



ORIGINAL ARTICLE

Compressive strength of premolars restored with ceramic crowns and supported with a glass fiber post using different luting agents



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KEYWORDS

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Abstract *Objective:* The retention of glass fiber post (GFP) is considered a key factor for the long-term success of restorations of endodontically treated teeth. This study aimed to compare the compressive strength of a ceramic crown supported by a GFP using different luting agents.

Methods: Forty single-rooted premolars were randomly divided into four groups (n = 10 each): control group (teeth without a GFP), Ketac Cem group (glass ionomer), RelyX ARC group (conventional dual-curing resin), and RelyX U200 group (self-adhesive dual-curing resin). After luting of the posts and placement of all-ceramic crowns made using feldspathic porcelain (Noritake EX-3), they were exposed to thermocycling for 1000 cycles and compressive strength tests. Statistical analysis included Kruskal–Wallis test with Dunn’s multi-comparison test.

Abbreviations: β , coefficient of regression; GFP, glass fiber post; N, newtons; PTFE, polytetrafluoroethylene; R^2 , coefficient of determination

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Results: The Ketac Cem group and RelyX U200 group showed significantly greater fracture resistance to compressive loading than the control group.

Conclusion: This study indicates a possible role of the luting agent used with the GFP in influencing the compressive strength of the restored teeth. In this study, the self-adhesive dual-curing resin and glass ionomer both offered resistance to fractures.

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1. Introduction

The use of a glass fiber post (GFP) as an alternative for the restoration of endodontically treated teeth has increased because of its good aesthetics, low cost, higher flexural strength, an elastic modulus to the dentin allows even distribution of any stress along the root, thereby improving the tooth fracture resistance (Lamichhane et al., 2014).

The retention of a GFP is considered a key factor for the long-term success of restorations of endodontically treated teeth (Skupien et al., 2015). Failures occur most often following post displacement (Cagidiaco et al., 2008). Glass ionomer luting agents have been used for the attachment of the GFP because they can form chemical bonds with the dentin, have a low coefficient of thermal expansion, and can micromechanically bond to the tooth structure (Pereira et al., 2013). However, their low mechanical strength undermines their use in areas of high stress because they can demonstrate poor clinical performance in those settings (Fuhrmann et al., 2020).

Conventional resin-based luting agents present the advantages of having a dual cure, low solubility, good mechanical qualities, and adequate adhesive properties (Walcher et al., 2019). However, these luting agents are technique sensitive, require prolonged time for application, and are moisture sensitive (Maroulakos et al., 2018). Contamination (Pedreira et al., 2009), type of luting agent, interaction with the adhesive system (Durski et al., 2016), and accumulation of stress within the root canal by polymerization shrinkage can lead to the formation of gaps in the post/luting agent/dentin interfaces.

Conventional resin luting agents need pretreatment to obtain dentinal bonding; however, these procedures prolong the clinical treatment time (Kawashima et al., 2019). Self-adhesive resin luting agents do not need pretreatment of the dentin, simplifying their clinical application (Han et al., 2020). Self-adhesive resin luting agents have excellent mechanical properties, good dimensional stability, and micromechanical adherence (Scholz et al., 2021). Moreover, they have high tolerance to moisture because water forms during the neutralization reaction of the phosphoric-acid methacrylate, basic fillers, and hydroxyapatite, providing adhesion to the root canals (Bitter et al., 2006).

Some studies have compared the retention of GFP when using resin versus glass ionomer luting agents (Farina et al., 2016; Li et al., 2014). However, no studies have compared the use of ionomer or resin luting agents as GFP luting agents in endodontically treated premolars restored with a ceramic crown and subjected to thermos-cycling to better simulate the actual clinical situation. Thus, this study aimed to evaluate the compressive strength of premolars restored with ceramic crowns and supported with a GFP with different luting agents.

