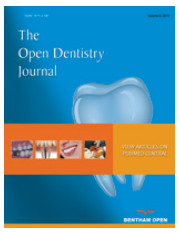

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RESEARCH ARTICLE

A Comparative Study of Fracture Resistance of Endodontically Treated Compromised Teeth with Different Post Systems: An *In Vitro* Study

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Abstract:

Aims:

This *in-vitro* study was conducted to compare structural reinforcement with composite resin and two different types of posts in structurally compromised teeth.

Methods and Materials:

Forty-eight human maxillary central incisors were instrumented and obturated. Specimens were randomly divided into four groups. The control group was not compromised and was just restored with a resin composite. In the composite-reinforced group, the access cavity of the compromised teeth was restored only with composite to the cemento-enamel junction (CEJ). In the reinforced glass fiber post group, the compromised cervical area of the teeth was reinforced with a dual-cured composite and a glass fiber post. The reinforced metal cast post group was reinforced with a dual-cured composite and a casting post. The mean fracture load was measured. Data were analyzed by SPSS software using one-way analysis of variance (ANOVA) and chi-square statistical analysis tests. For pair comparison, Duncan was used. $P<0.05$ was considered statistically significant.

Results:

The highest fracture resistance values were for the non-compromised samples (170.12 ± 12.44), while the lowest values were for the compromised ones restored only with the resin composite (71.40 ± 17.00). There was no statistically significant difference between the mean fracture resistances of the fiber (129.36 ± 21.34) and cast (116.60 ± 22.60) post groups ($P>0.05$).

Conclusion:

The use of a composite resin in a root with thin walls will reinforce the compromised tooth, but the type of the post will not influence the final results.

Keywords: Composite resin, Fracture resistance, Post and core technique, Permanent teeth, Resin cements, Tooth resorption.

Article History	Received: September 27, 2022	Revised: February 22, 2023	Accepted: February 27, 2023

1. INTRODUCTION

The rehabilitation of extensively damaged teeth with no dentinal support at the coronal portion of the root canal is very difficult [1]. This situation can be seen clinically when the developing permanent tooth (especially maxillary central incisors in children aged 9-10) suffers trauma, and its root formation remains incomplete [2]. The amount of residual dentin and tooth canal shape play critical roles in the strength and resistance of a tooth with posts. Hence, a post is not commonly used in teeth with flared canals, and the lack of dentinal structure also precludes the placement of reinforcing posts [3, 4]. In teeth with a significant loss of coronal and radicular tooth structures, it is important to assess the alternatives to cast posts and cores or common prefabricated posts that are also resistant to fatigue effects [5, 6]. Studies

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have suggested resin composites for strengthening the treated teeth with immature roots [7]. This method, in combination with the prefabricated post, has been advised for use during and after apexification [8].

There are numerous studies on the fracture resistance of devitalized teeth with different post systems, but some contradictory results have been observed in the literature concerning how the post materials affect the resistance fracture mode and stress distribution of the restored teeth [9, 10]. Some studies claim that metal posts perform better than fiber posts; others, however, state the opposite [11, 12]. Numerous studies have used composite resins along with fiber posts to strengthen the structure of damaged endodontically treated teeth [13, 14]. However, to the best of our knowledge, no study has ever compared the effect of application or non-application of a post and different kinds of posts on increasing the fracture resistance of cervically weakened teeth, such as the teeth with internal cervical resorption or necrotic immature permanent teeth. Therefore, this study aimed to evaluate and compare the effects of two strengthening methods on the weakened cervical structure with and without a post and different post types. The null hypothesis formulated in this study was that composite alone and in combination with a fiber post or a cast post would have similar strengthening effects on the weakened endodontically treated teeth at the cervical region.

