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Original Research

Comparative Evaluation of Fracture Resistance of Teeth Restored with Biological Dentin Post to that of Glass Fiber and Composite Posts

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ABSTRACT

Objective: Although different materials have been used for post-fabrication, none can completely simulate natural dentin. Thus, biological dentin posts (BDP) have been introduced in daily practice as a novel approach. The purpose of this study was to compare the fracture strength of endodontically treated teeth with BDP, glass fiber posts (GFP), and composite posts (CP).

Methods: Forty extracted maxillary central incisors were divided into a control and three study groups (n=10). The coronal portions of the teeth were sectioned perpendicular to the long axis below the cementoenamel junction, and 14 mm roots were obtained. Following root canal filling and post-space preparation, the samples were divided into four groups as follows: Group 1 (control group): neither post-space preparation nor post-core restoration; Group 2: GFP and composite core; Group 3: CP and composite core; and Group 4: BDP and composite core. The samples were subjected to load using a Universal Testing Machine. Results were statistically analyzed with the One-Way ANOVA test.

Results: The control group had the highest fracture resistance ($p < 0.05$). The fracture resistance of the study groups was similar ($p > 0.05$). The ratios of re-restorable samples were 40%, 50%, and 30% for groups 2, 3, and 4, respectively.

Conclusion: All post types resulted in similar fracture resistance. BDPs may be preferable because of their low costs.

Keywords: biological dentin post, composite post, fracture resistance

INTRODUCTION

The restoration of endodontically treated teeth is crucial for achieving long-term success. Conventionally, direct composite filling and post-retained restorations are the most commonly used modalities [1]. Post supported restorations are the treatment of choice for reconstructing teeth with significant loss. However, it should be noted that the material from which the posts are manufactured affects the physical behavior of restored teeth. Cast or prefabricated metal posts have been used for several years; however, these conventional posts have certain drawbacks, such

as a high coefficient of elasticity, which necessitates substantial resorption of hard tissue and can result in root fractures [2]. Furthermore, metal posts may predispose to wedging forces and subsequently cause fractures in the coronal portion [3]. Because of the undesirable effects of metal posts, more contemporary materials, such as glass fibers, carbon fibers, and composite resins, are being used for post-production [4].

The use of fiber-reinforced glass fiber posts (GFP) and composite cores for intracanal cementation has become more popular because of their lower modulus of elasticity, thereby reducing the risk of root fractures in comparison to metal posts. Currently, composite resin materials are used directly for the fabrication of single-unit post cores, owing to their physical properties, which are comparable to those of dentin. Previous studies have found that composite resin strengthens dentin, improves adhesion, and prevents root fractures [4,5].

Although the different materials mentioned above have been marketed to achieve ideal post-material properties, none can completely simulate natural dentin [6]. Thus, biological dentin posts (BDP) have been introduced in daily practice as a novel approach [7].

Biological dentin was manufactured from sterilized extracted natural teeth [8]. Recently, a limited number of case studies have demonstrated successful outcomes when dentin has been utilized as a post material [9-12]. However, laboratory studies evaluating the physical properties and resistance of BDP are limited [13-15]. The objective of this investigation was to examine the resistance of teeth that underwent endodontic treatment and were subsequently reinforced using BDP, GFP, and Composite Posts (CP) to fractures. To our knowledge, a comparative analysis of the fracture resistance characteristics of these three materials has not been conducted previously. The null hypothesis proposed that BDP demonstrated superior fracture resistance compared to the other options.

Main Points

- Biological dentin posts (BDP) were compared with glass fiber and composite posts.
- BDP, glass fiber posts, and composite posts showed similar fracture resistance.
- BDP may be preferable due to their low cost compared to other options.
- Further studies are needed to better evaluate the performance of BDP.

MATERIALS AND METHODS

This study was approved by the Gaziantep University Clinical Research Ethics Committee on 26.02.2018 with the protocol number 2018/249.

Sample Size Determination

A power analysis was performed to determine the sample size. In the study, using the One-Way ANOVA test from the F test family, it was calculated that a total of N = 40 human teeth should be included, with each group n = 10 for four groups, at the alpha = 0.05 first type error level, 0.95 power of the test, taking into account the ideal effect size of 0.7 for the four groups.