2. Materials and methods

2.1. Study design and sample preparation

This *in vitro* study was approved by the Research Ethics Committee Federal University of Maranhão (no. 23115-005523/2011-03). The brands, manufacturers, and chemical compositions of the main materials used in this study are listed in Table 1.

Forty single-rooted premolars with a root length of 16 mm (± 2 mm) were obtained. The teeth were cleaned with periodontal curettes Gracey 5–6 (Millenium, São Paulo, Brazil) and polished with fluoride-free pumice. The teeth were stored in 0.1% thymol solution at 4 °C for 7 days. Then, they were kept in saline solution at 4 °C.

The crowns were sectioned at 2 mm from the cementoenamel junction in a cutting machine (Isomet Low Speed Saw, Buehler ITW Company, USA) with a double-sided diamond disk (Extac Wafer Blade, Cerius, São Paulo, Brazil) under constant cooling. The roots were bound with a polytetrafluoroethylene (PTFE) sealant tape to a thickness of 1 mm (Tigre SA, Joinville, Brazil), coated with petroleum jelly, and embedded in polyvinyl tubes (Tigre SA) filled with chemically cured acrylic resin (Jet Classic, São Paulo, Brazil), maintaining a root exposure of 3 mm (Fig. 1a–c).

Following acrylic resin polymerization, the roots were removed from the tubes, and the PTFE sealant tape was removed. To simulate the periodontal ligament, the 1-mm space caused by removing the PTFE sealant tape was filled with polyether (Impregum Soft, 3M ESPE St. Paul, USA) (Fig. 1d–e). The specimens were labeled and stored in saline solution at 4 °C for 24 h.

2.2. Endodontic treatment

Endodontic access was performed with a diamond bur 1012 (KG Sorensen, Cotia, Brazil), and the cervical and middle thirds were prepared with Gates–Glidden drills no. 3 and 2 (Dentsply Maillefer, Ballaigues, Switzerland). The length of the root was measured from the outside. The working length was established as 1 mm short of the apical foramen. This measurement was confirmed by periapical radiography. Root canal preparation was performed using the crown-down technique with K files (Dentsply Maillefer) up to the diameter of 50.

Root canal preparation was performed using 1 mL of 0.5% NaOCl solution after every change of file size throughout root canal cleaning and shaping. The smear layer was removed with 17% ethylenediaminetetraacetic acid, and 15 mL of saline was used for final irrigation. The root canals were dried with absorbent paper cones (Dentsply Ind. and Co. Ltd., Petrópolis,

Table 1 The brand, manufacturer, and chemical composition of the main materials used in this study.

Brand	Manufacturer	Chemical composition
AH Plus sealer	Dentsply Intl	Paste A: Bisphenol A epoxy resin, bisphenol F epoxy resin, calcium tungstate, zirconium oxide, silica, iron oxide pigments Paste B: Dibenzylidiamine, aminoadamantane, tricyclodecane-diamine, calcium tungstate, zirconium oxide, silica, silicon oil
Ketac Cem	3M ESPE	Water, polycarboxylic acid, tartaric acid, glass powder, pigments and conservation agents
RelyX ARC	3M ESPE	Paste A: Bis-GMA, TEGDMA, zirconia and silica inorganic fillers (68% wt), photoinitiators, amines and pigments. Paste B: Bis-GMA, TEGDMA, benzoyl peroxide, zirconia and silica inorganic fillers (67% wt).
RelyX U200	3M ESPE	Base: fiberglass, esters, phosphoric acid, methacrylate, triethylene glycol dimethacrylate (TEGDMA), silanated silica and sodium persulfate, inorganic fillers (45% wt). Catalyst: fiberglass, substitute dimethacrylate, silanated silica, sodium p-toluenesulfonate and calcium hydroxide.
Adper Scotchbond multipurpose Plus adhesive	3M ESPE	Activator: ethanol solution of sulfinic acid salt and a photoinitiator component. Primer: HEMA and polialcenoic acid copolymer. Catalyst: HEMA and Bis-GMA, BPO.
Adper Single Bond 2	3M ESPE	Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, and a methacrylate functional, copolymer of polyacrylic and polyitaconic acids.
Silano Mais	Dentsply Sirona	Ethanol, glacial acetic acid, silane.
Number 1 post	FGM	80% fiberglass, 20% Epoxy resin.
Whitepost DC	3M ESPE	Bis-GMA, Bis-EMA, UDMA, TEGDMA, nanoparticles (silica: 20 nm, zirconia: 4–11 nm, agglomerate of 0.6–1 μ m).
Filetek Z350		
Noritake EX-3	Noritake Kizai Co.	Leucite-containing feldspathic porcelain SiO ₂ , Al ₂ O ₃ , CaO, MgO, K ₂ O, Na ₂ O, Li ₂ O, B ₂ O ₃ , pigments.

