Fracture resistance of weakened roots restored with different types of posts

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Abstract: ***Background:*** Many post systems are available to clinicians, yet no consensus exists about which one is better in restoring endodontically treated teeth. ***Purpose:*** This study evaluated the fracture resistance of weakened roots restored with custom made metal posts, zirconia custom made posts and fiber reinforced custom made posts. ***Methods:*** Forty five maxillary central incisors had their crowns removed 2mm above the cement-enamel junction and were endodontic ally treated. The canals were prepared for post fixation, and the canal walls were flared using a taper diamond bur. The prepared roots were randomly divided into three groups according to the post system. All posts were cemented with adhesive resin cement. For the fiber-reinforced resin posts, cores were built up using microhybrid composite. Specimens were loaded at 45 degrees in a universal testing machine at a crosshead speed of 0.5 mm/min until failure. The mode of failure was classified as favorable or unfavorable. ***Results:*** Teeth restored with cast posts had the highest fracture resistance. Fiber-reinforced resin posts failed at a compressive force comparable to clinical conditions, but most failures were repairable. Thinner root dentin walls significantly decrease the fracture resistance of endodontically treated teeth. ***Conclusion:*** Fracture resistance and mode of failure in anterior teeth with flared canals variedaccording to the type of post used to support a crown.
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1. Introduction

Many options are available for the reconstruction of endodontically treated teeth, but clinical decision is complicated when teeth are weakened and the root canals are compromised. This situation occurs with open apices, overprepared teeth for previous post-retained restorations, inadequate post removal, caries, fractures, or internal resorption.

The selection of the most adequate post system is influenced by the treatment plan to restore aesthetics and function, remaining tooth structure, post design, and mechanical properties.

These flared root canals with thin dentin walls may require reinforcement and restoration using dentin bonding agents and composite, posts, and cores(1,2). The selection of the most adequate post system for each case is influenced by treatment plan to restore aesthetics and function, remaining tooth structure, post design and mechanical properties(3).

Endodontically treated teeth have been restored using cast metal posts for decades; however, these conventional posts have biological and mechanical disadvantages, such as high modulus of elasticity, excessive tooth reduction, lack of retention, and root fracture(1,4,5).

Direct post and core restorations with prefabricated fiber-reinforced resin posts became popular because of their lower modulus of elasticity compared with metal posts, decreasing the risk for root fracture(6). But even when using posts with modulus of elasticity similar to that of dentine, root fracture strength seems to be related to the amount of remaining dentin around the post(7,8).

Prefabricated posts associated with resin reinforcement of the root dentin walls have been used to increase fracture strength of flared canals(2,9). Nevertheless, up to date, there is no consensus in the literature about which material and technique are better to restore endodontically treated teeth with enlarged root canals.

In vitro and *in vivo* studies with different post systems have showed variability of fracture strength and mode of failure(10).

So, the goal of this study was to high light the importance of the proper selection of the most suitable post systems restoring endodontically treated teeth through comparing the conventional posts (cast metal custom made posts) versus newly introduced glass fiber reinforced composite resin posts (customized ready made post system).

2. Materials and Methods

Forty-five caries-free maxillary central incisors with roots of similar form were selected. The teeth were examined carefully to determine any decay, cracks or anatomical defects which were discarded.

All selected teeth have a single canal and straight root measuring approximately (14±1 mm) root length (6.2±0.2mm) in bucco-lingual width and (6±0.2mm) in mesiodistal width. All measurements were taken at the cemento-enamel junction level.

The selected teeth were stored in saline of 0.9% concentration at room temperature until being used.

The crowns of all teeth were sectioned perpendicular to their long axis 2 mm coronal to the cemento-enamel junction (the most incisal point of the proximal cement-enamel junction). The working lengths were registered for the subsequent procedures.

After endodontic instrumentation up to file size #50 by conventional and manual method using K-file (Mani, Inc., 8-3 Kiyohara Industrial Park, Utsunomiya, Japan) and irrigation was performed using 2.5% sodium hypochlorite and finally with normal saline. Gutta-percha points (Dentsply Maillefer, CH Switzerland) were coated with a non-eugenol sealer (Apexit Plus, Ivoclar Vivadent, Liechtenstein) and placed into the root canal applying the lateral condensation technique until complete root obturation. The canals orifices were sealed with eugenol-free temporary filling (Coltosol- F, Coltene/Whaledent AG, Switzerland). The root canal filled specimens were stored again in saline solution until use.

