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Edited by Ritik Kashwani
E-mail: docritikkashwani@yahoo.com
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Fracture resistance in endodontically treated teeth using different post systems and luting agents - An *in vitro* study

Seemran Panda*, Ajay Kumar Nagpal, Sunil Kumar, Muhammad Mutiur Rahman, Jugal Kishore Das, Arunima Jana & Akanksha Kumari

Department of Conservative Dentistry and Endodontics, K.D Dental College and Hospital, Mathura, Uttar Pradesh, India; *Corresponding author

Affiliation URL:
https://www.kddental.in/

Author contact:

Seemran Panda - E-mail: seemranpanda4@gmail.com
Ajay Kumar Nagpal - E-mail: drajayendodontist@gmail.com
Sunil Kumar - E-mail: drskumar2009@gmail.com
Muhammad Mutiur Rahman - Email: mutiur90@gmail.com
Jugal Kishore Das - E-mail: jugaldas1414@gmail.com
Arunima Jana - E-mail: arunimajana1998@gmail.com
Akanksha Kumari - E-mail: akkirexmusix@gmail.com

Abstract:
Endodontically treated teeth are susceptible to fracture, making optimal post and luting material selection critical for long-term restoration. Therefore, it is of interest to compare the fracture resistance of glass fiber and Ribbond posts luted with dual-cure resin cement or flowable composite in 55 extracted single-rooted premolars. Following standardized endodontic treatment and core build-up, specimens underwent compressive loading in a universal testing machine, and fracture resistance values were statistically analyzed using one-way ANOVA and Tukey's post-hoc test ($p < 0.05$). All restored groups exhibited significantly greater fracture resistance than the control, with glass fiber posts luted using dual-cure resin cement showing the highest strength and Ribbond posts luted with flowable composite the lowest. Thus, data shows the both post type and luting material significantly affect fracture resistance; supporting glass fiber posts with dual-cure resin cement as that most effective restorative combination.

Keywords: Fracture resistance, glass fiber post, ribbond fiber post, dual-cure resin cement, flowable composite, universal testing machine

Background:
Root canal treated teeth have a more propensity for fracturing compared to healthy teeth due to reduced moisture absorb in dentin, potentially compromising the tooth's structural integrity **[1]**. Restoring RC treated teeth poses a challenging and debatable task for dentists due to substantial loss of natural tooth structure resulting from factors such as dental caries, fractures, or trauma, which are essential for retaining coronal restorations **[2]**. Certainly, the successful outcome of root canal treated teeth relies on appropriate rehabilitation techniques. Rehabilitation of RCT teeth typically involves the use of a post in the radicular portion and coronal portion of the teeth is strengthening with core. The main goals of post and core technique are to build lost coronal part as well as to provide sufficient resistance and retention form to final restoration **[3]**. The selection of post materials plays a critical role in root canal treatment success. When selecting a post material for dental restorations, it is indeed beneficial to consider the material's modulus of elasticity to ensure compatibility with the tooth's dentin (*i.e.,* 18.6 GPa). The goal is to maintain uniform force distribution along the length of the post and root and to reduce concentrated areas of stress. The cast post and core repair method has been recommended as best available for years. However, this conventional approach is labour-intensive, requires extensive laboratory operations and is expensive in terms of materials **[4]**. Prefabricated post systems were introduced and the outcomes have greatly improved. Glass fiber posts are the widely used because of their favourable esthetics, high strength, biocompatibility, translucency which mimics the natural tooth colour and MOE similar to dentin, which helps distribute functional stresses evenly and reduces the risk of root fracture **[5].** Their translucency also allows effective light curing in shallow post spaces **[8]**. Ribbond posts, composed of ultra-high molecular weight polyethylene fibers, offer flexibility, high strength, radiolucency and effective stress distribution, making them suitable for reinforcing weakened roots while maintaining esthetics **[9]**. Luting cements significantly enhance tooth strength in complex restoration scenarios. The choice of luting cement significantly influences the overall performance of post-retained restorations **[6]**. Dual-cure resin cements create a hybrid layer that bond with tooth structure through impregnation, diffusion and monomer polymerization **[7]**. It is ideal for luting posts as it ensures complete polymerization even in deep or opaque root canals where light cannot reach. It provides strong adhesion to both dentin and the post, enhancing retention and long-term stability **[8]**. Flowable composites, due to their lower filler content and higher resin concentration, show excellent adaptation to canal irregularities, improved micromechanical retention and potential monoblock formation, contributing to enhanced fracture resistance **[9]**. Therefore, it is of interest to assess the restorative combinations to provide clearer clinical guidance for optimizing fracture resistance and long-term outcomes.

