Effect of Post Material and Length on Fracture Resistance of Endodontically Treated Premolars: An In-Vitro Study
G S Amarnath1, M U Swetha2, B C Muddugangadhar3, Radhika Sonika4, Ashu Garg5, T R Poonam Rao4

Contributors:
1Head, Department of Prosthodontics including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India; 2Private Practitioner, Bengaluru, Karnataka, India; 3Reader, Department of Prosthodontics Including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India; 4Post Graduate Student, Department of Prosthodontics including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India; 5Post-graduate Student, Department of Prosthodontics Including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India.

Correspondence:
Dr. Amarnath GS. Department of Prosthodontics including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India. Phone: +91-9916472790. Email: dramarnathgs@gmail.com

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Abstract:
Background: Endodontically treated teeth with posts are more prone to fracture. Hence, the purpose of this study was to investigate the in-vitro fracture resistance of devitalized teeth and mode of failure restored with posts of different materials and different lengths.

Materials and Methods: Sixty freshly extracted human mandibular premolars were endodontically treated and then restored with 1 of 2 prefabricated posts: Stainless-steel (SS) and glass-fiber (fiber posts [FP]) with intraradicular lengths of 4, 5 or 10 mm (n = 10). Following core restoration, a static compressive load was applied perpendicular to the long-axis of the teeth. Initial failure of each specimen was recorded in Newton. The mode of failure was also determined radiographically. The data were analyzed using two-way ANOVA and Tukey's post-hoc analysis with Bonferroni adjustment.

Results: Analysis indicated significant differences (P < 0.001) among the groups. Among the SS posts, SS/7 (246 N) exhibited the highest failure load and SS/4 (122 N) the lowest. FP/10 (140.5 N) exhibited the highest failure load among the FP and FP/4 (68.5 N) the lowest. SS posts showed post pull out, followed by core fracture while FP showed core debonding, followed by core fracture as the primary mode of failure.

Conclusion: Fracture resistance of the teeth proportionately increased with increase in the length of FP while it decreased with that of metal post. SS posts showed greater fracture resistance than FP when 90° load was applied.

Key Words: Elastic modulus, fiber post, fracture resistance, mode of failure, stainless-steel

Introduction
Endodontically treated teeth present a high-risk of biomechanical failure due to the loss of tooth substance resulting from pre-existing decay and endodontic therapy itself. In treating these teeth, intra radicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots.1 Different post systems have been proposed over the years, from the early cast metallic posts to the pre-fabricated metallic posts or the more recently introduced, translucent fiber posts (FP).2

Over the years, various pre-fabricated post systems have been introduced and successfully used in clinical situations, which decreases chair-side time and reduce the cost to the patient.3 Opaque metal posts may, however, shine through semi-translucent all-ceramic crowns and thin cervical areas influencing the esthetic outcome of the restoration. Among the materials used for esthetic restorations, glass-FP have gained popularity because of their purported favorable biomechanical properties.2 These posts are intended to be adhesively luted into the root canal using resin cements, and the core is subsequently built up with a resin composite.5

Use of resin cement with a bonding agent when placing a post may help to limit microleakage and increase retention of prefabricated posts. Nonetheless, the quality of bonding may diminish at greater apical post space depths. Therefore, an increased post length may not provide any increase in the predictable bonding area. It has been shown that resin bonding can reinforce the remaining root structure to help counteract the effects of a flared canal or poorly adapted post.6 Some studies have suggested that a shorter post length may be used without loss of retention, and that serrations on a post may increase retention.7

An ideal post system should exhibit fracture resistance higher than the average masticatory forces.8 It has been suggested that post length be at least equal to the crown height or two-thirds of the root length to facilitate stress distribution and provide resistance to occlusal forces leaving at least 4 mm of gutta-percha. In contrast, increasing post length could decrease the root strength.1 Furthermore, it is important to notice that it
may not always be possible to use a long post, especially when the remaining root is short or curved.9

As no consensus exists concerning the proper length for posts, its influence of these posts needs to be determined. There is a continuous need for evaluation of various post systems to make evidence-based decision in the clinical context. The purpose of this study was to compare the fracture resistance and mode of failure of endodontically treated teeth restored with two different post systems of three different lengths.

