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Original Article

# The effect of touch-cure polymerization on the push-out bond strength of fiber posts

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ABSTRACT

*Objective:* To assess the impact of a novel touch-cure polymerization of dual-curing resin cement on the push-out bonding strength (PBS) of the conventional prefabricated glass fiber-reinforced composite (GFRC) and custom-made glass fiber (GF) posts at different root sections.

*Methods:* Forty single-root mandibular first premolars were treated endodontically and prepared for receiving the posts, the prepared roots were randomly divided into 4 groups. Group I: A prefabricated (GFRC) post was cemented by G-CEM ONE resin cement with adhesive-enhancing primer (AEP). Group II: A prefabricated (GFRC) post was cemented by G-CEM ONE without AEP. Group III: A customized (GF) post was cemented by G-CEM ONE with AEP. Group IV: A customized (GF) post was cemented by G-CEM ONE without AEP. (n = 10 for each group). The PBS was tested with a universal testing machine, and the values were analyzed with (ANOVA) and Tukey's post hoc test at a $P \leq 0.05$ significance level.

*Results:* Group III revealed the greatest PBS values, followed by Group IV, Group I, and finally, Group II showed the lowest PBS values. The coronal root slices showed the highest PBS in comparison with the middle and apical third.

*Conclusion:* The touch-cure polymerization improved the PBS of the prefabricated and customized fiber posts. Therefore, "touch and cure" cement may be considered a clinical alternative to conventional types of resin cement. The customized (GF) posts exhibited a higher PBS than the prefabricated (GFRC). The combination of customized posts and G-CEM ONE with AEP is recommended as a new strategic approach to improve interfacial adhesion.

## 1. Introduction

The extreme loss of tooth structure of endodontically treated teeth can increase the risk of internal stress and fractures. For many years, numerous kinds of endodontic posts have been used to rehabilitate these teeth, for instance, metal, composite, zirconia, and ceramic posts. However, clinical limitations have been associated with the mismatch in modulus of elasticity and over-instrumentation. In the past few years, prefabricated fiber posts have become another technique to reduce the possibility of tooth fracture (Alamdari et al., 2023; Pamato et al., 2023). Prefabricated glass fiber-reinforced composite (GFRC) posts have received more attention owing to their better clinical performance, aesthetics, and high flexural strength (Duarte Santos Lopes et al., 2021; Al Najajrah et al., 2023).

A major documented disadvantage of the conventional prefabricated (GFRC) posts is the need to prepare the canal to accommodate the posts because their geometries are cylindrical representing an imperfect design of non-circular root canals resulting in additional removal of the tooth structure. In addition, the use of these posts in oval-shaped canals increases the thickness of the cement around the posts (Santos et al., 2022; Ata et al., 2023). Recently, several efforts have been made to develop new post-core systems, for instance, multiple bundled fiber posts (Zaghloul et al., 2022) and customized fiber posts via composite relining to make it more anatomical and to reduce the bulk of cement (Alves et al., 2022).

Recent advances have provided a new option for customization techniques including the use of bondable reinforcing fibers such as polyethylene fiber posts (Ribbon fiber posts) and glass fibers (GFs) as intracanal posts. Customized fiber posts were developed to improve the fit and adaptation of the post to dentin, and prevent the removal of

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additional tooth structure (Devraj et al., 2022; Santi et al., 2022). GFs have been widely used as reinforcing materials in dentistry owing to their high tensile strength, transparent appearance, and low-cost material (Abdulla, 2022; Jamel and Yahya, 2022; Jamel et al., 2023).

The adhesion at post-dentin and post-cement interfaces is also critical to avoid post-debonding, gap formation, and microleakage (Alshahrani et al., 2020). As revealed in previous studies, incomplete polymerization of the resin cement increases shrinkage stress leading to post-debonding (Ata et al., 2022; Jamel, 2023). Conventional dual-curing resin cements have an acidic nature that protonates (tertiary amine) and prevents complete polymerization (Lee et al., 2021; Jitumori et al., 2023). To enhance the self-cured activity and interfacial bond strength of dual-curing resin materials with dentin, the manufacturers recently introduced a new "touch and cure" technology. In this technology, polymerization starts when the chemical cure accelerators in adhesives come in contact with the resinous cement which can enhance the chemical polymerization (Pimpinee, 2020; Dwiandhany et al., 2022).

