The Fracture Resistance of Endodontically Treated Teeth with Biologic Posts of Different Lengths: in Vitro-Study

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Abstract

This study aims to evaluate the resistance to fracture of endodontically treated anterior permanent teeth restored with dentin posts of 3 different lengths and compare it with fiber posts with two-thirds of the length of the root canal.

Thirty-six extracted mandibular premolars were used for the preparation of the dentin posts, while forty-eight extracted maxillary central incisors were endodontically treated and radicular post preparations were performed, then the teeth were randomly divided into four groups (n=12); group A (comparative group): restored with fiber-reinforced posts two-third of the canal length, group B, C and D were restored with dentin posts of two-third, half-length, and one-third of the intra-canal length respectively. The resistance to fracture of the samples was tested using a Universal Testing Machine, and the location of the fracture was examined under a stereomicroscope (x10).

One–way ANOVA showed that dentin posts of two-thirds length had a statistically significant higher fracture resistance than fiber posts of two-thirds length, with favorable fracture patterns.

Dentin posts with two-thirds of the root canal length can be a promising substitute for conventional glass fiber posts by acting as a micro-mechanical homogenous unit along with the root dentin.

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Introduction

Dental professionals face considerable challenges achieving satisfactory aesthetic and functional outcomes during coronary reconstructions of extensively damaged endodontically treated teeth.[1] It is recommended to utilize intra-radicular posts to treat these teeth to maintain the core build-up before rebuilding the compromised tooth structure and to evenly distribute the intraoral forces along the longitudinal axis of the root. [2,3]

The post material must possess physical, mechanical, and aesthetic characteristics similar to dentin. The material should also be biocompatible and exhibit the ability to adhere to the tooth structure.[4] To ensure consistent distribution of the occlusal load over the whole length of the root, it is advised that the rigidity of the post be similar or close to that of the tooth.[5] Post systems come in a variety of materials, including metal, glass fiber, carbon fiber, and ceramics. Nevertheless, the currently available prefabricated posts fail to meet the desired ideal biological and mechanical criteria. Natural dentin is considered the most suitable material for substantiating these properties.[1,3]

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Post's length and diameter are the factors that have reportedly been linked to post survival.[6] Nevertheless, the posts' material and design choices can affect how the stress is distributed throughout the tooth. Glass and carbon fiber posts had more uniform stress distributions than metallic posts, which reduced the likelihood of biomechanical failure in teeth that had undergone endodontic treatment. It is generally advised that posts should have Young's modulus closer to dentin, because it is supposed to produce better stress distribution.[7] Therefore, the utilization of biologic posts composed of root dentin is regarded as a viable alternative that maintains and decreases stresses on the internal dentin walls of the root canal. This approach provides full biocompatibility and exhibits resilience similar to that of the natural tooth, thereby promoting enhanced tooth durability and retention.[5]

Few studies reported that teeth restored with dentin as post material have shown the greatest fracture resistance and reparability compared to fiber-reinforced glass post systems.[8,9] Among the various factors affecting the retention of a post, the post length is still controversial. The root's resistance to fracture is influenced by the stress distribution caused by the length of the post. It has been proposed that in order to resist the occlusal forces and facilitate stress distribution, the post length should be equivalent to the crown height, or two-thirds of the root length.[10] On the other hand, an increase in post length could potentially reduce root strength.[11] Post-length did not significantly improve the fracture resistance of endodontically treated teeth, according to another study.[4] although biologic dentin post have been recommended as a biomimetic alternative to the conventional post systems,[1,8] the ideal length to optimize the fracture resistance of such posts is not yet well studied. Hence, there is a need for further investigation of the influence of different lengths of dentin posts on the resistance to fracture of endodontically treated teeth. The null hypotheses in this study was that there is no difference in the fracture resistance between biologic dentin posts of different lengths compared to the fiber post of two-thirds canal length.

