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Influence of different post luting cements on the fracture strength of endodontically treated teeth: An in vitro study

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ABSTRACT

Objective: To evaluate the fracture resistance of endodontically treated mandibular premolars restored with glass fiber posts using different luting agents.

Methods: Twenty-four extracted single-rooted mandibular premolars were endodontically treated, and post spaces were prepared to receive fiber posts. They were assigned to three test groups (n=8) according to the type of cement used for the cementation of glass fiber posts: RC group: adhesive resin cement group (etch and rinse), SC group: self-adhesive resin cement group, and GC group: glass ionomer cement group. Teeth in all groups were adhesively restored with a composite resin core material and crowned with Ni-Cr crowns. All specimens were subjected to tangential loading using a universal testing machine until fracture at 30°. Failure loads were recorded, and data were analyzed using one-way ANOVA followed by Tukey's HSD test (α=.05).

Results: Specimens in the RC group were more resistant (258.3±12.7 N) to fracture than those in the SC (218.7±11.1 N) and GC (165.4±8.9 N) groups (P≤.001). One-way ANOVA indicated that the type of cement had a significant effect on the fracture resistance of endodontically treated lower premolars (P≤.001).

Conclusion: The type of cement that was used to fix glass fiber posts was a determining factor of the fracture resistance of endodontically treated lower premolars.

Keywords: Resin cement, self-adhesive resin cement, glass ionomer cement, fracture strength, glass fiber post

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HIGHLIGHTS

- The type of cement influences the fracture strengths of endodontically treated lower premolars.
- Fracture strengths of endodontically treated mandibular premolars with fiber posts cemented with resin cement had the highest fracture strengths.
- Fracture strengths of endodontically treated mandibular premolars with fiber posts cemented with glass ionomer cement were lower than those of premolars with self-adhesive cement.

INTRODUCTION

Endodontically treated teeth (ETT) are at a higher risk of fracture than vital teeth due to the removal of their structure during restorative procedures and root canal treatment (1). The loss of this structure increases the susceptibility to tooth fracture (2). The prognosis of ETT depends on several factors, such as the amount of residual tooth structure, ferrule height, restorative materials, and the design of post and core material used (3). A study has reported that the treatment of ETT using different posts systems should be used only for the retention of a core and not for reinforcing the tooth (4). Mangold and Kern (5) stated that the loss of around more than 50% of the coronal structure requires the use of posts to retain the final restoration.

Two types of post systems, namely prefabricated posts and custom-made cast post and core, are available. The custom-made cast post and core system has been used for decades as the gold standard for restoring extensively damaged teeth, but using this system is time consuming (6). Prefabricated posts can be made of metals, such as titanium and stainless steel (7), or nonmetals, such as zirconia (8), and fiber posts (9). Restoring ETT with high elastic modulus posts might lead to root fracture (10). In addition, using metallic posts has many concerns due to the unequal redistribution of stress, microleakage and corrosion, and the gray color (11). Patients' aesthetic demands have led to the development of metal-free post and core systems (12). Fiber posts have become popular because they have a similar modulus of elasticity to dentine (approximately 20 GPa) (13), and they have comparable bond strength to dentine (14). They can distribute stress in a homogeneous manner that increases the load threshold wherein the post begins to show evidence of microfractures (15).

A number of dental materials have been introduced in the market for cementation of fiber posts (16). Adhesive resin cement has been reported to have better mechanical properties than other cements, such as self-adhesive resin cements (17). Self-adhesive resin cements can be used with fiber post as an alternative to regular adhesive resin cements that do not require dentine pretreatment before cementation, which is a sensitive technique and time-consuming procedure (17). Additionally, self-adhesive and other resin cements can bond to the tooth structure and restorative materials (18). In addition, glass ionomer cement can be utilized for the cementation of post systems (19). It offers several advantages for the cementation of fiber posts, which includes chemical and micromechanical bonding to the tooth structure, and it does not require dentine conditioning.

Mangold and Kern evaluated the influence of fiber post placement on the fracture resistance of ETT with different degree of substance loss, but the effect of the type of cement was not determined in their study (5). Moreover, Samran et al (9). described the effect of structure removal, ferrule height, and ferrule location on the fracture resistance of ETT, but the effect of the type of cement was not determined in their studies (9, 20). Therefore, the aim of this in vitro study was to evaluate the influence of three luting agents (used with fiber posts) on the fracture resistance of ETPs. The null hypothesis of the current study is that the luting agents used with fiber posts would not affect the fracture resistance of ETPs.

