

Fracture resistance in severely damaged primary maxillary central incisors restored with glass fiber and composite posts: An in vitro study

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Abstract

Background. A variety of non-metal prefabricated posts, including fiber posts, can be used as an alternative to metal posts due to their numerous feasible characteristics. Further research is necessary to assess physical and mechanical properties of restorations supported by intracanal posts in primary teeth.

Objectives. The aim of the study was to compare fracture resistance of maxillary central incisors that were extensively restored with glass fiber and composite posts.

Material and methods. A total of 40 primary maxillary central incisors were randomly divided into 4 equal groups. Group 1 received conventional intracanal composite posts, group 2 was treated with prefabricated intracanal glass fiber posts, group 3 received precured intracanal composite posts, and group 4 was treated with intracanal lucent glass fiber posts. Crowns were restored using composite resin, and the specimens were subsequently exposed to 5,000 thermal cycles and progressive load at a crosshead speed of 0.5 mm/min until fracture. The fracture resistance values were compared via one-way analysis of variance (ANOVA) followed by Tukey's test for pairwise comparisons ($\alpha = 0.05$).

Results. The highest fracture resistance was observed in the lucent post group (343.2 N), followed by the prefabricated glass fiber post (284.8 N), conventional composite post (270.3 N) and precured composite post (261.1 N) groups, respectively. A statistically significant difference in the mean fracture resistance was observed among the 4 groups ($p < 0.05$). Pairwise comparisons revealed that the mean fracture resistance of the lucent post group was significantly higher than that of the other groups ($p < 0.05$).

Conclusions. All of the intracanal posts provided apt fracture resistance and can be used to restore severely damaged primary maxillary central incisors. However, lucent posts demonstrated significantly higher levels of fracture resistance.

Keywords: deciduous teeth, flexural strength, composite resins, post and core technique

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Highlights

- Lucent glass fiber posts demonstrated the highest fracture resistance, significantly outperforming other post types.
- Precured composite posts exhibited the lowest mean fracture resistance among all groups.
- Precured composite posts had the highest number of repairable fractures, followed by lucent and prefabricated glass fiber posts, and conventional composite posts.

Introduction

Dental caries is the most prevalent chronic disease in children.¹ Early childhood caries (ECC) is a category of dental caries in young children representing a certain pattern of decays. Primary maxillary central and lateral incisors and primary first molars of both jaws are most commonly involved.² Primary maxillary incisors are often most severely involved with deep caries, extending to the dental pulp space. In severe cases, ECC can lead to complete loss of the coronal structure of the teeth.³ Early childhood caries and early loss of primary teeth can result in abnormal tongue position, compromised masticatory force, impaired mastication, speech impairment, psychological issues arising from aesthetic problems, decreased facial vertical height, mouth breathing, etc. Moreover, literature states that children with ECC are more likely to develop growth retardation compared with non-ECC children.^{4–6}

Extensive reconstruction of primary anterior teeth has been challenging due to the small anatomical size of the crown, the large pulp space and the relatively limited cooperation of younger patients. Insufficient sound remnant tooth structure and low fracture resistance frequently result in subsequent restorative failures.^{7,8}

In the domain of dental restoration, particularly for anterior teeth, aesthetics can be equally important as the preservation of tooth structure or the restoration of the primary contour and function of the teeth. In this regard, composite resins are the optimal material of choice.

Due to structural differences between primary and permanent teeth, including their lower amount of accessible enamel for bonding purposes, the application of composite resins for the restoration of primary teeth can be quite demanding.⁹ In severely carious incisors that have undergone pulpectomy, the fabrication of an intracanal post for further retention is required to ensure optimal clinical durability of the composite restoration.¹⁰ Various types of intracanal posts are commercially available for pediatric patients, such as prefabricated posts,¹¹ γ , α^{11} and Ω^{12} forms of orthodontic wires, retentive cast posts,¹³ short composite resin posts,¹⁴ fiber posts,¹¹ and biological posts.¹⁵

Recently, a range of non-metal prefabricated posts have been introduced, including fiber posts, which exhibit excellent biocompatibility with different core materials, high fatigue, high corrosion resistance, and high tensile

strength.¹⁶ These posts have been proposed as an alternative to prefabricated metal posts.