Materials and Methods:
The teeth indicated for extraction due to poor periodontal prognosis or orthodontic reasons were collected from the Department of Oral and Maxillofacial Surgery, K.D. Dental College and Hospital, Mathura. Immediately after extraction, the teeth were thoroughly cleaned under running water, followed by ultrasonic scaling to remove any adherent soft tissues and debris. The cleaned specimens were then rinsed with normal saline and disinfected by immersion in 0.2% thymol solution for a period of 24 hours. After disinfection, the teeth were stored in distilled water, which was periodically replaced to maintain hydration until the time of use. A total of 55 permanent human mandibular single-rooted premolars were selected based on the calculated sample size for the study. These teeth were randomly allocated into five groups, each comprising 11 specimens. Group 1 served as the control group, Group 2 included glass fiber posts

with dual-cure resin cement, Group 3 consisted of glass fiber posts with flowable composite, Group 4 comprised Ribbond fiber posts with dual-cure resin cement and Group 5 included Ribbond fiber posts with flowable composite. For standardization, all selected teeth were decoronated to achieve a uniform root length of 13 mm measured from the anatomical apex. A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into each canal until its tip became visible at the apical foramen, allowing accurate determination of working length, which was set 1 mm short of the apex. Root canal preparation was carried out using ProTaper rotary instruments up to the F2 size. During instrumentation, canals were irrigated copiously with 5 ml of 5.25% sodium hypochlorite, followed by 5 ml of 17% EDTA and normal saline after each file to ensure effective debridement and smear layer removal. The canals were subsequently dried with paper points and the apical 5 mm was obturated using gutta-percha F2 cones and AH Plus sealer employing a sectional obturation technique. The coronal portion was sealed provisionally using a temporary restorative material and the samples were incubated at 37°C with 100% humidity for seven days to allow complete setting of the sealer. Each root was then wrapped with a thin layer of aluminum foil and embedded vertically into cylindrical acrylic resin blocks measuring 15 mm in diameter and 20 mm in height, with 4 mm of the apical portion embedded and 9 mm remaining exposed coronally. After polymerization of the acrylic resin, the foil was removed to create space around the root, which was subsequently filled with polyvinyl siloxane impression material to simulate the periodontal ligament. Post space preparation was performed using Peeso reamers of sizes 1, 2 and 3, maintaining a uniform depth of 8 mm in all specimens. In Group 1, no intracanal post was placed and only a core build-up was performed using nanohybrid bulk-fill composite to standardized dimensions of 7 mm × 5 mm × 5 mm. In Groups 2 and 3, glass fiber posts were used. The post spaces were etched with 37% phosphoric acid for 15 seconds, while the posts were treated with 2% hydrofluoric acid for 10 seconds. Both the canal and posts were rinsed and air-dried, followed by application of a silane coupling agent and bonding agent. In Group 2, dual-cure resin cement was used for luting, whereas in Group 3, flowable composite was employed. The posts were inserted into the canals with finger pressure, excess material was removed and light curing was carried out for 20 seconds. A 3 mm coronal extension of the post was maintained for core build-up and the remaining length was trimmed. Core build-up was completed using nanohybrid bulk-fill composite. In Groups 4 and 5, Ribbond fiber was utilized as the post material. A 2 mm wide strip of 22 mm length was prepared for each specimen, soaked in adhesive resin and blotted dry. Canal conditioning and adhesive application were performed following the same protocol as for the glass fiber post groups. In Group 4, dual-cure resin cement was used, while in Group 5, flowable composite was used as the luting material. The Ribbond fiber was folded over a plugger and inserted into the canal, ensuring proper adaptation to the canal walls. The fiber was advanced to the apical extent and then disengaged from the plugger with a gentle motion, followed by light curing for 20 seconds. The intraradicular portion measured approximately 16 mm, while the coronal extensions were used for core build-up to standardized dimensions using nanohybrid composite. Fracture resistance testing was conducted using a universal testing machine. The acrylic blocks containing the mounted specimens were positioned on the lower platform of the machine with the coronal portion facing upward. A metal loading tip with a diameter of 0.5 mm was attached to the upper arm and a vertical compressive force was applied along the long axis of the root. Each sample was subjected to a gradually increasing load at a crosshead speed of 0.5 mm/min until fracture occurred. The maximum force required to cause fracture, whether by root fracture, post bending, or debonding, was recorded in kilo newtons as the failure threshold. Statistical analysis of the obtained data was carried out using SPSS software version 22.0. A confidence interval of 95% was maintained and a p-value of less than 0.05 was considered statistically significant. The mean fracture resistance values among the five groups were compared using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test for multiple pairwise comparisons to identify specific group differences. This analytical approach ensured accurate evaluation of the comparative performance of different post and core systems.