MATERIALS AND METHODS

Test groups

Twenty-four intact, crack- and caries-free, unrestored human single-rooted mandibular first premolars (with an average length of 22±1 mm, a buccolingual dimension of 7±0.5 mm, and a mesiodistal dimension of 7±0.5 mm) in a straight canal, which were freshly extracted for orthodontic reasons, were anonymously collected. Ethics committee approval was obtained. Teeth were cleaned of calculus and other deposits with a hand scaler and were kept at room temperature in 0.1% thymol solution (Caelo, Hilden, Germany). Pulp chambers were accessed, and root canals were instrumented to ISO size 50 for root canal treatment (K-files, Thomas, Bourges Cedex, France). The working length was considered to be 0.5 mm from the apex. After washing canals with 5.25% sodium hypochlorite and EDTA solutions and drying with paper points (Spident, Meta Biomed Co, Incheon, Korea), canals were then obturated with laterally compacted gutta-percha points (Spident, Meta Biomed Co, Incheon, Korea) using a thin layer of an AH canal sealer (AH Plus Sealer, Dentsply DeTrey, Constance, Germany). Then, apical foramina and access cavities were covered with temporary fillings (Coltosol, Coltene/WhaledentInc, Altstätten, Switzerland). All teeth specimens were then stored in distilled water at room temperature for 72 hrs. Thereafter, tooth roots were inserted in acrylic resin blocks (IdofastUnipol, Unidesa-Odi, Madrid, Spain) with plastic rings up to 2 mm below the cementoenamel junction (CEJ) to simulate the alveolar bone level, with their long axes perpendicular to the horizon. All teeth were prepared with 1-mm chamfer finish lines (Long taper diamond bur; SS White, NJ, USA), which were cervical to the CEJ with a 3° taper to obtain a 6° convergence angle. Burs were replaced in each group to ensure a high cutting performance. For tooth preparations, diamond rotary cutting instruments were used in a high-speed handpiece, which is attached to a paralleling machine to ensure standardization of all specimens under copious air–water cooling. Mesial, distal, and lingual walls were removed, leaving only the facial wall and 1.5-mm circumferential ferrule. After leaving the root canal filling to set for 72 h, gutta percha was removed from the root canals with Gates Glidden drills 1, 2, 3, and 4 (Gates Glidden Drills, Mani, Tochigi, Japan), leaving 4 mm of the root canal filling in the apical portion. The final enlargement of the post space was accomplished with the corresponding tapered drill supplied by the manufacturer to achieve a length of 10 mm for the standardization of all groups. Then, post spaces were irrigated with 2.5% NaOCl and 17% EDTA (MD-Cleanser, Meta Biomed Co, Incheon, Korea) for 1 min and finally with distilled water.

The coronal orifices of the root canals were widened in the faciolingual direction to a 3-mm width and 3-mm depth to prevent rotation and standardize the coronal openings and the thickness of the remaining coronal structure. Then, teeth were randomly assigned to three groups, with eight specimens in each group according to the type of cement used:

RC group: Adhesive resin cement group (RelyX Ultimate Clicker, 3M Espe, St Paul, MN, USA)

SC group: Self-adhesive resin cement group (Breez, Pentron, Orange, CA, USA)

GC group: Glass ionomer cement group (Ketac Cem, 3M Espe, St Paul, MN, USA)

For cementation procedures of posts, all cements were used according to the manufacturers' instructions. All glass fiber posts were abraded by airborne particles for 5 secs using 50-μm alumina particles (Aluminum Oxide Abrasive, Heraeus Kulzer, Hanau, Germany) at 0.1 MPa. Then, glass fiber posts were ultrasonically cleaned in 99% isopropanol path (Isopropanol, Saher Alreef Co, Riyadh, KSA) for 3 mins. Thereafter, for only the RC group (etch and rinse), posts spaces were etched with 37% phosphoric acid for 20 secs and rinsed with water using an endodontic syringe. Then, the root canals were dried with a gentle air blast and paper points, leaving the surface moist. Thereafter, dentine walls were treated with a dentine adhesive (Single Bond Universal Adhesive, 3M Espe, St Paul, MN, USA). Posts were coated with the corresponding cement according to the group and were inserted in the canals. Resin composites (MultiCore Flow, Ivoclar-Vivadent, Schaan, Lichtenstein) were used as the core material. Using a low-speed handpiece with a fine grain diamond, cores were prepared and finished to the