Despite the existence of several clinical reports on restorations in primary teeth and their follow-up courses, comprehensive data regarding the physical and mechanical properties of restorations supported by intracanal posts, particularly fiber posts, is lacking. Moreover, the application of precured composite posts in primary teeth has not been assessed. In light of these observations, this study aimed to compare the fracture resistance of prefabricated glass fiber posts, precured composite posts, lucent glass fiber posts, and conventional composite posts for the restoration of severely damaged primary maxillary central incisors.

Material and methods

This study was conducted on 40 extracted primary maxillary central incisors. The study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.DRC.REC.1398.222).

The sample size was calculated to be 40, assuming α of 0.05, β of 0.2 and study power of 80%.

The teeth were immersed in 0.5% chloramine T for 7 days, and then stored in distilled water at 4°C until use. Distilled water was periodically refreshed.

Primary maxillary central incisors with at least $\frac{2}{3}$ of sound root structure were included in the study. The teeth were decoronated at 1 mm above the cemento-enamel junction (CEJ) by a fissure diamond bur and a high-speed handpiece. Thereafter, the root canals were instrumented 1 mm shorter than their established working length by files that were 3 sizes larger than the initial file size. Patency and canal rinsing were carried out using saline. Upon drying with paper points, the canals were filled with calcium hydroxide paste along with iodoform (Forendo paste; Metapex, Colmar, USA), 1 mm shorter than their established working length. Then, the teeth were randomly divided into 4 equal groups by block randomization, and coded. The coronal 4 mm of the canal was emptied by a fissure diamond bur to create a post space. Subsequently, a light-cure cavity liner (Lime-Lite™; PULPDENT Corporation, Watertown, USA) was applied in 1-mm thickness and cured by a light-emitting diode (LED) curing unit for 40 s. Excess material was carefully

removed, preserving a 3-mm-long corono-apical space for the placement of the post. The remaining procedures were performed according to group indicators and the pertaining manufacturers' instructions.

Conventional composite posts

In group 1, the teeth were rinsed and dried. After acid etching and rinsing for 15 s and 10 s, respectively, the teeth were gently dried to allow for the preservation of slight moisture in the dentin. Two layers of bonding agent (Single Bond; 3M ESPE, St. Paul, USA) were applied using a microbrush, gently air-thinned for 2–5 s, and light-cured for 10 s. Subsequently, composite resin (3M™ Filtek™ Z250 Universal Restorative; 3M ESPE) was applied incrementally into the canal, condensed and light-cured. A 4 mm-high tooth crown was formed by a plastic filling instrument. Each layer of composite resin for crown restoration had a thickness of 2 mm and was light-cured for 20 s.

Prefabricated glass fiber posts

In group 2, cylindrical glass fiber posts (Reforpost; angelus®, Londrina, Brazil) with a diameter of 1.1 mm were cut into individual 5-mm segments using diamond burs and a high-speed handpiece, under copious water irrigation. Each post was aimed to be 3 mm inside the canal, with the remaining 2 mm available for utilization as a core. The posts were cleaned with alcohol and air-dried. The canal was prepared through rinsing and gentle drying so that the dentin remained slightly moist. Dual-cure cement (Embrace™ WetBond™ Resin Cement; PULPDENT Corporation) was applied, the posts were inserted in the canals, and excess cement was eliminated. The cement was subsequently light-cured for 40 s. After acid etching and rinsing for 15 s and 10 s, respectively, the teeth were gently dried to ensure that the remnant exposed dentin remained slightly moist. The application of the bonding agent and composite was performed as outlined for group 1 to achieve the final coronal restoration.