Collection of Samples

A cohort of 40 maxillary central incisors, characterized by homogeneous root dimensions and the absence of dental pathologies such as caries, restorations, fractures, or cracks, was meticulously chosen for inclusion in the study. The calculus and soft-tissue remnants were removed using a scaler. Subsequently, the teeth specimens were immersed in distilled water and maintained at 37°C until subsequent experimentation. The experimental design incorporated 40 samples, which were allocated into four distinct groups: one control group and three treatment groups. Each group consisted of an equal number of ten samples.

Application of Root Canal Treatment

The tooth samples were sectioned along a longitudinal axis below the cementoenamel junction (CEJ) using a water-cooled diamond rotary cutting instrument, resulting in sections of 14 mm roots. The canals were carefully probed using a size 10 K-file (Sybron Endo, Scafati, Italy) until the instrument was accessible at the apical foramen. The designated working length was accepted at a point 1 mm inferior to the reference value. Working length was established as 1 mm short of this point. Canals were prepared with Bio race endodontic files (FKG Dentaire SA, La ChauxdeFonds, Switzerland) up to size 35.04. Two milliliters of 5.25% sodium hypochlorite (Chloraxid, Cerkamed, Poland) were used for 1 minute between each instrument. A total of 10 ml sodium hypochlorite was administered for 5 min in each canal. All canals were then dried using paper points

(DentPlus, Choonchong, Korea). The canals were sealed using a combination of gutta-percha (Dentplus, Choonchong, Korea) and a resin-based sealer (Dentsply, Konstanz, Germany), which were condensed laterally.

Preparation of Post Cavities

Post spaces were prepared using Gates Glidden size 3 and 4 burs (Thomas Bourges, France). The top 4 mm of the root canal filling was preserved. Following cleansing of the post cavities with 0.2% chlorhexidine, they were irrigated with distilled water for 10 seconds and subsequently desiccated using a paper point.

Formation of Working Groups

After the completion of the root canal filling and post-space preparation, the specimens were allocated into four separate groups, as described in the subsequent section.

Group 1 (control group): Neither post-space preparation nor post-core restoration was performed.

Group 2 (glass fiber post and composite core): Glass fiber posts sized 1 (CYTEC Blanco, Mannenkratt, Germany) with a diameter of 1.1 mm were cemented using dual-cure self-adhesive resin cement (RelyXU100, 3M ESPE, St. Paul, Germany), according to the manufacturer's instructions. Excess glass fiber posts with a length of 6 mm were removed. Therefore, the overall length of the post was 13 mm, and three millimeters of the fiber post was retained outside the root canal for core reinforcement. Following cementation, the core build-up was performed with a composite resin material (Solare X, GC Corporation, Tokyo, Japan) following the application of a bonding agent (Clearfil SE, Kuraray Noritake Dental Inc., Tokyo, Japan) to both the post and the surrounding dentin. All cores were prepared in a standard manner using standard molds (4 mm in height and 3 mm in the mesiodistal direction).

Group 3 (composite post and composite core): For the preparation of the composite post, 13 mm long cylindrical molds with a diameter of 1.1 mm were used. The composite resin was poured into a mold and exposed to light for curing. In this way, composite posts with dimensions similar to those of GFPs were obtained. Post-cementation and core build-up were performed in the same manner as in the previous group.

Group 4 (biological dentine post and composite core): Dentin posts were prepared using the roots of 10 canine teeth. The selected teeth were placed in a milling machine to prepare ten dentin posts of standard shape and size. Milling was performed using manual programming on a 3-axis Computer Numerical Control (CNC) machine.

A computer model was designed to obtain dentin posts and was loaded into the CAM software that produced 10 dentin posts, similar to glass fiber posts (Figure 1). All prepared dentin posts were sterilized in the autoclave at 121°C for 15 minutes to ensure all biosafety standards for dental disinfection. Post-cementation and core build-up were performed in the same manner as in the previous groups. Apical 2-3 mm composite and biological dentine posts were further tapered to obtain a shape similar to that of glass fiber posts. The samples were embedded vertically at the root half level of the acrylic resin blocks. All materials used and their properties are given in Table 3 (Table 1).

