Original Article

Comparative Evaluation of the Reinforcing Effect of Different Post Systems in the Restoration of Endodontically Treated Human Anterior Teeth at Two Different Lengths of Post Space Preparation- An in Vitro Study

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Abstract

Objectives: Comparative evaluation of the reinforcing effect of different post systems in the restoration of endodontically treated human anterior teeth at two different lengths of post space preparation- an in vitro study

Materials and Methods: 135 extracted human incisors were endodontically treated, out of which 120 teeth were decoronated 2mm above the cementoenamel junction and divided into four experimental groups based on the post system to be used: Glass fiber post (GFP) and stainless steel post (SSP), titanium post (TTP), cast metal post (CMP). Each group was divided into two sub-groups according to the length of post space preparation: 5mm and 10mm. All the samples were restored with metal crowns. The fracture resistance was measured by applying loads at an angle of 135º to the long axis of teeth in an instron universal testing machine. Fracture mode was analyzed for all the samples. Results from the four test groups were compared and analysed using one-way ANOVA test and the Post-hoc Bonferroni test to demonstrate differences between pairs of groups.

Results: The results revealed that SSP group at 10mm post space length showed the significantly ("P-value< 0.05") highest fracture resistance (793.7787 N). Decrease in post length resulted in the decrease in fracture resistance in all the groups reduced to values even lesser than the control (437.8733N).

Conclusion: The different post systems used in the study were able to reinforce endodontically treated teeth only at 10mm post space length.

INTRODUCTION

After root canal treatment, restoring teeth to rehabilitate oral functions is a major concern in dentistry. Most of the endodontically-treated teeth are structurally compromised and weaker due to the peripheral destruction caused by the

carious process as well as the central destruction that was caused by the endodontic treatment itself. Since the amount of remaining dentin directly determines the strength of the tooth [1, 2], these teeth are at higher risk of biomechanical failure than the vital teeth [3, 4)]. In the pulpless teeth with significant loss of tooth structure, retention of the functional restoration is often compromised. There is need of a restoration that can provide coronoradicular reinforcement as well as prevent any further physical damage to the remaining tooth structure. The suggested technique for restoration of endodontically treated teeth is the use of post systems [5]. A post was placed in an endeavour to strengthen the tooth [6-8] and also to provide retention for the core material when there is insufficient remaining clinical crown [9-12]. However, various ex vivo [9-12] and in vivo [4] studies have demonstrated that posts do not reinforce root filled teeth. The main purpose of a post is to provide retention to the core material. Application of a post often contributes to further loss of tooth structure that may interfere with the mechanical resistance of the teeth, increasing the risk of damage to residual tooth structure [13-16]. But these statements are mainly related to cast metal posts that have a high elastic modulus and only frictional retention in the root canal.

These statements cannot be applied to prefabricated metal posts and fiber posts, which have different mechanical properties and the capacity of bonding to dentine, with the use of adhesive systems and resin cements. Moreover, non-metallic posts such as glass fiber posts have a modulus of elasticity closest to dentin allowing homogenous stress distribution along the tooth.

The effect of different variables such as post length diameter, geometric design, surface configuration, and cement type on the outcome of the final restoration also cannot be overlooked. There is consensus that a post that is too short or too long places the tooth at risk of fractures [17-19].

An increase in the success rate of endodontically treated teeth has been noted when the length of the post is equal to or greater than the crown length [20, 21].So this study was conducted to determine the reinforcing effect of different post systems with different fabrication material at two post space preparation lengths. The post systems evaluated were: cast metal posts, glass fiber posts, stainless steel posts and titanium posts at 10mm and 5mm of post space preparation. The mode and strength of fracture were compared in the endodontically treated. Considering the fracture mode is very important. Stiffness of the core material alter the stress distribution along the root and cervical stresses increased in concentration and magnitude as the physical properties of the core materials improved [22]. The null hypothesis tested was that there was no effect of post system and post length on the fracture strength of the endodontically treated teeth.