According to the authors' information, no other articles have assessed the effects of touch-cure polymerization in combination with customized (GF) posts as a new approach for restoring endodontically treated teeth. Therefore, this in vitro study was designed to assess the impact of a novel touch-cure polymerization of G-CEM ONE on the PBS of conventional single prefabricated (GFRC) and customized (GF) posts at different root levels. The null hypotheses were that the "touch-cure polymerization will not influence the PBS of fiber posts and that no significant changes will be observed between the different types of glass fiber posts or between the different root levels".

## 2. Materials and methods

### 2.1. Specimens' selection and root preparation

Forty single-root mandibular first premolars were selected for this research. All selected teeth were thoroughly cleaned and kept in normal saline and then decorated at the cervical line and adjusted to be the same length of 13 mm with a double-faced diamond disc (Komet Dental, Lemgo, Germany) in constant cool. The working length for the canals was established by inserting an endodontic file size 15 K-type (Dentsply, Switzerland) into the anatomic apex and subtracting (1 mm) from the determined (WL).

All roots were prepared using (Pro Taper Next, Dentsply, Malifer, Switzerland) rotary system to size X3 file and irrigated thoroughly with (2 ml) of sodium-hypochlorite (concentration of 5.25 %) during root canal instrumentation. After that, it was flushed with (10 ml) of distilled water and dried then obturated with size X3 gutta-percha and bioceramic endodontic sealer (Total Fill, FKG Swiss endo, Le Cretdu-Locle Switzerland). The coronal canal openings were sealed with Glass Ionomer Cement (GIC) (Tokuyama, Tokyo, Japan). Finally, the roots were kept for 1 day in a digital incubator at 37 °C and 100 % humidity (Alkhalidi, 2020; Hassoon, 2022).

### 2.2. Grouping of the specimens

After the storage period, a size 1, 2, and 3 peeso reamer was used to remove the gutta-percha from the root leaving at least 5 mm for the apical seal. The roots were randomly divided into 4 groups based on the endodontic posts, and the cementation technique (n = 10):

**Group I**: A prefabricated (GFRC) post was cemented using G-CEM ONE resin cement with adhesive-enhancing primer.

**Group II**: A prefabricated (GFRC) post was cemented using G-CEM ONE resin cement without adhesive-enhancing primer.

**Group III**: A customized (GF) post was cemented using G-CEM ONE resin cement with adhesive-enhancing primer.

**Group IV**: A customized (GF) post was cemented using G-CEM ONE resin cement without adhesive-enhancing primer.

### 2.3. Cementation of the conventional prefabricated fiber posts

In the first group, the roots were restored using prefabricated (GFRC) posts (Luxa post, DMG, Germany), 1.25 mm in diameter single tapered posts. Before the cementation procedure, each prefabricated post was disinfected with 70 % alcohol, and dried, a layer of Mono bond plus (silane coupling agent, Ivoclar; Vivadent Schaan, Liechtenstein) was utilized on the post surface for approximately the 60 s. The root dentin surfaces were conditioned using G-CEM ONE (AEP) which consists of (MDP, MDTP, 4-MET, methacrylate, initiators, water, and ethanol) for 10 s based on the manufacturer's recommendation. After that G-CEM ONE resin cement which consists of (Fluoro alumina silicate glass, UDMA, phosphoric monomer, and initiators) was loaded into the root canals by the application instrument. Then, the post was introduced into the canals within 1 min after cement application and light cured utilizing an LED light-curing device (Guilin Woodpecker, Ltd., Germany) from the occlusal directions for 40 s with a light intensity of 1600 MW/ $cm^2$. The intensity of the light was carefully checked before use with a digital radiometer (Blue Phase Meter II, Ivoclar Vivadent) and rechecked after each curing. The roots in the second group were restored in the same procedure as mentioned previously but without the use of the G-CEM ONE (AEP).