Materials and methods

After obtaining clearance from the Institutional Ethical Committee Ref. No. SDC/SMG/2015/477, 48 extracted maxillary central incisors and 36 extracted single-rooted mandibular premolars, extracted for therapeutic purposes and dully donated, were selected randomly from the Department of Oral and maxillofacial surgery, Sharavathi Dental College and Hospital, Shivamogga, according to inclusion and exclusion criteria, The inclusion criteria for this study included teeth that had fully developed apices, teeth that were approximately equal in size, and teeth that did not display any evident craze lines. The exclusion criteria included teeth that exhibited incomplete maturation of apices, teeth that displayed indications of dental caries, as well as teeth that presented with craze lines or fracture lines on the root surfaces.

The extracted teeth were rinsed using a continuous water flow, and any soft tissue remaining on the root surfaces was carefully removed. Subsequently, the teeth were autoclaved to ensure proper sterilization and prevent potential infections. Following the criteria set by the International Standards Organization, the sterilized teeth were stored in sealed containers filled with distilled water.[8,12]

Sample size estimation:

The sample size was calculated using G* Power software version 3.1, on expecting the largest difference between any two means and standard deviation as 36 and on anticipating Cohen's effect size (f) of 0.69 from previous studies [3] with α (type I error) as 0.05 and probability of β (type II error) as 0.10 and the power as 90%, the minimum sample size calculated is 9 per group. To minimize sampling error, the sample size was increased to 12 per group.

The grouping of samples:

GROUP A (Comparative Group): 12 prepared samples were restored with Fiber reinforced post (Reforpost®, Angelus, Prana, Brazil), 1.6 mm diameter of 2/3rd (7.3mm) of intracanal length and a standardized composite core.

GROUP B: 12 prepared samples were restored with dentin posts of 2/3rd (7.3mm) of intracanal length and a standardized composite core.

GROUP C: 12 prepared samples were restored with dentin posts of 1/2 (5.5mm) of intracanal length and a standardized composite core.

GROUP D: 12 prepared samples were restored with dentin posts of 1/3rd (3.7mm) of intracanal length and a standardized composite core.

Specimens' preparation

The anatomic crowns of the extracted maxillary central incisors were dissected at a 90-degree angle to the tooth's long axis using a water-cooled diamond disc positioned 2 mm above the cementoenamel junction (CEJ). This ensured that the coronal surface was perpendicular to the root's long axis. The resulting root length measured 13 ± 2 mm, and the cut coronal surface was smoothed using an abrasive stone.

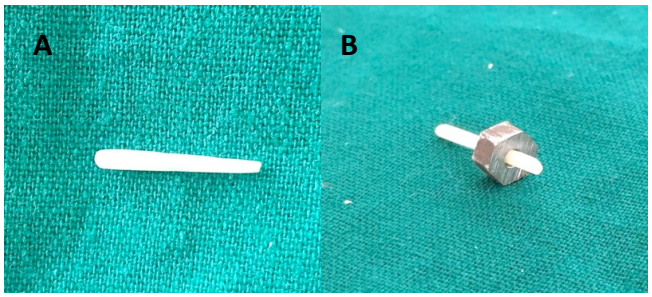

Figure 1. A: the dentin biologic post, B: the post standardization using a gauge ring.

Following establishing straight-line access using a round bur, the pulp chamber and root canal were thoroughly irrigated with saline solution to eliminate any debris present. Subsequently, a K-file #10 (Dentsply, Maillefer, USA) was inserted into each root canal to ensure the canal's patency. Once the tip of the file was observed at the apex, the final working length was determined to be 1 mm less than the measured length. Then, mechanical instrumentation was done using rotary Protaper Universal files (Dentsply, Maillefer, USA). The pulp space was prepared utilizing the crown down approach till master apical size of 30 and a taper of 6%, then teeth were obturated with laterally condensed Gutta-percha (Dentsply, Maillefer, USA). In each specimen, a No.4 Gates Glidden drill (Dentsply, Maillefer, USA) was utilized to eliminate 2 mm of coronal Gutta-percha, after which post space preparation was conducted up to the size 3 Peeso-reamer (Dentsply, Maillefer, USA).