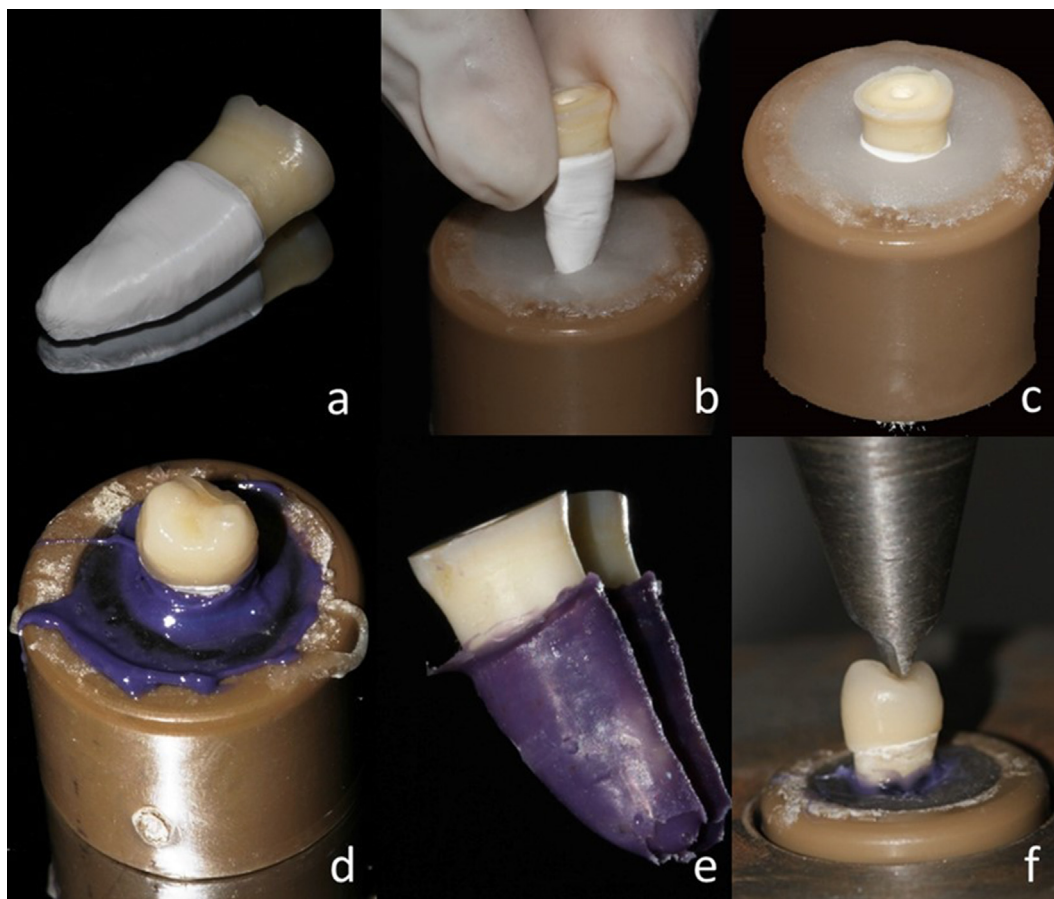


Fig. 1 Specimen preparation: Periodontal ligament space simulation with PTFE sealant tape to a thickness of 1 mm, and the roots were embedded in acrylic resin blocks (a–c); Periodontal ligament simulated with a polyether elastomeric material (d, e); Compressive loading of the specimen in the universal testing machine.