Gutta-percha removal was performed with size #3 & 4 Gates Glidden (Dentsply Maillefer, Ballaigues, Switzerland) until a depth of 9 mm leaving a 4±1mm apical seal. For standardization, all root canals were prepared for post placement with pessoreamers (#1.5 in diameter) (PEESO, Engine reamers, Switzerland). The prepared post space was then irrigated using normal saline and dried with paper points.

The roots were divided randomly into three groups according to canal preparation design: (15 for each group).

- Group I: Control group with post space 1.5mm diameter and 9mm length.
- Group II: Partial weakened root group with enlarged post space 2.3mm diameter till length 7mm. using round bur (size #023 SWS Rotary, Turkey) to make a diameter 2.3mm from the coronal dentin to a length of 7mm inside the root canal.
- Group III: Excessive weakened root group with more enlarged post space 3.1mm diameter till length 5mm. using large round bur (size #031 SWS Rotary, Turkey) to make a diameter 3.1mm from the coronal dentin to a length of 5mm inside the root canal.

Each group was subdivided into three groups (5 teeth each) according to the material of the intended post to be used.

Subgroup (A): Metallic cast post-core.

Subgroup (B): FRC post with Tetric N ceram core.

Subgroup (C): Zirconia custom made post-core.

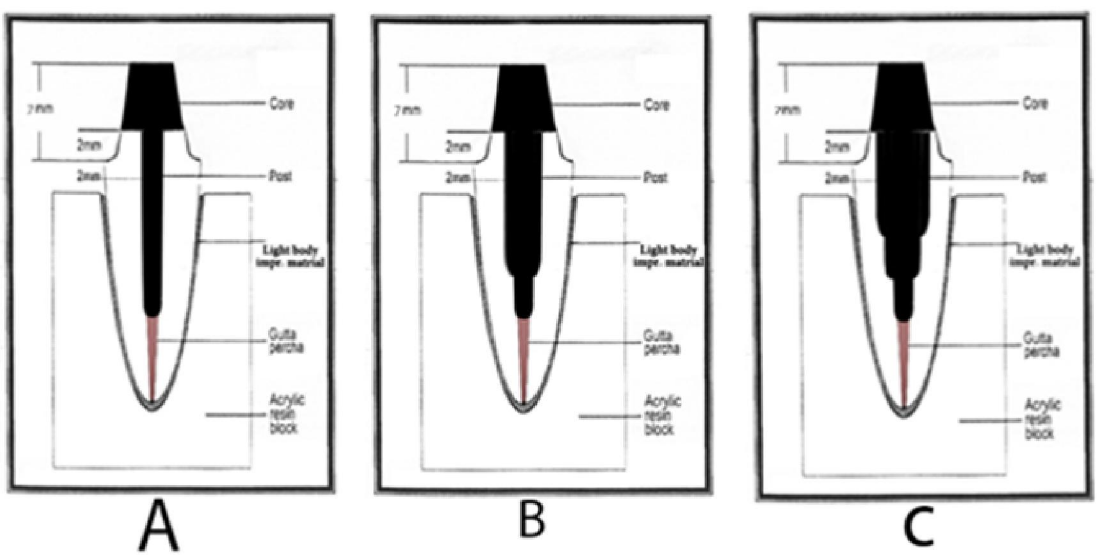

Fig. (1) Schematic drawings illustrating types of preparations
A- Schematic drawing illustrating samples of gp. I control group.
B- Schematic drawing illustrating samples of gp. II partially weakened roots group.
C- Schematic drawing illustrating samples of gp. III excessive weakened roots group.

To standardize the core dimensions for all samples, a rubber mold (Speedex, Coltene/Whaledent AG, Switzerland) with incisal central hole was constructed on one of the selected unprepared teeth after preparing it to the following dimensions 7mm in height (measured from the labial cemento-enamel junction) and with 4mm mesio-distal width, a total convergence 15^0 angles and deep chamfer finish line of 1mm depth. The resin pattern was constructed using a chemical cure acrylic resin (Duralay-Pattern

Resin Standard Package Reliance, Dental Mfg. Co., Worth Illinois 60482). The final resin pattern had intraradicular portion with passive taper and three shapes according to type of canal preparation, and coronal portion with a standardized dimensions mentioned before for all samples.

