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Fracture Resistance of Bulk Fill Composite Restorations of Anterior Primary Teeth with Four Different Reinforcement Methods

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Abstract

Background: The study compared the fracture resistance of bulk fill composite restorations of anterior primary teeth using four different reinforcement methods.

Methods: Forty-eight extracted human maxillary primary incisors were randomly divided into four groups: The first group was the conventional composite posts (CCP), the second group was the fiberglass posts (FGP), the third group was the pin and composite posts (PCP), and the fourth group was the dentinal pin (DP). The samples were prepared and underwent 5000 thermo-cycles. A Universal Testing Machine applied an increasing force at a 0.5 mm/min crosshead speed until fracture occurred. The fracture resistance was then reported in Newtons (N). Data were analyzed using SPSS version 20. One-way ANOVA and Tukey HSD tests were applied with a significance level of 0.05.

Results: The mean fracture resistance in the four groups was 825.61 ± 74.54 N, 540.10 ± 51.61 N, 758.03 ± 60.94 N, and 498.88 ± 54.59 N, respectively. The results of the one-way ANOVA showed a significant difference among the study groups in terms of fracture resistance (P = 0.001). The fracture resistance of the CCP group was significantly different from the DP group (P = 0.022), with CCP exhibiting a significantly higher mean fracture resistance. The fracture resistance of the FGP was significantly different from the PCP and DP groups (P = 0.010 and P = 0.003, respectively), with FGP exhibiting a significantly higher mean fracture resistance.

Conclusions: According to the results of this study, the best reinforcement methods for bulk fill composite restorations in anterior primary incisors were FGP and CCP.

Keywords: Primary Teeth, Composite Posts, Fiber Post, Fracture Resistance, Inter-Dental Pin, Bulk Fill Composite

1. Background

The premature loss of maxillary anterior primary teeth in children affects speech, chewing ability, esthetics, and appearance (1). To reconstruct lost maxillary primary teeth, resin composites, polycarbonate crowns, composite crowns (strip crowns), zirconia crowns, and stainless-steel crowns (SSC) can be used. Among these materials and methods, composite resins are highly recommended and cost-effective (2, 3). Composite resins are typically applied using the conventional incremental method to reduce polymerization shrinkage stress and achieve appropriate mechanical properties (4). However, this method has limitations, including the creation of voids among layers, bond failure, and long chair time due to placing and curing each layer separately (5, 6). To overcome these limitations, bulk-fill resin composites were introduced. These composites can be placed and polymerized in layers of 4 - 5 mm with minimal polymerization shrinkage (7). Therefore, they simplify

the treatment process, reduce chair time, and are particularly desirable for uncooperative children (8).

The destruction of primary teeth is often extensive, extending under the gingiva, and the remaining tooth tissue provides inadequate bonding (9). Thus, reinforcement methods were introduced to provide bonds from the root. Composite resin posts, fiberglass posts (FGP), fiber-reinforced composites, and dentinal pins (DPs) are among these reinforcement methods (10, 11). According to previous studies, condensing resin composite into the root canal to prepare a composite post is a simple yet effective method. Composite posts have the same elasticity coefficient as dentin, offer sufficient mechanical retention, distribute occlusal forces evenly, are convenient, require no laboratory process, have a reasonable cost, and are optimally compatible with tooth structure (12, 13). Prefabricated non-metallic posts, known as FGP, were introduced as substitutes for prefabricated metal posts (14). The FGP are biocompatible, tooth-colored, and have an elasticity coefficient close to dentin (15). Fiber-reinforced composites offer advantages such as acceptable tensile strength, aesthetics, translucency, adequate fatigue resistance, flexibility, good adaptation with root canals, and an elasticity coefficient close to dentin, which reduces stress accumulation and root fracture (16). The DP is a cost-effective, conservative, and esthetic treatment. This method does not interfere with the growth of the permanent tooth, can be used in vital teeth, and increases the fracture resistance of composite restorations (17, 18).

