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Original Article

Fracture resistance of three different posts in restoration of severely damaged primary anterior teeth: An *in vitro* study

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ABSTRACT

Background: Restoration of anterior primary teeth with severe caries lesion is a big challenge. The aim of this study was to compare the fracture resistance of three types of post, including composite resin, customized quartz fiber and prefabricated glass fiber in restoration of severely damaged primary anterior teeth.

Materials and Methods: Sixty extracted human primary maxillary incisors were randomly divided into three groups: Group 1: Customized quartz fiber post, Group 2: Composite post and Group 3: Prefabricated glass fiber post. Due to the effect of bonded area on the fracture resistance, the bonded surface of each sample was measured 1 mm above cementoenamel junction. An increasing force was subjected with a crosshead speed of 0.5 mm/min by a universal testing machine until fracture occurred, and the failure mode was assessed afterwards. Data were analyzed using One-way analysis of variance and Kruskal–Wallis tests. The level of significance was considered at $P < 0.05$.

Results: The mean fracture resistance values of three groups were 343.28 N, 278.70 N and 284.76 N, respectively. Although customized quartz fiber post showed the greatest fracture resistance, statistical analysis revealed no significant difference between groups ($P = 0.21$). The mean fracture strength values of three groups were 12.82 N/mm^{-2}, 11.93 N/mm^{-2} and 11.31 N/mm^{-2}, respectively; however, the differences were not statistically significant ($P = 0.72$). Favorable failure mode was more frequent in all groups ($P = 0.12$).

Conclusion: Within the limitations of this study, it can be concluded that all three types of studied posts can be successfully used to restore badly destructed primary anterior teeth.

Key Words: Composite resins, post techniques, primary teeth

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INTRODUCTION

Dental caries is the most common chronic disease of childhood.[1] Dental caries in very young children is known as early childhood caries that clinically shows a distinct pattern. The teeth most involved include maxillary central, lateral incisors and first primary molars in both jaws.[2] Maxillary primary incisors are usually extremely involved (deep decay extends to the pulp) and in some cases can lead to complete loss of coronal structure.[3] In the past, the extraction of these teeth was the only treatment option. The early loss of these teeth leads to an abnormal position of the tongue, reduction of bite force, mastication problems, speech disorders, psychological problems due to esthetic concerns, reduction of facial vertical height and mouth breathing habit.[4-6]

Extensive restorative treatments of anterior primary teeth have always been a big challenge in pediatric dentistry. The restoration of these teeth is difficult due to the small size of the crown, relatively large pulp chamber and the age of the child. Lack of strength of

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restorations and consequently their fracture are often associated with inadequate remaining sound tooth structure.[7,8]

In addition to preserving the tooth structure and reconstructing the primary form, considering the beauty and use of composite resins are highly regarded in anterior teeth. Meanwhile, the use of composite restorations for primary teeth harbors some problems due to structural differences between primary and permanent teeth such as less available dentin for bonding.[9]

In severe decayed incisors where pulpectomy is carried out, intracanal retention is necessary for durability of the composite crown.[10] Several types of posts are available to use in pediatric dentistry such as prefabricated posts,[11] orthodontic wires in "α", "γ"[11] and "Ω" form,[12] cast post with macro retentive element,[13] reverse metallic post,[14] composite resin posts,[15] fiber posts[11] and biologic posts.[16]

In recent years, many non-metallic prefabricated posts have been introduced such as fiber based posts with excellent properties like the biocompatibility with different core materials, fatigue and corrosion resistance and high tensile strength, which are considered as a substitute for metallic prefabricated posts.[17]

Currently, the available fiber-based posts consist of fibers of carbon or silica surrounded by a matrix of polymer resin. The silica-fiber posts, being translucent and more tooth colored, are also called glass-fiber and quartz-fiber.[18] Fiber reinforced composite posts are available in both prefabricated and customized forms.[19]

Despite numerous clinical reports on primary teeth restoration,[11-13,16] there is not enough information about the physical and mechanical properties of post-supported restorations, especially fiber posts. Furthermore, no study has been conducted on customized quartz fiber posts so far. The aim of this *in vitro* study was to evaluate and compare the fracture resistance of three types of post, including composite resin, customized quartz fiber and prefabricated glass fiber.

