Evaluation of the Mechanical Properties of 3D-Printed Post and Core Systems

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Purpose: To evaluate and compare the fracture resistance and elastic modulus of 3D-printed post and core systems and fiber posts and composite cores. ***Materials and Methods:*** Endodontic treatment was performed on 30 mandibular premolars, and post space preparation was performed. The teeth were then randomly divided into two groups (n = 15 per group): the 3D-printed (3DP) group and the fiber post and composite core (FPC) group. In the FPC group, fiber posts (Cytec Blanco 43.604, Hahnenkratt) were bonded with resin cement (RelyX U200, 3M), and the composite core dimension was standardized with a silicone index. In the 3DP group, the impression of the post space for each specimen was taken with pattern resin (Pattern Resin, GC America), and the coronal core was produced with the same silicone index. The impressions of the posts and cores were scanned, and then the custom post and core structures were fabricated from permanent crown resin material (Permanent Crown Resin, Formlabs) with a 3D printer (Form3B, Formlabs). Specimens were subjected to load tests with a universal testing machine (M500-25AT, Testometric). After fracture occurred, the fracture force and elastic modulus were calculated. The data were analyzed by independent sample *t* test (α = .05) ***Results:*** There was no statistically significant difference between the two groups in terms of peak fracture force (*P* = .626) and elastic modulus (*P* = .125), and no catastrophic root fractures were observed in either group. ***Conclusions:*** The fracture resistance of endodontically treated teeth was not significantly influenced by the post material. 3D-printed, custom-made resin posts were as effective as fiber glass posts with regard to fracture resistance. *Int J Prosthodont 2024;37(suppl):s127–s131. doi: 10.11607/ijp.8860*

It is difficult to restore severely damaged teeth, especially when the coronal structure is insufficient to provide retention and resistance for crown restoration.[1,2] If the damaged tooth is in the esthetic zone, the situation presents considerably more of a challenge. To enhance the retention and resistance of crown restorations, endodontic posts and cores composed of various materials with different physical and mechanical properties are used. Materials used for these posts and cores include zirconia, composite fibers, and custom-made cast posts and cores from different alloys. Among these options, composite fiber posts are recommended because they possess mechanical properties similar to those of the natural dentin structure.[3] It is well documented that dissimilarity between the elastic modulus of dentin and post

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material may result in root cracks or fractures, eventually jeopardizing the survival of the tooth.[4,5] What's more, after root conditioning, fiber posts can adhere to root canal dentin better than other post materials.[6] However, fiber posts require a core fabricated with composite. This results in creating extra joints, which may be a potential cause of restoration failure.

With the introduction of digital dentistry to clinical practice, CAD/CAM techniques have become popular. There are two main CAD/CAM methods: milling (subtractive manufacturing) and 3D printing (additive manufacturing).[7] 3D printing has been introduced to clinical practice recently and has gained popularity among dentists. Various types of restorations can be fabricated with 3D printing and dedicated liquid resin specific to the restoration type.[8] Among them are provisional restorations, single crowns, and inlay and onlay restorations. According to the manufacturer, the flexural strength of resin used for fabricating permanent single crowns and inlay and onlay restorations is similar to that of prefabricated fiber posts. It may have potential for the fabrication of custom, 3D-printed post and core monoblock structures for supporting crown restorations.[4] With 3D-printed monoblock post and core systems, the extra joints between fiber posts and composite cores can be avoided.

There are studies in the literature comparing CAD/CAM-fabricated custom post and core systems with fiber post and composite core structures.[9–11] However, in those studies, milling was used to fabricate test specimens rather than 3D printing. There is no study in the literature concerning the fracture resistance of 3D-printed post and core systems. The aim of this study was to evaluate and compare the fracture force and elastic modulus of 3D-printed post and core systems and fiber post and composite core systems. The null hypothesis was that there is no difference between the mode of fracture, maximum fracture force, and elastic modulus of 3D-printed systems versus fiber post and composite core systems.

MATERIALS AND METHODS

This study was approved by the Çukurova University Faculty of Medicine Clinical Research Ethics Committee (approval no. 2022/116.48) and involved a total of 30 mandibular premolars removed for periodontal or orthodontic reasons. Teeth with root curvature less than 5 degrees and with only one canal were included in the study to reduce anatomical differences. The extracted teeth were immediately cleaned and stored in a 0.1% thymol solution at 4°C. The teeth were examined for surface fracture under an operating microscope (Zeiss OPMI Pico) at ×40 magnification.

Teeth were decoronated under water cooling with a diamond disk cutting vertical to the long axis of the tooth at the cementoenamel junction. The roots were cut to a uniform length of 13 mm to standardize the root canal lengths and were then shaped with an R25 file (Reciproc, VDW Dental) at 12-mm working length. Irrigation was conducted every three pecking motions, with a total of 10 mL of distilled water used. Using the cold lateral condensation procedure, the roots were dried with paper points and obturated with gutta-percha (Dia-Dent) and an epoxy-based resin sealant (Adseal, Meta Biomed). The root canal orifices were then temporarily sealed. For 1 week, the specimens were kept at 37°C and 100% humidity.

