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Comparative evaluation of fracture resistance in endodontically treated permanent mandibular first premolar restored using glass fiber posts and dentin posts: An *ex vivo* study

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Abstract:

It remains unknown whether restoring endodontically treated mandibular first premolars with dentin posts provides superior fracture resistance and more favorable failure modes compared to glass fiber posts. Therefore, it is of interest to compare the fracture resistance and mode of fracture of 24 endodontically treated teeth (ETT), human mandibular first premolars restored with CAD-CAM fabricated dentin posts or prefabricated glass fibre posts using universal testing and stereomicroscopic analysis. There was statistical indifference between the two groups in fracture strength ($p = 1.000$). The most frequent mode of failure in both groups was the failure of the luting cement, followed by adhesive failure at the dentin-cement interfaces and no catastrophic post or root fractures were noted. Thus, dentin posts and glass fibre posts showed similar biomechanical performance and are clinically acceptable for the rehabilitation of ETT.

Keywords: Biomimetic post systems, dentin post, endodontically treated teeth (ETT), fracture strength and glass fibre post

Background:

Restoration of endodontically treated teeth (ETT) poses significant biomechanical and aesthetic challenges in restorative dentistry. Loss of pulpal vitality, combined with removal of tooth structure during endodontic procedures, renders these teeth more susceptible to fracture compared to vital teeth [1]. When substantial coronal tooth structure is missing, the placement of an intra-radicular post becomes necessary to retain the core and provide adequate support for the final prosthetic restoration [2]. Several methods and materials for post and core restorations have been documented, ranging from custom-made cast metal posts to prefabricated metal and non-metal posts and bonded posts, each with its own advantages and drawbacks [3]. The selection of post material plays as a decisive role in determining the longevity and biomechanical performance of ETT. Ideally, a post material should closely simulate the physical and mechanical traits of natural dentin, including modulus of elasticity, thermal expansion coefficient, compressive strength and optical characteristics, while also establishing a reliable bond with root dentin [4]. With increasing aesthetic demands, metal-free post systems such as zirconia and glass/quartz fibre-reinforced composite posts have gained popularity. Although ceramic (zirconia) posts offer superior aesthetics and corrosion resistance, their high modulus of elasticity and inherent stiffness may result in stress concentration within the radicular dentin, predisposing the tooth to catastrophic root fractures [5]. Conversely, fiber-reinforced composite posts have demonstrated favourable clinical outcomes due to their relatively dentin-like elastic modulus, which promotes more uniform stress distribution along the root. However, concerns have been raised regarding their mechanical behaviour, as some studies report that their rigidity and flexural strength may exceed that of root dentin by several folds [6]. It is well established that a post material with mechanical properties closely approximating

dentin minimizes stress concentration at the dentin-post interface and allows harmonious force transmission throughout the root structure, thereby reducing fracture risk. Despite advances in biomaterials, replicating the complex hierarchical microstructure and biomechanical characteristics of dentin remains challenging [7]. An adhesion between the dental structure, cement agent and dentin post forms a monoblock, which better distributes stress along the root and reduces adhesive and cohesive failure [5]. Therefore, it is of interest to evaluate the fracture resistance and mode of debonding failure of endodontically treated permanent mandibular first premolars restored with glass fiber posts and dentin posts.

Material and Methods:

The *ex vivo* experimental investigation was carried out at the Department of Prosthodontics, Crown & Bridge and Implantology, MES Dental College, Perinthalmanna, Malappuram, Kerala, CIPET Institute of Petrochemicals Technology (IPT), T.V.K. Industrial Estate, Guindy, Chennai and National Institute of Technology, Calicut, Kerala. The study was approved by the Institutional Ethics Committee (IEC/MES/102/24) and included 24 extracted sound mandibular first premolars, randomly allocated into two groups employing a convenience sampling technique. Groups 1 and 2 ($n=12$ /group) included ETT restored with a dentin post and a glass Fiber post (control group), respectively. The exclusion criteria were: teeth with dental caries, teeth with fracture, teeth with restoration, fluorosis, attrition, erosion and abrasion, hypoplastic teeth, teeth undergone previous endodontic treatments, those with ossified canals, flared roots or any other pathology.