2. MATERIALS AND METHODS

Research ethics committees of the vice-chancellor in research affairs of the Medical University of Isfahan ethically approved this study (Approval ID: 384176). Based on the previous studies [15, 16], forty-eight extracted intact human maxillary central incisors without significant differences in diameter (about 11 ± 1 mm occlusogingival height and 8.5 ± 1 mm width) were selected for this study. The approximate length of all roots was considered to be 15 mm. All samples were stored in 0.5% chloramine T solution (Merck, Darmstadt, Germany) until the time of the experiment.

All teeth were prepared by the same trained operator. An access cavity was prepared, and then all the teeth were instrumented up to file #70 and obturated with AH26 sealer and gutta-percha using a lateral condensation technique. After that, the specimens were randomly divided into four groups of 12 teeth each:

1. The control group that was not compromised (teeth were not cervically prepared),

2. In this group, a laboratory bur (Ivomil, IVOCLAR AG, Germany) was used to thin the cervical area of the root and simulate the thin dentinal wall of the compromised teeth. The preparation was extended to 5 mm apical to CEJ (the height of the palatal wall was 2 mm from CEJ), and nearly 1 mm thickness of dentin remained at all walls. The thickness of the remaining residual dentin at the cervical area was estimated by a digital Vernier caliper (Aerospace) and Radio Visio Graphy (RVG), which was then reinforced by resin composite (composite reinforced group),

3. In this group, Gates Glidden #1-4 and then Peeso reamers #4-6 were used (Dentsply, LD Caulk, USA) to remove the gutta-percha and prepare canals. The gutta-percha was evacuated up to 5 mm under CEJ. Then laboratory bur was used to thin the cervical area of the root and simulate the thin dentinal wall of the compromised teeth as described in group 2. Then, it was reinforced by glass fiber post (glass fiber post reinforced group),

4. Gates Glidden #1-4 and then Peeso reamers #4-6 were used (Dentsply, LD Caulk, USA) as described in group 3. Then, laboratory bur was used to thin the cervical area of the root and simulate the thin dentinal wall of the compromised teeth as described in group 2. Then, it was reinforced by a metal cast post (metal cast post reinforced group).

Then, all teeth were restored as follows: (the list of materials used in this study is provided in Table **1**.

Table 1. Materials, manufacturers, and composition.

Material	Manufacturer	Composition
Adper Single Bond	3M Espe. St. Paul, MN., USA.	BisGMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, and a methacrylate functional copolymer of polyacrylic and poly (itaconic) acids. (Approximately 10 wt % filled).
37% phosphoric acid etch-gel	Total etch, Ivoclar Vivadent, Swiss.lot no.	Phosphoric acid, colloidal silica, pigments, water
Bis-coreTM	Bisco INC, Schaumburg, USA	Bisphenol A diglycidyl methacrylate, glass filler, Urethane thriethylene glycol dimethacrylate, fused silica
Z100	ESPE, 3M Dental Product, USA	Mikrohibridna kompozitna smola • Microhybrid composite resin - matrix; BIS-GMA i TEGDMA • Matrix: BIS-GMA and TEGDMA - punilo cirkonija/silika, anorgansko punilo 66%w, veličina čestica od 3, 5 do 0,01µm • Filler: zirconia/silica; inorganic filler loading is 66% w, particle size ranging from 3.5 to 0.01 µm
RelyX Unicem resin cement	3M ESPE, Seefeld, Germany	Powder: Alkaline and silane fillers, starting components, pigments Liquid: Phosphoric acid methacrylates, methacrylate monomers, starting components, stabilizers
AH26	Dentsply, De Trey, Konstanz, Germany	Silver-free powder: bismuth oxide, methenamine epoxy resin

(Table 1) contd.....