Materials and Methods
This study was carried out in the Department of Prosthodontics including Crown and Bridge and Implantology, M R Ambedkar Dental College and Hospital, Bengaluru, Karnataka, India.

60 extracted intact single-rooted human premolars of similar size and shape of the approximate age group of 12-14 years was selected having the following inclusion and exclusion criteria.

Inclusion criteria
1. Teeth with almost straight roots with similar size and shape
2. 6 mm of mean mesio-distal width at cement-enamel junction (CEJ) and mean root length of 14 mm from the buccal CEJ
3. Completely formed apices
4. Intact clinical crowns.

Exclusion criteria
1. Presence of caries in the root
2. Presence of visible fracture lines in the root
3. Previous endodontic treatment or restoration closer than 2 mm from the CEJ
4. Roots with distinctly oval canal and diameter of more than 2.

Blood debris from the specimens was cleaned off using detergent. Soft tissue deposits and calculus were removed by ultrasonic scaling and were disinfected in 5.25% sodium hypochlorite. Thereafter, teeth were stored in distilled water at room temperature for further procedures. Specimens were sectioned horizontally flat with a rotating carborundum disc using a high speed hand piece and motor (marathon 4 high power) at 1 mm coronal to the buccal CEJ perpendicular to the long axis of the teeth (Figure 1). The endodontic treatment was carried out conventionally using Dentsply Protapers files 6 mm × 25 mm and an Endo-Express rotary handpiece keeping 1 mm short of the root apex (Wein’s concept) up to file no. 30. Obturation was carried out with the corresponding Dentsply Protaper Universal gutta-percha points 60 × F3 Ø30 and non-eugenol sealer. Consequently gutta-percha cones were cut off till CEJ and sealed.

The sample size was set at 10 for each six experimental groups to receive parallel posts of either stainless-steel (SS), Parapost, Coltene Whaledent or glass fiber (FP), Parapost Fiber-lux, Coltene Whaledent. Post diameter being constant at 1.25 mm. A parallel post system will have consistent size and diameter at each length.

Group I: SS/4, 4 mm insertion length.
Group II: SS/7, 7 mm insertion length.
Group III: SS/10, 10 mm insertion length.
Group IV: FP/4, 4 mm insertion length.
Group V: FP/7, 7 mm insertion length.
Group VI: FP/10, 10 mm insertion length.

Manufacturer supplied parapost drills were used for post space preparation. An additional 3 mm of post length was allowed to extend coronal to the CEJ. The post space and posts were etched, bonded and light cured. Posts were cemented with Paracore dual cure resin cement, Coltene Whaledent, USA (Figure 2). Core formers were used for core build-up up to 4 mm from the coronal tooth floor (Figures 3 and 4). Each sample was mounted and positioned in an acrylic block with their longitudinal axis perpendicular to the load direction. A universal testing machine with a custom made loading plunger was used to load the specimens at 90° to the long axis and 3 mm from the tooth-core interface with a crosshead speed of 0.5 mm/min until primary failure occurred (Figure 5). The failure load was recorded. In addition, the mode of failure was also recorded as root fracture, core fracture, post fracture or any interface.
De-bonding. Teeth were radiographed by using radiographic film to determine the mode of failure (Figure 6).

The effect of the post material and length, as well as the interaction between each variable, was evaluated. Data were analyzed through statistical analysis software, version 9.2 at a level of significance of 0.05 and at a confidence interval of 95% by two-way ANOVA. Tukey’s post-hoc analysis was used to evaluate the pairwise comparison of individual post with other two posts within the SS and FP groups separately.

