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ORIGINAL RESEARCH

Impact of Root Dentin Thickness on the *in vitro* Compressive Strength of Teeth treated with Recent Post and Core Systems

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ABSTRACT

Introduction: Endodontically treated teeth dry with time, and its dentin undergoes changes making the teeth brittle and friable. The main function of a post is to strengthen or reinforce a weakened root. However, doing a post and core frequently requires the removal of sound tooth tissue. Recent materials introduced in the market for post and cores have been promising.

Aim: The aim of this study is to evaluate the fracture resistance of endodontically treated extracted permanent teeth with variable remaining root dentin thickness after post space preparation.

Materials and methods: A total of 270 freshly extracted permanent maxillary central incisors with fully formed apices were selected, decoronated at cementoenamel junction, and divided into three main groups according to remaining root dentin thickness, determined using a Vernier caliper into 0.5, 1, and 1.50 mm after post space preparation. Each group was further divided into three subgroups (subgroup a: Custom-made cobalt–chromium alloy post and core; subgroup b: Prefabricated glass fiber post and composite core; and subgroup c: EverStick fiber post). Each specimen was subjected to compressive load using universal testing machine. The force required to fracture was recorded and data were analyzed using analysis of variance (ANOVA) test.

Results: Analysis of variance revealed that compressive strength of the tooth is significantly affected by the increase in the remaining dentin thickness after post space preparation ($p < 0.05$). Furthermore, teeth with custom fabricated posts showed a significantly higher compressive strength ($p < 0.05$) than prefabricated glass fiber post and EverStick fiber post groups except the group with minimum remaining dentin thickness.

Conclusion: The present *in vitro* study revealed that compressive strength of the post and core systems is directly related to the amount of healthy remaining dentin thickness. Hence, efforts to maximize the preservation of natural dentin should be taken during post space preparation.

Keywords: Compressive strength, Custom-made posts, EverStick fiber post, Glass fiber posts, Post and core, Remaining dentin thickness.

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INTRODUCTION

Dental professionals have been searching for the best way to restore root-filled teeth while protecting the remaining dental tissues. Many options are available for the reconstruction of endodontically treated teeth, but taking decision clinically can become complicated when teeth get weakened and root canals are compromised. It has been suggested that endodontically treated teeth dry with time and the dentin in such teeth does undergo certain changes in the cross-linking pattern of collagen, thereby making the teeth brittle and friable.[1] As root canal-treated teeth often have significantly damaged coronal tooth structures, they commonly require posts to support the core material and promote retention of the final restoration.[2] The main function of a post is the retention of a core and to strengthen or reinforce a weakened root. The selection of the most suitable post system in each case is subjective to remaining sound tooth structure, root anatomy, esthetics, and functions. Several reports have concluded that the resistance of a root-filled tooth is directly related to amount of remaining tooth structure.[1] For this reason, the provision of a post and core must be done with care, since their use often requires deduction of sound tooth structure.

A variety of materials have been used for posts ranging from wooden posts of the 18th century to metal posts, and moreover, in recent times, carbon fiber, glass fiber, and ceramic posts have been introduced. With a variety of post systems available and by the fact that new posts are introduced before existing ones are fully evaluated in laboratory and clinical studies, it becomes often difficult to decide which one to use.[3]

The fundamental importance of preserving the remaining tooth structure to provide strength and resistance to fracture after both endodontic therapy and post space preparation is essential for endodontics. Different sorts of prefabricated glass fiber posts (in relation to design, shape, and material) have been introduced in the market, and a major shift has been noticed from metal custom cast posts and cores toward prefabricated fiber-reinforced posts and resin-based composite cores. These prefabricated fiber-reinforced resin posts have become prevalent due to their ease of operation and lower modulus of elasticity in comparison with metal posts, thereby reducing the risk for root fracture.[4] Fiber-reinforced composite materials have been introduced nowadays as a viable alternative to metal/glass fiber posts for fabrication of custom-made posts.[5] The fiber bundles can be adapted directly into the post space, so as to obtain a customized post, which is then adhesively luted.

