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Original Article

Effect of photo core, LuxaCore, and core max II core building materials on fracture resistance of endodontically-treated teeth restored with fiber-reinforced composite posts and ParaPosts

Alireza Izadi[1], Bijan Heidari[2], Farnoush Fotovat[1], Armaghan Shahbazi[1], Hanif Allahbakhshi[3], Ghodratollah Roshanaei[4], Zohre Farhangian[5], Kioumars Kiani[6]

[1]Department of Prosthodontics, School of Dentistry, Hamadan University of Medical Sciences, [4]Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, Hamadan, [2]Department of Prosthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, [3]Department of Prosthodontics, School of Dentistry, Kashan University of Medical Sciences, Kashan, [5]Department of Aesthetic and Restorative, School of Dentistry, Kermanshah University of Medical Sciences, Kermanshah, [6]Dentist, Private Practice, Tehran, Iran

ABSTRACT

Background: Post and core treatment is commonly performed for endodontically treated teeth to replace the lost tooth structure and reinforce and protect the remaining dental tissue. This study aimed to compare the effect of three-core building materials on fracture resistance of endodontically-treated teeth restored with fiber-reinforced composite (FRC) posts and ParaPosts.

Materials and Methods: This *in vitro*, experimental study evaluated 108 sound, single-rooted mandibular first premolars extracted for orthodontic purposes. The teeth were randomly divided into nine groups (n = 12) of control (no endodontic or restorative treatment), FRC + Photo Core (Group 2), FRC + LuxaCore (Group 3), FRC + Core Max II with bonding agent (Group 4), FRC + Core Max II without bonding agent (Group 5), ParaPost + Photo Core (Group 6), ParaPost + LuxaCore (Group 7), ParaPost + Core Max II with bonding agent (Group 8), and ParaPost + Core Max II without bonding agent (Group 9). The fracture resistance was measured by applying the load at 45° angle relative to the longitudinal axis of the tooth with a crosshead speed of 1 mm/min using a universal testing machine. Data were through descriptive statistics, Tukey's test, and one-way analysis of variance (α = 0.05).

Results: The mean fracture resistance was 454.0 ± 62.7, 410.8 ± 48.3, 365.1 ± 42.1, 423.7 ± 111.7, 392.4 ± 90.0, 292.3 ± 83.9, 242.3 ± 73.4, 278.2 ± 67.9, and 247.3 ± 49.6 N in Groups 1–9, respectively. Group 4 showed the highest fracture resistance, which was significantly higher than this study the value in all ParaPost and control groups (P < 0.05) but had no significant difference with the fracture resistance of other groups (P > 0.05).

Conclusion: Fracture resistance is independent of the type of core building material used, and the tested products had no superiority over each other. The mean fracture resistance of FRC post groups were significantly higher than that of ParaPost groups. Furthermore, Core Max II + bonding agent yielded insignificantly higher fracture resistance than Core Max II without bonding agent.

Key Words: Flexural strength, post and core technique, root canal therapy

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Address for correspondence: Dr. Farnoush Fotovat, Department of Prosthodontics, School of Dentistry, Hamadan University of Medical Sciences, Shahid Fahmideh Blvd., In Front of Mardom Park, 6516647447 Hamadan, Iran.
E-mail: ffotovat96@gmail.com

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INTRODUCTION

Dental restorative treatments are performed aiming to replace the lost tooth structure, reinforce and protect the remaining dental tissue. As a general rule, post and core restorations are performed for teeth with <50% of the coronal tooth structure remaining.[1] Functional rehabilitation of the teeth with severely damaged crowns requires core build-up to support the prosthetic crown, which necessitates crown-root stability to create a resistant and retentive form.[2,3] Fiber posts have a lower hardness than metal posts and consequently enable more appropriate stress distribution in the root; thus, they exhibit lower risk to fracture. Fiber-reinforced composite (FRC) posts have a hardness number similar to that of dentin and therefore, have optimal durability and some other advantages over the metal casting posts. For instance, the flexural strength of FRC posts is higher than that of metal posts.[4] The use of prefabricated posts along with amalgam or composite core build-up has simplified the process of tooth reconstruction because all the steps can be performed within one single chairside visit.[5] Some researchers believe that higher post material hardness results in better stress distribution and prolongs their clinical service while some others believe that the hardness number of posts should be close to that of dentin. Thus, the latter group recommends fiber posts and composite cores plus the adhesive systems.[6]