Precured composite posts

In the third group, 5 fiber posts with a diameter of 1.1 mm were selected as the initial models for the duplication of their dimensional characteristics in precured composite posts. The fiber posts were affixed onto clear plastic acrylic resin, and a vacuum machine (MINISTAR S®; SCHEU-DENTAL GmbH, Iserlohn, Germany) formed the plastic acrylic resin around the fiber posts like a mold. Subsequently, the fiber posts were removed, and the composite was applied, condensed and cured for 40 s. Thereafter, the molds were discarded and the composite posts were cut into 5-mm-long sections using diamond burs and a high-speed handpiece, under copious water irrigation.

The aim was to position each post 3 mm inside the canal, with the remaining 2 mm serving as a prosthetic core. The canal was prepared through rinsing and gentle drying so that the dentin remained slightly moist. Dual-cure cement (Embrace™ WetBond™ Resin Cement; PULPDENT Corporation) was applied in the canal, the post was inserted, and excess cement was eliminated. Then, the cement was light-cured for 40 s. After acid etching and rinsing for 15 s and 10 s, respectively, the teeth were gently dried to ensure that the remnant exposed dentin remained slightly moist. The application of the bonding agent and composite was performed as outlined for group 1 to achieve the final coronal restoration.

Lucent glass fiber posts

In group 4, cylindrical lucent glass fiber posts (Reforpost; angelus®) with a diameter of 1.1 mm were cut into 5-mm segments with the use of diamond burs and a high-speed handpiece, under copious water irrigation. The posts were cleaned with alcohol and air-dried. The canals were then rinsed and dried, ensuring that the dentin remained slightly moist. Dual-cure cement (Embrace™ WetBond™ Resin Cement; PULPDENT Corporation) was applied to the canal, the post was inserted, and excess cement was eliminated. Subsequently, the cement was light-cured for 40 s. The application of the bonding agent and the composite was performed as outlined for group 1 to achieve the final coronal restoration.

The length and crown height of the posts were 3 mm and 4 mm, respectively, in all groups.^{7,11} All restorations were finished with composite finishing burs and polished under copious water irrigation. Restored teeth were then mounted in acrylic resin molds, leveled at 1 mm below their CEJs, and subjected to 5,000 thermal cycles between 5°C and 55°C.

To assess the fracture resistance, the teeth were subjected to compressive load at a 148° angle¹⁷ with a crosshead speed of 0.5 mm/min¹⁶ in a universal testing machine (UTM) (ZwickRoell ProLine Z050; ZwickRoell, Ulm, Germany) (Fig. 1,2). The middle third of the palatal surface close to the incisal edge underwent loading until fracture. The load at fracture was recorded as fracture resistance in Newtons [N].

To determine the mode of failure, the fractured specimens were examined by an observer who was blinded to the group allocation of the specimens. The mode of failure was categorized as repairable (fractures above CEJ) or irreparable (fractures below CEJ).

Statistical analysis

The data was analyzed using the IBM SPSS Statistics for Windows software, v. 20.0 (IBM Corp., Armonk, USA). The Kolmogorov–Smirnov test was used to assess the normality of data, analysis of variance (ANOVA) was