The cast metal post –core samples were constructed using these resin patterns which were cast with Ni-Cr alloy (Metapluse, Germany) by following the conventional casting procedure.

Construction of the zirconia post-core samples by using these resin patterns as a mock up and then the zirconia block size 12 was copy milled using the Zirconzahn system (Super Attak Flex gel, Zircon Zahn, Italy) into post and core.

Construction of the FRC post and composite core samples; glass fiber reinforced composite posts (ever Stick post; Stick Tech Ltd, Turku, Finland) with the same dimensions and shape of group I (1.5mm diameter). For groups II & III atailor made fiber posts were fit into the canal (main post; 1.5mm diameter and shorter post; 0.9mm & 1.5mm diameter, respectively). Adhesive resin (N-Bond, Ivoclar Vivadent, Liechtenstein) was applied on the ever Stick posts to dissolve the fiber post surfaces. The fiberreinforcedresin posts were cut, leaving 2 mm above the root canalentrance to retain a composite cores.

To fabricate composite core for FRC posts, the inner surface of the previously constructed rubber mold was filled with Tetric N-Ceram (Ivoclar Vivadent, Liechtenstein), and seated on to the preparation and allowed to light-cure for 40 seconds through the hole to standardize the shape and dimensions of composite cores in all samples.

All posts were cemented with Dual curing Self-adhesive universal resin cement (RelyX Unicem Aplicap, 3M ESPE, Seefeld, Germany) according to manufacturer's instruction and under static load.

To simulate the periodontal ligament for simulating the periodontal ligament space, a sheet of pink wax (Pink Wax, Cavex, Holand) 0.2-0.3 mm in thickness was closely and evenly adapted to the root surface of each test sample. The proper powder/liquid ratio of self curing acrylic resin (Acrostone, Industrial area, El Salam city, Egypt) was mixed according to the manufacturer's instructions and applied into the sample holder. The attached tooth was moved downward allowing the tooth to be introduced along its long axis into the center of the resin filled sample holder. Excess acrylic resin was removed from the upper surface with a clean wax carver. Before complete polymerization, the tooth was moved upward, the sheet of wax was removed and a light body silicone impression material (Smile VPS, iSmile Dental Product, USA) was injected into the space previously occupied by the wax. The tooth was immediately replaced into its previous position and kept stable till complete polymerization of the material thus simulating the periodontal ligament space. Excess impression material was removed from the upper surface of the sample.

Specimens were submitted to the fracture strength test. All samples were individually mounted in custom made jig with 45^o angulation then secured to the lower fixed compartment of a computer controlled materials testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5 kN and data were recorded using computer software (Nexygen-MT; Lloyd Instruments). Then samples were statically compression loaded until fracture at a crosshead speed of 0.5 mm/min. Load was applied at an angle of 135 to the long axis of the tooth with a custom made load applicator [steel rod with round end 3.4 mm diameter] placed at core edge palatally and attached to the upper movable compartment of the machine.

The samples were loaded until fracture and the force of fracture was automatically recorded. The obtained results were tabulated and statistically analyzed.

Subsequently, fracture pattern and failure mode of all roots were examined and each specimen was classified as favorable failure (any failure at or above the simulated bone level (edge of the epoxy block), displacement or fracture of the core, displacement or fracture of the post) or unfavorable failure (Any crack or fracture in the root below the simulated bone level; middle 1/3and apical 1/3).

Data were presented as mean and standard deviation (SD) values. Data were explored for normality using Kolmogorov-Smirnov test.

Fracture resistance data showed parametric distribution; so regression model using Two-way Analysis of Variance (ANOVA) was used in testing significance for the effect of post type, post preparation and their interactions on mean fracture resistance. Tukey's post-hoc test was used for pair-wise comparison between the groups when ANOVA test is significant.

Fracture mode data were presented as frequencies and percentages. Chi-square test (x^2) was used to compare between the groups.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS®Statistics Version 20.

Two-way ANOVA results

The results showed that post type, preparation and the interaction between the two variables had a statistically significant effect on mean fracture resistance.