MATERIALS AND METHODS

Sixty extracted maxillary anterior primary teeth with intact roots were selected for this study. The teeth were cleaned and stored in 0.5% chloramine-T solution for 1 week and thereafter stored in distilled water at 4°C until use. The teeth were sectioned horizontally 1 mm above the cement-enamel junction with a diamond bur in a high-speed hand piece, and the root canals were prepared to size 45 by k-files (Mani, Japan) 1 mm short of the apex. Then, the root canals were dried using paper points and filled with calcium hydroxide paste with iodoform (Metapex, META BIOMED Co. Ltd, Korea). After removing 4 mm of Metapex from the coronal part of canals, the orifices were covered with 1 mm light cured Dycal Lime-Lite (Pulpdent Co, MA USA) and cured by light-emitting diode (LED) (Radii, SDI co) for 40 s to leave 3 mm space for posts.

Then, the teeth were randomly divided into three groups using block randomization. Afterwards, each sample received a code, including the group and the number of sample. Due to the effect of the bonded surface on the samples' fracture resistance, photographs were taken from the samples from the same distance with the scale on the picture [Figure 1]. Then, the bonded cross-sectional area of each tooth was calculated using two methods by Autocad 2012 English software [Figure 2]. In the first method:

a. The bonded cross-sectional surface (total area of the tooth cross section minus the canal cross section) was calculated precisely, and in the second method.
b. Which is a simpler technique, the inscribed rectangle area on the outer surface of the tooth was calculated.

The reason that this method is simpler is that instead of taking a photograph, the tooth mesiodistal and the buccolingual diameter (the equivalent of the length and width of encompassing rectangle) can be computed by a caliper to obtain the inscribed rectangle area. After performing the above steps, the following steps were performed in each group. (It

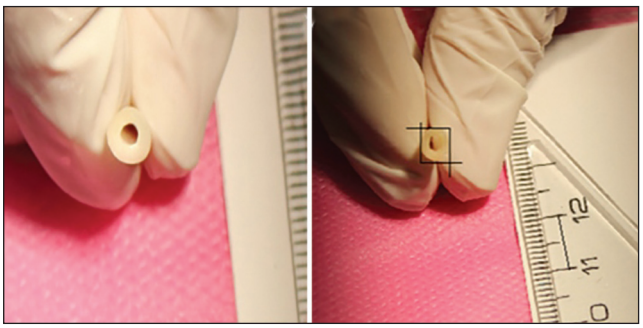

Figure 1: Photographs taken from samples for calculation of the bonded area.

should be noted that all times were in accordance with the manufacturer's instructions).

Group 1 (Customized quartz fiber post)

To prepare this type of post, three units quartz fiber reinforced pontics substructure (RTD co, France) were used. These Pontics were cut with a disc in lengths of 5 mm and were formed with a diamond bur to conform to the canal. Following irrigation, the post space was lightly dried. Dual-cured cement (Embrace WetBond Resin Cement, pulpdent Co., USA) was placed into the canal, and the post was seated. The excess cement was removed and cured with LED for 40 s.

The tooth was etched with etching gel (Scotchbond™ Etchant, 3M ESPE, MN, USA) for 15 s and rinsed for 10 s. Then, two consecutive coats of light cured bonding agent (Adper Single Bond, 3M ESPE, MN, USA) were applied on the etched surface, uniformly dispersed by a compressed air blast for 2-5 s and cured for 10 s. Finally, the teeth were incrementally restored with composite resin Filtek Z250 (3M ESPE, USA) and each 2 mm was cured for 20 s and 4 mm crown was formed.

Group 2 (Composite resin post)

Acid was applied on the rinsed and dried tooth and intracanal area for 15 s. Acid was rinsed for 10 s and dried, whereas the dentin areas remained slightly wet.

Then, two consecutive coats of light cured bonding agent were applied on the etched surface, uniformly dispersed by a compressed air blast for 2–5 s and cured for 10 s. The composite was condensed into the canal and placed incrementally to restore the crown with 4 mm height.

Group 3 (Prefabricated glass fiber post)

Proper lengths (5 mm) of glass fiber post (Reforpost, Angelus, Brazil) with a diameter of 1.1 mm were cut with a diamond bur using a high-speed hand piece under copious water cooling and were cleaned with alcohol. After irrigation of the post space, it was lightly dried, and the dual-cured cement and the post were placed in the canal. The excess cement was removed, and the cement was cured for 40 s. Further steps were performed similarly to the first group. It is noteworthy that the post length and the crown height were 3 mm and 4 mm, respectively in all groups [Figure 3].