### 2.4. Cementation of the customized fiber posts

In the third group, the roots were restored using customized (GF) posts. Customizing of (GF) post was made using two pieces of braided glass fiber (Gulf glass fibers; Tech. Ind, Saudi Arabia). Each piece was determined to be 2 mm wide and 7 mm long. The pieces of (GFs) were cut with special scissors, and impregnated with a (Mono bond Plus) for 60 s at room temperature to wet the fibers and improve their adherence, then were dried in a hot air oven for 10 min at 110_120 C° (Jamel et al., 2023). The dentin surfaces were conditioned using G-CEM ONE (AEP) for 10 s and dried. Then G-CEM ONE resin cement was loaded into the root canals. The first piece of (GFs) was folded and adapted tightly into the root canal space with an endodontic plugger. A second piece was then condensed and adapted perpendicular to the first piece until the post space was filled to increase the reinforcing substance and decrease the amount of resin cement. This complex was light-cured for 40 s. The fourth group was restored with the same procedure but without the use of G-CEM ONE (AEP). Finally, the roots were kept in the digital incubator for 3 days.

### 2.5. Push-out bonding strength test

All roots were sectioned via a 0.3 mm thick double-faced disc (Micra cut, Metkon, Turkey) perpendicular to the long axis at low-speed rotation and a constantly cooled system. Each root sample was sectioned into 3 slices (2.0 ± 0.1 mm) thickness from the (coronal, middle, and apical) thirds. A universal testing machine (GESTER International Co., LTD, Quanzhou, China) was used for the PBS test. Each slice was placed on a device consisting of a stainless-steel rod (1.0, 0.8, and 0.5 mm) in diameter to accommodate the diameter of each root canal and a special steel base for holding the specimens. The punch pin of the rod was located directly in contact with the endodontic post without any pressure on the periphery of the root canal. The rod exerted a downward force at a 0.5 mm/ min speed apical to the cervical path until the post was completely extruded. The PBS of each slice was calculated as the maximum failure force (F) in Newton divided by the bonded surface area (A) in ($mm^2$) and expressed in (MPa) (Attash and AL-Ashou, 2022).

$$PBS(Mpa) = F(N)/A\left(mm^2\right)$$

The surface area (A) of each slice was calculated by the following equation:

**Table 1**
Comparisons of mean PBS (MPa) values for different experimental groups at each root canal level.

| Root canal levels | Groups | Mean ± SD | SE | F-value | P-value |
|---|---|---|---|---|---|
| **Coronal** | Group I | 8.14C ± 0.386 | 0.122 | 439.183 | 0.000* |
| | Group II | 5.70 D ± 0.525 | 0.166 | | |
| | Group III | 14.89 A ± 0.663 | 0.210 | | |
| | Group IV | 11.45B ± 0.770 | 0.243 | | |
| **Middle** | Group I | 5.59C ± 1.105 | 0.349 | 256.416 | 0.000* |
| | Group II | 3.01 D ± 0.384 | 0.121 | | |
| | Group III | 11.86 A ± 0.506 | 0.151 | | |
| | Group IV | 8.61B ± 0.811 | 0.257 | | |
| **Apical** | Group I | 3.28C ± 0.4159 | 0.132 | 292.271 | 0.000* |
| | Group II | 1.56 D ± 0.159 | 0.050 | | |
| | Group III | 8.01 A ± 0.906 | 0.286 | | |
| | Group IV | 5.23B ± 0.161 | 0.054 | | |

* Significant differences at $P \leq 0.05$, Number of samples = 10, groups with different letters are significantly different, SE: Standard error, SD: Standard deviation.

**Table 2**
Comparisons of mean PBS (MPa) values for each experimental group at different root canal levels.

| Groups | Root canal levels | Mean ± SD | SE | F-value | P-value |
|---|---|---|---|---|---|
| **Group I** | Coronal | 8.14 A ± 0.386 | 0.122 | 115.366 | 0.000* |
| | Middle | 5.59B ± 1.105 | 0.349 | | |
| | Apical | 3.28C ± 0.4159 | 0.132 | | |
| **Group II** | Coronal | 5.70 A ± 0.525 | 0.166 | 296.032 | 0.000* |
| | Middle | 3.01B ± 0.384 | 0.121 | | |
| | Apical | 1.56C ± 0.159 | 0.050 | | |
| **Group III** | Coronal | 14.89 A ± 0.663 | 0.210 | 235.941 | 0.000* |
| | Middle | 11.86B ± 0.506 | 0.151 | | |
| | Apical | 8.01C ± 0.906 | 0.286 | | |
| **Group IV** | Coronal | 11.45A ± 0.770 | 0.243 | 227.562 | 0.000* |
| | Middle | 8.61B ± 0.811 | 0.257 | | |
| | Apical | 5.23C ± 0.161 | 0.054 | | |

* Significant differences at $P \leq 0.05$, Number of samples = 10, groups with different letters are significantly different, SE: Standard error, SD: Standard deviation.

$$A(mm)^2 = \pi(r_1 + r_2)\sqrt{\left[(r_1 - r_2)^2 + h^2\right]}$$

Where:
$\pi$ is 3.14 (constant value).
$r_1$ is the cervical radius.
$r_2$ is the apical radius.
h is the thickness of the slice.