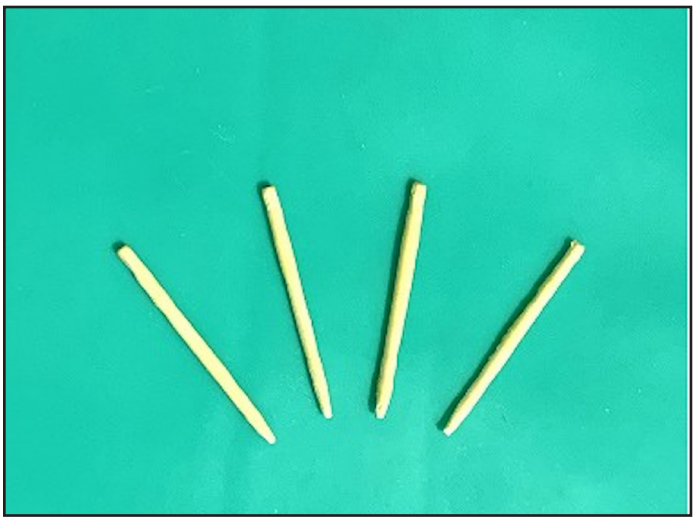

Figure 1. Biological dentine post milled from human dentin.

Table 1. Materials used in the preparation of the hides and their properties

Used of the Materials	Content of the Materials
Glass Fiber Posts	Prefabricate Fiber Posts (CYTEC Blanco, Mannenkratt, Germany-Glass Fiber)
Composite Posts and Core	Composite (Solare X, GC Corporation, Tokyo, Japan, Light-Cured Radiopaque Composite)
Biological Dentin Posts	Extracted Human Teeth (Human Dentin Tissue)

Fracture Strength Test

The thermocycling procedure (5000 cycles between 5 0C-55 0C with a dwell time of 30 s at each temperature) was applied to all teeth to simulate physiological aging. The samples were positioned at an angle of 45 0C (ISO) along the longitudinal axis (Figure 2) with an exclusive gauge loaded with a ball end (of diameter φ = 2 mm) and subjected to fracture testing using a Universal Testing Machine until failure occurred (AGS-X; Shimadzu, Kyoto, Japan).

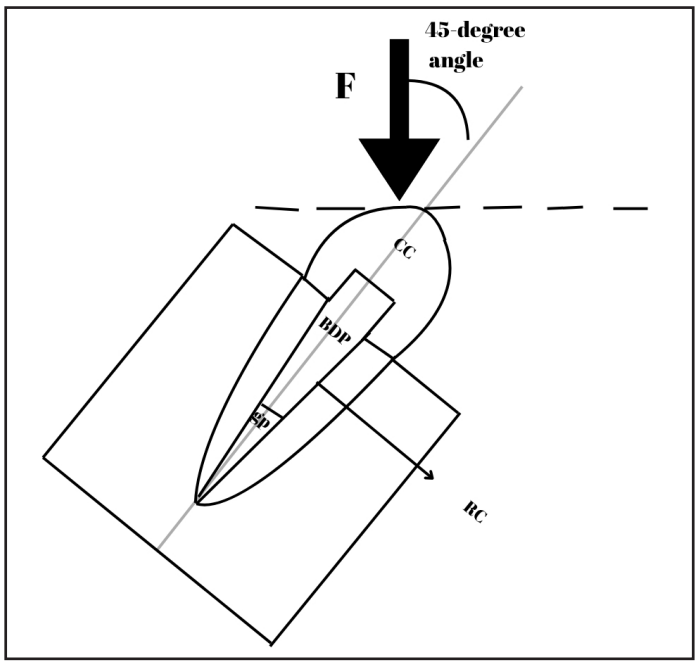

Figure 2. Post-core restored and acrylic embedded sample.

A force was applied to individual teeth at a constant crosshead velocity of 1 mm/min, and the magnitude of the force resulting in tooth fracture was measured and recorded in Newtons (N). The line of fracture was also recorded as either re-restorable (core material fracture) or non-re-restorable (root fracture). One-way analysis of variance (ANOVA) following Türkiye's honest significant difference (HSD) tests was performed for the statistical analysis of the fracture forces. P values less than 0.05 were considered statistically significant. The SPSS (S version 26.0; IBM Corp., Armonk, NY) was used for statistical analysis. Data were expressed as the mean fracture load ±standard deviation.