TABLE 1. Materials used in the restorative procedures

Batch number	Company	Material	Batch
	White post DC 0.5, FGM	Glass fiber posts	160415
	RelyX Ultimate Clicker, 3M Espe	Adhesive resin cement	150618
	Breeze, Pentron	Self-adhesive resin cement	5613030
	KetacCem, 3M Espe	Glass ionomer cement	599223
	Multicore flow, Ivoclar-Vivadent	Composite resin	U 51357

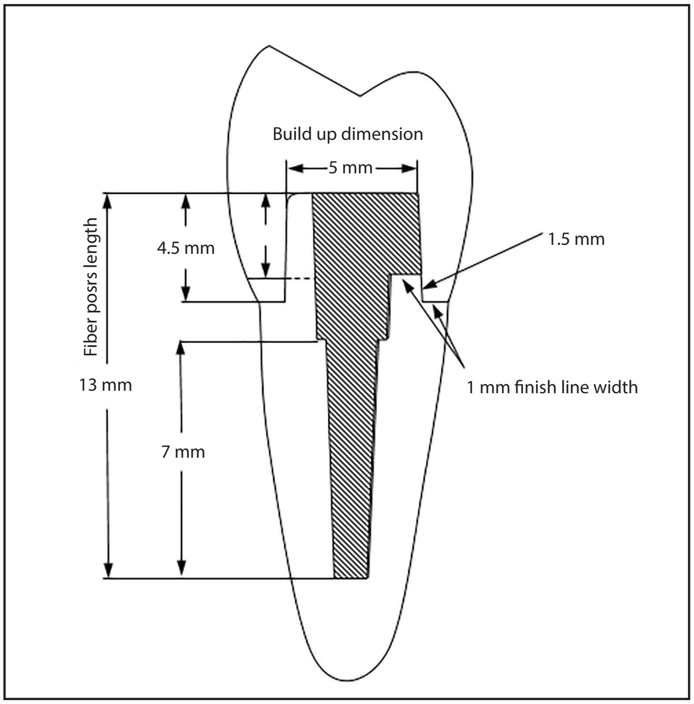

Figure 1. Schematic illustrations of preparation dimensions (in mm)

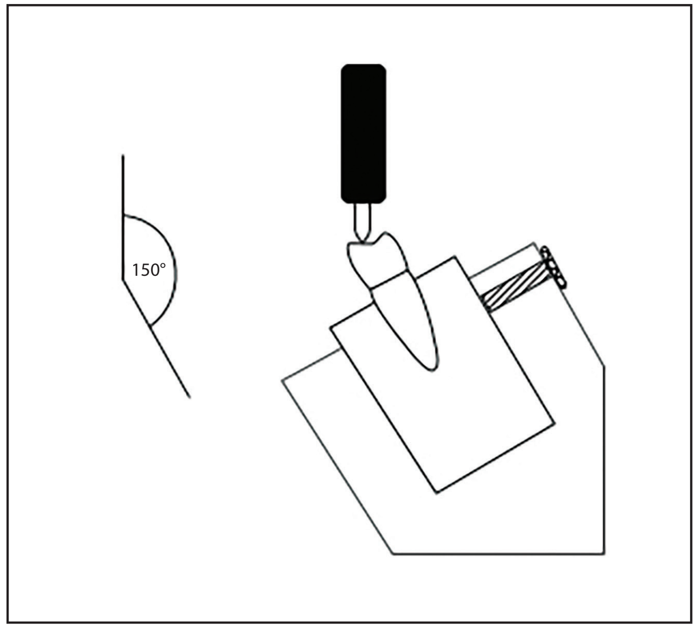

Figure 2. Schematic view of a specimen in the universal testing machine

required dimensions (Fig. 1). All materials used in the restorative procedures are listed in Table 1.

Cast crown fabrication

After post and core placement, impressions of prepared teeth were taken with a polyvinyl siloxane impression material (Express XT, 3M Espe, St Paul, MN, USA). Then, the impressions were poured with type IV stone (Fujirock, GC Corp, Leuven, Belgium). A calibrated reference crown with a 30° inclination of the buccal cusp to the vertical axis was prepared in wax to obtain similar crown dimensions in all specimens. The crowns were then duplicated onto other dyes by adding heated liquid wax to a custom-made silicone mold. Then, crown wax patterns were converted to Ni-Cr metal crowns (Bellabond plus C, Bego, Bremen, Germany). Intaglio surfaces of the metal crowns were abraded by airborne particles for 15 secs with 50-µm alumina particles at 0.25 MPa and cleaned in 99% isopropanol ultrasonic path for 3 min. The coronal structures were cleaned with a rotary brush and fluoride-free pumice for 15 secs and thoroughly rinsed with water for 15 secs. The crowns were then cemented using glass ionomer cement (Ketac-Cem Aplicap, 3MEspe, St Paul, MN, USA) according to the manufacturer's instructions.