The root canal filling of each specimen was removed for post space preparation with rotary instruments nos. 2 and 3 (Peeso Reamers, Mani) until a 3-mm remnant was left in the apical part. The fiber post system provided drills to expand the post space of the specimens. Cytec Blanco drills (Hahnenkratt) marked 43.002, 43.003, and 43.004 were used with a low-speed handpiece. The roots were then randomly divided into two groups (n = 15): the 3D-printed (3DP) group and the fiber post and composite core (FPC) group.

In the FPC group, a 2.2-mm-diameter fiber post (Cytec Blanco 43.604) suitable for the drill size was bonded with resin cement (RelyX U200, 3M) and finger pressure in accordance with manufacturer instructions. The core dimension was standardized using a prefabricated silicone index. An etch and rinse adhesive (Adper Scotchbond, 3M) and a composite (Z350, 3M) were applied for the coronal core structure according to manufacturer instructions.

In the 3DP group, the post space impression of each root was taken with pattern resin (Pattern Resin, GC America), and the coronal core was produced with the same prefabricated silicone index used for each specimen. The impression of the post and core was scanned with a laboratory scanner (inEos X5, Dentsply Sirona) (Fig 1). The obtained data were transferred to a 3D printer (Form3B, Formlabs) in STL format, and the post and core structures were fabricated from permanent crown resin material (Permanent Crown Resin, Formlabs). Then, the custom post and core structures for each root were cemented with the same resin cement procedure. All root canal treatment steps and the cementation procedure were completed by one experienced operator (C.K.).

After the cemented post and core restorations were stored at 37°C and 100% humidity for 1 week, the specimens were embedded into acrylic resin 2 mm below the crown margin. Before the fracture test, a chart was prepared using a free software program (Research Randomizer, version 4.0) to determine a random testing order. The specimens were subjected to load testing with a universal testing machine (M500-25AT, Testometric) with a crosshead speed of 1 mm per minute (Fig 2). The mode of fracture was noted, and the fracture force and

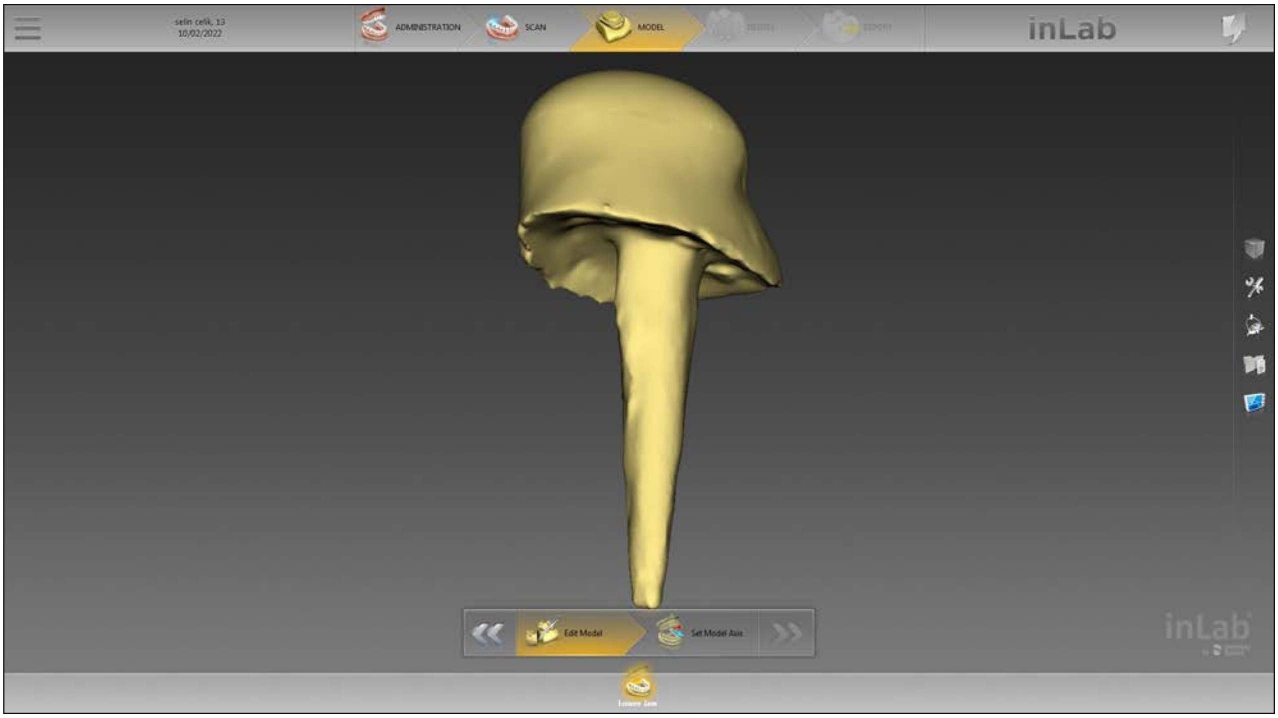

Fig 1 Monoblock post and core structure created with a laboratory scanner.