Results

During mechanical loading of the samples, it was determined that an initial failure of the post and core was occurring, by visual observation of separation of the core at the tooth interface. On review of the loading data, the initial failure load was designated as the first drop in the load values. Failure load, group means, and standard deviations were determined. Table 1 displays the data. Analysis of the data demonstrated normal distributions.

The interaction between post type and post length on initial failure loads were evaluated by using two-way ANOVA. Table 2 depicts a highly significant difference between the post lengths of all the three SS posts ($P < 0.001$) and between all three FP ($P < 0.001$). The highest mean strength was obtained for SS/7, (246 N) and the lowest was obtained for FP/4 (68.5 N). The highest amongst SS groups was followed by SS/10 (188.5 N) then SS/4 (122 N). The highest amongst FP groups.

| Groups | Post length (mm) | Estimate mean | Standard error | Lower limit of mean | Upper limit of mean |
|--------|-----------------|---------------|----------------|---------------------|---------------------|
| I      | 4               | 122           | 7.11           | 107.1               | 136.9               |
| II     | 7               | 246           | 6.81           | 231.7               | 260.3               |
| III    | 10              | 188.5         | 5.74           | 176.4               | 200.6               |
| IV     | 4               | 68.5          | 7.11           | 53.6                | 83.4                |
| V      | 7               | 137.5         | 6.81           | 123.2               | 151.8               |
| VI     | 10              | 140.5         | 5.74           | 128.4               | 152.6               |

SS: Stainless-steel, FP: Fiber post
Tukey’s Post-hoc analysis with Bonferroni adjustment shows the pairwise comparison of SS posts and FP with the other two post lengths of the same group in Table 3. There was a significant difference in the mean fracture resistance of post lengths 4, 7 and 10 mm among SS groups (P < 0.01). Whereas, FP group showed a significant difference in mean fracture resistance between post lengths with 4, 7 and 10 mm (P < 0.01). However, the difference between post length 10 mm and 7 mm was not statistically significant (P = 0.76). It was observed that 7 mm of post length was seen to be the superior most among both SS followed by 10 mm then 4 mm while 10 mm fiber reinforced posts showed the maximum failure load, followed by 7 mm and 4 mm. Although only a small difference was seen between 7 mm and 10 mm of post lengths.

The mode of ultimate failure for each test group has been listed in Table 4. The visual and radiographic analysis was carried out for each sample. The number of tooth-core de-bonds, post bending or post pull-out for each group was observed (Figure 6). Root fracture was not an observation in any of the specimen.

Discussion
Fracture resistance is of greater importance than retention because the post can be re-cemented if dislodged from the tooth. However, if the root fractures, the tooth is invariably lost.10 Many factors have been attributed for the decrease in the fracture resistance of endodontically treated teeth. They are tooth structure loss, loss of free unbound water from the lumen and dentinal tubules, age-induced changes in dentine, reduced level of proprioception, effect of endodontic irrigant and medicament on dentine, effect of bacterial interaction with dentine substrate. Coronal destruction from dental caries, previous restorations/fracture and endodontic access preparations are considered to be the main cause. Therefore many authors emphasize conserving the bulk of dentine to maintain the structural integrity of post endodontically restored teeth.11 An ideal post system should exhibit fracture resistance higher than the average masticatory forces. There exists a definite correlation between post material and fracture of roots.8

Different post systems have been proposed over the years, from the early cast metallic posts to the pre-fabricated metallic posts or the more recently introduced, translucent FP.2 Some authors have advised the use of posts with a high modulus of elasticity. In contrast, others have recommended posts with a modulus of elasticity similar to that of dentin and have stated that teeth restored with FP and composite resin core materials have a higher fracture resistance than those restored with cast post cores because the elastic post material, luting cement, and dentin demonstrated similar structural deformations under load.12-14 The documented approximate values of elastic modulus of dentin is 18.5-21.8 GPa, Parapost SS post is 207 and Parapost Paracore resin cement is 20 GPa.15,16 Ideally a balance between the post length within the root and the coronal extension should exist. Laboratory studies have shown that increasing the length of the post in teeth with a post and core increases the retention of the post and results in a more favorable stress distribution along the post.17 Whereas the studies performed by Chuang et al. proved that increasing post length could decrease the root strength.1

Placement of a crown ferrule has been shown to be an important factor in increasing the fracture resistance and clinical prognosis of teeth with posts and cores. However, this study aimed to eliminate ferrules and crowns from the methodology because these features could introduce many more variables that could complicate interpretation of the results of load testing.