There is a general agreement that teeth treated endodontically are brittle. Hence, there should be a complete knowledge of the anatomy and biology of the dentin and root supporting the restoration, as both endodontic and restorative methods weaken the tooth structure.[6] Therefore, in these cases, additional retention for restoration and compensation for the lost tooth structure is usually required, which can be attained by fabricating a post and core in the root canal of the tooth.[7]

The purpose of this study was to compare the fracture resistance of endodontically treated roots with different dentin wall thickness restored using three different post and core systems so that minimum required dentin thickness can be ascertained for each specific type of post based on different clinical situations. The null hypothesis for the present study is that all three systems can be effectively used for a successful post and core system with any of the three available remaining dentin thicknesses.

MATERIALS AND METHODS

The present prospective *in vitro* study carried out in the Department of Conservative Dentistry and Endodontics of Sri Guru Ram Das Dental College and Hospital, Amritsar, Punjab, India, during the period of 1 year from January to December 2011.

Two hundred and seventy freshly extracted sound noncarious permanent maxillary central incisors were selected from patients with grade III mobility and who had to be taken up for complete dentures. This sample size was agreed on after subjecting the study variables, i.e., three different type of posts used in three subgroups based on remaining dentin thickness (0.5, 1 and 1.5 mm), to adequate power sampling. A sample power of 98% was attained by this method.

Ethical clearance was obtained from the Institutional Ethical Committee. Teeth were thoroughly cleaned and any soft tissue attached to root surface was removed with a hand scaler. During subsequent preparation and testing, to prevent dehydration, all the specimens were stored in distilled water till root canal preparation was done.

Teeth were sectioned at cementoenamel junction, pulp tissue was removed, and working length was determined with No. 15 K-file (Dentsply, LD Caulk, USA). After biomechanical preparation was carried out by step-back technique up to No. 50 K-file, obturation was done with gutta-percha points and resin cement (Panavia F; Kuraray Co., Ltd., Tokyo, Japan).

Post space preparation was carried out using Peeso reamers (Dentsply, LD Caulk, USA) and shaping drills (Parapost X Drills, Coltene Whaledent, USA), and the thickness of remaining residual dentin at the cervical area was estimated by digital Vernier caliper (Aerospace) (Table 1 and Fig. 1) and radiovisuography (RVG) after post channel preparation (Table 1 and Fig. 2).

Teeth were randomly divided equally into three main groups of 90 teeth each according to the remaining dentin thickness of root:

Group I: remaining dentin thickness of 0.5 mm

Table 1: Mean compressive strengths of teeth restored with custom cast posts and core, prefabricated glass fiber posts and composite core or EverStick posts, and composite cores with remaining dentin thickness of 0.5, 1.0, and 1.5 mm

Groups	*Subgroups*	*Compressive strength (n)*	*p-value*
I	Ia	612.13 ± 71.014	0.032
	Ib	682.32 ± 81.27	
	Ic	763.26 ± 64.23	
II	IIa	1,088.84 ± 202.56	0.008
	IIb	727.89 ± 52.94	
	IIc	800.55 ± 47.12	
III	IIIa	1,494.09 ± 157.10	0.005
	IIIb	879.35 ± 127.34	
	IIIc	884.32 ± 73.12	

Fig. 1: Estimation of thickness of dentin in groups I, II, and III after post space preparation using digital Vernier caliper

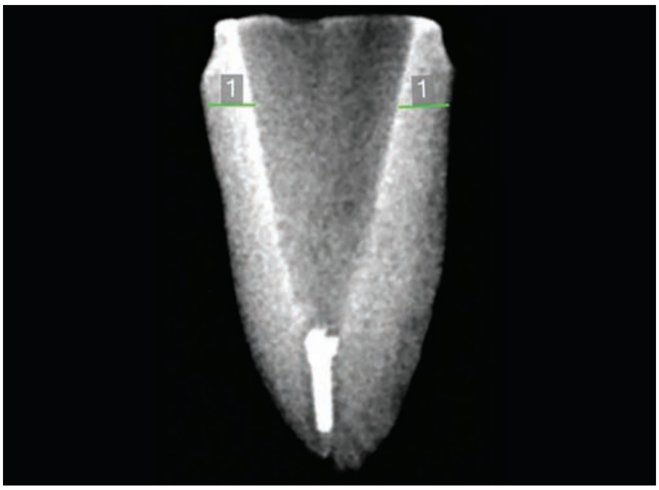


Fig. 2: Estimation of thickness of dentin after post space preparation using RVG

Group II: remaining dentin thickness of 1 mm
Group III: remaining dentin thickness of 1.5 mm