Procedure:

For this study, 24 healthy human permanent mandibular first premolar teeth extracted for treatment were collected. The teeth were visually assessed for no evidence of caries, restoration or fracture. Selected specimens were cleaned of blood, debris and calculus by immersing in 10% formalin for 2 hours and then were stored in 0.9% normal saline until the commencement of the tests. The collection, storage and handling of extracted teeth were in compliance with the Occupational Safety and Health Administration (OSHA) and the Centres for Disease Control and Prevention (CDC) guidelines. A dental surveyor was used to align the long axis of the tooth vertically to the horizontal plane of the mold. Each tooth sample was inserted into a 5 × 5 × 5 cm silicone mold containing freshly mixed cold-cure acrylic resin, ensuring that the cemento-enamel junction (CEJ) remained above the level of the acrylic.

Preparation of specimens:

Placing a size #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) little beyond the apical foramen showed apical patency of the removed mandibular first premolars the working length (WL) was 1 mm less. Root canal preparation was done utilising the ProTaper Rotary System (Dentsply Maillefer, Ballaigues, Switzerland) in a crown-down approach, brushing up to size F3 (speed: 300 rpm; torque: 3.0 N cm). After each instrument, 2 mL of 3% NaOCl (Septodont, Saint-Maur-des-Fossés, France) was irrigated. The canals were washed with 1 mL of 17% EDTA (Prevest Denpro Ltd., Jammu, India) for 1 minute and 2 mL of 3% NaOCl for 30 seconds using a 30-gauge side-vented irrigating needle (Neoendo; Orikam Healthcare India Pvt. Ltd.) placed 1 mm short of the WL. The canals were irrigated with normal saline and dried with paper points (#30, Dentsply Maillefer, Ballaigues, Switzerland). Standard gutta-percha cones (Dentsply Maillefer, Ballaigues, Switzerland) and root canal sealer (ADSEAL, META BIOMED) were used for obturation. Canal filling was confirmed by post-obturation radiography. Using Peeso reamers, post space was made, leaving 4–5 mm gutta-percha apically to preserve the seal.

Preparation of dentin posts:

The dentin posts were prepared from six extracted maxillary central incisors. The roots were separated from the crowns below the cemento-enamel junction (CEJ) and sectioned mesiodistal into two vertical halves, yielding a total of 12 dentin segments. Sound dentin blocks were harvested from the roots and milled using a specialized bur in a Computer Numerical Control milling machine. Computer-aided design and computer-aided manufacturing (CAD-CAM) technology was utilized to fabricate dentin posts with standardized dimensions (17 × 1.8 mm), matching the dimensions of the glass fiber posts used in the study. All prepared dentin posts underwent autoclaving at 121°C for 20 minutes to guarantee adherence to biosecurity guidelines for tooth disinfection and to replicate clinical settings.

Cementation and core build-up:

Table 1: Comparison of fracture strength between dentin post and glass fibre post

Variable	Grou	N	Mean±S	Median	Mea	U-	p-
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All posts were placed in intracanal spaces. After confirming satisfactory adaptation of all 24 specimens (divided into group 1 and group 2), a clinical evaluation was performed to ensure that the posts were not tightly fitted and that there was a discernible space between the post and the dentinal canal wall. Para Core cement (Coltene) was employed to secure the supports into the root canals. Following the cementation process, digital radiographs were obtained to confirm that the seating was complete and that the cementation was acceptable. In the prepared teeth of each group, coronal restoration was performed using a light-activated composite restorative material (Filtek™ Supreme XT). The core was constructed using a layer-by-layer approach, with each increment measuring 1–2 mm, until the core was completed with standardised specifications for all samples.