Loading of the specimens

The specimens were stored in distilled water for 3 days at 37°C. Then, all specimens were subjected to a compressive load using a universal testing machine (Instron Corp, Canton, MA, USA) until fracture (Fig. 2). The force was applied 30° to the longitudinal axis of the tooth until the first sharp drop of the load was observed on the displacement–load curve. Loading was applied to the lingual inclination of the buccal cusp (2 mm from the central fossa of the crown) with a crosshead speed of 1 mm/min. The failure load was recorded, and the modes of failure were visually inspected.

Statistical analysis

Data were analyzed for normality using the Anderson–Darling test, which demonstrated that data were normally distributed. Among the three groups, fracture load data were analyzed using one-way ANOVA, followed by multiple comparisons using Tukey's HSD test. Fracture load data were analyzed with SPSS 18.0 (SPSS 22.0 for Windows, SPSS, Inc, Chicago, IL). Depending on the significance level (α=.05) and specimen size (n=8), the test of choice has the capacity to detect significant differences that could justify clinical relevance.

RESULTS

The mean values of the failure loads (N) ranged from 165.4±8.9 to 258.3±12.7 (Table 2). One-way ANOVA revealed that the type of cement had a significant effect on fracture resistance ($P \leq .001$). Using Tukey's post hoc test at a significance level of 0.05 revealed differences between the groups. Specimens restored with glass fiber posts cemented with adhesive resin cement were more resistant to fractures than those cemented

TABLE 2. Fracture loads in N (mean±standard deviation)

Group	Fracture loads in N
RC	258.3 ± 12.7^{A}
SC	218.7 ± 11.1^{B}
GC	165.4 ± 8.9^{C}

Statistically different means (P≤.05) are indicated by different superscript letters

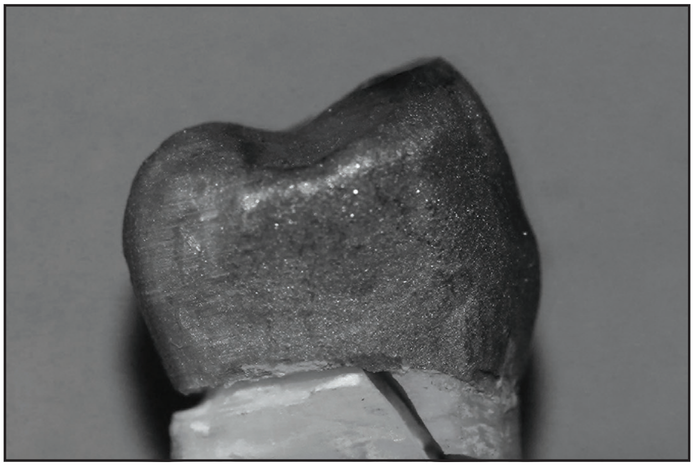

Figure 3. Fracture mode observed after static loading (favourable fracture mode)

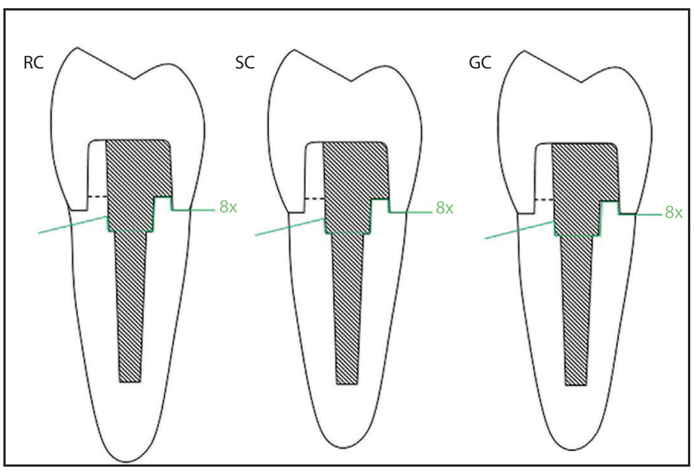

Figure 4. Schematic view of the fracture pattern and the frequency of subgroups

with self-adhesive resin cement and glass ionomer cement (Table 2). Regarding failure modes, two types were observed: the favourable mode, which started from the lingual margin of the crown and extended in the buccal direction at the same level (cervical third), and the catastrophic mode, which started from the lingual margin of the crown and extended in the apical direction (middle or apical third). All groups had complete favourable fracture modes (Fig. 3). All specimens had favourable fracture modes that were 2–4 mm below the remaining facial walls. The fracture pattern and frequency are illustrated in Figure 4.