Preparation of the biologic dentin posts:

The crowns of the extracted mandibular premolars were separated, and the roots sectioned mesiodistally along the long axis of the tooth using a diamond disc under water cooling. The irregular surfaces of these sectioned roots were smoothed using a diamond bur and shaped to obtain biologic posts of various lengths. Standardization of the prepared posts was done by passing through a ring gauge of diameter 1.6 mm (Fig. 1) and the final dentin posts were finished using Arkansas's stone.

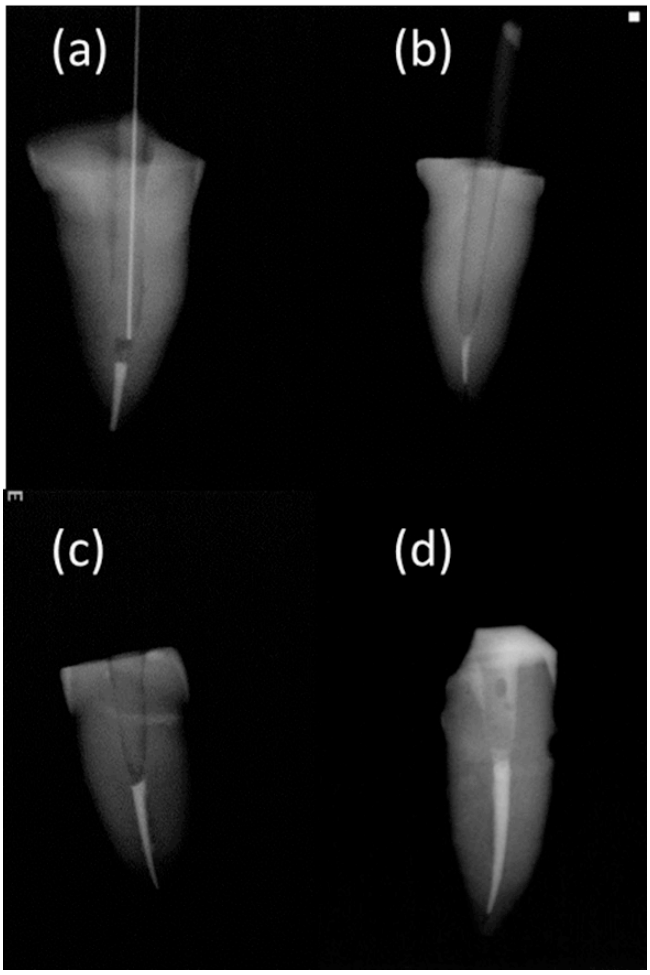

Figure 2. Radiographs confirming the posts fitting inside the prepared root canals, A: fiber posts ⅔ length, B: dentin post ⅔ length, C: dentin post ½ length, D: dentin post 1⁄3 length of the root canals.

The posts and the walls of the canals were conditioned with 37% phosphoric acid for 15 sec and washed thoroughly for the cementation of the biologic post and fiber post. A bonding agent was applied and polymerized (Parabond, Coltene/Whaledent, Altstätten, Switzerland). The posts were cemented using dual cure resin cement (Paracore,

Coltene/Whaledent, Altstätten, Switzerland). The resin cement was applied to the canal walls using a spreader and the post surface, which was then inserted into the prepared canal space under constant pressure. Light curing was done for 30 sec, followed by core build using dual cure resin cement. The fitting of the posts inside the prepared canals was checked through radiographs done for all the specimens (Fig.2). Nickel chromium crowns were fabricated and cemented with luting glass ionomer cement (Fuji I, GC. Japan).