Table (1): Regression model results for the effect of different variables on mean fracture resistance

Source of variation	Type III Sum of Squares	df	Mean Square	*F*-value	*P-value*
Post type	307520.9	2	153760.5	88.3	<0.001*
Preparation	265761.7	2	132880.9	76.3	<0.001*
Post type x Preparation	68808.6	4	17202.2	9.9	<0.001*

*df: degrees of freedom = (n-1), *: Significant at P ≤ 0.05*

Effect of Post type: Metal post showed the statistically significant highest mean fracture resistance.

Table (2): Comparison between fracture resistance of post types regardless of preparation

Metal		Fiber		Ceramic		*P*-value
Mean	±SD	Mean	±SD	Mean	±SD	
444.1 [a]	144.4	196.6 [c]	36.6	388.8 [b]	112.3	<0.001*

**: Significant at P ≤ 0.05, Different letters are statistically significantly different*

Effect of preparation: Group I control preparation showed the statistically significant highest mean fracture resistance.

Table (3): Comparison between fracture resistances of preparations regardless of post types

Standard		Partially weakened		Largely weakened		*P*-value
Mean	±SD	Mean	±SD	Mean	±SD	
470.9 [a]	151.8	361.4 [b]	108.7	222.3 [c]	41.7	<0.001*

**: Significant at P ≤ 0.05, Different letters are statistically significant different*

Effect of different interactions Metal post with control preparation showed the statistically significant highest mean fracture resistance. There was no statistically significant difference between fiber posts with partially or excessively weakened preparations; both showed the statistically significant lowest mean fracture resistance values.

Table (4): Comparison between fracture resistances of different variables' interactions

Post type	Preparation	Mean	±SD	*P*-value
Metal	control	591.8 [a]	55.9	<0.001*
	Partial weakened	448.9 [b]	27	
	Excessive weakened	253.4 [d]	18.3	
Fiber	control	235.9 [d]	33.6	
	Partial weakened	185 [e]	6.1	
	Excessive weakened	168.8 [e]	22.8	
Zirconia	control	490.8 [b]	72.5	
	Partial weakened	379.6 [c]	36.8	
	Excessive weakened	234.3 [d]	19.5	

**: Significant at P ≤ 0.05, Different letters are statistically significant different*

Fracture mode: There was a statistically significant difference between fracture modes of different groups.

Table (5): Frequencies (n), percentages and results of chi-square test for comparison between failure modes in different groups

Group	Mode				*P*-value
	Favorable		Unfavorable		
	n	%	n	%	
Metal post with Control preparation	2	40	3	60	<0.001*
Metal post with Partially weakened preparation	0	0	5	100	
Metal post with Excessive weakened preparation	1	20	4	80	
Fiber post with Control preparation	5	100	0	0	
Fiber post with Partially weakened preparation	3	60	2	40	
Fiber post with Excessive weakened preparation	4	80	1	20	
Zirconia post with Control preparation	1	20	4	80	
Zirconia post with Partially weakened preparation	0	0	5	100	
Zirconia post with Excessive weakened preparation	0	0	5	100	

**: Significant at P ≤ 0.05*

4. Discussion

In the present study, it has been shown that there was a significant difference in the effect of different thickness of cervical dentin on the fracture resistance of endodontically treated teeth. Control group preparation showed the statistically significant highest mean fracture resistance (470.9 ± 151.8 N) [table 2]. Partially weakened group preparation showed statistically significant lower mean value (361.4 ± 108.7 N) [table 2]. Excessive weakened group preparation showed the statistically significant lowest mean fracture resistance (222.3 ± 41.7 N) [Table 2]. This is because of greater dentin wall thickness around the prefabricated post, demonstrating that the resistance to fracture of endodontically treated teeth is directly proportional to the amount of remaining dentin structure [11,12]. The findings of the present study are in agreement with those of Tjan *et al.*[12], who found that canals with 1 mm of remaining buccal dentin walls were apparently more prone to fracture than those that had 2 and 3 mm of dentin walls.

In the present study it has been shown that the existence of different post-core materials has influenced the fracture resistance of restored endodontically treated teeth. This approach is however very critical with the reduced remaining sound tooth structure. Several deciding factors might play a role in this aspect among which, the inherent mechanical properties of the post and core material, its relative adaptation to the root fitting surface and finally the modulus of elasticity of the dentin and post material.

Results of the present study have indicated that the cast metal post-cores possessed the highest mean failure load (441.1 ± 144.4 N) [table 2] compared to the two post-core systems. Zirconia post showed statistically significant lower mean value (388.8 ± 112.3 N) [Table 3]. Fiber post showed the statistically significant lowest mean fracture resistance (196.6 ± 36.6 N) [Table 3].