In addition, Raygot et al. have emphasized clinical cases where little or no coronal tooth structure remained and crown lengthening or a sufficient ferrule could not be placed, post and core restoration served as the primary source of retention for a
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crown. Considering the authors observations, in the present study, all the teeth were sectioned at 1 mm coronal to the CEJ perpendicular to the long axis of the tooth.

A study done by Borer et al.14 have directly related to the successful use of adhesive resin cements allowing for significant chemical bond between the dentin and the post. The dual-cure composite core material was selected because of its ability to bond to both the fiber-reinforced posts and tooth structure, and still be cured with the SS post where light activation within the root was not possible. An integrated mono-block technique was used to cement the posts and fabricate the core with the same composite resin material. This allowed for a uniform material to bond to the post and tooth structure and reduced the variability at the tooth-core interface. A post and core restoration are subjected to repeated tension, compression and torqueing forces. The present study used horizontal compressive force used as it has been shown to be the most traumatic to a post-core system and induced high dentinal stresses within the root in which many systems failed as a result of coronal seal breakage or debonding of a core.19

During specimen loading, it was determined that primary failure was occurring due to a drop in values within the loading curve. This drop corresponded with a visible separation of the core from the tooth or catastrophic core fracture or failure of any individual components within the post-core system. Each loading curve was analyzed and the decrease in load values was reported as the primary failure load and was measured in Newton (N). Many studies have suggested similar method of calculation.2,4,15

In this study, post type and post length down the root proved to be significant variables for the primary failure of the endodontically treated teeth. Medium sized SS posts of length 7 mm showed the highest mean fracture resistance followed by length 10 mm then 4 mm. A rigid long SS post with a high modulus of elasticity submitted to stress did not show to absorb any energy. Rather, it transmits energy to a less rigid structure, in this case, the dentin, which has a lower modulus of elasticity. Deeper post-space preparation may also jeopardize the root by removing more of the internal structure from the tooth and consequently reducing the root strength. This may explain the reduced fracture resistance at increased post length. Therefore, a more conservative approach could be clinically advisable when dentists choose to restore endodontically treated teeth with FP.

Many laboratory and clinical studies have showed a significant correlation with fracture resistance of endodontically treated and FP length. An increased survival rate has been correlated with increased post length with enhanced retention and favorable stress distribution.17 FP with a modulus of elasticity similar to dentin, when submitted to a compressive load, can better absorb the forces concentrated along the root. Longer FP, with their larger mass volume, possessed the capacity to absorb a greater amount of stress, rather than transferring stress to the dentin.4,20 This study showed maximum failure load was though seen with the tallest post of 10 mm. However, no significant difference existed between post length of 7 mm and 10 mm.

The loading parameters in this study were designed to be similar to a cantilever arrangement; thus, the post-and-core restoration was subjected to bending stress with the maximum stress at the interface with the tooth. Once the bending stress surpasses the tensile bond strength between the core and the tooth, the core de-bonds from the tooth. However, the compressive bond strength of the core and tooth may not be reached until a greater load is applied. Therefore, the post-and-core system may remain intact, with only slight separation of the core at the tensile load interface as observed with most of the SS specimens.