Further, teeth in each group were equally divided into three subgroups according to the post and core system used:

Subgroup I: Custom-made post and core—30 teeth
Subgroup II: Prefabricated glass fiber post and composite core—30 teeth
Subgroup III: Fiber-reinforced composite post (EverStick) and core—30 teeth

In case of the custom-made cobalt–chromium post and core group, blue inlay wax was used to model internal anatomy of root canal and for core buildup. Core patterns were built up with an inclination of 45° to the long axis of tooth. The post and core patterns were invested in phosphate-bonded investment material and cast in cobalt–chromium alloy (Wironit®, Bego, USA). After the removal of casting defects, if any, the post was sandblasted and cemented using dual-polymerizing adhesive resin cement (Panavia F; Kuraray Co., Ltd., Tokyo, Japan).

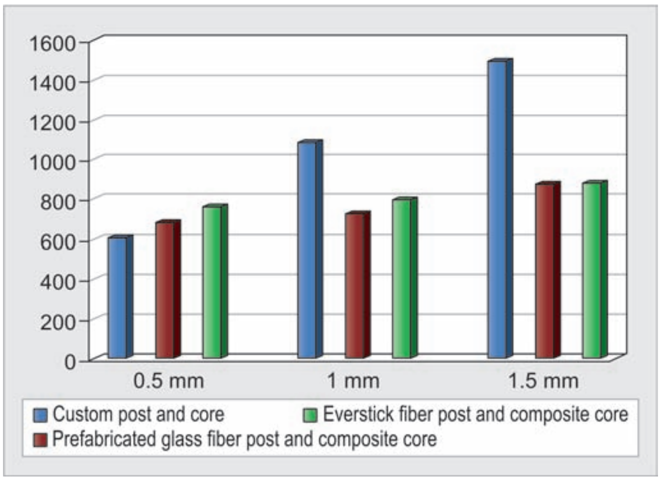
For the second subgroup, prefabricated glass fiber posts (Parapost, Coltene Whaledent, USA) were selected after using the specific shape drill. The root canals were treated with a self-etching ED primer (Panavia F; Kuraray Co., Ltd., Tokyo, Japan) for 60 seconds. The fiber posts were cemented using a dual-polymerizing adhesive resin cement (Panavia F; Kuraray Co., Ltd., Tokyo, Japan). Composite resin core (Clearfil Photocore, Kuraray Co., Ltd., Tokyo, Japan) was added in increments, and core buildup was done at an inclination of 45° to vertical axis of tooth.

The third subgroup consisted of fiber-reinforced composite posts of the selected size after using the specific size drill. The root canals were etched, bonded, and luted with bulk-fill flowable composite along with the EverStick post (EverStick, Stick Tech Ltd., Turku, Finland). Composite resin core (Clearfil Photocore, Kuraray Co., Ltd., Tokyo, Japan) was added in increments, and core buildup was done at an inclination of 45° to the vertical axis of the tooth.

The specimens were subjected to compressive loads using a universal testing machine (Instron, Instron Corp., UK), by applying controlled loads to the core, 2 mm from its incisal edge, on the palatal side at an angle of 135° to the long axis of the root. The testing machine (Table 1) was set at a crosshead speed of 0.5 mm/minute, and failure threshold was defined as a point at which a specimen no longer withstood increasing load and fracture of post–core complex or root occurred.

Statistical Analysis

The findings were recorded and subjected to suitable statistical analysis using Statistical Package for the Social Sciences software version 22.0. Mean ± standard deviation values were subjected to ANOVA for evaluation. *Post hoc* Tukey's test was employed to evaluate the statistical significance of the obtained results with $p < 0.05$ considered as statistically significant value.