2. Objectives

This study aimed to assess the fracture resistance of bulk fill composite restorations of anterior primary teeth using four different reinforcement methods

3. Methods

This in vitro study was conducted on 48 primary canine teeth. Ethical approval was obtained from the Research Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.DRC.REC.1400.045).

Primary canine teeth with similar dimensions were included if two-thirds of the roots and one-third of the cervical crown were intact. Teeth were excluded if they had previously undergone pulpotomy or pulpectomy, exhibited root cracks or fractures, or had root anomalies.

The selected primary canine teeth were cleaned and stored in 0.5% chloramine-T for one week and subsequently kept in distilled water at 4°C in a refrigerator until the beginning of the study. The collected teeth were sectioned 1 mm apically to the cementoenamel junction (CEJ) using a high-speed handpiece and fissure diamond bur. Root canals were cleaned and shaped to 1 mm short of the apical constriction using the initial file and three sequential files. Normal saline was used to rinse the canals. The root canals were then dried using paper cones and filled with calcium hydroxide and iodoform.

The prepared samples were numbered from 1 to 48 and randomly assigned to four study groups using a simple randomization method generated by a computer-based tool (https://randomizer.org/#randomize). The four study groups were as follows: Conventional composite posts (CCP), FGP, pin and composite posts (PCP), and dentinal pin (DP). In the CCP, FGP, and PCP groups, 4 mm of the root canal filling was removed to create post space, and a 1 mm light-cure liner was placed and cured for 40 seconds.

In the CCP group, the teeth were etched for 15 seconds, rinsed for 10 seconds, and dried. Bonding (Single Bond, 3M, ESPE, USA) was applied in two layers using a micro-brush and light-cured for 20 seconds according to the manufacturer's instructions. Bulk-fill composite (X-tra Fil, VOCO, Germany) was placed into the root canal using a high-burnished condenser and light-cured for 20 seconds. The tooth crown was then restored with bulk-fill composite to 4 mm above the CEJ.

In the FGP group, cylindrical FGP measuring 5 mm in length and 1.1 mm in diameter were prepared using a diamond bur and a high-speed handpiece with a cooling mechanism. The posts were cleaned with alcohol per the manufacturer's instructions and dried. The root canals were rinsed and dried before placing a dual-cure cement (Embrace Wet Bond Resin Cement, Pulpdent Co, USA). The FGP were inserted into the root canals so that 3 mm remained within the canal and 2 mm extended above it. The cement and posts were light-cured for 40 seconds. The teeth were then etched for 15 seconds, rinsed for 10 seconds, and dried. Bonding (Single Bond, 3M, ESPE, USA) was applied in two layers using a micro-brush and light-cured for 20 seconds according to the manufacturer's instructions. Bulk-fill composite (X-tra Fil, VOCO, Germany) was used to restore the tooth crown to 4 mm above the CEJ.

In the PCP group, a DP (Trijet, Germany) was inserted into the palatal region where the tooth thickness was greatest, ensuring that at least 1 mm of intact tooth structure remained around the pinhole. The teeth were then etched for 15 seconds, rinsed for 10 seconds, and

dried. Bonding (Single Bond, 3M, ESPE, USA) was applied in two layers using a micro-brush and light-cured for 20 seconds according to the manufacturer's instructions. Bulk-fill composite (X-tra Fil, VOCO, Germany) was placed into the root canal using a high-burnished condenser and light-cured for 20 seconds. The tooth crown was then restored with bulk-fill composite to 4 mm above the CEJ.

In the DP group, a DP (Trijet, Germany) was inserted into the palatal region where the tooth thickness was greatest, maintaining at least 1 mm of intact tooth structure around the pinhole. The tooth crown was then restored with bulk-fill composite to 4 mm above the CEJ.

All samples were polished using a high-speed handpiece and composite polishing burs. The samples were then mounted in acrylic up to 1 mm apically to the CEJ and underwent 5000 thermocycling cycles (5 to 55°C).