Radiographically it was seen that mode of failure among the SS posts was determined mostly to be post pull out followed by core debonding and core fracture. This suggests the adhesive failure between the post and the teeth. There was a dissimilarity of the adhesive properties of the posts at deeper lengths down the canal, or other mechanical property disparities that accounted for this difference. This warrants further investigation.13 Whereas the FP showed mostly core debonding followed by core fracture (cohesive failure). Post debonding is considered as the most common complication found clinically with post-core systems and may have a significant role in the incidence of root fractures that occur clinically. However, there was no evidence of post de-bonding in any of FP groups. Adhesive failure was minimum.21

The higher fracture resistance of the SS post likely provided more support for the core than any of the fiber-reinforced posts due to resistance to bending and better stress transfer to the root. Post was pulled out prior to complete core de-bonding (adhesive failure with the tooth structure). The core being still retained by the post, resulted in several other modes of failure like core fracture, root fracture, post bending and pullout and core-post debonding. 7 mm and 10 mm did not typically exhibit complete core debonding, but some evidence of buccal core debonding. Whereas, short length post transfers more of the stress to the core and tooth. Accordingly 4 mm displayed total core debonding with post bending or core fracture was the predominant outcome. There was no significant difference with respect to post material. Post fracture or root fracture was not witnessed in the study as ultimate mode of failure was not investigated.

Clinically, the failure with a metal post may present loss of post retention. Failure with a fiber-reinforced post may present as core debonding, resulting in microleakage and subsequent core or crown failure. The stress appeared to be transferred to the
core and the post cement in the case of FP. This observation would account for the complete core debonding as was seen in all FP groups. Stronger adhesive bond between the post and cement did not allow for their post pullout.

Preventing microleakage within post-core restorations is of primary importance. Once the coronal seal is broken, the root canal is susceptible to bacterial penetration, and endodontic failure may occur. Therefore, separation of the core material from the coronal tooth structure is of clinical relevance because it will almost certainly cause microleakage. It was found that the post length had a statistically significant effect on the fracture resistance of post-core systems when resin cement was used. Thus, a shorter post may neither provide adequate retention for a core nor provide as much resistance to bending and may place more stress on the root dentin when loaded. In addition, the breakdown of the bond weakens the post-core system during cyclic loading and places more of the stress on the post and remaining root.

Clinically, it could be argued that a longer post is preferable to a shorter post, but is of even greater importance when horizontal stresses on the coronal tooth are great while using esthetic posts. In cases of heavy occlusal load, SS posts of medium length can be used while 4-5 mm of gutta-percha remaining in the apex of the teeth. This study found that the post length has a statistically significant effect on the fracture resistance of post-core systems when resin cement was used. Thus, a rigid post may provide adequate retention for a core, but may not provide as much resistance to bending and may place more stress on the root dentin when loaded. However, flexible FP can be used alternatively in esthetic zone or where the occlusal load is mediocre. Using FP in cases with short post length is questionable.

The extrapolation of the results from work of a purely in-vitro nature must always be made with caution. Clinically a post and core restoration is subjected to repeated tension, compression and torquing force. The dislodgement and fracture of post-retained restorations commonly occur after several years of function. This study assessed the failure of posts after 24 h of water storage. It is possible that a longer storage time and/ or thermal cycling and also the use of full veneer crowns with ferrule would give additional variables to the results.

All the posts evaluated in the study have several advantages and disadvantages. The ultimate clinical decision making should consider the patient related variables, such as amount of remaining tooth structure, root canal morphology, occlusion, masticatory force and para-functional habits to maximize the long-term prognosis of endodontically treated teeth.

**Conclusion**

The following conclusions can be made from this in-vitro study:

1. The fracture resistance of endodontically treated teeth was significantly influenced by the post material and post length.
2. The initial failure load with FP was significantly lower than that of SS posts.
3. Post length increased the fracture resistance of the teeth to an extent of two-third the root length restored with SS posts and thereafter it decreased.
4. Fracture resistance of the teeth proportionately increased with increase in FP length.
5. Complete core de-bonding was seen with short length posts.
6. SS posts showed adhesive failure whereas FP showed cohesive failure.

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