Brazil), followed by filling with AH Plus sealer (Dentsply Ind. and Co. Ltd) and gutta-percha points (Dentsply Ind. and Co. Ltd.), using lateral compaction technique.

The filling quality was assessed by radiography, and the root was then prepared with Largo burs #2 and 3 (Dentsply Maillefer), leaving a 5-mm obturation in the apical region. The specimens were kept for 7 days at 37 °C and 100% relative humidity to simulate the oral environment.

2.3. Experimental groups

The specimens were randomly divided into four groups ($n = 10$): negative control group the teeth without GFP (control group), glass ionomer Ketac Cem (group 1), conventional resin RelyX ARC dual curing (group 2), and self-adhesive resin RelyX U200 (group 3).

Initially, the posts were placed in the root canal, and the reference post was identified with a permanent marker to direct the axis of the introduction of the GFP during luting. Then, each GFP was immersed individually in 24% hydrogen peroxide (Magistral Homeocosmiatria, Fortaleza, CE, Brazil) for 1 min and left in a dish of distilled water for 1 min. The solution was used only once for each post. After drying, the GFP was silanized for 60 s according to the manufacturer's guidelines (Silano Mais, Dentsply Ind. and Co. Ltd.). The root canal preparation for the luting of the GFP was performed with a specific bur for the post (Whitepost DC #1 - FGM, Joinville, Brazil). Finally, the conduits were washed with saline and dried with absorbent paper points (Dentsply Ind. and Co. Ltd.).

Control Group: There was no luting of the GFP. The root canals were prepared with only 5 mm of filling with AH Plus sealer (Dentsply Ind. and Co. Ltd.) and gutta-percha points (Dentsply Ind. and Co. Ltd.) and were kept at 37 °C for 7 days.

Group 1: The posts (Whitepost DC #1) were luted with the glass ionomer Ketac Cem (3M ESPE). The manipulation was performed according to the manufacturer's instructions, and the luting agent was introduced into the canal with a Centrix syringe (DFL Indústria and Comércio SA, Rio de Janeiro, RJ, Brazil). The post was inserted into the root canal and kept under light pressure. After 5 min, the excess luting agent was removed.

Group 2: The posts (Whitepost DC #1) were luted with conventional dual-curing RelyX ARC (3M ESPE). The root canals were etched with 37% phosphoric acid (DFL Indústria and Comércio SA) for 15 s, followed by washing for 15 s and drying with air and absorbent paper points. Adper Scotchbond Multi-Purpose Plus (3M ESPE) was applied to the canal. After the application of each product, the excess was removed with absorbent paper points. The manipulation was performed according to the manufacturer's instructions, and the luting agent was inserted into the canal with a Centrix syringe (DFL Indústria and Comércio SA). The post was inserted and held under light pressure for 5 min. The excess luting agent was removed, and photoactivation was performed on the occlusal surface for 40 s.

Group 3: The posts (Whitepost DC #1) were luted with self-adhesive dual-cure RelyX U200 (3M ESPE). The luting agent was mixed according to the manufacturer's instructions and introduced into the canal with a Centrix syringe (DFL Indústria and Comércio SA). The post was inserted and kept under light pressure. The excess luting agent was removed, and then the post was cured on the occlusal surface for 40 s.

2.4. Manufacturing of crowns

After core build with Adper Single Bond 2 and Filtek Z350 composite resin (3M ESPE), all teeth received cervical preparation using a cylindrical diamond bur with a 1.2-mm chamfer. The teeth were molded with silicone, and using the individual models, 40 all-ceramic crowns were made using feldspathic porcelain (Noritake EX-3, Noritake, Kisai CO Limited, Nagoya, Japan). The crowns were then luted to the teeth. The crowns in the control group were luted with a glass ionomer.