All samples were polished after restoration by composite polishing bur and high-speed hand piece under water cooling.

Then, the teeth were mounted in acrylic resin blocks, so that 1 mm of the cervical part of the root was out of acrylic resin. Next, the samples were thermocycled for 5,000 cycles between water baths at 5°C and 55°C with a dwell time of 30 s per bath.

To evaluate the fracture resistance, the samples were fixed in a special fixture and received a progressively increasing load with a crosshead speed of 0.5 mm/min at 148°[17,20] along the long axis of the primary incisors on the mid-palatal surface in a Universal Testing Machine (Zwick, Germany) until fracture occurred. In the current study, the force was imposed on the tested teeth at an angle of 148°. This angle is 135° in the permanent teeth that simulate occlusal forces on maxilla incisors in class 1 occlusion.[21] Because primary incisor teeth are straight, this angle is considered 148° as suggested by Baker *et al*.[20]

By dividing the fracture resistance values by bonded cross-sectional area, which has been described previously, the sample fracture strength (stress) was calculated (N/mm^{-2}). The fracture mode was assessed. Those fractures were considered favorable if it occurred above the cementoenamel junction (CEJ) and

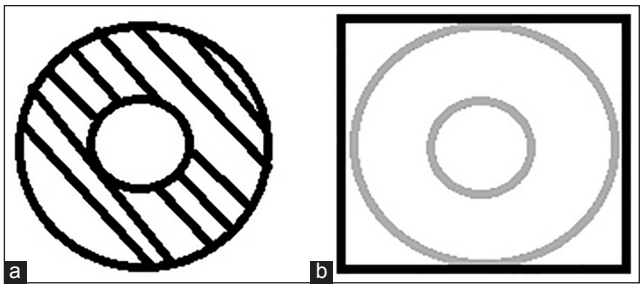

Figure 2: The bonded cross-sectional area and inscribed rectangle were calculated. (a) Bonded surface; total area of the tooth minus the canal cross section (the area of shaded part). (b) The inscribed rectangle area on the outer surface of the tooth.

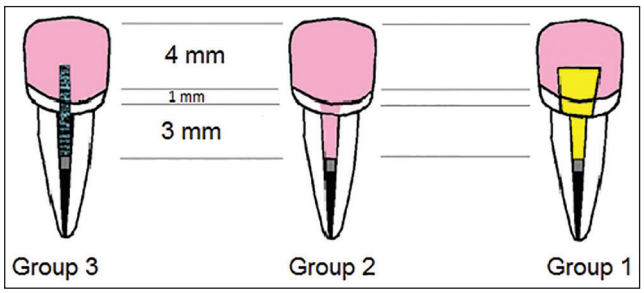

Figure 3: Schematic view of three study groups. Group 1: Customized quartz fiber post, Group 2: Composite post and Group 3: Prefabricated glass fiber post.

was restorable. Non-favorable fractures are defined as fractures below CEJ which are not repairable.

Data were analyzed using statistical package for the social sciences software version 20 (SPSS Inc., Chicago, IL, USA) using one way Analysis of Variance (ANOVA) test, Kruskal–Wallis test and intraclass correlation test (ICC). The level of significance was considered at $P < 0.05$.

RESULTS

The average cross-sectional area of the bonded surface for each group of specimens is presented in Table 1. To assess the possible effect of different bonded surfaces on the fracture resistance, one-way ANOVA was applied, and no statistically significant difference was found ($P = 0.44$).

The fracture resistance and fracture strength of three groups are shown in Table 2. According to the results of one-way ANOVA, the mean of fracture resistance and fracture strength showed no significant difference in three groups ($P > 0.05$).

The Kruskal–Wallis test was used for assessing the fracture mode distribution between three study groups. A fracture line above the CEJ was recorded for 90% of specimens in prefabricated glass fiber post and 60% and 85% in composite post and customized quartz fiber post, respectively [Table 3]. No statistically significant differences were found between the study groups in terms of the location of fracture line against CEJ ($P = 0.12$).