MATERIALS AND METHODS
This study was conducted on 135 extracted human maxillary central incisors. The teeth were collected irrespective of age, sex, and side of the arch. None of the teeth had coronal/root caries, coronal/root fillings, root cracks and had a minimum of 13 mm root length with mesio-distal and bucco-palatal dimensions varying between 6 and 8mm. The selected teeth were disinfected in 0.2% thymol solution and were cleaned for any root deposits with the help of ultrasonic scaler (ARTP3II, Bonart, Taiwan). To avoid dehydration, the teeth were stored in normal saline solution at room temperature until they were used for the study. The root canal preparation of all the selected teeth was done with K-files (Mani, Japan) using the conventional step-back method. Repeated recapitulation and irrigation with 2% sodium hypochlorite and normal saline was done to avoid any clogging of the canals. Each tooth was instrumented to ISO # 60 master apical file (for standardization) to

achieve final contour of root canals. After drying the canals with absorbent paper points (Dentsply), polymeric resin sealer (Bioseal ,Equinox) was mixed and coated into the walls of the canals. Endodontic spreaders (Mani, Japan) were used to condense the gutta-percha cones and to obturate the canals using the lateral condensation technique. Out of 135 endodontically treated teeth, 15 teeth were kept as control in which no further treatment was done and remaining 120 teeth were decoronated at 2mm from the incisal. The remaining 120 teeth were decoronated at 2mm from the incisal-most aspect on the cement-enamel junction perpendicular to the long axis of the teeth with the help of diamond disk at high speed mounted on a straight handpiece using a micro motor (NSK, Japan). The decoronated 120 teeth were randomly divided into four experimental groups (n=30) based upon the type of post system used as follows: GFP, prefabricated glass fiber posts (Fibrapost no. 2, Produits Dentaires S.A, Switzerland); SSP, prefabricated stainless steel posts (Parapost System no. 5, Coltene Whaledent, USA); TTP, prefabricated titanium posts (Filpost, S J Filhol, Ireland); CMP, custom made cast metal posts (co-cr alloy, Bego, Germany). Each group was further divided into two subgroups (n=15) depending upon the length of the post space prepared i.e. 10mm and 5mm. In each group, the gutta percha was removed up to the required length with no.2 and no. 3 peeso (Mani, Japan) reamers. In group GFP, TTP and CMP, post spaces up to the desired lengths were prepared with specialized drill no. 2 supplied with the glass fiber post kit (Fibrapost, Produits Dentaires S.A, Switzerland) of diameter 0.85 at tip and 1.30 mm at 11mm from the tip. In group SSP, the post spaces were prepared up to the desired length by a specialized drill 1.3mm diameter for the entire length. In group TTP, the grooves were also placed in the post canal walls with the help of a groover provided by the manufacturer. For group CMP, single unit

post and core were casted with co-cr alloy in a centrifugal casting machine with a core height of 6 mm above the proximal cervical line and bucco-lingual and mesio-distal dimensions corresponding to the total bucco-lingual and mesio-distal dimensions of the sample. In all other groups, cores were prepared from composite resin after cementation of the posts. For cementation of the posts, dual cure resin cement (Monocem, Shofu Dental, Japan) was used. The canals were irrigated with normal saline solution to remove any debris. The prepared root canals were irrigated with distilled water and dried with absorbent points (Dentsply Maillefer, Switzerland). The posts were seated into the canals with normal finger pressure and the excess cement was removed. It was then light-cured for 40 sec to achieve complete polymerization. The prefabricated posts in GFP, TTP and SSP groups were then submitted to a new adhesive treatment for fabrication of the coronal portion of the post with composite resin. One hundred thirty five acrylic resin cylinders were fabricated by mixing the self-cure acrylic resin and pouring it into plastic pipes of 6 cm height and 1.5 cm diameter.

All the samples were coated with silicon based impression material (Impregum, 3M ESPE) before insertion to give the effect of periodontal ligament. Samples were embedded in acrylic resin (Rapid Repair, Pyrax Polymers, India) exposing 3mm of the root surface just apical to the buccal cervical line (to simulate alveolar bone) and held under digital pressure until the material set. Excess material was removed with the help of B.P knife (GlassVan, India). In groups GFP, TTP and SSP, light cured composite resin (Nexcomp, Meta Bio-Med, Korea) was used for core fabrication. Exposed post length was limited to 3 mm by cutting the excessive length with the help of a diamond disk. Samples were washed and dried. Etching of the samples was done for 15 sec.
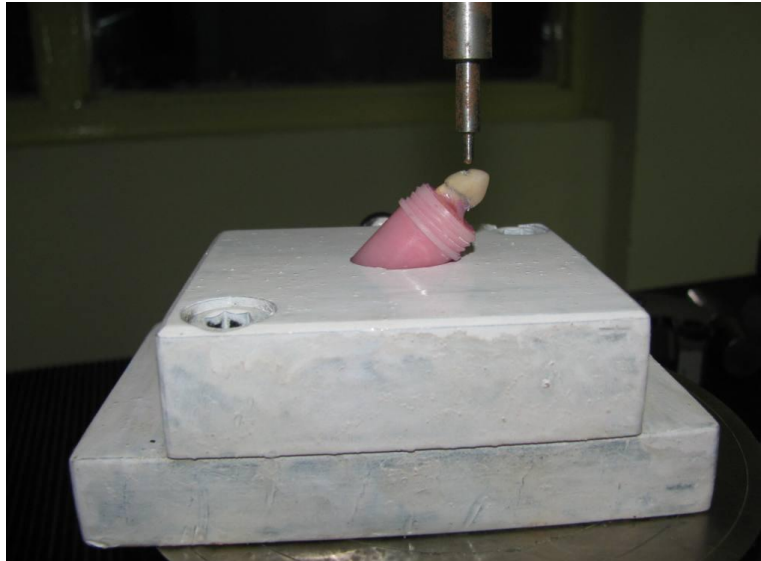
Fig.1 Loading of the specimens in the instron universal testing machine