Each tooth was marked with a pencil at 2 mm below the cemento-enamel line, spanning around 11 mm of the root, to represent the periodontal ligament. This region was covered with #7 wax (Wilson, So Paulo, Brazil), which was melted in a water bath until it reached the demarcation line and had a thickness of roughly 0.3 mm. Prepared tooth samples were then embedded in acrylic resin with dimensions of 1cm×1cm×3cm.

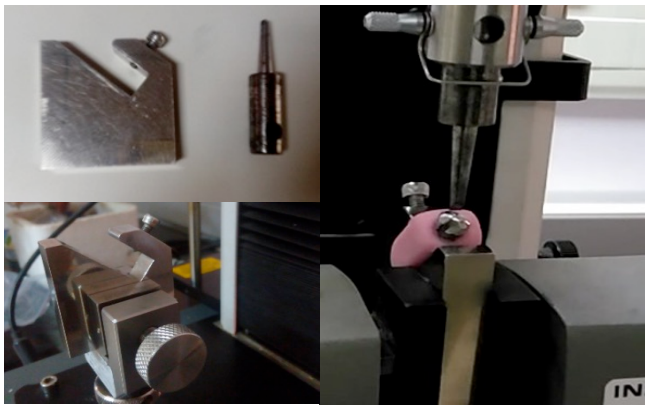

Figure 3. The customized inclined jig used for loading the specimens at 135 degree in the Universal Testing machine.

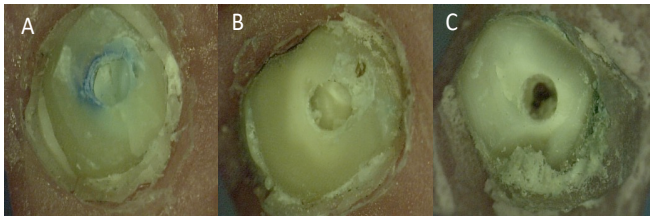

Figure 4. The locations of root fracture as seen under the stereomicroscope (10x), A: cervical fracture, B: middle root fractures, C: apical fracture.

Evaluation of fracture resistance

The samples were placed on a customized inclined position jig (Fig.3) and exposed to a compressive load at a crosshead speed of 1mm/min using a Universal Testing Machine (Instron, Model 2619-107, USA) until they reached the point of fracture. The specimens were subjected to a load on the palatal aspect at an angle of 135° relative to the long axis of the teeth. The fracture strength values were measured in units of Newton (N).

Evaluation of location of failure

Following testing, stereomicroscopic analysis was performed to categorize the failure site (x10). The failure location was recorded as favorable and catastrophic (Fig. 4). Root fractures at the cervical third and core were classified as favorable (repairable fractures). In contrast, root fractures at the middle and apical thirds were classified as unfavorable (non-repairable fractures).[13]

Statistical analysis:

Numerical data were explored for normality of distribution using Kolmogorov-Smirnov and Shapiro-Wilk tests; the data demonstrated normal distribution; hence, a parametric evaluation was adopted. The data were analyzed initially using One–Way Analysis Of Variance (ANOVA); the intergroup and intra-group comparisons were done using the Bonferroni's multiple comparison post hoc test. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 27 for Windows.

Groups	Mean (N)	SD	F- Value	P-value
Group A	631.79_a	9.34		
Group B	796.35_b	13.24	1750.15	0.00*
Group C	629.06_a	20.14		
Group D	337.15_c	18.25		

Table 1. The fracture resistance means and standard deviations of the tested groups.
*: Significant at P≤ 0.05.
Means with different letters states for significant difference, means with the same letter states for non-significant difference.