In this study, ICC was used to measure the compliance of the cross-sectional area of tooth measurements with two methods of bonded cross-sectional area and inscribed rectangle. Accordingly, the compliance obtained was 0.725 ($P < 0.001$), which indicated a very good adjustment of measurements in these two methods.

Table 1: The average cross-sectional area of the bonded surface of each group (mm²)

Group	The cross-sectional area of the bonded surface (total area of tooth cross-section minus the canal cross-section)
	Mean ± SD
Customized quartz fiber post	28.18±12.62
Composite post	24.39±6.33
Prefabricated glass fiber post	26.72±7.76
P	0.44

SD: Standard deviation

DISCUSSION

Fracture resistance is one of the main characteristics of restoration materials, especially during mastication and the most important factor in achieving a durable restoration.[17] Since few studies have been performed on the fracture resistance of primary teeth, we had some limitations in comparing the results of our study with others.

In the current study, the customized quartz fiber post group (343.28 N) had the maximum fracture resistance and the composite post group (278.7 N) showed the lowest fracture resistance; however, the difference between three groups was not statistically significant. This difference may be due to high tensile strength and similar modulus of elasticity to dentin in quartz fiber posts.[22] In addition, the customized posts are formed by the dentists. These posts maintain the shape and strength of the roots, and drilling and shaping the canals are not required.[19]

Our findings were consistent with the results of the study by Hegde *et al*., in which the fracture strength of three posts including cast post, glass fiber post and quartz fiber post was compared in the permanent teeth. Hegde *et al*. showed that although the mean fracture strength was greater in quartz fiber post (480.9 N) than glass fiber post (432.2 N), the difference between the two groups was not statistically significant.[23] The higher fracture strength in the study of Hegde *et al*. can be attributed to larger teeth diameter and

Table 2: The mean fracture resistance and fracture strength values in each group

Group	Fracture resistance (N)		Fracture strength (N/mm)	
	Mean ± SD	Minimum-maximum	Mean ± SD	Minimum-maximum
Customized quartz fiber post	343.28±147.39	267.5-419	12.82±7.52	9.3-16.34
Composite post	278.70±113.94	225.4-232	11.93±5.24	9.47-14.38
Prefabricated glass fiber post	284.76±94.60	240.9-329	11.31±4.45	9.23-13.39
P	0.21		0.72	

SD: Standard deviation

Table 3: Distribution of fracture mode in the three study groups

Fracture mode	Groups			*P*
	Customized quartz fiber post *n* (%)	Composite post *n* (%)	Prefabricated glass fiber post *n* (%)	
Favorable	17 (85)	13 (65)	18 (90)	0.12
Nonfavorable	3 (15)	7 (35)	2 (10)	

enamel area available for bond, higher post length, lack of thermocycling and use of different cements. In contrast to our results, the fracture resistance was increased significantly when the fiber post was used compared to the composite post in Sharaf study.[24] In their study, the means of fracture resistance in the composite post and glass fiber post groups were 230.6 and 277.9 N, respectively, which were lower than our results.[24] This difference may be due to the difference in post, cement and composite resin. In a study done by Ambica *et al*., the fracture resistance of permanent teeth was evaluated after restoration by four methods: Without using post, carbon fiber post, glass fiber post, and dentin post. The mean fracture resistance in glass fiber post group was 603.44 N,[25] which can be due to the larger diameter of the tooth and the posts. Further, different posts, cements and specimens used in their study did not undergo thermocycling.

In an *in vivo* study, Eshghi *et al*. showed that retention of different techniques, including fiber post, composite post and reverse metallic post did not change significantly after 12 months follow-up and was 90, 98 and 100%, respectively.[26] This finding is consistent with the results of the Sharaf and Judd *et al*. that reported 100% success for the composite posts and fiber posts.[24,27]