When the ferrule effect is insignificant, a high level of stress accumulates in the core build-up material, which highlights the need for its optimal strength. Durability, resistance, hardness, and the bond strength of the core material to the post and dentin can affect the longevity of the reconstructed crown and subsequently the survival rate of the prosthetic crown.[6]

Composite core build-up materials are under constant development. Adequate moisture control is imperative for the clinical service of these materials. They are bonded to tooth structure, and their fast setting enables tooth preparation within the same session. Moreover, composite resins well adapt to pins, and the pins provide retention for the composite cores.[7,8] Some of the composite core build-up materials have compressive and tensile strength values similar to those of amalgam cores. Composite resins are suitable for direct core build-up when part of the tooth structure has remained, and the area can be efficiently isolated for moisture control. Some composite core build-up materials contain fluoride and prevent caries by releasing fluoride ions.[8,9]

Core Max II (Dentsply, Sankin, Korea) is a resin-based core build-up material containing Bisphenol A glycidyl methacrylate (bis-GMA) and Triethylene glycol dimethacrylate (TEGDMA). It is supplied in the form of powder and liquid and is utilized as a paste. Its strength and consistency (concentration) can be modified by changing the powder to liquid ratio. It can be formed and shaped as desired when applied and yields high strength after setting. It has high wettability on the tooth structure and can be easily applied with a syringe. It is cost-effective as well.[10]

LuxaCore (DMG, NJ, USA) is a radiopaque dual-cure composite, which is automatically mixed and can be used for extensive restorations, crown build-up, and cementation of intracanal posts. It is suitable for areas where high compressive strength is required, and its properties are similar to those of dentin.[11]

Photo Core (Kuraray Noritake Dental Inc., NY, USA) is a light-cure composite resin used for coronal reconstruction of vital and nonvital teeth. It has a high filler content and provides considerably high compressive, flexural, and tensile strength. It has low polymerization shrinkage, high curing depth, short curing time, and easy application. It does not stick to instruments and enables single session preparation of tooth.[12] Low radiopacity, high coefficient of thermal expansion, and high potential for water sorption are among the drawbacks of this composite resin. Moreover, eugenol present in the composition of temporary cements can soften the composite surface and prevent the bonding of resin base of the cement.[8]

In the recent years, many studies have evaluated the fracture resistance of endodontically treated teeth and their mode of failure following the application of different post and core systems. Furthermore, different methods of restoration and reconstruction of teeth have been investigated.[13-16] Thus, this study aimed to compare the effect of three core build-up materials namely Core Max II, LuxaCore, and Photo Core on fracture resistance of endodontically-treated teeth restored with FRC posts and ParaPosts.

MATERIALS AND METHODS

This *in vitro* experimental study was conducted in the School of Dentistry of Hamadan University of

Medical Sciences. A total of 108 single-rooted sound mandibular first premolars of the same size and form were collected. The teeth had been extracted for orthodontic treatment. The root length was measured, and the samples were stored in 0.9% saline at room temperature until the experiment.

The sample size was calculated to be 12 in each group according to a previous study by Abduljabbar *et al*.,[5] assuming the difference between the maximum and minimum mean values to be 25, standard deviation of 37, the effect size of 0.6, alpha = 0.05 and beta = 0.2.

The inclusion criteria were the absence of root cracks, root caries, or root restoration and no history of previous root canal treatment.[5] The teeth were randomly divided into nine groups (n = 12). Group 1 served as the control group and the teeth in this group did not receive any endodontic or restorative treatment. In Group 2, the teeth received FRC posts + Photo Core. In Group 3, the teeth received FRC posts + LuxaCore. Group 4 received FRC posts + Core Max II with bonding agent. Group 5 received FRC posts + Core Max II without bonding agent. Group 6 received ParaPosts + Photo Core. Group 7 received ParaPosts + LuxaCore. Group 8 received ParaPosts + Core Max II with bonding agent, and Group 9 received ParaPosts + Core Max II without bonding agent.