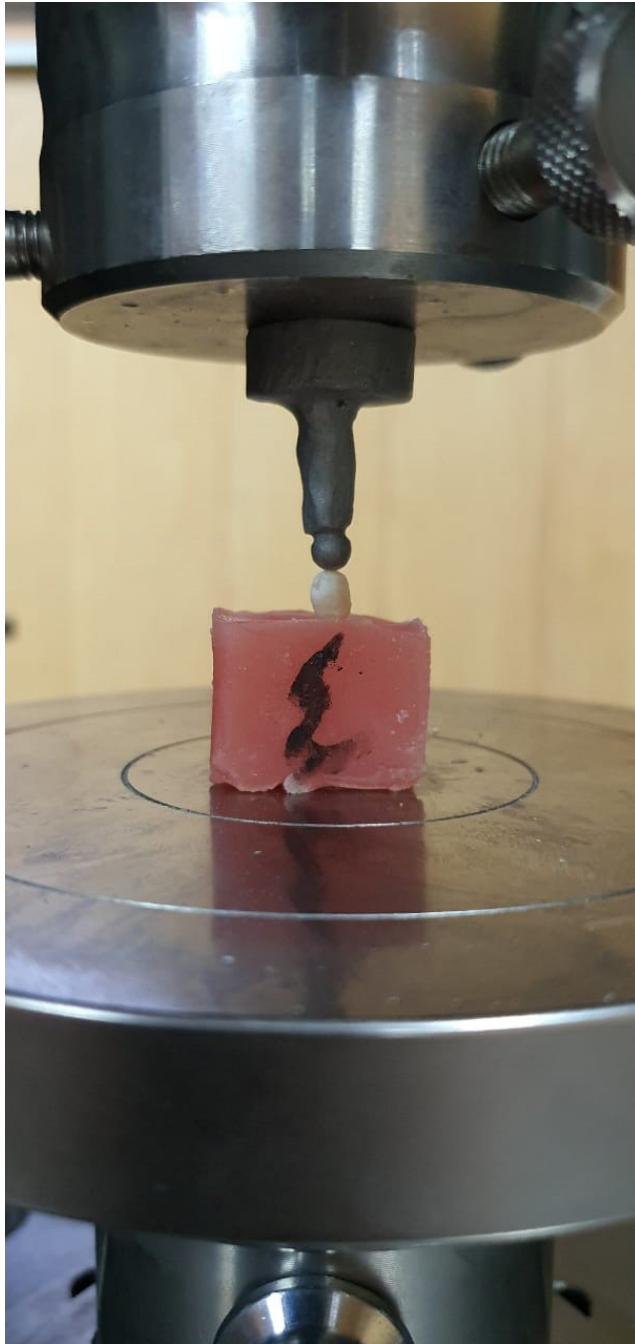


Fig. 1. Process of loading posts in the universal testing machine (UTM) (ZwickRoell ProLine Z050) at a crosshead speed of 0.5 mm/min

utilized for general comparisons, and Tukey's post hoc test was employed for pairwise comparisons. The value of $p < 0.05$ was considered statistically significant.

Results

The lucent post group exhibited the highest mean fracture resistance, while the precured composite post group demonstrated the lowest fracture resistance. The Kolmogorov–Smirnov test confirmed the normality of data distribution ($p \geq 0.05$). The mean fracture



Fig. 2. Universal testing machine (UTM) (ZwickRoell ProLine Z050)

resistance of the study groups is presented in Table 1. Analysis of variance revealed a significant difference in fracture resistance among all 4 groups ($p < 0.001$). Thus, pairwise comparisons were conducted using Tukey's test (Table 2). The lucent post group demonstrated a significantly higher fracture resistance compared to the other groups ($p < 0.05$). However, the differences among the other groups were non-significant.

An examination of the failure modes among the 4 groups revealed no statistically significant differences between them ($p = 0.116$). The frequency of repairable and irreparable fractures across all groups is presented in Table 3.

Table 1. Fracture resistance of the study groups

Group	Fracture resistance [N]		
	$M \pm SD$	95% CI	
		lower bound	upper bound
Conventional composite posts	270.3 $\pm$ 30.8	248.25	292.35
Prefabricated glass fiber posts	284.8 $\pm$ 23.8	267.74	301.87
Precured composite posts	261.1 $\pm$ 33.3	237.27	284.96
Lucent glass fiber posts	343.3 $\pm$ 50.4	307.23	379.30

M – mean; SD – standard deviation; CI – confidence interval.