Results:

Each group consisted of 11 samples, contributing equally to the total sample size of 55 (20.0% per group), ensuring uniform allocation across controls and different post–luting agent combinations. The highest mean fracture resistance was observed in the Glass Fiber Post with Dual Cure Resin Cement group (0.873 ± 0.036 kN), followed by Glass Fiber Post with Flowable Composite (0.765 ± 0.030 kN) **(Table 1, Figure 1)**. Ribbond fiber with dual cure resin cement showed a mean fracture resistance of 0.668 ± 0.025 kN, while ribbond fiber with flowable composite showed 0.579 ± 0.022 kN **(Table 2)**. The control group exhibited the lowest mean fracture resistance (0.505 ± 0.014 kN) **(Table 1)**. A highly statistically significant difference was observed between the groups, with an F value of 335.4445 and a p value of <0.001, indicating that the type of post system and luting agent significantly influenced fracture resistance **(Table 2)**. All intergroup comparisons showed statistically significant differences ($p < 0.001$) **(Table 3)**. The glass fiber post with dual cure resin cement group showed significantly higher fracture resistance compared to all other groups. Both glass fiber post groups showed significantly higher fracture resistance than the corresponding Ribbond fiber groups, while all experimental groups exhibited significantly higher fracture resistance compared to the control group.

Table 1: Descriptive statistics of fracture resistance (kN) observed in samples of various groups.

Name of group	Mean	Std. Deviation
Group 1	0.505	0.014
Group 2	0.873	0.036
Group 3	0.765	0.03
Group 4	0.668	0.025
Group 5	0.579	0.022

Table 2: Comparison of mean fracture resistance observed in samples of various groups using one way ANOVA

	Sum of Squares	df	Mean Square	F value	p value
Between Groups	0.938	4	0.235		
Within Groups	0.035	50	0.001	335.4445	<0.001*
Total	0.973	54			

Table 3: Pairwise comparison of mean fracture resistance observed in samples of various groups using post-hoc tukey test

		Mean Difference	p value
Group 1	Group 2	-0.368	<0.001*
	Group 3	-0.25918	<0.001*
	Group 4	-0.163	<0.001*
	Group 5	-0.074	<0.001*
Group 2	Group 1	0.368	<0.001*
	Group 3	0.10882	<0.001*
	Group 4	0.205	<0.001*
	Group 5	0.294	<0.001*
Group 3	Group 1	0.25918	<0.001*
	Group 2	-0.10882	<0.001*
	Group 4	0.09618	<0.001*
	Group 5	0.18518	<0.001*
Group 4	Group 1	0.163	<0.001*
	Group 2	-0.205	<0.001*
	Group 3	-0.09618	<0.001*
	Group 5	0.089	<0.001*
Group 5	Group 1	0.074	<0.001*
	Group 2	-0.294	<0.001*
	Group 3	-0.18518	<0.001*
	Group 4	-0.089	<0.001*

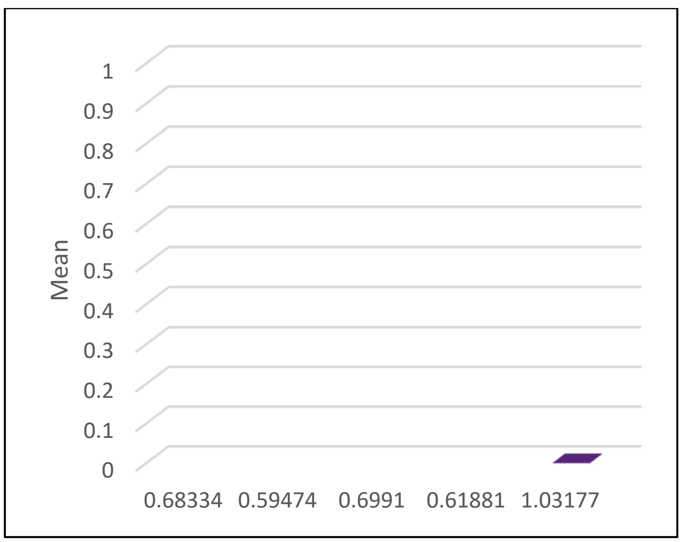

Figure 1: Graph of mean fracture resistance observed in samples of various groups