RESULTS

The mean fracture resistance of each group along with their respective standard deviations is presented in Table 2. Under static loading conditions, the control group demonstrated superior fracture resistance compared with all other groups, with statistical significance (p = 0.0597). The other groups showed statistically similar fracture resistance. The three groups were as follows: Group 3 (composite post and composite core), Group 4 (biological dentine post and composite core), and Group 2 (glass fiber post and composite core).

Table 2. Mean fracture resistance (newton) and standard deviation

Groups	n	Mean ± SD	p
Group 1	10	1238.67[a] ± 320.65	p = 0.597
Group 2	10	853.05[a] ± 163.26	
Group 3	10	960.51[a] ± 310.46	
Group 4	10	921.38[a] ± 233.65	

*One-way Anova statistical test was used. SD.: Standard Deviation.

The ratios of re-restorable samples for each group are presented in Table 3. 40%, 50%, and 30% of Group 2 (glass fiber post and composite core), Group 3 (composite post and composite core), and Group 4 (biological dentine post and composite core), respectively, were found to be reliable. Restorability between groups was evaluated using One-Way ANOVA statistical analysis. Tukey HSD was used for differences between subgroups. The restoration rate of group 1 was 100% and statistically significant (p = 0.005).

Table 3. Re-restorable fracture patterns of groups (%)

Group Number	n	Re-restorable pattern	p
Group 1	10	%100	p = 0.005
Group 2	10	%40	
Group 3	10	%50	
Group 4	10	%30	

*One-way Anova statistical test was used. Tukey HSD statistical test was used in the evaluation of subgroups.

DISCUSSION

The attainment of successful long-term outcomes in the restoration of root-filled teeth necessitates the use of materials with physical properties analogous to those of dentin. The dentin microstructure is complex. The modulus of elasticity varies between 13-18 GPa, in different parts, which may prevent crack propagation [16]. The physical properties of the post

systems agree with dentin, and the greater their resistance to breakage, as micromovements such as stretching, expansion, and contraction are associated with dentin [17]. Therefore, in this study, we hypothesized that BDP would have the highest fracture resistance. Several instances have been documented in which dentin has been used as a post material, resulting in favorable outcomes [18, 19]. A comprehensive systematic review revealed that biological dentin posts exhibited enhanced fracture resistance when used in anterior teeth [20]. Our study revealed that teeth restored with BDP exhibited a comparable level of fracture resistance to both CFP and composite posts. Thus, the null hypothesis is rejected. This may be related to the advanced physical properties of the novel FRP and composite resin materials. The potential source of controversy between prior research and the present study could lie in the employment of various brands of glass fiber post systems. However, it should be noted that even if any glass fiber post system represents physical properties similar to BDP, dentine posts do not incur any cost. Furthermore, if there are several glass fiber post brands, the use of natural dentin as a post material seems safer and more advantageous. A further advantage of BDP is that it does not generate stress in dentin, preserves canal walls, is biocompatible, adapts to canal configuration, and has higher retention of these posts than prefabricated posts [21,22], resulting from a unique biomechanical (monoblok) system that is compatible with bonded and cemented posts [8,23].

The mechanical attributes of dental posts, notably their modulus of elasticity, compressive strength, and coefficient of thermal expansion, demonstrate a striking correspondence with those observed in root dentin. Moreover, the fracture resistance of dentin is higher than that of current restorative materials. A dentin post is a structure that functions as a single unit and exhibits properties similar to those of root dentin. It is capable of uniformly distributing stresses [24-26]. The ability of dentin posts to flex in response to movement of the tooth and dentin near the root is a critical factor in maintaining the structural integrity of the tooth and post. By allowing this coordinated flexion, the tooth and post can withstand the forces exerted upon them during chewing and other movements, ensuring that the post remains securely in place and the tooth remains stable. This property of elasticity is essential for the effective functioning of the dentin post and the surrounding tooth structure, and is a key consideration in the design and placement of dental restorations. In this way, the post absorbs the shock and transmits only a small amount of [26]. On the other hand, the use of natural dentin for post restorations has limitations including finding suitable extracted teeth, and the patient may not accept a tooth obtained from another individual [22,27].