Material	Manufacturer	Composition
C. silicone impression putty and light body and activator	Spidex®, Coltene AG, Altstatten, Switzerland	Base: Hydroxyl-terminated polydimethylsiloxane (liquid silicone prepolymer) Liquid: alkyl silicate, such as tetracthylsilicate, tin compound, such as dibutyltin dilaurate
Silane coupling agent	Monobond-S, Ivoclar-vivadent, Liechtenstein, Germany	Ethanol, [3-(methacryloyloxy) propyl] trimethoxysilane

In the non-compromised group (control group) with unprepared teeth, the coronal internal cavity surface of the tooth was etched for 15 seconds using a 37% phosphoric acid etch-gel, rinsed, and gently air-dried. Then, the root canals were treated with a resin adhesive (Single Bond) after air drying for 5 seconds, followed by light curing for 20 seconds with Coltlux 75 (Colten, Swiss) with 1000 mW/cm2 power intensity. A hybrid composite resin Z100 was used by vertical layering technique in two layers and was cured, each time for 40 seconds. In this study, all light activation steps were done by this light-curing unit.

In the composite reinforced group, the compromised region was obturated with gutta-percha by lateral condensation technique. Then, after acid etching and treatment with Single Bond, as described before, the access cavity of the tooth was restored only with Z100 composite resin in two stages. It was then cured by light activation.

In the glass fiber post-reinforced group, the post space was prepared by RTD universal burs (RTD Grenoble, France) 7 mm apical to the palatal margin of the access cavity.

1. The translucent glass fiber post: D.T Light post (RTD Grenoble, France) was tested in the prepared space, and its height was adjusted so that no direct load was applied to it.

2. After preparing the dentinal walls of the cavity with 37% phosphoric acid etch gel for 15 seconds, the etchant was rinsed and air-dried. In the second stage, the Single Bond adhesive was applied and air-dried for 5 seconds. Finally, it was light-cured for 20 seconds. For a complete cure of adhesive in this deep cavity, the light was guided through a handmade translucent sprue formed by heat with similar dimensions to the post.

3. D.T. post surfaces were cleaned with alcohol and air-dried. Then, a layer of silane coupling agent was applied according to the manufacturer's instructions and then treated with Single Bond adhesive and light-cured for 20 seconds.

4. The compromised cervical area of the teeth was restored with a dual-cure composite resin, Bis-coreTM, 1 mm apical to the CEJ, according to the manufacturer's instructions. D.T. Light-Post (DT) was inserted into this composite bulk along the longitudinal axis of the tooth and light-cured for 20 seconds as the initial curing so that the light tip was in contact with the light post.

5. The rest of the cavity was restored with Z100, similar to the control groups.

In the metal cast post-reinforced group:

1. To create a cast post similar to the D.T. light post in the reinforced glass fiber post group, the putty of C. silicone impression material was mixed with its activator and placed in a cylinder generator. Then, D.T. light post was placed in the putty in size similar to the glass fiber post group to obtain a negative image. After the putty was hardened, the post impression was taken again more accurately using a light body (C. Silicon Spidex) mixed with the activator.

2. Using transparent heat-formed sprues, similar to the light posts and Duralay acrylic resin mixed with the relevant monomer (Acropars, Marlic Medical Industries Co, Tehran, Iran), an impression was taken from the space created in the putty to obtain a positive image of the post.

3. The cast post was made in the laboratory using nickel-chrome alloy, a common alloy used to make these posts.

4. Before cementation, the fabricated cast posts were cut at the same height as the D.T. light post. They were then sandblasted with aluminum oxide with 20-µm diameter and 2-bar pressure and cleaned with alcohol.

5. The teeth were prepared for adhesion, similarly to the second step of the light post group.

6. The compromised cervical area of the teeth was restored with a dual-cure composite resin, Bis-core TM, 1mm apical to the CEJ, according to the manufacturer's instructions.

7. The cast post was covered with a biofilm layer to prevent the bonding of the composite inside the cavity. It was then put in the composite so that its longitudinal axis was in line with the longitudinal axis of the tooth. Next, it was extracted, etched, and rinsed with 37% phosphoric acid for 20 seconds to remove the debris, followed by drying.

8. The cleaned cast post was cemented by a dual-cure resin cement, RelyX Unicem, according to the manufacturer's instructions and then light-cured for 40 seconds. The rest of the cavity was restored with Z100, as described before.