2.5. Thermocycling and mechanical loading

After crown attachment, the teeth were subjected to thermocycling for 1000 cycles (Thermocycle, Biopdi, São Carlos, Brazil). Each cycle took 60 s: 30 s of being submerged in a tub of water at 5 °C and 30 s in a tub of water at 55 °C. For the compressive strength test, the specimens were placed perpendicular to the horizontal plane (90°) in a universal testing machine (DL 3000, Emic, Pinhais, Brazil) with a load cell of 500 N, 1 mm/min, using a cylindrical tip with an area of 2.01 mm² positioned in the center of the occlusal groove crown (Fig. 1f). The maximum force required to complete crown fracture was recorded in Newtons (N).

2.6. Statistical analysis

Statistical analyses were performed using GraphPad Prism version 8 (GraphPad Software Inc., San Diego, USA). The median and interquartile range (IQR) were used to describe continuous data. Data were assessed for normality using the Shapiro-Wilk test. The Kruskal-Wallis test with Dunn's multi-comparison test was used to determine statistical differences between groups. The level of significance was set at 5%.

3. Results

Fig. 2 illustrates that group 1 (median, 388.1; IQR, 369–488) and group 3 (median, 432.4; IQR, 320–519.7) showed significantly higher values in compressive strength ($P < 0.05$) than the control group (median, 285.6; IQR, 254.5–323.1). No significant differences in the compressive strength were found between group 2 (median, 282.3; IQR, 215.4–429.2) and other groups.

4. Discussion

This study compared the compressive strength of a ceramic crown supported by a GFP with different luting agents. The findings suggest significant differences between the groups, thus rejecting the null hypothesis. When analyzing the influences of the types of luting agents used in the modification of the compressive strength, the glass ionomer and self-adhesive resin resulted in higher compressive resistance.

This performance can be explained because the glass ionomer has a low coefficient of expansion and ensures good adhesion by binding chemically to the tooth (Garcia-Contreras et al., 2015). Furthermore, the self-adhesive resin has been considered an alternative for luting GFP, since it significantly reduces the risk of failure by the application of an adhesive system. It is used in one step application and has excellent mechanical properties and dimensional sta-

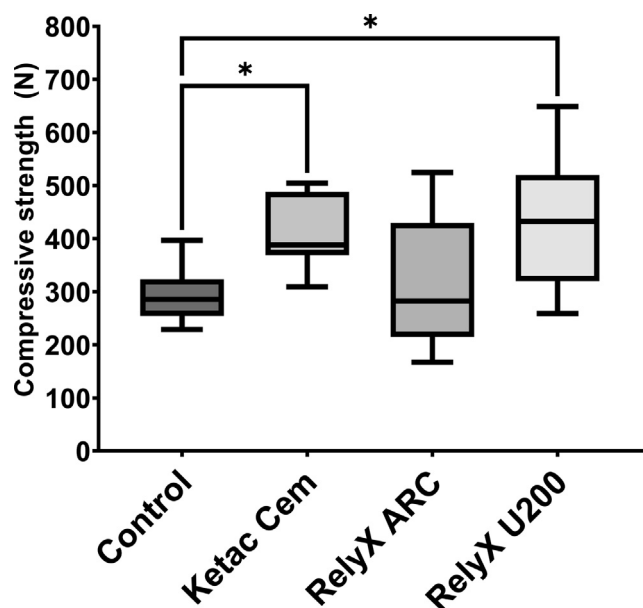


Fig. 2 Compressive strength among the groups evaluated. Each box plot represents the median, interquartile range, minimum, and maximum values. *Indicates significant differences between groups ($P < 0.05$).

bility (Scholz et al., 2021), high tolerance to moisture, favors adhesion to dentin intraradicular (Bitter et al., 2006), and has a higher bond strength to dentin (Sarkis-Onofre et al., 2014).