All the teeth (except for the control group) underwent root canal treatment with the step-back technique with International Standards Organization 40 apical size. The canals were then dried with moisture absorbent paper points and filled with gutta-percha (Meta Biomed; Hand Rolled, Korea) and AH26 sealer (DeTrey; Dentsply GmbH, Konstanz, Germany) through the lateral compaction technique. After root canal treatment and root filling, a chamfer finish line with 1 mm depth was prepared 0.5 mm above the cementoenamel junction for a full-metal crown using a Torpedo diamond bur (Tizkavan, Tehran, Iran). The teeth were stored in water at 37°C during the experiment. After endodontic treatment, the roots were covered with a thin layer of silicone impression material to simulate the periodontal ligament and were mounted in cubic acrylic molds. The post space was prepared for all teeth in FRC post groups using #1 to #4 Gates Glidden drills. About 4 or 5 mm of the gutta-percha remained at the root end for apical seal. In ParaPost groups, the teeth were drilled for placement of ParaPost (titanium vented and serrated NO. 4; Coltene/Whaledent) as follows: First, a #2 peeso-reamer was used and then #4 ParaPost drill (NO.4; Coltene/Whaledent) with 12 mm length was used. A radiograph was obtained afterward. Of the post length, 12 mm was inside the canal and 3 mm was outside the canal. The excess length was cut from the occlusal end using a disc (Diatec, Germany).[5]

The canal space was etched with 37% phosphoric acid for 5 s and rinsed to eliminate any contamination. It was then dried with air spray and paper points. The intracanal posts were then cemented into the canal using Panavia F2 resin cement (Kuraray, Japan) according to the manufacturer's instructions. Next, the tooth crown was built-up using LuxaCore, Photo Core or Core Max II with/without bonding agent according to the manufacturers' instructions. In Group 1 (control), the periodontal ligament was simulated, and the teeth were mounted. No other intervention was performed in this group. After cementation of intracanal posts and fabrication of cores, a final impression was made using Speedex impression material. The dies, wax patterns, and full-metal crowns were then fabricated. The crowns were cleaned with ethanol and cemented using type I glass ionomer cement (GC Corporation, Tokyo, Japan) according to the manufacturer's instructions. The crowns were seated on the teeth by finger pressure for 30 s, and the excess cement was removed after 10 min. Next, the samples were transferred to a universal testing machine and subjected to load application at 45° angle relative to the longitudinal axis of the tooth at a crosshead speed of 1 mm/min. The load was applied to a point between the central groove of the occlusal surface and lingual slope of the buccal cusp.[5] The load was applied until fracture, and the load at fracture was calculated in megapascals (MPa) using the formula below:

Shear bond strength (MPa) = Load (N)/Surface area (mm^2).

Data were analyzed using SPSS version 20 (SPSS Inc., Chicago, IL, USA) through descriptive statistics (tables and diagrams), and comparisons were made using analysis of variance (ANOVA) and Tukey's test. The level of significance was set at 5%.

RESULTS

The mean fracture resistance of the nine groups was significantly different (P < 0.05). ANOVA showed that only the difference between the control group and FRC post groups was statistically significant ($P < 0.05$). The Tukey's test revealed significant differences between Groups 2 and 6 (ParaPosts + Photo Care and FRC posts + Photo Care), 3 and 7 (ParaPosts + LuxaCore and FRC posts + LuxaCore), 4 and 8 (FRC posts + Core Max II with bonding agent and ParaPosts + Core Max II with bonding agent), and 5 and 9 (FRC posts + Core Max II without bonding agent and ParaPosts + Core Max II without bonding agent) ($P < 0.05$).

The highest mean fracture resistance was noted in Group 4 (FRC posts + Core Max II with bonding agent), which had significant differences with the value in ParaPost and control groups ($P < 0.05$) but had no significant difference with other FRC post groups. The lowest fracture resistance was noted in Group 7 (ParaPosts + LuxaCore), which only had significant differences with FRC post groups. Table 1 shows the mean, standard deviation, minimum and maximum fracture resistance of the groups.

The mean fracture resistance of Core Max II with bonding agent was higher than that of Photo Core and Luxa Core when used with FRC posts. The mean fracture resistance of Core Max II with bonding agent was also higher than that of LuxaCore but lower than that of Photo Core when used with prefabricated serrated ParaPosts; however, these differences were not statistically significant ($P > 0.05$). The fracture resistance of Photo Core was higher than that of LuxaCore but not significantly ($P > 0.05$). The mean fracture resistance of the four groups with FRC posts was not significantly different. The mean fracture resistance of the four groups with ParaPosts was not significantly different either ($P > 0.005$). However, the mean total fracture resistance of groups with FRC posts was significantly higher than that of groups with ParaPosts [$P < 0.001$, Table 2].

The Core Max II groups with bonding agent showed higher mean fracture resistance than Core Max II groups without bonding agent, but this difference was not statistically significant ($P > 0.05$). In addition, the mean fracture resistance of FRC posts + Core Max II with bonding agent was significantly higher than that of ParaPosts + Core Max II with bonding agent ($P < 0.05$).