### 2.6. Statistical analysis

The values were analyzed via version 25 (SPSS) system (IBM Corp.; Armonk, USA). Normal data distribution was tested. A one-way (ANOVA) determined the significant changes among the groups and Tukey's test compared between the significant groups. The significance level was $P \leq 0.05$.

### 2.7. Failure modes evaluation

The failure pattern of all samples was assessed utilizing a digital stereomicroscope at 40X magnification (Optica, Italy). The failure form was recorded as follows: an *adhesive* failure at the cement-dentin and cement-post interfaces, *cohesive* failure in (dentin, cement, or post), and *mixed* failure (areas of adhesive and cohesive failure) (Manouchehri et al., 2023).

**Table 3**
Percentages of failure modes for the different groups at different root canal levels.

| Groups | Root canal levels | Failure Modes % | | |
|---|---|---|---|---|
| | | Cohesive | Adhesive | Mixed |
| **Group I** | Coronal | 20 | 50 | 30 |
| | Middle | 10 | 60 | 30 |
| | Apical | 0 | 70 | 30 |
| **Group II** | Coronal | 10 | 70 | 20 |
| | Middle | 0 | 80 | 20 |
| | Apical | 0 | 80 | 20 |
| **Group III** | Coronal | 60 | 10 | 30 |
| | Middle | 40 | 20 | 40 |
| | Apical | 30 | 40 | 30 |
| **Group IV** | Coronal | 40 | 40 | 20 |
| | Middle | 20 | 50 | 30 |
| | Apical | 10 | 60 | 30 |

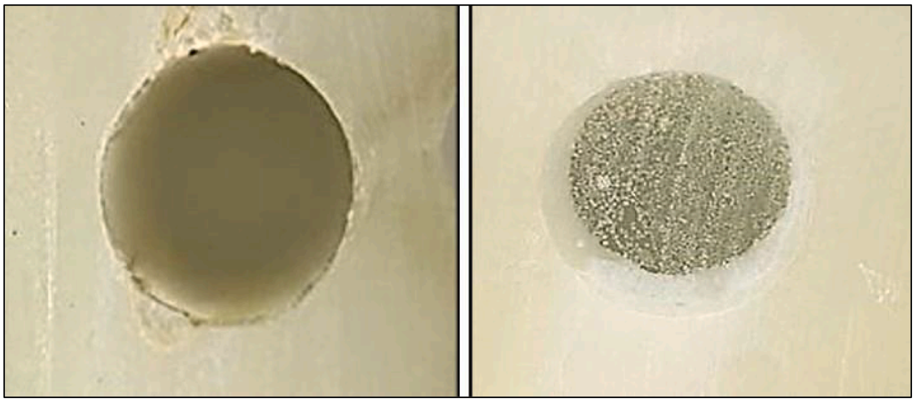
## 3. Results

The mean values, standard errors, and standard deviations of the PBS test for the prefabricated and customized posts cemented with or without G-CEM ONE (AEP) are presented in Tables 1 and 2. One-way (ANOVA) exhibited significant changes in the mean values of the glass fiber posts and cementation techniques. At the different levels (coronal, middle, and apical), the customized (GF) posts cemented using the G-CEM ONE (AEP) revealed the highest PBS values (14.89 ± 0.663, 11.86 ± 0.506, 8.01 ± 0.906), followed by the customized (GF) posts cemented without AEP (11.45 ± 0.770, 8.61 ± 0.811, 5.23 ± 0.161), the prefabricated (GFRC) posts cemented with AEP (8.14 ± 0.386, 5.59 ± 1.105, 3.28 ± 0.4159). Finally, prefabricated (GFRC) posts were cemented without the AEP that showed the lowest PBS values (5.70 ± 0.525, 3.01 ± 0.384, 1.56 ± 0.159). Regarding the root levels, for all experimental groups, the coronal root slices showed the highest PBS values followed by the root slices of the middle and apical third. The microscopical observations of the failure modes are recorded in Table 3.