Results

The fracture resistance group means, and standard deviations are presented in Table 1 and the graph in Figure 5. One-way ANOVA revealed significant difference between the tested groups. The greatest fracture resistance was found in group B (two-thirds length dentin post group),

with a 796.35 N value, followed by group A (the comparative two-third length fiber post group) 631.79, followed by group C (half-length dentin post group) and group D (one –third length dentin post group), with 629.06 N and 337.615 N, respectively. The Bonferroni's multiple comparison post hoc test showed a significantly higher fracture resistance for group B (two-thirds dentin post-length group) than the comparative fiber post group of two-thirds length (group A), while the one-third length dentin posts (group D) was significantly lower and the half-length dentin post (group C) had no statistically significant difference than the comparative fiber post group of two-thirds length (group A) respectively.

On the evaluation of the mode of failure, in group A, 10/12 (83%) of the specimens showed cervical third fracture (favorable), while 2/12 showed root fracture (unfavorable). In group B, 100 % of the specimens showed a fracture at the cervical third (favorable). In group C, 7/12 (58%) of the samples showed a cervical-third fracture, and 5/12 (41%) showed a middle third fracture. In group D, 100% of the samples showed a middle third fracture, which is considered a favorable fracture.

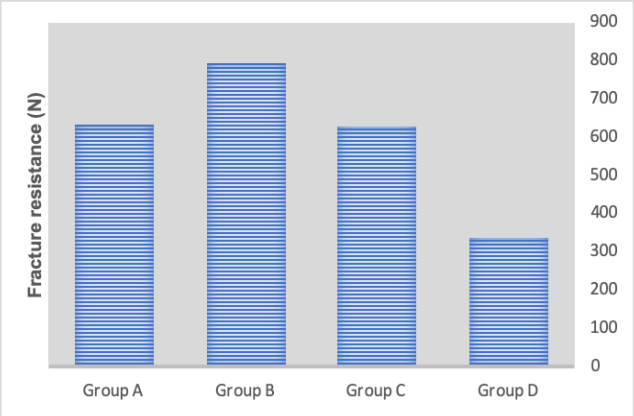

Figure 5. Fracture resistance mean values of the different tested post groups. A: fiber posts ⅔ length, B: dentin post ⅔ length, C: dentin post ½ length, D: dentin $^{1}/_{3}$ the root canals.

Discussion

The reconstruction of severely compromised endodontically treated teeth is still critical; the physical and mechanical properties of these teeth differ dramatically from those of vital teeth.[1] There is a general assumption that teeth that were endodontically treated have reduced strength and have increased susceptibility to fracture because of dehydration and lack of nutrient supply.[2] Besides, intra-radicular posts are required to support a core foundation when the remaining clinical crown is insufficient. [2,3] Custom-made or prefabricated post such as metal, carbon fiber, glass fiber, or ceramic has been used. Existing research indicates that it is recommended for the stiffness of the post to be approximately equivalent to or near that of the tooth to provide a uniform distribution of occlusal stresses along the entire root. The susceptibility to root fracture is found to be higher in metal posts[3]. As a result, a significant goal in dentistry is to restore endodontically treated teeth using metal-free, homogeneous materials that possess physical qualities comparable to dentin. The use of dentin as a post could be an alternative, as it has properties similar to root dentin. Few reported cases showed successful outcomes with dentin as post-material.[14-16] Therefore, additional research was required to investigate the likelihood of human dentin being suitable as a post material.

The current study evaluated the fracture resistance of endodontically treated permanent central incisors restored with biologic dentin posts with different lengths and compared it with fiber posts; the null hypothesis was rejected, because there was a significant difference in the fracture resistance between the tested groups.