Discussion:

Endodontically treated teeth (ETT) with extensive loss of coronal structure present a major restorative challenge, as root canal therapy preserves the root but does not restore the structural integrity of the tooth. Therefore, post and core systems are required to retain the core and distribute occlusal stresses along the root **[10]**. Among clinical considerations, fracture resistance (FR) is more critical than post retention because post dislodgement can be managed, whereas root fracture often results in tooth loss **[11]**. Fractures occur when stresses transmitted through the post–core complex exceed the strength of the remaining dentin; hence, post systems with an elastic modulus similar to dentin are preferred to achieve favorable stress distribution **[12]**. Mandibular premolars were selected due to their high susceptibility to fracture, which is attributed to their anatomy, crown-to-root ratio and functional loading. Their position in the dental arch subjects them to both compressive and shears forces, making them suitable for biomechanical evaluation. Standardization was achieved by decoronating all teeth to a uniform root length of 13 mm; however, inherent variability in extracted teeth remains a limitation **[13]**. Root canal preparation was performed using ProTaper rotary instruments up to F2 to achieve adequate shaping while preserving radicular dentin. Irrigation with sodium hypochlorite, EDTA and saline followed established protocols to ensure effective cleaning and smear layer removal **[14]**. Sectional obturation of the apical 5 mm was carried out to maintain apical seal while allowing standardized post space preparation. Preservation of 4–5 mm of gutta-percha is essential for preventing microleakage and maintaining apical integrity. Simulation of the periodontal ligament (PDL) was incorporated to better replicate clinical conditions. Direct embedding in acrylic resin leads to unrealistic stress concentration and overestimation of fracture resistance. Studies have shown that PDL simulation allows more accurate stress distribution and better mimics *in vivo* conditions **[15]**. Post space preparation was standardized using Peeso reamers to ensure uniform canal dimensions. Adhesive procedures play a critical role in improving bonding and stress distribution. Etching of canal walls with phosphoric acid enhances micromechanical retention, while silanization of glass fiber posts improves chemical bonding between the posts and luting cement. Application of bonding agents facilitates the formation of a stable resin–dentin interface, which is essential for improving fracture resistance **[16]**. Limiting the coronal extension of the post to 3 mm allows the core material to act as the primary stress-absorbing component, promoting uniform stress distribution. Composite resin was selected for core build-up due to its modulus of elasticity being comparable to dentin and its ability to form a durable adhesive bond with tooth structure. Fracture resistance testing was conducted using a universal testing machine with axial loading applied along the long axis of the tooth. This method simulates masticatory forces acting on premolars and allows uniform stress transmission through the post–core–root complex. A crosshead speed of 0.5 mm/min was used to ensure controlled loading conditions and reliable comparison between groups **[17].** The results showed that all post-restored groups exhibited significantly higher fracture resistance than the control group, which showed the lowest mean FR. This finding supports previous studies indicating that absence of a post leads to inadequate stress distribution and reduced reinforcement of ETT. Among the experimental groups, the glass fiber post with dual-cure resin cement showed the highest fracture resistance **[18]**. This can be attributed to the dentin-like elastic modulus of glass fiber posts, which enables uniform stress distribution and reduces stress concentration at the post–dentin interface. Additionally, dual-cure resin cement enhances bonding and ensures adequate polymerization in deeper regions, improving load transfer **[19]**. Overall, the findings support the use of fiber-reinforced posts combined with adhesive resin cements to enhance fracture resistance of endodontically treated teeth. However, as this was an *in vitro* study, further long-term clinical investigations incorporating functional loading and aging are necessary to validate these results under clinical conditions.

Conclusion:

Endodontically treated teeth restored with post–core systems showed significantly higher fracture resistance than those without posts, confirming their reinforcing effect. Glass fiber posts performed better than Ribbond fiber posts, with the combination of glass fiber post and dual-cure resin cement showing the highest strength. Thus, glass fiber posts luted with dual-cure resin cement appear to be the most effective option, although further long-term clinical studies are required.

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