The samples were washed and dried with oil free compressed air. Bonding of exposed post and cut dentin surfaces were done with the dentin bonding agent (Meta P & Bond, Meta Biomed, Korea). The preformed polyester matrix (Coltene Whaledent, USA) was filled with the composite resin and placed on the sample. It was then light-cured for 40 sec. The matrix was peeled-off after curing was completed with the help of a scalpel. It was finished to the final core height of 6 mm above the proximal cervical line, the bucco-lingual and mesio-distal dimensions corresponding to that of the tooth with the help of composite finishing instruments. After the fabrication and cementation of post and core, the final finishing of crown preparation was done with super fine diamond points (Shofu Dental, Japan).

All the samples were finally restored with cast crowns. The wax pattern was given the final crown shape and height of 8 mm .The patterns were then sprued and invested with phosphate bonded investment (Bego, Germany) and cast in Ni-Cr alloy (Bego, Germany) using lost wax technique.

The cast Crowns thus obtained were finished and polished. Tooth colored cold cure acrylic resin (Pyrax Polymers, India) layer was applied on the crown castings. A small step was prepared with carborundum disc at a distance of 3mm from the incisal edge as a standardized point for load application on the palatal aspect. After pre-cement trial and necessary adjustment, the crowns were cemented with dual cure resin cement (Monocem, Shofu dental, Japan) following the manufacturer's instructions. The samples were stored in normal saline until tested.

For holding the specimens during testing, the stainless steel metal jig and an attachment clutch were custom made of the desired dimensions according to the testing machine used in the study. Metal jig had the provision for holding acrylic resin blocks and orienting the sample at an angle of $135°$ to the load application tip of the attachment clutch.

The whole assembly was fitted in the digital instron Universal testing machine (LR 100K, UK; Maximum capacity- 100 kilo Newton). The load was applied on the palatal surface of the cast crown on a step 3

mm from its most incisal edge, at an angle of 135 degrees to the long axis of the root, at a cross-head speed of 0.5 mm/min until fracture occurred [Fig. 1]. Each sample was then carefully inspected to record the mode of failure.

The fracture mode was determined using the classification proposed by Zhi-Yue & Yu-Xing (2003):

a. Resin core or post fracture
b. Cervical root fracture
c. Mid root fracture
d. Apical root fracture
e. Vertical root fracture

The resin core/post fracture was considered as the favorable mode of fracture; whereas, all other fracture modes involving root were considered as unfavorable.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) computer software version 11.0 (SPSS, Inc., Chicago, IL, USA) was used to conduct data analysis. Descriptive statistics including means, standard deviations and frequency distribution were calculated for each group. Results from the four test groups were compared and analyzed using one-way ANOVA test and the Post-hoc Bonferroni test to demonstrate differences between pairs of groups. Probability values less than 0.05 were set as the reference for statistically significant results.

RESULT

Fracture resistance

The results revealed that there was significant difference in the fracture resistance among various groups and sub-groups. At 10mm post space length, SSP subgroup (stainless steel post system) showed the highest fracture resistance (793.78N); whereas, at 5mm post space length, the GFP subgroup (glass fiber post system) displayed the highest fracture resistance (425.19 N). At 5mm post space length, all the subgroups showed significant decrease in fracture resistance reducing to values even less than the control group (437.88 N) (Table 1).

Fracture modes

The fracture mode analysis revealed that specimens in group GFP at 10mm showed dominance of favorable fractures with 80% of the fractures occurring as core/post fractures. In all the remaining groups, unfavourable fractures mostly in the form of cervical and mid root fractures dominated [Fig. 2, 3]. Table 2 shows the fracture mode distribution of the specimens tested.

DISCUSSION

The results from this study did not support the null hypothesis and there was an effect of both the post system and post length on the fracture strength of endodontically treated teeth.