Fig 2 Load test assembly.

Table 1 Maximum Fracture Force

	Mean	SD	*P*
3DP group	394 N	123 N	.626
FPC group	394 N	123 N	

Table 2 Elastic Modulus

	Mean	SD	*P*
3DP group	3,809 MPa	76 MPa	.125
FPC group	4,505 MPa	1,517 MPa	

elastic modulus were calculated by Testometric machine software (winTest Analysis). The data were analyzed by independent *t* test (α = .05).

RESULTS

The mean maximum fracture forces for the test specimens are shown in Table 1. The mean elastic modulus values are provided in Table 2. There was no statistically significant difference between the 3D-printed posts and the fiber posts in terms of peak fracture force (P = .626) and elastic modulus (P = .125). No catastrophic root fracture was observed for either of the groups.

DISCUSSION

This in vitro study was designed to compare the 3D-printed post and core and fiber post and composite core systems in terms of mode of fracture, maximum fracture force, and elastic modulus. The null hypothesis was not rejected, as statistically no significant difference was found between the groups in terms of the investigated mechanical properties.

One important consideration when using endodontic dental posts is the potential for damage to the tooth structure.[2] The placement of a post can weaken the tooth and increase the risk of fracture.[1,3,4] Endodontic fiber posts are commonly used in dental treatments to provide additional support and retention to the restoration. The use of endodontic fiber posts has become increasingly popular because their elastic modulus is similar to that of dentin, resulting in higher survival rates compared to teeth treated with metal posts and cores.[1,3,4] One of the drawbacks of using fiber posts, however, is the weak bond strength of the resin composites that are employed as the core material. Clinically, the elastic behavior of fiber posts results in microgaps between the crown and core build-up during cyclic bending while chewing.[2] The monolithic structure of 3D-printed endodontic posts and cores could be a good alternative to prefabricated fiber post and composite core systems because there is no need for fabricating a core build-up. This design that could prolong the life of the restoration.

The results of the current study showed that the fracture force and elastic modulus of the 3D-printed posts were similar to those of the prefabricated posts and core build-ups. However, the fracture force of the fiber posts and core build-ups was higher than the results reported in previously published studies, which vary depending on the study's selected testing methods, the teeth being restored, the type of cement used, and the thickness of the fiber posts. Fadag et al[12] reported a mean fracture load of 764.1 ± 156 N when the maxillary central incisors were restored with glass fiber composite core build-ups. Torres-Sánchez et al,[13] on the other hand, reported a mean fracture load of 127.91 ± 14.02 N when single-rooted premolars were treated with glass fiber posts and composite core build-ups. Habibzadeh et al[14] reported much higher fracture values (915.70 ± 323 N) when mandibular premolars were treated with glass fiber posts and composite cores. However, they had cemented all ceramic crowns with zirconia copings to the specimens before testing, in contrast to the other studies where specimens were loaded directly onto the core. Nokar et al[15] investigated the fracture resistance of endodontically treated maxillary canine teeth with glass fiber posts of various diameters and reported a mean fracture force of 467 ± 99.42 N, stating that increasing the diameter of the fiber post up to 1.6 mm significantly increased the fracture resistance of the restored teeth.

In a pilot study, Eid et al[9] compared the fracture resistance of endodontically treated teeth restored with CAD/CAM posts and cores with those of teeth restored with prefabricated glass fiber posts and composite cores. The group reported values of 426.08 ± 128.26 N for glass fiber posts and composite cores and 367.06 ± 72.34 N for one-piece posts and cores milled from fiber-reinforced composite blocks. Even though a subtractive manufacturing method was used as opposed to an additive method, the results are in accordance with the current study. These similar results may be due to the similar composition of the materials used to fabricate the custom posts.

After the fracture resistance analysis, it was found that the fracture lines were limited to the crown margins in the cervical region, and the groups showed a similar failure pattern. However, in the 3DP group, the broken part often contained the post, whereas in the FPC group, it was observed that the broken part contained almost no fiber structure. This situation indicates that the fiber posts were adhered to the coronal part more weakly.

The major limitation of laboratory studies is that they do not exactly replicate variables encountered in a clinical setting. Considering that thermal stress and water absorption lead to material deterioration,[15] one of the limitations of this study is that it did not include an aging procedure to provide indications about the long-term clinical effectiveness of the restorations. Furthermore, thermal and load cycling methods affecting the adhesive interface should be included in future studies as part of the fracture analysis. The application of different adhesives should also be considered.

CONCLUSIONS

The current study found that 3D-printed, custom resin posts and fiber glass posts were equally effective with regard to fracture resistance. The fracture resistance of endodontically treated teeth was not found to be significantly influenced by the post material.

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