindrical glass fiber dowels outperformed metal dowels in fracture resistance when utilized in endodontically treated teeth. A clinical study by Lin et al. [18] looked at the root fracture, post-retention, and marginal gap for digitally and glass fiber-reinforced posts. The fiber-reinforced post had a 100% survival rate, while the digitally created post had a 97.5 percent survival rate. However, the differences in survival rates were not statistically significant. After a 6 month examination, no post-fracture nor de-cementation was seen. Their findings indicated that fiber posts outperformed digitally produced posts under compressive pressures [19].

Additionally, there was a notable variation in the fracture load values across the materials under Additionally, there was a notable variation in the fracture load values across the materials under investigation, with zirconia posts having a higher fracture load than fiber and carbon posts. One zirconium block is the main difference. These results align with earlier studies on zirconia posts [20, 21]. Other studies [22, 23] found that veneering dental composite fracture and/or debonding was the most common failure. Das [25] observed the same results as in this investigation and concluded that PEEK (polyetheretherketone) exhibited greater resilience to fracture than fiber post. Nevertheless, the total difference between these two materials was minimal. Jrab et al. showed lower fracture resistance among every substance in contrast to the zirconia post [26]. Other investigations reported similar results, indicating that zirconium crowns had a lower significant fracture load [23, 27].

According to Singh et al. [16], zirconia posts restored teeth exhibited superior fracture resistance compared to fiber posts when subjected to compressive pressure. teeth with less resistance to fracture with fiber-reinforced posts might be explained by modulus of elasticity, which in the present study is closer to dentin's modulus and lower for glass fiber posts. In order to transmit applied loads evenly over the length of the post and core, post materials need to have an elasticity modulus that is comparable to that of dentin [28, 29]. A definitive correlation was discovered between post-system and post-length regarding the fracture loads of teeth that had endodontic treatment [10,11]. The zirconia group reported greater fracture loads at two locations than the fiber group lengths [24].

The maximum fracture loads of zirconia posts at the 10mm subgroup may be explained by the concept of zirconium monobloc formation, which indicates the success of a single biomechanical complex of block in restorative material capable of resisting more considerable stresses. With the post length reduced to 7.5mm in the subgroup, the strengthening effect of glass fiber posts was reduced.

Increased pressure concentration in the teeth was most likely caused by a somewhat negative crown-to-root ratio [30]. This investigation produced different results from those found by Zyürek et al. [20], who found that the glass fiber post group had values for fracture resistance much higher than those of the zirconia post group and the control group that did not have a post. As a result of the reduced post mass volume and the decreased tendency for force sorption, which occurs at shorter post lengths in the glass fiber post group, they concluded that the stress is now passed to receive less care of teeth or dentin, increasing the likelihood of a greater catastrophic crack of the tooth structure, hence figuring out the appropriate post length is essential [31].

The impact of different post lengths on the three different types of posts was also examined in the current study: zirconia, fiber, and carbon. A 10mm zirconia post was discovered to have a higher fracture load than a 7.5mm post. Malik et al. [31] determined in their investigation that It is not required to perform extensive post-space preparation to increase tooth fracture resistance. In addition, compared to carbon posts, the fracture resistance of fiber posts at a maximum size of 10 mm is statistically negligible. The study also indicates that at 10mm post length, fiber posts give superior fracture resistance than carbon posts of the same length and the opposite at a post length of 7.5 mm.

The location of the endodontically treated tooth influences the type of post used as well since fiber posts are nonmetallic and do not reflect the greyness of metallic posts through all ceramic crowns [28]. However, anatomical features, thickness, root length, and the clinical height-to-root ratio all influence post-length and post-space preparation [30]. The in vitro backdrop of this study, which does not always match oral circumstances, is one of its limitations. In teeth that have had endodontic treatment, fatigue stresses and breakage might arise from the cyclic and dynamic loads that teeth encounter in the oral environment [32]. The oral environment's effects on teeth include masticatory stress, as well as changes in temperature, *p*H, moisture content, and exposure to different bacteria and enzymes. Future studies have to take these factors into account as they might have a detrimental impact on the degree of dentin ties between the post and the root, changing the findings for more significant outcomes.

4. Conclusions

The study's limitations led to the following results being reached:

The teeth in the control group had the lowest fracture resistance, whereas those replaced with two-thirds-length zirconia posts showed the highest fracture resistance. The post's length rises despite the material's higher fracture resistance. Zirconia posts exhibited more excellent fracture resistance than fiber and carbon posts across all measurements under investigation; however, no statistically significant difference was seen concerning fracture resistance for any specific length.

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