Then, each tooth was mounted in an acrylic resin in the form of a cylinder. For simulating the PDLs, a thin layer of wax was wrapped around the roots before pouring the acrylic mix. By using boiling water, the wax was dewaxed and substituted with light body silicone impression material. With this silicone layer around the root of the tooth, the PDL was simulated, and small movements similar to the movement of the tooth in the dental socket were reconstructed (Fig. **1**).

After mounting, the specimens were subjected to compressive loads using a universal testing machine (Instron, Instron Corp, UK). Controlled loads were applied to the core on the palatal side exactly on the mesial and distal marginal ridges above the cingulum at an angle of 135° to the longitudinal axis of the root. The testing machine was set at a crosshead speed of 0.5 mm/min, and the failure threshold was defined as a point at which a specimen no longer withstood the increasing load and fracture of the post-crown complex or root occurred.

At the fracture point, the amount of force was recorded in a

computer, and the fracture patterns for each specimen were visually analysed. The data were statistically analyzed by SPSS software (SPSS ver. 23, IBM, Somers, NJ, USA) using one-way analysis of variance (ANOVA) and chi-square statistical analysis tests. For pair comparison, Duncan was used. $P<0.05$ was considered statistically significant.

3. RESULTS

At first, the normality of the research data was confirmed using the Kolmogorov-Smirnov test ($p>0.05$). The results and the means of resistance to fracture (kgf) of teeth are shown in Table **2**. The highest resistance to fracture belongs to the non-compromised group (170.12 ± 12.44) and the lowest to the composite reinforced group (71.40 ± 17.00).

The results of ANOVA showed a statistically significant difference, and Dunkan analysis showed that the differences in resistance to fracture were significant between all groups except the reinforced glass fiber post group and the reinforced metal cast post group.

The results of fracture mode in different groups are shown in Table **3**. The results of the chi-square test showed a statistically significant difference among all groups. The maximum non-restorable fractures were reported for composite reinforced and reinforced cast post groups, respectively.

4. DISCUSSION

The null hypothesis was slightly accepted. The results showed that irrespective of the type of the system used for the restoration of endodontically treated teeth, the highest fracture resistance was obtained when there was more dental tissue, which was in line with the results of the study conducted by Bhagat *et al.* on the thickness of the remaining dentin of post and core pretreatment in endodontically treated teeth [17].

Fig. (1). Using a thin layer of light body silicon impression material for simulating the PDLs.

Table 2. Fracture resistance in different groups (kgf).

Group Results	Non-compromised Group	Composite Reinforced Group	Reinforced Glass Fiber Post Group	Reinforced Cast Post Group
Minimum	143.60	30.71	101.93a	82.04a
Maximum	185.80	95.97	167.65	185.2
Mean	170.12	71.40	129.36	116.60
SD	12.44	17.00	21.34	22.60

Note: Same letters show no statistically significant differences, but other pair comparisons between study groups show statistically significant differences.

Table 3. Mode of fracture in different groups.

Group Results	Restorable		Non-Restorable	
	Count	Percentage	Count	Percentage
Non-compromised group	12	100%	0	0%
Compromised composite reinforced group	0	0%	12	100%
Reinforced glass fiber post group	9	75%	3	25%
Reinforced cast post group	3	25%	9	75%

On the other hand, the results of this study indicated that in the case of the weakened remaining tissue, the application of similar fiber posts or metal cast posts within the dual cure composite strengthens the weakened tissue so that it is completely bonded to it, whether directly or using resin systems, and causes a relatively similar increase in tooth fracture resistance under functional forces and can partly recover the lost resistance. However, the use of gutta-percha in the weakened teeth or restoration of the access cavity does not increase tooth fracture resistance.