According to previous studies, the diameter of the tooth is one of the factors affecting fracture resistance.[28] The researchers reduce this effect by measuring and matching the mesiodistal and buccopalatal width of samples in the CEJ area in different groups.[28,29] In this study, we evaluated and compared the specimen's fracture strength by exact calculation of the cross-sectional area, which is one of the strengths of the current study. This effect has not been considered in other studies. Despite using the "fracture strength" term in other studies, in fact, they have calculated the fracture resistance according to the definitions. In the current study, the customized quartz fiber post group (12.82 N/mm^2) had the highest fracture strength and prefabricated glass fiber post group (11.31 N/mm^2) had the lowest fracture strength, although the difference was not statistically significant between groups. Due to lack of similar studies, we were unable to compare our results. In this study, in addition to the exact calculation of the cross-sectional area, we also calculated the inscribed rectangle area of the outer surface of the tooth and compared these two methods. The results of this study showed that these two methods are in good agreement with each other, which can be due to the small tooth dimensions. Due to the very good agreement between these two methods, it is possible to calculate the inscribed rectangle rather than the cross-sectional area to match the samples. Hence, the mesiodistal and buccolingual widths of the tooth can be measured by a digital caliper to calculate the inscribed rectangle area.

The clinical study of Sharaf showed that the use of fiber posts in severely decayed anterior primary teeth is an acceptable method. After 1 year, of 30 teeth only two teeth were extracted, one due to luxation and the other one because of pulp therapy failure. In their *in vitro* study, Sharaf showed that fiber posts increased the fracture resistance of the teeth significantly and the use of composite post compared to using no post significantly increased the fracture resistance.[24]

Gujjar and Indushekar compared the retentive strength of three different posts, including composite post, orthodontic wire γ and glass fiber post in the primary incisors. Their findings showed that the glass fiber post group had the highest, and the composite post group had the lowest tensile strength, indicating a statistically significant difference. They attributed the higher retentive strength of fiber posts to the better bond of these posts to the cement and better light transmission through these posts, which improves the polymerization of the cement in the apical area.[30]

In this study, the fracture mode was divided into two categories: favorable (fractures above the CEJ) and catastrophic (fractures below the CEJ). Varvara *et al*. studied the permanent central tooth and considered cracks above the bone margin as restorable and cracks under the margin non-restorable in permanent central incisors.[28] Some other researchers have considered the incisal third of the root as restorable,[31] but since crown lengthening surgery is not performed routinely in pediatric dentistry, the fractures above the CEJ are considered as restorable fractures.

In the current study, the frequencies of non-restorable fracture mode were 35% in composite group, 15%

in customized quartz fiber post group and 10% in prefabricated glass fiber post group. Although the difference was not significant, it indicated that the use of fiber post reduced catastrophic fractures, which is consistent with the results of the study carried out by Sherfudhin *et al.*[29] In the study of Hegde *et al*., 100% of glass fiber and quartz fiber posts had restorable fracture mode; however, 13.3% of the cast posts showed restorable fracture.[23] Pithan showed that the fracture mode of 80% for glass fiber posts and 47% for composite posts were adhesive,[32] whereas these values in the study of Gujjar and Indushekar were 100% and 20%, respectively.[30] They attributed the adhesive fracture to the bond failure between cement and root canal. It should be noted that the mentioned studies used resin composite for post cementation. Therefore, in this study, dual cured resin cements were used to cement fiber posts. Among other benefits, we can refer to the high bond strength, reduced chairside time increased working time, high degree of conversion and good mechanical properties.[21,33-35]

The length of the post was considered 3 mm in our study (1/3 of the canal length). This is the proper length of the post in the primary teeth; hence, it does not interfere with the eruption of permanent teeth.[7,11]

Another strength of the present study is the thermocycling of samples between 5°C and 55°C for better simulation of the oral environment. Since these cycles can affect the strength and durability of the restoration in the mouth,[36] they can reduce the fracture resistance and increase the accuracy of results in addition to reconstructing the clinical conditions.

In a study conducted by Mountain *et al*., carried out on 3 to 6-year old children, the maximum bite force measured at three areas, including the first and second molars and central incisors was from 12.61 to 353.6 N (mean = 196.6 N).[37] In the study of Owais *et al*., this value was 176 N in the early primary stage and 240 N in the late primary stage.[38] It should be noted that these forces are considerably greater in the oral environment under physiological conditions[39] and affect the materials used through constant stresses. Since, in our study, the fracture resistance values were ranged between 270 N and 343 N, it can be predicted that all groups in this study are clinically acceptable.

CONCLUSION

According to the findings of this study, there was no significant difference between fracture strength, fracture resistance and fracture mode of resin composite, prefabricated glass fiber and customized quartz fiber posts.

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