To assess fracture resistance, the samples were subjected to a compressive force using a universal testing machine. The force was applied to the middle third of the teeth at an angle of 148 degrees and a speed of 5 mm/min until fracture occurred. The recorded value represented the fracture resistance of each sample.

Data were analyzed using SPSS version 20, and one-way ANOVA and Tukey HSD tests were applied at a significance level of 0.05.

4. Results

This study included 48 samples, and the data from all samples were analyzed. The fracture resistance of the study groups is presented in Table 1. The results of the one-way ANOVA showed a significant difference among the study groups in terms of fracture resistance (P = 0.001). The results indicated that the fracture resistance of the CCP group had no significant difference with the FGP group (P = 0.862) and with the PCP group (P = 0.070). However, the fracture resistance of the CCP group was significantly different from the DP group (P = 0.022), with CCP exhibiting a significantly higher mean fracture resistance than the DP group. According to the data analysis, the fracture resistance of the FGP group had no significant difference with the CCP group (P = 0.862), while the fracture resistance of the FGP group was significantly different from the PCP and DP groups (P = 0.010 and P = 0.003, respectively). Thus, the FGP group exhibited a significantly higher mean fracture resistance than the PCP and DP groups. The results showed that the fracture resistance of the PCP group had no significant difference with the CCP group (P = 0.070) and the DP group (P = 0.964), while the fracture resistance of the PCP group was significantly different from the FGP group (P = 0.010).

5. Discussion

Fracture resistance is one of the most important characteristics of restorative materials, influencing the survival and durability of restorations. This study aimed to assess the fracture resistance of bulk fill composite restorations of anterior primary teeth using four different reinforcement methods. In the present study, the force was applied to the teeth at an angle of 148 degrees. In permanent teeth, this angle is 135 degrees, which imitates the direction of occlusal forces entering the maxillary incisors in class I occlusion. According to another study, this angle is considered to be 148 degrees in primary teeth because the primary incisors are in a more upright alignment than the permanent incisors.

One of the strengths of this study is the use of 5000 cycles of thermocycling at temperatures of 5 and 55°C to simulate the oral environment. Since these cycles in the mouth can affect the resistance and durability of the restoration, using them while reconstructing the clinical conditions can increase the accuracy of the results (19). The DPs were first introduced in the 1960s to increase the mechanical retention of amalgam restorations (17, 18). Bonsor reported the complications of DPs. To prepare the dentin for the placement of these pins, microcracks are created in the tooth structure. As the tooth undergoes occlusal forces, the microcracks extend and lead to cracks and tooth fractures (20). The possibility of this complication is higher in non-vital teeth, as these teeth are extensively destructed following access cavity preparation and root canal cleaning and shaping (17, 18, 20). Ibbetson claimed that DPs are contraindicated in teeth with root canal treatment (21).

The results of the current study showed that the fracture resistance of the DP and PCP groups was not significantly different, while both groups had significantly lower fracture resistance compared to the FGP and CCP groups. The creation of small cracks around the pin during drilling or even when placing the pin inside the dentin, and the lack of support from the root canal, explain why the fracture resistance was lower in the third and fourth study groups, in which DPs were used, compared to the other two groups. Similar to the current study, Ansari et al. reported similar findings (22). However, in the study by Ansari et al., the fracture resistance was 93.65, 95.92, 131.72, and 95.34 N in the composite post, fiber post, composite post with the DP, and DP groups, respectively, which were lower than the results of the current study (22). The difference in the type of composite resin used can explain this difference.

Table 1. The Mean and Standard Deviation of Fracture Resistance in Study Groups

Study Groups	Number of Samples	Mean ± SD	95% CI for Mean; (Min - Max)
CCP	12	758.03 ± 60.94	623.89 - 892.17
FGP	12	825.61 ± 74.54	661.53 - 989.69
PCP	12	540.10 ± 51.61	426.49 - 653.70
DP	12	498.88 ± 54.59	378.72 - 619.04

Abbreviations: CCP, conventional composite posts; FGP, fiberglass posts; PCP, pin and composite posts; DP, dentinal pin.