Table 1. Mean Value of Fracture Resistance of Different Groups and Sub-Groups in Newton

Group	Post space length	N	Mean	Std. Deviation	Minimum	Maximum
Control		15	437.88[c]	32.81	374.70	497.70
Glass Fiber	10 mm	15	738.21[a]	29.87	650.30	770.20
(GFP)	5mm	15	425.19[c]	42.73	378.60	484
Stainless Steel	10 mm	15	793.78[a]	44.52	735.90	861
(SSP)	5mm	15	305.31[d]	49.00	231.40	389.00
Titanium	10 mm	15	593.59[b]	75.22	520.20	757
(TTP)	5mm	15	387.67[c]	36.90	326.60	472.60
Cast Metal	10 mm	15	688.66[a]	56.69	598.60	787.40
(CMP)	5mm	15	400.01[c]	38.10	338	453.30

*Different superscripts indicate the significant difference "p-value<0.05" verified by Mann-Whitney and post-hoc Bonferroni tests

The results clearly indicated the ability of different post systems at 10mm post space length to strengthen an endodontically treated tooth. There was a definite effect of post length observed on the reinforcing capability of different post systems. SSP group showed highest fracture resistance as compared to all the other groups at 10mm post space length; whereas, at 5mm post space length, the GFP group showed the highest fracture resistance.

In this study, extracted human teeth were used to prepare the specimens. Human teeth have been commonly used for the in vitro testing of the post restorations [23-26].

Apart from human teeth, some authors have used either bovine teeth [27-29] or resin teeth [30, 31]. Bovine teeth are comparable to human teeth in modulus of elasticity, tensile strength and bonding characteristics, but they suffer from an unacceptably high size discrepancy relative to human teeth [32].

Resin material teeth can be standardized in terms of size, but they do not properly simulate the elastic and bonding properties of the natural human teeth [32]. Their adhesion to the post is unrealistic and not similar to clinical situations [33, 34]. All teeth in this study received endodontic treatment.

This was done keeping in mind that teeth receiving post anchored restorations are always endodontically treated [35] resulting in a small but significant loss of tooth structure [32].

The resin cement was used for luting various post systems. Resin cements reduce potential stress as their elasticity approaches to that of dentin [36-38]. The periodontal ligament simulation was done by coating the roots of the specimens with poly ether impression material. This allowed limited freedom of movement [39]. The PDL simulation is essential as it was found by Soares et al. that the presence of simulated PDL significantly affected the result of fracture testing [40]. The use of a rigid material to embed the extracted teeth may lead to distorted load values and may possibly affect the mode of failure of the specimens [41]. All the specimens in this study were given the full metal crowns. According to Martelli et al. the presence of a prosthetic restoration generates a different biomechanical effect [42].

The testing of the specimens was done by applying compressive load in a universal testing machine at an angle of 135 degree to the long axis and standardized palatal steps were fabricated to mark the level of loading on each metal crown.

Table 2. Fracture Mode Distribution of the Specimens Tested

Failure Modes	GFP n=15		SSP n=15		TTP n=15		CMP n=15	
	10mm	5mm	10mm	5mm	10mm	5mm	10mm	5mm
Resin Core or Post Fracture	12 (80%)	3 (20%)	1 (6.67%)	0	1 (6.67%)	1 (6.67%)	0	0
Cervical Root Fracture	3 (20%)	9 (60%)	2 (13.33%)	9 (60%)	8 (53.33%)	13 (86.67%)	3 (20%)	8 (53.33%)
Mid Root Fracture	0	2 (13.33%)	8 (53.33%)	5 (33.33%)	6 (40%)	1 (6.67%)	7 (46.67%)	7 (46.67%)
Apical Root Fracture	0	1 (6.67%)	4 (26.67%)	1 (6.67%)	0	0	4 (26.67%)	0
Vertical Root Fracture	0	0	0	0	0	0	1 (6.67%)	0
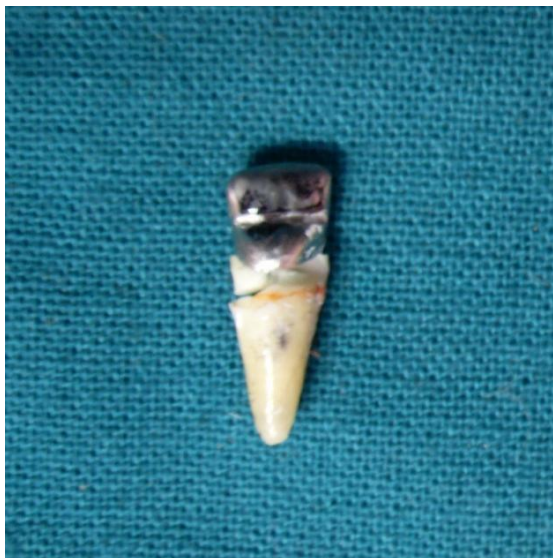
Fig 2. Irreparable cervical root fracture in SSP group at 5mm post space length