## 4. Discussion

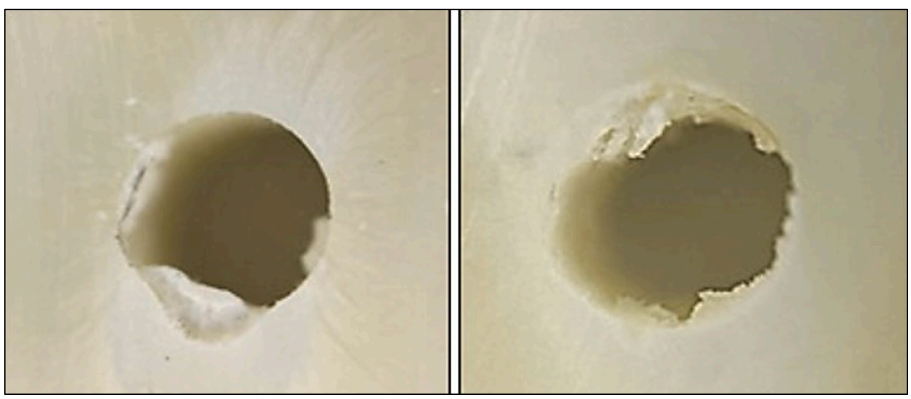
In the present study, the first null hypothesis was that the "touch-cure polymerization will not influence the PBS of fiber posts". The outcomes exhibited that (Group I and Group III) where root slices were treated with G-CEM ONE (AEP), an increasing trend in PBS values was observed compared to (Group II and Group IV) cemented without using G-CEM ONE (AEP) as shown in Table 1. According to these results, the first null hypothesis was rejected. These findings can be explained by the benefit of the touch-cure polymerization of G-CEM ONE (AEP) which improved the PBS of both fiber posts. These findings were consistent with several recent articles that found that "touch and cure" types of cement enhanced adhesion to tooth structures, particularly in areas not exposed to light compared to conventional ones. The polymerization reaction starts immediately after the direct contact of the resinous cement with the dentin which is previously treated with accelerator-containing adhesives. The chemical-curing capacity of the dual-cure resin materials at the tooth-cement interface was significantly enhanced leading to significant improvement in the degree of monomer conversion (DC), and interfacial bonding strength (Pimpinee, 2020; Dimitriadi et al., 2021; Dwiandhany et al., 2022).

Although G-CEM ONE (AEP) contains an acid functional monomer (10-MDP) for improving adhesion to the tooth structure, it also contains a "touch and cure" catalyst in the cement and primer. This activation mode improves the polymerization efficiency and provides the highest and fastest DC. Generally, for chemical polymerization, camphor quinone (CQ) comes together with a (tertiary amine) in the dual-curing



**(a)** **(b)**

**Fig. 1.** Mode of failure (Original magnification X 40). **(a)** An adhesive failure at the cement-dentin interface. **(b)** Prefabricated post with an increase in the volume of the resin cement.

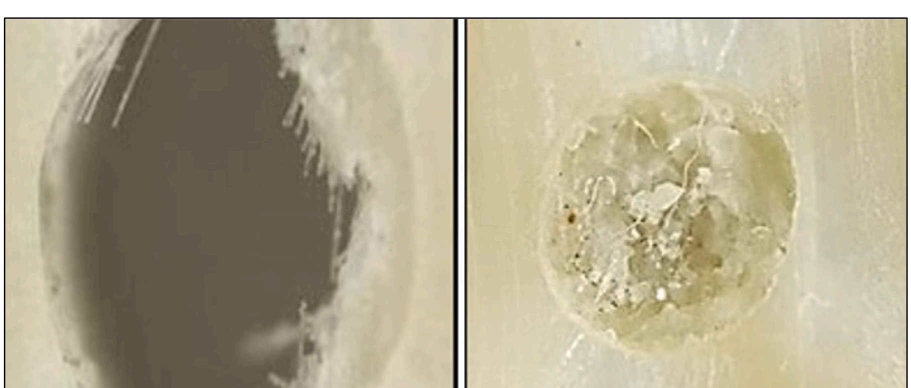


**(a)** **(b)**

**Fig. 2.** Mode of failure (Original magnification X 40) **(a)** Mixed failure. **(b)** Cohesive failure within resin cement.