Table 2. Pairwise comparisons of the study groups regarding fracture resistance

Group (I)	Group (J)	p -value
Conventional composite posts	prefabricated glass fiber posts	0.803
	precured composite posts	0.940
	lucent glass fiber posts	0.000*
Prefabricated glass fiber posts	precured composite posts	0.463
	lucent glass fiber posts	0.000*
Precured composite posts	lucent glass fiber posts	0.000*

* statistically significant ($p < 0.05$, Tukey's post hoc test).

Table 3. Frequency of repairable and irreparable fractures in the study groups

Failure mode	Lucent glass fiber posts	Precured composite posts	Prefabricated glass fiber posts	Conventional composite posts
Irreparable	3 (30)	2 (20)	3 (30)	4 (40)
Repairable	7 (70)	8 (80)	7 (70)	6 (60)

Data presented as frequency (percentage) (n (%)).

Discussion

Obtaining a feasible fracture resistance with restorative materials is of crucial importance and can determine the durability of the restoration.¹⁶ Fiber-reinforced composites consist of fibers embedded in a resin matrix. These composites have favorable mechanical properties, including optimal tensile and bond strength, translucency and facile manipulation.¹⁸ In comparison to metal posts, fiber-reinforced composites demonstrate higher levels of flexibility, an elasticity efficiency comparable to dentin, and optimal aesthetics. Moreover, they enable the formation of an integrated root–post complex.¹⁸ Fiber-reinforced composites are available in prefabricated and conventional forms. Precured composite posts had not been previously employed in pediatric dentistry.

The present study compared fracture resistance in prefabricated glass fiber posts, precured composite posts, lucent glass fiber posts, and conventional composite posts in restored severely damaged primary maxillary

central incisors. The results indicated that the highest fracture resistance belonged to the lucent post group (343.27 $\pm$ 50.37 N). This value was significantly different from the other groups ($p < 0.05$). Sharaf reported that glass fiber posts provided a significantly lower fracture resistance (230.6 N) compared to composite posts (277.9 N).¹⁹ However, the difference between the mean fracture resistance of glass fiber and composite posts was statistically insignificant in the present study. Additionally, in the study conducted by Sharaf,¹⁹ the mean fracture resistance of composite and glass fiber posts was found to be lower than in our study. This discrepancy may be attributed to differences in the type of employed posts, cements and composite resins. In addition, Seraj et al. reported the mean fracture resistance of composite posts to be 564.4 N, whereas, in the present study, the value of 270.3 N was obtained for conventional composite posts.²⁰ This discrepancy can be attributed to the 5,000 thermal cycles to which we subjected our specimens, which is in contrast with the study by Seraj et al.²⁰ Eshghi et al. reported no statistically significant differences in the retention of teeth clinically restored with fiber posts, composite posts, or metal posts, inspected after 12 months.²¹ The authors demonstrated 90%, 98% and 100% success rates, respectively, which aligns with the studies by Judd et al.²² and Sharaf,¹⁹ who reported 100% success rates in teeth restored with composite posts and fiber posts.

The studies demonstrate that prefabricated posts with a smaller diameter can improve fracture resistance in teeth.²³ However, researchers often focus on the mesio-distal and labio-palatal widths of teeth at CEJ. They categorize specimens into different groups to mitigate potential confounding results.^{23–26} Sharaf stated that the application of fiber posts in severely damaged primary anterior teeth can be a reliable method.¹⁹ Only 2 out of 30 teeth were extracted over 1-year follow-up, due to mobility or failed pulp therapy. According to Sharaf, the application of fiber posts significantly increased the mean fracture resistance of teeth in vitro.¹⁹ Similar to Seraj et al.²⁰ who stated that composite posts yield superior results over no post applications, the author observed that the application of composite posts significantly increased fracture resistance, as compared to teeth restored without intracanal posts.^{10,19} In a similar study, Gujar and Indushekar compared the retentive strength of composite posts, γ orthodontic wires and glass fiber posts in primary incisors.²⁷ Their findings indicated that glass fiber posts demonstrated a significantly higher tensile strength than composite posts. Notably, the composite post group displayed the lowest tensile strength among all groups. The enhanced strength of fiber posts can be attributed to the stronger post–cement bond and superior light transfer, which enhances cement polymerization at the apical region. Memarpour et al. evaluated the retentive strength of composite posts, glass fiber posts and polyethylene posts cemented with resin cement and