Graph 1: Comparison of compressive strengths of various groups for remaining dentin thickness of 0.5, 1, and 1.5 mm thickness

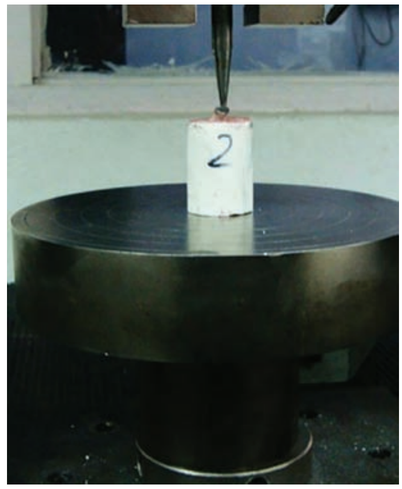


Fig. 3: Specimens subjected to compressive loads using a universal testing machine

RESULTS

In the present study, the compressive strength of specimens with 0.5 mm dentin thickness was found to be the lowest (Table 1 and Graph 1). Teeth restored with custom-made post and core (group Ia) reported a compressive strength that ranged from 399 to 721 N with an average mean of 612.13 ± 71.014 N. The results obtained had a statistically significant difference in comparison with prefabricated glass fiber post group (group Ib) where compressive strength ranged from 510 to 910 N with an average of 682.32 ± 81.27 N and the EverStick post group (group Ic) where the strengths ranged from 580 to 1,086 N with an average of 763.26 ± 64.23 N ($p < 0.05$). The compressive strength of specimens with 1 mm thickness restored with custom-made post and core (group IIa) ranging from 737 to 1,840 N with a mean of 1,088.84 ± 202.56 N was found to be highly significant statistically in comparison with that for prefabricated glass fiber post (group IIb) from 591 to 830 N with a mean of 727.89 ± 52.94 N and also the EverStick post group (group IIc) where the strengths ranged from 596 to 760 N with an average of 800.55 ± 47.12 N ($p < 0.01$).

Specimens with a remaining dentin thickness of 1.5 mm restored with custom-made post and core (group IIIa) showed a compressive strength ranging from 1,084 to 1,831 N with an average mean of 1,494.09 ± 157.10 N, which was found to be highly significant in comparison with values obtained for prefabricated glass fiber post (group IIIb) from 638 to 1,188 N with an average mean of 879.35 ± 127.34 N and also the EverStick post group (group IIIc) where the strengths ranged from 784 to 1,132 N with an average of 884.32 ± 73.12 N ($p < 0.01$) (Table 1 and Fig. 3).

DISCUSSION

Root canal treatment is usually the consequence of caries, followed by pulpal infection or traumatic damage to a tooth. Trauma and caries are mostly associated with an extensive loss of tooth structure. The pulpless tooth has already lost substantial coronal tooth structure from the access preparation for the endodontic treatment which necessitates restoration of the tooth with a complete crown for esthetic and functional rehabilitation.[8]

In the past, it was thought that posts reinforce endodontically treated teeth and that the placement of a metal alloy post in a tooth made the tooth and the subsequent restoration stronger.[3] An unnatural restored tooth structure is created after the placement of posts as it fills the root canal space with a material that has a defined stiffness, unlike the pulp. Consequently, the characteristics of the interface between dental structure and the restorative materials as well as the rigidity of the restorative materials are factors that influence the mechanical behavior of endodontically treated teeth.[9] Hence, the diameter of the post and remaining root dentin is identified as parameters that have an impact on the resistance of endodontically treated teeth to fracture.[10] The fracture resistance should be enhanced by minimizing tooth structure loss, and diameter of the post should be kept as small as possible to increase.[11]

In the present study, compressive strength of permanent maxillary central incisors with variable root dentin thickness of 0.5, 1 and 1.5 mm restored with three different post and core systems was compared (Table 1). The result showed that compressive strength of specimens with 0.5 mm remaining dentin thickness restored with custom-made post and core was lowest among all the groups including those restored with prefabricated glass fiber post and core and fiber-reinforced composite posts having same dentin thickness. Such is the impact of the remaining dentin thickness that when compared with any of the other groups, it showed highly significant statistical differences ($p < 0.001$).

The fiber-reinforced composite posts consist of mixed polymer network wherein glass fibers are interspersed with the 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)phenyl]propane matrix. Such type of posts can be modified like custom posts as well as also consist of effect of monobloc kind of prefabricated glass fiber posts.[12] Hence, in cases of minimum dentin thickness, these posts were found to be significantly better as compared with any of the other post and core systems.