The glass ionomer and self-adhesive resin luting agent had mean values of compressive strength that were higher than the control group, as represented by the tooth without post luting. These treatment groups were examined to assess the effect of luting agents on compressive resistance. The removal of the dentin during the instrumentation of the root canal was reported to negatively affect fracture resistance; increasing tooth resistance can be allowed by the use of GFPs (Junqueira et al., 2017). Thus, GFP is indicated to improve the retention of the occlusal restoration and distribute the loads over the remaining tooth structure (Zarow et al., 2020). In addition, the posts were pretreated with silane, which may have led to better adhesion and improved the retention of the luted GFPs (Mishra et al., 2020).

The conventional resin group had a higher mean compressive strength than the negative control group; however, this difference was not significant. The conventional resin showed lower compressive strength despite the advantages of being a dual-cure material. This could be attributed to the application of the luting agent that requires additional steps, increasing the risk of errors (Sarkis-Onofre et al., 2014). Increasing the number of steps and the procedure time may have contributed to the occurrence of technical errors and thus reduced the compressive strength of this experimental group.

Composite resin core fractures were only observed in the control group. These findings suggest that Filtek Z350, used as core build-up material, demonstrates lower resistance to deformation caused by compressive loading than GFP. Compressive strength is a very important feature to study in dental

composites and depends on the composition of the resin matrix, filler type, percentage of filler loading, and particle size (Meenakumari et al., 2018; Azad et al., 2018). Understanding this behavior can help in choosing the most appropriate material available for clinical use.

Fractures in ceramic material were observed in most of the crowns in the experimental groups. This high incidence of ceramic fractures can be attributed to several factors, such as ceramic thickness, preparation method, loading directed at the center of the occlusal groove of the ceramic crown, luting agents, and/or internal defects in the feldspathic ceramic (Sasse et al., 2015). In addition, feldspathic ceramics have a higher fracture risk than other types of ceramics in regions of high stress (Talibi et al., 2022).

In this study, the load was directed only in the center of the occlusal groove, an area that also has a thinner ceramic thickness. This aspect may have contributed to the high occurrence of dental crown fractures in the experimental groups. Moreover, no root fractures or dislocations due to the failure of the GFP were observed. This finding could be attributed to the mechanical properties that improve the flexibility of the teeth under applied loads, thus reducing the intensity, and concentration of such loads in the root canal (Ferrari et al., 2000).

In this study, for a better simulation of the clinical situation, the premolars received GFP luted with different materials, a core made of composite resin, and rehabilitated with a ceramic full crown, forming a restorative complex. Thus, this complex was subjected to compressive strength tests with a perpendicular load (90°) to the long axis of the tooth to simulate a masticatory load, and the behavior of the restorative complex was observed.

Nevertheless, this study has some limitations, such as the small sample size, thermocycling of all specimens, and the in vitro design. Therefore, further studies including larger samples, evaluating the aging factor, analyzing other mechanical properties, and investigating clinical trials are needed.

5. Conclusion

The findings suggested that the type of luting agent can influence the compressive resistance of the teeth restored with a GFP. The RelyX U200 and Ketac Cem groups showed significantly higher compressive strengths than the control group.

CRedit authorship contribution statement

Flávia Carvalho de Oliveira Paixão: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **Vandilson Pinheiro Rodrigues:** Formal analysis, Investigation, Methodology, Software, Supervision, Writing – review & editing. **Roy George:** Formal analysis, Writing – review & editing. **Soraia de Fátima Carvalho Souza:** Investigation, Methodology, Writing – original draft. **Antonio Ernandes Macêdo Paiva:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **Adriana de Fátima Vasconcelos Pereira:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – review & editing.

Ethical statement

This present study was approved by the Research Ethics Committee Federal University of Maranhão (number 23115-005523/2011-03).

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