flowable composite.²⁸ They reported that composite posts with undercuts yielded the maximum mean retentive strength. However, the difference between composite posts and glass fiber or polyethylene fiber posts was not significant when cemented with flowable composite. The authors attributed the higher retentive strength of teeth restored using composite posts with undercuts to both their mechanical and micro-mechanical bonding to tooth structure. Nevertheless, this method is associated with an elevated risk of lateral root perforation. In addition, they correlated the higher retentive strength of posts cemented with flowable composite to the lower viscosity of flowable composite and, consequently, its better adaptation with prepared canal walls when compared to posts cemented with resin.²⁸

In the present study, the mode of failure of teeth was indicated through the categorization of cracked teeth into 2 groups, namely repairable and irreparable, using CEJ as the reference. However, Varvara et al. categorized modes of failure in permanent central incisors as repairable and irreparable, with the alveolar bone margin as the reference.²⁶ Since crown lengthening operation is not routinely performed for pediatric patients, CEJ was used as a reference to differentiate the reparability of primary maxillary central incisors. The frequency of irreparable fractures was 40% in conventional composite posts, 30% in glass fiber posts, 20% in precured composite posts, and 30% in lucent posts, with no statistically significant differences observed.

Pithan et al.¹⁴ reported 80% of glass fiber posts and 47% of composite posts to cause an adhesive mode of failure, whereas Gujjar and Indushekar²⁷ provided values of 100% and 20%, respectively. This difference may be attributed to the occurrence of adhesive failure at the cement–root canal interface. In both studies, composite resin was used for the cementation of posts.^{14,27} In our study, dual-cure resin cement was utilized for the cementation of glass fiber posts, due to its provision of high bond strength, facile manipulation and consequent accelerated procedure, longer working time, higher degree of conversion, and optimal mechanical properties.^{29–31}

A study by Bitter and Kielbassa compared the efficacy of fiber posts and cast posts, revealing that the former resulted in more repairable fracture patterns.³² In addition, Cai et al. observed that upon the application of fiber posts, the fracture site was limited to the coronal third of the root.²⁵

In the present study, the minimum fracture resistance was 230 N. Mountain et al. reported that the maximum bite force at 3 points on first molars, second molars and central incisors ranged from 12.61 N to 353.6 N (with a mean value of 196.6 N) in children aged 3–6 years.³³ According to Owais et al., the maximum bite force was 126 N in the early primary stage and 240 N in the late primary stage.³⁴ Of note, bite force values are considerably higher in the oral cavity environment and under

physiological conditions. Furthermore, the continuous application of stress can increase these values. In the current study, a mean fracture resistance of 237–370 N was observed, which remained within the clinically acceptable range for all groups. The thermocycling procedure was conducted to better simulate physiologic stresses.

A standardized canal diameter is necessary to obtain accurate results in terms of evaluating the impact of post adaptation with canal walls on fracture resistance. Post adaptation could be compared between composite and conventional posts, as well as prefabricated glass fiber posts. However, the lack of standardization of the canal diameters is a limitation of the current study. In addition, the in vitro design of our study constrains the generalization of the obtained data to the clinic.

Controlled clinical trials are warranted to obtain more clinically reliable results. Moreover, since bond failure has been suggested as a possible cause of fracture in glass fiber posts, the comparison of different adhesive systems for the cementation of fiber posts necessitates further studies.

Conclusions

All of the intracanal posts studied demonstrated adequate fracture resistance and are suitable for the restoration of severely damaged primary maxillary central incisors. However, lucent glass fiber posts exhibited significantly higher fracture resistance.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.DRC.REC.1398.222).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Use of AI and AI-assisted technologies

Not applicable.

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