The results obtained for group I are in concordance with another study wherein custom cast post failed at a much lower loads of 155.98 ± 18.90 N than quartz fiber post which failed at 396.08 ± 31.40 N.[13]

The reason for this could be that quartz fiber posts with the latest generation bonding systems provide an integrated tooth, post, and core bonded restoration, which results in a metal-free, physiochemically homogeneous material often referred to as the monobloc type of restoration. The reinforcement and replacement of post preparation pulpal space area with materials that show elastic compatibility with dentin are better than the morphologic dowels that have a high elastic modulus.

Tjan and Nemetz[14] also found that canals with 1 mm of remaining buccal dentin walls were apparently more prone to fracture than those that had 2 and 3 mm of dentin walls. Studies by other authors[15,16] also found that the custom cast post failed at much lower loads when compared with prefabricated fiber post and core system for lesser remaining dentin thickness cases.

The results of the present study also show that with increase in remaining dentin thickness, especially with 1 and 1.5 mm of remaining dentin thickness, the custom-made cast post and core system showed dramatically higher compressive strengths that were statistically found to be highly significant in comparison with those of prefabricated glass fiber post and core systems or for that matter even in comparison with fiber-reinforced composite post systems.

Such high compressive strengths have previously been reported by various authors. Kivanç et al[17] also found that higher fracture resistance for central incisors with dentin thickness of 1.5 mm restored with cast post and core was 1,659.96 N, while specimens restored with prefabricated fiber post and core showed a fracture load resistance of 708.93 N. Giovani et al[16] justified that posts with a modulus of elasticity similar to dentin, such as the glass fiber post, when submitted to a compressive load, can better absorb the forces concentrated along the root, decreasing the probability of fracture. This explains the higher capacity of glass fiber posts to absorb a greater amount of stress, rather than transferring stress to the dentin when compared with custom-made post and core. However, in the present study, fracture resistance of specimens with 1.5 mm remaining dentin thickness restored with custom-made post and core was highest.

Zogheib et al[18] compared mean failure load values for control teeth (566.7 N) with those having partially weakened roots (409.6 N) and largely weakened root (410.9 N). They found that the fracture resistance decreased when remaining dentin thickness was less than the thickness of the leftover dentin following procedures of root canal preparation for post fabrication; consequently, it may be the most imperative iatrogenic factor that shows correlation to fracture resistance of the root.[19]

A significant amount of sound structure might have a successful prognostic factor when the root canal is bonded and filled with composite resin. Conversely, in the present study, the fracture resistance of prefabricated post and composite resin core and even fiber-reinforced composite posts was lower when compared with custom-made post and core for remaining root dentin thickness of 1 and 1.5 mm. Similar results have been obtained in previous studies.[20] The difference can be attributed to better fit and marginal integrity leading to lesser voids in custom-made cast post and cores in comparison with prefabricated or fiber-reinforced composite posts. This has been proven by Maccari et al[13] in their studies reporting a lower fracture strength of fiber-reinforced composite posts compared with the values for cast metal posts. They attributed it to the displacement or fracture of the resin cement layer, composite core, or resin post during mechanical testing. Haralur et al[20] commenced a study and revealed that the endodontic post is essential for a tooth with <1.5 mm dentin wall width to improve fracture resistance, whereas post is not required in root canal-treated teeth with >2.5 mm coronal dentin wall width.

The limitations of the present study are that teeth inside the oral cavity are subjected not only to compressive but also tensile and shear stresses. Hence, the results of the present study cannot mimic exact oral conditions. Furthermore, the fit of the post is directly linked to the microleakage which inherently can affect the longevity of the restoration. Future studies focusing on *in vivo* results among large number of sample group should be taken up to better evaluate the best type of post in a specific clinical situation.

CONCLUSION

To sum up, in the present study, it was found that fracture resistance of specimens with remaining dentin thickness of 0.5 mm was less when compared with 1 and 1.5 mm. The results also show that remaining dentin thickness was a significant determinant factor on the fracture resistance of roots restored with custom cast, prefabricated post, as well as fiber-reinforced post and cores.

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