resins. Diphenyl (2,4,6 Trimethyl benzoyl) Phosphine Oxide has recently developed as another initiator to (CQ) which can be used without a co-initiator to overcome the neutralization of tertiary amine. This is an advantage of the new (TPO) initiator over (CQ) which results in higher DC (Pongprueksa et al., 2014). One of the commercially available TPO-based resin materials is G-Premio BOND tested in this study. The presence of this unique chemical initiator in G-CEM ONE is a reason for better clinical performance. The company document provides this data (Pimpinee, 2020).

Regarding the second hypothesis that " no significant changes will be observed between the different types of glass fiber posts", the results exhibited that the average PBS values of customized (GF) groups were superior to the prefabricated (GFRC) groups as shown in Table 1. According to these results, this hypothesis was rejected. These findings may be related to the use of a new trend of customized (GF) posts that adapt to the root walls more effectively than the prefabricated single fiber posts and reduce the volume of the luting agent around the posts increasing the fit of the posts and reducing the possibility of post-



**(a)** **(b)**

**Fig. 3.** Mode of failure (Original magnification X 40). **(a)** Cohesive failure within a customized post. **(b)** customized post with a low volume of resin cement.

debonding. Thick cement film is prone to voids, pores, and cracks increasing the risk of catastrophic fractures or post-debonding (Jamel et al., 2019; Pamato et al., 2023). In addition, the braided structure of the (GFs) modulates the applied forces before they are transferred to the tooth structure and enhances the plastic deformation of the dentin walls forming a post-dentin-cement mono-block structure in the root to resist loads as a single unit. This complex improves fracture resistance through the good distribution of stresses along the root canal. These outcomes are consistent with previous articles (Gutiérrez et al., 2022; Pamato et al., 2023).

The third hypothesis that " no significant changes exist between root regions" was rejected. This result agreed with previous articles that demonstrated superior bonding strength values for cervical slices than those of the apical and middle slices (Lee et al., 2021; Generali et al., 2023). The light intensity becomes attenuated with increasing distance resulting in incomplete polymerization of the luting agents (Pinto et al, 2023). This fact highlights the importance of using "touch and cure" adhesive systems in deeper sections.

According to the results of failure modes in Table 3, most of the failure pattern observed in (Groups I and II) was an adhesive failure due to the increased thickness of the cement layer as shown in Fig. 1 a and b compared to Groups III and IV which showed mixed failure as shown in Fig. 2 a and cohesive failure within the cement layer Fig. 2 b in addition to cohesive failure within the customized posts as shown in Fig. 3 a due to good adaptation of these posts to dentin with thin layer of cement in Fig. 3 b. This finding agrees with Jitumori et al., 2023.

Based on the positive outcomes of our in vitro study, the combined use of customized (GF) posts and G-CEM ONE with (AEP) may be an alternative to the traditional course of endodontic rehabilitation especially in patients with large, weak, and/or oval canals owing to excellent functional outcomes of this combination such as increased in post-retention, reduced the volume of luting agent, and strengthened weakened teeth which will create endodontic restorations with extended clinical performance and reduce the chance of tooth loss.

The study conditions did not perfectly mimic the oral cavity, e.g., occlusal function, temperature changes, and humidity. In addition, the impact of the thermal cycling and fatigue loading was not examined. Hence, future in vivo studies should be conducted considering the aging period under dynamic loading.

## 5. Conclusion

- The touch-cure polymerization of G-CEM ONE improved the PBS of the conventional prefabricated (GFRC) and customized (GF) posts. Therefore, "touch and cure" cement may be considered a clinical alternative to conventional types of cement.
- The customized (GF) posts enhanced bonding strength to root compared to prefabricated (GFRC) posts.
- The coronal thirds exhibited superior PBS values than the middle and apical thirds.
- The combination of customized (GF) posts and G-CEM ONE with AEP significantly improved interfacial bond strength. This combination is recommended as a new strategic approach that will produce endodontic restorations with extended clinical service.

## Ethical statement

The Research Ethics Committee of the "College of Dentistry and University of Mosul" in Iraq approved the study project (Ethical Approval Reference No.: UoM.Dent/ H.DM.31/ 22).

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2023.12.015.

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