Fig 3. Irreparable mid root fracture in CMP group at 10mm post space length

The loading angle of teeth with post restoration can strongly affect the fracture resistance [43, 44]. Guzy and Nicholls reported that for incisor teeth, a loading angle of 135 degree was chosen to simulate a contact angle found in class 1 occlusions between maxillary and mandibular anterior teeth [39]. Several other authors had also found this angle as the most clinically comparable angle of loading in the anterior teeth [45, 46]. During testing, the lingual side was chosen for the application of loading forces to simulate oral conditions. The cross head speed was chosen at 0.5mm/min. In literature it has been reported to range from 0.5 (47) to 76.2mm/min [45]. This speed of 0.5mm/min was chosen because the low cross head speed resembles the slow loading forces acting during normal mastication, while high cross head speed resembles the higher loading forces acting during traumatic injuries. The 0.5 mm/min speed employed in this study is not excessive and allows optimum analysis of the responses of the experimental set up [48].

In the present study, all the post systems were able to reinforce the endodontically treated teeth only at a higher post length.

At 10mm post length, stainless steel posts showed the highest fracture resistance because this was the only parallel post group used in the study. As explained by Goldman et al., Mendoza and Eakle, passively cemented parallel sized posts are the most retentive and cementation with resin cement can further enhance the retention of parallel sized post and this increases the fracture resistance [49, 50]. The results of all the post groups at 5mm post space lengths showed that the placement of post adversely affected the strength of an endodontically treated tooth and decreased its fracture resistance. When the post length was reduced, fracture strength of the post restored specimens even became lesser than the endodontically treated intact teeth revealing the importance of optimal post length determination while restoring endodontically treated teeth.

Although all post systems at 10mm post space lengths showed a fracture resistance higher than the control group, the principal of preventing further damage to the toot structure was only followed by the glass fiber post system. When the fracture mode was considered, only the glass fiber post group showed favora-

ble fracture in the form of core/post fractures sparing the remaining tooth structure while all the metal post groups showed unfavorable root fracture. The core/post fractures are considered as favorable fractures as re-treatment is possible in these types of failures, whereas root fractures jeopardize the integrity of the natural tooth. The root fractures observed for various metallic post groups can be explained on the basis of high modulus of elasticity of the post materials (modulus of elasticity of dentin-18.3Gpa, Co-Cr alloy- 170Gpa, Stainless steel-200Gpa, Titanium-120 Gpa). Post material should have the same modulus of elasticity as root dentin to allow the distribution of the applied forces evenly along the length of the post and root [51-53]. When a system with components of different rigidity are loaded, the more rigid component is capable of resisting greater forces without distortion transferring the stresses to less rigid tooth structure causing intraradicular stress concentrations resulting in root fractures [54]. The favorable mode of fracture for glass fiber posts can be attributed to the low modulus of elasticity of glass fiber posts which is closest to that of dentin (modulus of elasticity of glass fiber- 16Gpa). Low elastic modulus materials such as glass fiber posts follow the natural flexural movements of the tooth, reducing stress arising at the interfaces, enabling the restored tooth to mimic the mechanical behavior of a natural tooth [55]. At 5mm post space length, all the groups including the glass fiber post group exhibited unfavorable root fracture mostly in the form of cervical root fractures. The increase in the frequency of root fracture among various groups at 5mm post space length can be explained on the basis of study carried out by Giovani et al., which stated that at shorter post lengths as the mass volume of posts decreases, the absorption of forces by the post system decreases to a considerable degree and they more efficiently transfer the forces to less rigid tooth dentin endangering the tooth structure to more root/catastrophic fractures [56].

Therefore, it can be concluded from the present study that longer post lengths favor the concept of coronoradicular reinforcement by the use of post system (57, 58), but as the post length was reduced, this concept was not followed and the post placement further worsened the strength of already weakened endodontically treated tooth [13-15]. The use of post systems with physical properties comparable to that of the tooth provides good fracture strength as well as a favorable mode of fracture.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

1. Glass fiber posts efficiently increased the fracture resistance of an endodontically treated tooth as well as provided the favorable mode of fracture.

2. Although metallic post systems can increase the fracture strength of endodontically treated teeth, they can predispose the tooth structure to root fracture.

3. The concepts laid by various authors regarding the determination of optimal post length are extremely important and should be followed for better clinical outcomes.

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