Chang *et al.*[13] through the finite element analysis explained that the more rigid component was able to resist greater forces without distortion. The highest fracture resistance of the teeth restored with metal post-core was further confirmed by the findings of Albuquerque *et al.*[14] who deduced that the post material introduced higher variations in stress analysis of restored endodontically treated teeth. They explained that Posts made from material with high modulus of elasticity absorb most of the compressive loading leading to an increase in the fracture resistance of the endodontically treated teeth.

This is in agreement with the findings of Hegde *et al.*[15] who showed that teeth restored with cast posts had fracture strength twice that of teeth restored with glass or quartz fiber reinforced resin posts, but most fractures would not allow preservation of the teeth.

On the other hand, Silva *et al.*[11] proved that cast post-core presented lower fracture resistance and more catastrophic failure in flared roots.

The results of this study demonstrate that in cases of severely weakened roots, with very thin dentin walls, the use of glass fiber post associated to composite core does not rebuild the roots to the same levels of fracture resistance as the non-weakened roots. This is in agreement with the findings of Marchi *et al.*[7], who showed that root reinforcement does not recover the full resistance to fracture of roots. However, the findings of previous studies [9] and those of the present investigation suggest that reinforcement of weakened roots may actually be a viable choice to reduce fracture occurrence.

Assif and Gorfil[16] contradicted the results of the present study as they reported that the type of post-core systems lose their significance in teeth covered with crowns providing a 2mm ferrule. They agreed with the results of the present study as they found direct relationships between the fracture resistance of the endodontically treated teeth and remaining amount of the coronal tooth structure. They further added that the post does not reduce the forces at the margins of the crown and does not cause a more equal distribution of the forces along the root.

One limitation of this study is that it is an in vitro test. Bonding procedures were performed in vitro and the manufacturer's recommendations were followed, where as clinically, the moisture control may not be ideal.

The post space in this study was prepared with parallel walls, and the post always adapted to the post space well. However, clinically, it may not be possible to create an ideal canal space.

At the same time, the results of the failure mode indicated that two fracture patterns were observed in the current study. Tooth fractures were classified as favorable (repairable) where the fractures were located in the incisal third of the root and unfavorable (irreparable) which went down beyond the incisal third into acrylic resin, which simulates osseous level according to *Marce et al*[17].

Metal and zirconia post-cores have a high elasticity module, because they are more rigid. This gives them a greater capacity to withstand occlusal forces before flexing until fracture, but at the same time promotes the non-absorption of occlusal forces by the post, transmitting them irregularly to the dental structure, giving rise to aggressive fractures (unfavorable), On the contrary, the glass fiber posts, while still not exhibiting maximum fracture resistance values in this study, do feature bio-mechanical behavior similar to that of dental structure because they have a similar Young module. Presumably, they will therefore be capable of absorbing occlusal forces and transmitting these forces uniformly across all the structures of the system, resulting in a level of more favorable and reparable fractures [17].

Also cast metal and zirconia post-cores with greater rigidity value than those of dentin tend not to flex, thereby transmitting the forces to dental structure in a non-unifom way, which restrlts in-maximum expression in a fracture of aggressive or irreparable character. On the contrary, posts which exhibit a degree of flexion similar to that of dentin, like fiber posts, possibly have lower absolute fracture resistance values but tend to absorb the occlusal forces in part and transmit them uniformly, reducing the level of harm in the event of fracture[144].

The amount of remaining coronal tooth structure of the endodontically treated teeth together with the type of post-core system are paramount factors for an outstanding survival of endodontically treated teeth.

Conclusions

Within the limitation of this study, the following conclusions can be drawn:

1- Post-core materials affect the fracture resistance of endodontically treated teeth with weakened roots.

2- The thicker the root dentin wall, the more fracture resistance of endodontically treated teeth.

3- The mechanical properties of the post material affect the fracture resistance of restored endodontically treated teeth.

4- Endodontically treated teeth restored with the cast post-core were more resistant to fracture than those restored with zirconia and glass fiber posts.

5- Glass fiber reinforced post with composite core provided favorable fracture pattern (repairable) than metallic and zirconia custom made post-cores which provided unfavorable fracture pattern (irrepairable).

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