In contrast, the ratio of re-restorable fracture patterns was lower for BDP than for GFP and CP. Given that fiber posts share physical characteristics akin to dentin, they operate as shock absorbers, dispersing the majority of stresses uniformly across the ultimate restoration, with only an insignificant portion being transmitted to the dentinal walls. This results in favorable fractures. However, these features are superior those to of BDP, as mentioned above. However, our results showed that BDP represented the least amount of re-restorability, whereas composite posts had the highest. We assume that this may be related to the similarity in the physical properties of the composite resin core material and glass fiber or composite posts. In a case report by Correa-Faria et al. [11], both the post and the core were constructed from natural dentin. It may be possible to reduce the high risk of unrestorable fracture occurrence in such a manner (forming a single unit post-core from human dentin). Composite resin materials can also be used for post construction because of their reinforcing effects on dentin and adhesion. Schwartz et al. [28] reported that composite posts reinforce root dentin more than any other material, thus preventing unfavorable root fractures. This may explain why the ratio of unrestorable fracture patterns in the composite post group in the present study was the lowest.

In this research endeavor, coronal restorations were deliberately refrained from being conducted around the cores, with the intention of preventing external reinforcement from impacting both the post and core. By doing so, the investigation aimed to eliminate variables such as material composition, form, extent, and width while simultaneously promoting standardization within the dental restoration field. Thus, the strengths of the post and core were tested more accurately [15,29].

A force load was applied to the samples at an angle of 135 degrees. According to Guzy and Nicolls (1980), when the incisors in Class I occlusion are occluded, the teeth make contact with the opposites at an angle of 130-135 degrees. This angle was selected to replicate the contact angles of maxillary and mandibular incisors. The study used Rely X U100, a self-adhesive universal resin cement (dual-cure), to carry out a single-step luting procedure and consequently eradicate any sensitivity associated with procedural techniques.

Limitations

Biological dentin posts, which utilize the natural structure of dentin for dental restorations, have several limitations that must be carefully considered in clinical practice. A primary challenge is related to the inherent properties of dentin as a biological material. Dentin is a complex structure composed of an organic matrix primarily made of collagen, which interacts with water molecules. This interaction is crucial for structural integrity, but also poses limitations.

Additionally, while bioactive materials such as calcium phosphate and silicate-based compounds have demonstrated potential in promoting dental tissue regeneration and enhancing dentin durability, methodological heterogeneity and limited generalizability of research studies constitute challenges for widespread clinical application.

Another limitation of our in vitro test model is the multidirectional nature of the masticatory forces, which cannot be replicated in a Universal Testing Machine that applies only a single unidirectional load. This form of in vitro loading may not consistently replicate the in vivo conditions.

Overall, while biological dentin posts offer a promising avenue for dental restoration by leveraging the natural structure of dentin, their limitations related to bonding efficacy, material degradation, and variability in research outcomes must be carefully managed to optimize the clinical outcomes. Further investigation and technological advancements are necessary to address these challenges and to enhance the effectiveness of biological dentin posts in dental applications.

CONCLUSION

Within the constraints of the current research, it can be concluded that both natural dentin and prefabricated materials, such as post materials, exhibit comparable effectiveness in reinforcing root strength. However, BDPs can be considered advantageous in terms of their low cost and ease of handling. Further studies are required to evaluate the BDPs better.

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Informed Consent: Informed consent was obtained.

Ethical Approval: This study was approved by the Gaziantep University Clinical Research Ethics Committee on 26.02.2018 with the protocol number 2018/249.

Author Contributions: - Conception: B, E; Ö, S; S, F - Design: B, E; Ö, S - Supervision: F, S - Materials: B, E; Ö, S; S, F - Data Collection and/or Processing: B, E; S, F - Analysis and/or Interpretation: B, E; Ö, S; S, F -Literature: B, E; Ö, S; S, F - Review: S, F - Writing: B, E; Ö, S - Critical Review: B, E; Ö, S; S, F

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