Table 1: Descriptive statistics of the study groups in Newton (*n*=12)

Groups	Mean±SD (newton)	Minimum	Maximum	*P*
1	454±62.7	279.3	564.2	<0.001
2	410.8±48.3	318.8	518.9	
3	365.1±42.1	303.6	458.6	
4	423.7±111.7	287.4	636.7	
5	392.4±90.0	256.5	512.6	
6	292.3±83.9	117	402.4	
7	242.3±73.4	130	395.8	
8	278.2±67.9	200.6	426.1	
9	247.3±49.6	175.6	326.2	
Total	324.6±99.1	117	636.7	

Table 2: Comparison of fiber-reinforced composite post and ParaPost groups in terms of fracture resistance

Groups	*n*	Mean±SD (newton)	*t* student	*P*
2-5	46	397.56±77.93	8.4	<0.001
6-9	45	265.62±71.05		

DISCUSSION

Controversy exists regarding the restorative techniques of endodontically treated teeth especially severely damaged teeth. Dental clinicians have always been in search of restorative techniques with higher durability and survival rate, lower cost, and fewer procedural steps for such teeth. Casting post and cores, prefabricated posts, and coronal restorations with amalgam and composite are among the practiced techniques for this purpose.[17] Durability, resistance, hardness, and mechanism of bonding of core materials to intracanal posts and dentin can affect the longevity and clinical service of the reconstructed crowns and subsequently the survival rate of the prosthetic crowns.[6] This study aimed to compare the effect of three core materials on fracture resistance of endodontically treated teeth restored with two types of prefabricated posts, namely prefabricated serrated ParaPosts and FRC posts.

The parallel serrated titanium posts used in this study distribute loads and stresses more uniformly than tapered posts due to their specific morphology. In addition, due to their high modulus of elasticity and long serrated structure, they possess superior physical properties and higher hardness and strength than fiber posts. Thus, they optimally prevent the fracture of endodontically treated teeth. Titanium posts have lower strength than stainless steel posts but have higher corrosion resistance and are more biocompatible with the tooth structure. These posts are radiopaque and would be easily visible on radiographs.[18]

FRC posts were also used in this study, which are double-taper and highly similar to tooth root. Thus, they mainly absorb the stress rather than transferring it. Furthermore, they maximally preserve the sound tooth structure due to their conical shape, which matches the conical shape of the root canal.[19] Gallo *et al*. stated that FRC posts are highly resistant and have a favorable esthetic appearance.[20] They can absorb and distribute stresses, which explains the minimal risk of fracture of root and post in the use of these posts.[21] Moreover, these posts are radiopaque and easily visible on radiographs. Fokkinga *et al*. measured the fracture resistance of a control group, prefabricated metal posts and prefabricated glass fiber posts and showed that prefabricated metal posts had the highest and the control group had the lowest fracture resistance. It should be noted that the control group in their study included endodontically treated teeth without intracanal posts. However, the control group of this study comprised of sound teeth without endodontic and restorative treatments.[22]

Makade *et al*. evaluated maxillary incisors with casting post and cores, glass fiber posts and composite cores, ParaPosts and composite cores, and a control group and showed that the fracture resistance was the highest in the ParaPost and the lowest in the control group.[23] According to the results of the aforementioned two studies as well as our findings, the fracture resistance of the endodontically treated control groups without post and cores is lower than that of endodontically treated teeth restored with post and cores. In the present study, teeth in the control group were intact, and their fracture resistance was lower than that of other groups in most cases. However, this difference was only significant between the control and FRC post groups (P = 0.001). The core material should firmly bond to tooth structure. Durability, resistance, hardness, and bond strength of the core material to the posts and dentin can affect the longevity of the reconstructed crown and subsequently the survival and clinical service of the prosthetic crown.