Mechanical testing of the specimens:

The following parameters were evaluated:

- [1] **Fracture strength:** An electronically controlled universal testing machine was used to assess the fracture load of each tooth using a single load-to-failure test. All specimens were subjected to loading until failure occurred and the fracture load was automatically recorded in Newtons (N).
- [2] **Mode of fracture:** The mode of fracture for all samples was assessed using a stereomicroscope at 70× magnification. Type A failure involves post-luting material adhesive failure. Type B failure is dentin-luting material adhesive failure. Types C and D are post and luting material cohesive failures.

Statistical analysis:

The data were analysed using IBM SPSS Statistics Version 25.0 (IBM Corp., Armonk, NY, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests determined data normality. Fracture strength was not normally distributed. Therefore, the Mann-Whitney U-test was used to compare mean fracture resistance between groups. Fisher’s exact test was applied to analyse the mode of failure between the groups at a 5% level of significance.

Results:

The fracture strength of teeth restored using dentin posts and a glass fibre post was not significantly different. The fracture strength averaged 1133.55 ± 557.39 N for dentin post and 1131.17 ± 382.88 N for glass fibre post. The Mann-Whitney U test showed equal mean ranks (12.50 for both groups) with a p-value of 1.000, showing that the two restorative techniques do not significantly differ in fracture strength (Table 1). The dentin post and glass fibre post groups had similar failure patterns. The majority of specimens in each group had Type D failure (cohesive failure within the luting material), accounting for 83.3% of cases, while 16.7% had Type B failure (adhesive failure between dentin and luting material). No Type A, Type C, or Type E failures were recorded (Table 2).

s	p	D	(IQR)	n	test	valu
Fracture	Denti	1	1133.55 ±	rank	72.	e
			1316.91(712.14	12.5		1.00

strength	n post	2	557.39	)	0
Glass	1	1131.17 ±	1266.99(556.96	12.5	
fiber	2	382.88	)		
post					

Table 2: Comparison of mode of fracture between dentin and glass fibre posts

Mode of fracture	Dentin Post (n = 12)	Glass Fibre Post (n = 12)	Total	p-value
Type A	0 (0%)	0 (0%)	0 (0%)	1.00
Type B	2 (16.7%)	2 (16.7%)	4 (16.7%)	
Type C	0 (0%)	0 (0%)	0 (0%)	
Type D	10 (83.3%)	10 (83.3%)	20 (83.3%)	
Type E	0 (0%)	0 (0%)	0 (0%)	

Discussion:

This *ex vivo* study aimed to compare the fracture resistance, maximum stress and fracture mode of ETT mandibular first premolars restored with CAD-CAM manufactured dentin posts and prefabricated glass fibre posts. There were statistically insignificant differences between the two groups in fracture strength and maximal stress, indicating that the two post systems behave similarly biomechanically under compressive loading. These results support the concept that the success of stress distribution depends more on the similarity of the elastic modulus between the post and dentin than the material itself. Both dentin and fibre posts are more effective than metallic posts in distributing occlusal forces, leading to a reduction of localised stress concentration in the root dentin. This has also been showed in finite element and laboratory studies [8, 9]. Restoration of ETT poses a great challenge in restorative dentistry, due to extensive loss of tooth structure as a result of caries, trauma and endodontic access preparation. Post-core systems are not primarily meant to strengthen the root but to retain the core and to distribute the occlusal loads properly to the remaining radicular dentine. Currently, the restorative principles are based on the use of materials with mechanical traits similar to dentin to minimise stress concentration and the risk of catastrophic root fracture. Glass fibre and dentin posts have been extensively studied in this context, because their elastic modulus is comparable to that of natural dentin [10]. Dentin posts are fabricated from extracted human teeth and thus possess chemical composition, collagen matrix, tubular architecture and elastic modulus that are nearly identical to the host root dentin. Such homogeneity contributes to a monoblock-like restoration which can distribute functional stresses in the tooth-restoration complex more evenly [11]. Recent studies have shown that dentin posts can decrease stress concentration at the cervical region and enhance load transfer because of their structural compatibility with root dentin [8]. However, the variability seen in the dentin post group in the present study is likely to reflect the intrinsic biological variations between donor teeth, such as differences in dentin density, tubular orientation, mineralisation, age-related sclerosis and moisture content. This variation has also been reported in recent systematic reviews on biological post systems [12]. Glass fibre posts remain the most accepted post system, due to their good mechanical properties, aesthetics, ease of handling and predictable clinical performance. Their modulus of elasticity is about 20 to 40 GPA, which is