In the current study, bulk-fill composite resins were used, while in the study by Ansari et al., conventional resin composites were used and the layering technique was applied (22).

According to the results, the fracture resistance of the CCP and FGP groups was not significantly different, while both groups had significantly higher fracture resistance compared to the PCP and DP groups. Sharaf reported that the fracture resistance of FGP was significantly higher than that of composite posts (23). In the current study, the mean fracture resistance of the FGP group was higher than that of the CCP group; however, this finding was not significant. This discrepancy between the results of this study and those of Sharaf may be due to differences in the FGP, cement, and composite used (23). Sharaf conducted a clinical study, and their results indicated that FGP in anterior primary teeth lead to promising clinical outcomes (23). In their one-year follow-up, only 2 out of 30 treated teeth were extracted — one due to mobility and the other due to failed pulp treatment. Sharaf claimed that composite posts significantly increase fracture resistance compared to not using any posts (23).

In another study by Mosharrafian et al. (24), the fracture resistance of a bulk-fill and a conventional composite for the restoration of severely damaged primary anterior teeth was assessed. Unlike the current study, Mosharrafian et al. compared the fracture resistance of a bulk-fill composite and a conventional composite as restorative materials, while the current study evaluated the fracture resistance of a bulk-fill composite reinforced with CCP. Mosharrafian et al. concluded that the fracture resistance of bulk-fill composite was similar to that of conventional composite and suggested using bulk-fill composite in the restoration of severely damaged primary anterior teeth, as bulk-fill composites take less time (24).

The results of the current study found that the fracture resistance of bulk-fill composites reinforced with CCP was higher than with other reinforcement methods. Therefore, it can be concluded that in children, whose cooperation is not predictable during a dental session and where fast performance by the dentist can be advantageous, bulk-fill composites can be recommended as an option. If the primary teeth are severely damaged, reinforcing the bulk-fill composites with CCP can be beneficial.

5.1. Limitation

One of the limitations of this study was the lack of clinical assessment of the fracture resistance of bulk fill composite restorations using four different reinforcement methods. To address this limitation, 5000 cycles of thermocycling at temperatures of 5 and 55°C were used to simulate the oral environment.

5.2. Conclusions

The clinical significance of our study lies in its direct implications for pediatric dentistry, particularly in restoring severely damaged primary anterior teeth. The findings highlight that FGP and CCP provide significantly higher fracture resistance compared to other reinforcement methods such as PCP and DP. This demonstrates their suitability for clinical scenarios requiring durable restorations in primary teeth, especially in children, where maintaining dental integrity is crucial for aesthetics, speech, and mastication. This study emphasizes the advantage of using bulk-fill composites reinforced with fiberglass or composite posts, as this approach reduces chair time and improves efficiency, a key factor when treating uncooperative pediatric patients.

Furthermore, the use of FGP offers additional benefits of being tooth-colored, biocompatible, and aesthetically pleasing, meeting the demands of both patients and their parents. Composite posts, while cost-effective, still deliver adequate fracture resistance, making them a practical alternative. On the other hand, the results discourage the use of DPs due to their significantly lower fracture resistance and potential for inducing microcracks, which can compromise the integrity of the restoration. This aligns with modern dental practices favoring minimally invasive and

durable solutions. Overall, this study supports the adoption of advanced materials and methods in pediatric dental restoration to enhance outcomes for both patients and practitioners.

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Footnotes

Authors' Contribution: K. H.: Data collection, analysis writing - original draft preparation; Gh. A.: Conceptualization, methodology, project administration; A. A. S.: Conceptualization, methodology, project administration; D. M.: Writing - review and editing; F. A. F.: Writing - review and editing; N. P.: Conceptualization, methodology.

Conflict of Interests Statement: The authors declare no conflict of interests.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

Ethical Approval: The study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.DRC.REC.1400.045).

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