Several composite resins are available in the market for core build-up in endodontically treated teeth. They have optimal properties in terms of structural integrity and adaptation to prefabricated posts.[20,22,24] A composite core reinforces the remaining tooth structure. In addition to excellent esthetics, contemporary composite resins have high compressive strength for the restoration of posterior teeth. Furthermore, composite resins are able to bond to dental cusps and decrease cuspal deflection. Thus, the application of composite resin reinforces the hardness of tooth structure.[25] In the present study, Photo Core, LuxaCore, and Core Max II with/without bonding agent were used for core buildup. The results showed that the mean fracture resistance of Core Max II with bonding agent was higher than that of Photo Core and LuxaCore when used with FRC posts. Its fracture resistance was also higher than that of LuxaCore and lower than that of Photo Core when used with prefabricated serrated ParaPosts. However, none of these differences were statistically significant. Moreover, the fracture resistance of Photo Core was higher than that of LuxaCore but not significantly. This finding can be due to the superior mechanical properties of Photo Core as the result of a higher volume percentage of filler in its composition. Higher fracture resistance of this core material can also be attributed to the use of Photo Core specific bonding agent, which results in higher strength and integrity of the bond between the post and core and tooth structure. Since the mean fracture resistance of the four groups with FRC posts and the four groups with ParaPosts were not significantly different, it may be concluded that the fracture resistance is independent of the type of core material, and none of the tested core materials had any superiority over each other, although the mean fracture resistance of FRC post groups altogether were significantly higher than that of ParaPost groups (P < 0.001).

Shahryarpanah[26] evaluated the effect of four core materials (Tetric Ceram, Photo Core, LuxaCore and CoreCem) on fracture resistance of endodontically-treated teeth reinforced with quartz fiber posts and reported results similar to our findings regarding Photo Core and LuxaCore. They did not find a significant difference between Photo Core and LuxaCore in terms of fracture resistance. Asadzadeh Aghadaee *et al*. evaluated the casting post and cores, ParaPosts, Core Max II, and FRC posts + Core Max II and reported that the casting post and core group had the highest fracture resistance followed by the FRC post group. The lowest fracture resistance was noted in ParaPost group[27] probably due to the better adaptation of the casting post and core with the canal and optimal flexural strength of FRC posts. In this study, the mean fracture resistance of FRC post groups were significantly higher than that of ParaPost groups. Other studies on fracture resistance of endodontically treated teeth restored with different post and core systems revealed that groups with composite cores often have the highest fracture resistance.[23,28,29] Ahn and Sorensen measured the fracture resistance of Photo Core and LuxaCore and used prefabricated posts such as titanium ParaPosts, stainless steel posts, zirconia posts, fiber carbon posts, and glass fiber posts. They reported that the fracture resistance of Photo Core was significantly higher than that of LuxaCore.[1]

At present, different types of resin cements and bonding systems are available for cementation of FRC posts and ParaPosts. In the present study, Panavia F2 resin cement (Kuraray, Japan) was used for post cementation, which is a dual-cure resin cement. Panavia cement is a chemically activated dual-cure cement and has a specific functional monomer that contains phosphate groups and can bond well to the tooth structure. Thus, it confers a high fracture resistance to the tooth structure.[30,31]

Our findings indicated that Group 4 (FRC posts + Core Max II with bonding agent) yielded the highest fracture resistance which had significant differences with ParaPost and control groups but had no significant differences with other FRC post groups. The control group also had a significant difference with FRC post groups in terms of fracture resistance. Similarly, Nayakar *et al*.[32] compared core materials with different cements for casting crowns of mandibular second premolars and revealed that the combination of composite resin cores and resin cement yielded the highest tensile strength compared with other combinations of cores and cements.[21] Noorbakhsh *et al*. assessed the effect of zinc phosphate, glass ionomer, and resin cements on retention of FRC posts, and reported that resin cements yielded the highest retention.[33]

In the present study, Core Max II with bonding agent showed a higher mean fracture resistance than Core Max II without a bonding agent, but this difference did not reach statistical significance. In addition, the mean fracture resistance of FRC posts + Core Max II with bonding agent was significantly higher than that of ParaPosts + Core Max II with bonding agent. Hsu *et al*. compared central incisors restored with ParaPost and composite core with and without dentin bonding agent and showed that the group with bonding agent provided a stronger bond.[34]

One limitation of the current study was its *in vitro* design, which limited the generalization of the results to the clinical setting. Several variables such as tooth condition before extraction, age of tooth, storage conditions, and pulp status at the time of tooth extraction, root anatomy and its dimensions, angle of load application, and tooth position can affect the results *in vitro*.[21] Another limitation was that gradually increasing load was applied at a crosshead speed of 1 mm/min to the teeth until fracture, which is different from the pattern of load application in the oral environment that is dynamic and continuous. Thus, the reaction of materials may vary *in vivo* and *in vitro* depending on the material resistance and fatigue.

CONCLUSION

The current results revealed that the fracture resistance is independent of the type of core material used, and none of the tested core materials had any superiority over each other. In addition, the mean fracture resistance of FRC post groups were significantly higher than that of ParaPost groups. The application of bonding agent may increase the fracture resistance of Core Max II but is not imperative.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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