similar to dentine and provides better stress distribution than rigid metallic posts [13]. Recent clinical studies with a follow-up longer than five years have consistently confirmed the high survival rates of glass fibre posts when proper adhesive protocols are followed [14, 15]. The lower variability noted in the present study in the glass fibre post group might be attributed to the standardised industrial manufacturing process, which ensures uniform orientation of the fibres, regular impregnation of the resin and controlled physical properties. So, glass fibre posts are more reproducible than dentin posts derived biologically. The analysis of the fracture patterns revealed that the primary failure mechanism in both groups was cohesive failure within the luting cement and then adhesive failure at the dentin-cement interfaces. Importantly, none of the groups revealed any irreparable post fractures or vertical root fractures. These results are clinically important as cohesive or adhesive failures are generally considered preferable and rather repairable, while root fractures tend to require extraction [16]. Recent laboratory investigations have reported similar observations, concluding that the weakest component of modern post-core systems is the degradation of the adhesive interface and not the post fracture. The results also highlight that the long-term success depends not only on the post material but also on the durability of the adhesive bonding [17, 18]. The high incidence of cement failure shows the importance of adhesive strategies in luting procedures. In the present study, dual-cure resin cement was used for the post cementation because of its advantageous polymerisation characteristics and reliable bonding properties in deep root canals [19, 20]. However, polymerisation shrinkage, limited light transmission in deeper regions, incomplete hybrid layer formation and hydrolytic degradation remain important factors affecting longevity of adhesive interfaces. Recent studies underlined that progress in resin cement chemistry, universal adhesive systems and simplified bonding protocols could further enhance the long-term performance of fibre-reinforced restorations [21, 22]. The analogous mechanical behaviour of the dentin posts also supports the growing interest in biomimetic restorative dentistry. Biomimetic approaches are directed to restore the morphology and biomechanical function of the tooth with the use of materials that simulate the physical properties of natural tissues. Dentin posts meet many of these requirements due to the presence of natural dentinal tubules, similar coefficients of thermal expansion and almost identical elastic properties [23-25]. However, their clinical use is restricted by practical limitations, including the availability of donor teeth, ethical considerations, sterilisation, fabrication complexity and the absence of standardised manufacturing protocols. On the other hand, glass fibre posts are commercially available in standard dimensions and there is a large body of evidence of their long-term clinical use [26-28]. Some limitations of the current study should also be mentioned. As an *ex vivo* investigation, it was unable to replicate the complex intraoral environment of cyclic fatigue loading, thermal fluctuations, moisture changes, resilience of the periodontal ligament and biological ageing of restorative materials. Furthermore, static compressive loading does not

reproduce the multidirectional functional occlusal loads present in clinical situations. Our ability to detect subtle group differences may also have been limited by the relatively small sample size. Recent consensus statements have recommended the inclusion of thermo cycling, cyclic fatigue testing, finite element analysis and long-term clinical evaluation to generate more clinically relevant evidence regarding post-performance.

Conclusion:

Fracture resistance and stress distribution in dentin and glass fibre posts in the restoration of endodontically treated mandibular first premolars. Dentin posts present a promising biomimetic alternative, able to reproduce the mechanical behaviour of natural dentin. Glass fibre posts, however, offer greater standardisation, ease of use and predictable clinical outcomes.

Advancement to knowledge:

The study found that dentin and glass fiber posts show similar fracture resistance and stress distribution in restored mandibular first premolars. Dentin posts may be a promising biomimetic option, while glass fiber posts provide better standardization, easier use and more predictable clinical results.

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