The balance between post length and coronal extension is desirable. Few studies have shown that lengthening the post improves post retention and effectively distributes stress along the tooth's long axis.[17-21] According to Braga et al., and Pereira et al., when the post length was half the length of the root, the behavior of the root was comparable to that of roots that had been prepared up to two-thirds of their length.[20,21] Chuang et al., claim that lengthening the post could weaken the root system.[22]

The teeth were selected in the current study according to inclusion and exclusion criteria for standardization. The mean length of the roots was 13 ± 2 mm to ensure the samples were eligible for use as standards. Moreover, the incorporation of ferrule has been eliminated due to its potential to enhance the fracture resistance of post and core systems.[22,24] Dual cure composite core material was selected in the current study for the core build-up and

cementation of the posts, aiming to maximize the bond strength. According to a study by Rodig et al., luting with the core build-up material can significantly increase the chemical bond strength between the dentin and the post.[25] The load was applied at 135-degree angulations to the long axis of the tooth, which replicated the position, contacts, and loading characteristics of maxillary central incisors in class I occlusion.[24,26] Fracture resistance was recorded when there was a fall in the values within the loading curve, expressed in Newton's.

This study showed that the primary failure of endodontically treated teeth was significantly influenced by the post-material utilized, as the dentin posts with two-thirds length had more fracture resistance than fiber posts of the same length. Similar results were obtained by Kurthukoti et al., Ambica et al., and Palekar et al.,[27-29.] This study also showed a significant difference in the effect of post-length on fracture resistance. Dentin posts with two-thirds length showed higher fracture resistance than other tested groups; different results have been reported by Ghazawy and Badran, who discovered that compared to fiber posts, long biological dentin posts had statistically significant lower fracture resistance.[9] This might be explained by the histological variation between the permanent teeth utilized in the current investigation and the primary teeth used in their study.

When comparing fiber posts and dentin posts of three different lengths, dentin posts with two-thirds and half the length have shown better fracture resistance than fiber posts of two-thirds length. This is explained by the dentin post's physio - mechanical characteristics, uniform distribution of stress, and shock-absorbing abilities.[28,29]

In this study, 83% of the fiber posts group and 100% of the dentin posts group with two-thirds of intraradicular length showed fracture lines above or at the level of the cervical third. Both the dentin posts and fiber posts group showed a favorable fracture. Similar results were shown in the study conducted by Kurthukoti et al., in which 90% of the fiber posts group and 100% of the dentin post group showed favorable fracture.[7] This indicates that the utilization of dentin post resulted in reduced harm to the structure of the tooth during failure load. The current investigation also demonstrated a relationship between fracture resistance and the post material, since the dentin posts of two-thirds and half-length showed better results than fiber posts of two-thirds length of the root canal. The dentin post's physical characteristics, including its elastic modulus, viscoelastic behavior, compressive strength, thermal expansion, etc., are quite similar to those of root dentin.[27] Accordingly, the dentin post acts as a micromechanical homogenous unit along with the root dentin, and this helps in evenly distributing the forces along the long axis of the tooth, which helps in better fracture resistance compared to the fiber post. Barjao-Escribano et al. suggested that posts with elastic moduli similar to dentin will function better biomechanically.[28] The elastic modulus of the fiber post is 40 GP, and the elastic modulus of root dentin is roughly 14–20 GP, the failure of the fiber post can be related to the difference in biomechanical characteristics between the fiber post and root dentin,[29,30] which can lead to stress concentration at the interface, ending in posts separation and failure.

The limitations of the present investigation include the in-vitro character of the study and the relatively small sample size. The Universal Testing Machine cannot replicate the multi-directional attributes of masticatory forces. Further investigation is required to explore additional parameters that influence the fracture resistance of endodontically treated teeth with biologic dentin posts. These factors include post diameter, post design and adaptability, the quantity of surviving root dentin, as well as the core material and its design. For future investigations, it is also recommended to employ long-term randomized control studies with bigger sample sizes.

Conclusions

The present study suggests that biologic dentin post with two-thirds length of the root canal had better fracture resistance than fiber posts of the same length and other dentin post groups with different lengths, with a favorable fracture pattern, Hence can be a promising substitute for conventional glass fiber posts by acting as a micro-mechanical homogenous unit along with the root dentin.

Declaration of Interest

The authors report no conflict of interest.

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