D'Arcangelo *et al.* [18] reported that the use of fiber posts increased the resistance of endodontically treated anterior teeth, but some other studies have shown that the use of any post system, due to the different young modulus of these materials to the dental tissue, induces negative effects on tooth fracture resistance [19]. Furthermore, some studies have shown that the use of posts, due to the unfavorable distribution of stress in the tooth structure, weakens the tooth [20].

The present study indicated that despite approximately similar fracture resistance in teeth restored with metal and glass fiber posts within the strengthening dual-cure composite that have created monoblock, in the case of fracture, the fractures in fiber posts are mostly repairable, but fractures of cast posts are mostly catastrophic and irreparable. However, the results of a systematic review were in line with this study [21].

The posts in the restoration of endodontically treated teeth that have lost too much dentin tissue and require reconstruction for better function in the oral cavity have been used by dentists for many years. However, contradictory results have been reported for the use of these materials for endodontically treated teeth. Application of endodontic posts causes more weakness of the tooth root since they require more removal of the dentine structure of the root for their placement [22]. Moreover, this preparation increases the deformities due to reduced dental tissue [23], and the hardness coefficient of these materials is not adaptable to the tooth structure, thereby causing unfavourable stress distribution [24]. In an eleven-year clinical trial performed by Naumann *et al.*, the survival of restorations retained with metal and fiber posts, especially during the first eight years, was higher than that of the restorations without posts, but after that, it significantly reduced in glass fiber posts due to weakened dentin-cement-post bond [25].

In this study, dual-cure resin cement was used to bond the posts to the tooth structure, and also dual-cure composite was used to strengthen the weakened cervical region because polymerization was completed by chemical cure, especially in areas with highly reduced light exposure. Furthermore, it is less likely that the bond is weakened due to inadequate polymerization and remaining uncured monomers [26]. On the other hand, the curing of dual-cure resins is not influenced by the amount of translucency [27]. A reason for the similar strengthening effect of non-translucent metal cast posts and translucent glass fiber posts in this study may be due to the similar bond of these posts with the tooth structure and dual-cure composite owing to a high and similar degree of conversion and formation of monoblock in both groups. On the other hand, despite numerous studies conducted on various endodontic treatment methods for teeth with much coronal damage [13, 14], no comprehensive conclusion can be made regarding the efficacy of these materials in increasing the fracture resistance of endodontically treated teeth due to variation of method and type of substrate used (human or bovine teeth) [28]. This study was performed on the endodontically treated human central teeth weakened at the cervical region so that they would have similar conditions to immature necrotic teeth or teeth with internal cervical resorption. The results showed that similar fiber posts or metal cast posts, in case of complete adaptation with the internal tooth structure, had similar success in strengthening the tooth, and both would be successful if they were correctly bonded to the tooth structure with resin cement. Moreover, they are more effective than the use of composite resin alone for tooth structure strengthening. However, the fractures created in the teeth restored with metal cast posts would be more destructive than those in modified fiber posts.

Cyclic loads causing a decrease in material strength may result in dental restoration failures concluded by fatigue mechanisms [6]. Therefore, further *in vitro* and clinical studies, which include long-term analysis of functional cyclic forces or thermocycling, are required to obtain more definite results.

CONCLUSION

It can be concluded that the maxillary central incisors treated with minimum dentin omission have the highest fracture resistance. Moreover, the common methods used for the restoration of central incisors with thin walls of root crown by composite resins without the reinforcement of the cervical part of the root cannot increase their resistance against chewing forces, but the use of posts that have good adaptation can increase teeth fracture resistance.

LIST OF ABBREVIATIONS

CEJ	=	Cemento-enamel junction
ANOVA	=	Analysis of variance

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Research Ethics Committees of the Vice-Chancellor in Research Affairs of the Medical University of Isfahan ethically approved this study (Approval ID: 384176).

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent was obtained from all participants.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author [F.S] upon reasonable request.

FUNDING

This work was financially supported by Khorasgan dental school, Isfahan, Iran.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENTS

Declared none.

SUPPLEMENTARY MATERIALS

Some pictures of the research are included as supplementary materials.

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