DISCUSSION

This in vitro study explored the fracture resistance of ETPs with glass fiber posts cemented with different luting agents. Therefore, the aim of this in vitro study was to find the cement–post combination with the highest fracture resistance. Extracted mandibular first premolars of humans were used in this study, although human teeth show relatively large variations in size and mechanical properties. The use of human teeth is a reliable methodology in fracture testing, and it has also been validated by some authors (9, 20-22). The preparation of all specimens was standardized using a parallelometer to ensure that results can be compared among different groups. All posts spaces were irrigated with 2.5% sodium hypochlorite, 17% EDTA, and distilled water after preparation and before post cementation as this procedure is usually used in root canal treatment because of its ability to remove the smear layer (23). After core polymerization, a fine grain diamond attached to a low speed handpiece was used to achieve the required dimension of the preparation and only a minimal additional amount of dentine was removed. However, it is assumed that this procedure did not considerably influence the results because this was done in the same manner for each group. The composite core material was used in this study as it had a similar modulus of elasticity to dentine (24). In addition, several studies have shown that the fracture resistance of composite core materials in ETT is comparable to that of intact teeth (25) and higher than that of other core materials, such as amalgam and glass ionomer (26), because a stronger bond between the core and tooth structure was established using adhesive bonding agents.

Results of this study do not support the null hypothesis that the different cements would not affect the fracture resistance of ETPs. Significant differences in the fracture resistance among the three groups with cemented posts were found; therefore, the type of cement was a determining factor for the fracture resistance of ETPs. The fracture resistance of the restored specimens ranged from 165.4±8.9 N (for the GC group) to 258.3±12.7 N (for the RC group). The fracture resistance in the RC group was better than in the SC and GC groups, although a minimum of 3 mm of the remaining buccal wall and a ferrule height of 1.5 mm were maintained for all teeth. Greater loads were necessary to cause fracture in the RC group, which shows the effect of the type of cement in resisting tangential forces. This result can be explained by the bond strength of adhesive resin cement to dentine is stronger than that of self-adhesive resin cement and glass ionomer cement (18); therefore, adhesive resin cement can form a dentine–post–core monoblock system, which allows the homogeneous distribution of applied forces evenly along the root; thus, the excessive loads would be absorbed. An additional dentine-conditioning step when using resin cement in the RC group achieved greater bond strength and can form a dentine–post–core monoblock system. However, no additional steps are used to condition dentine with self-adhesive resin cement, and the smear layer may remain at the post space surface, which interferes with the bond strength (27). Glass ionomer cement is weaker and more brittle than resin-based materials (28) and exhibits unfavourable fatigue and compressive characteristics compared with resin-based luting cements (29). In addition, glass ionomer cement requires several days to reach maximum strength (30).

All teeth had favourable fracture modes in the cervical third because the physiological differences between cement, posts, and enamel can produce stress that is concentrated in the cervical region. In addition, the interface of materials with different modulus of elasticity values represents the weakest point of a restorative system.

The lack of resilient material that simulates the periodontal ligament was one of the limiting factors of this in vitro study. In addition, to mimic the intraoral situation, further in vitro studies should consider the aging process because thermocycling may affect the results.

CONCLUSION

Resin cement is most appropriate for luting glass fiber posts to increase the fracture resistance of ETPs. Glass ionomer is an unsuitable option as cement for glass fiber posts.

Disclosures

Conflict of interest: The authors deny any conflicts of interest.

Ethics Committee Approval: Dar Aluloom University, Saudi Arabia.

Peer-review: Externally peer-reviewed.

Authorship contributions: Concept – A.S.; Design – M.O.N.; Supervision – M.Ö.; Fundings – M.O.N.; Materials – M.O.N.; Data collection &/or processing – A.S.; Analysis and/or interpretation – M.A.A.; Literature search – S.A.A.M.; Writing – A.S.; Critical review – M.Ö.

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