RESEARCH ARTICLE

A Comparative Evaluation of Pushout Bond Strength of Comprehensive Techniques for Intracanal Rehabilitation of Structurally Compromised Roots: An *In Vitro* Study

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Abstract

Statement of problem: The restoration of teeth with flared canals and thin dentinal walls has been challenging as the weak radicular structure can be prone to fracture.

Materials and methods: Thirty freshly extracted maxillary central incisors adhering to inclusion criteria were selected and decoronated. Canals were made compromised by preparing with peso reamers. Sectional obturation was performed using the rolled cone gutta-percha (Prime Dental, India) technique along with AH Plus sealer (Dentsply). Randomly, the samples were divided into three groups. Group I—Fiber post (DT light post, Bisco, USA) + flowable composite (Tetric N Flow, Ivoclar Vivadent, USA), group II—Biological post + dual cure resin cement (Rely X, 3M, USA), and group III—Smart dentin replacement (SDR, Dentsply, USA) as post material. Two transverse sections of thickness of 1 mm were obtained, from the coronal third and the middle third of the canal from each sample. The pushout bond strengths were measured using a universal testing machine (Instron, Norwood, USA).

Results: Group III scored the highest mean with statistical significance compared to groups II and I. Groups II and I showed less pushout bond strength with no statistically significant difference.

Conclusion: Smart dentin replacement is a better material for intracanal rehabilitation of teeth with flared canals in terms of pushout bond strength when compared with other groups. DT light post + flowable composite could be used to reinforce weakened roots and is least technique sensitive. Depending on the clinical situation and the availability of doomed teeth, biological post may be preferred.

Keywords: Biological post, Compromised canals, Intracanal rehabilitation, Pushout bond strength, Smart dentin replacement.

Journal of Operative Dentistry and Endodontics (2020): 10.5005/jp-journals-10047-0086

Introduction

Trauma to anterior maxillary teeth is pervasive in the age group of 9 years and 10 years, and the roots of anterior teeth will still be maturing with very less intraradicular dentinal thickness.[1,2] Other conditions, such as internal root resorption, iatrogenic damage in complex cases, lead to flared root canals. Literature suggests the use of DT light post and flowable composite resin and biological post in these situations, which can reduce the amount of space taken up by the luting media. Smart dentin replacement (SDR) is a recent advancement in restorative materials with desirable properties. The adhesion in such cases is a crucial factor, and the hostile environment there makes it critical. There is limited literature comparing and evaluating pushout bond strength of intracanal rehabilitation techniques for structurally compromised roots.

Aim of the study was to evaluate the adhesive quality of comprehensive techniques for intracanal rehabilitation of structurally compromised roots.

Materials and Methods

The protocol was approved by the Institutional Review Board for Ethical Approval, Vishnu Dental College VDC/IEC/2018/01. Sample size calculation was performed based on a previous study.[3] A sample calculation was performed using 95% confidence intervals. Thirty freshly extracted maxillary central incisors with entirely formed apices were selected by similar root sizes and absence of caries, visible fracture lines or cracks. Teeth were then stored at 37°C in distilled water.

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How to cite this article: Sajjan GS, Sahu KK, Varma KM, *et al.* A Comparative Evaluation of Pushout Bond Strength of Comprehensive Techniques for Intracanal Rehabilitation of Structurally Compromised Roots: An *In Vitro* Study. J Oper Dent Endod 2020;5(1):1–5.

Source of support: Nil

Conflict of interest: None

Access cavities were prepared. Working length was established with 15K file (Mani, Japan) 1.0 mm short of apical foramina, and the root canals were prepared using a step-back technique to a master apical file size of 60 (Mani K file, Japan). Irrigation was performed using 27-gauge side-vented needle tips (RC Twents, Prime Dental, India), with alternating 3% sodium hypochlorite (Prime Dental, India) and 17% ethylenediaminetetraacetic acid (RC help, Prime Dental, India) for 1 minute each between the use of each instrument. This was followed by a final rinse with distilled water. Then, the canals were prepared with peso reamers (Mani, Japan) from size 1 to 6 except for the apical 4 mm of the root canal. Then, the apical 4 mm was prepared with peso reamer from size 1 to 3 from the tip of the root (retrograde preparation) to simulate the weakened root canals.

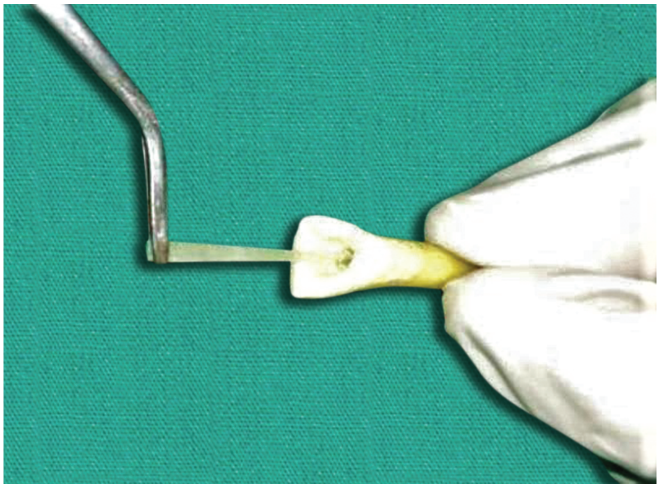


Fig. 1: Placement of DT light post in a sample of group I

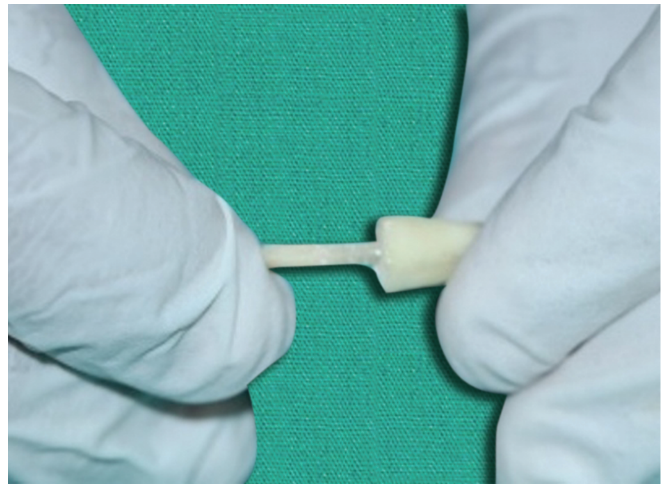


Fig. 2: Placement of biological post in a sample of group II

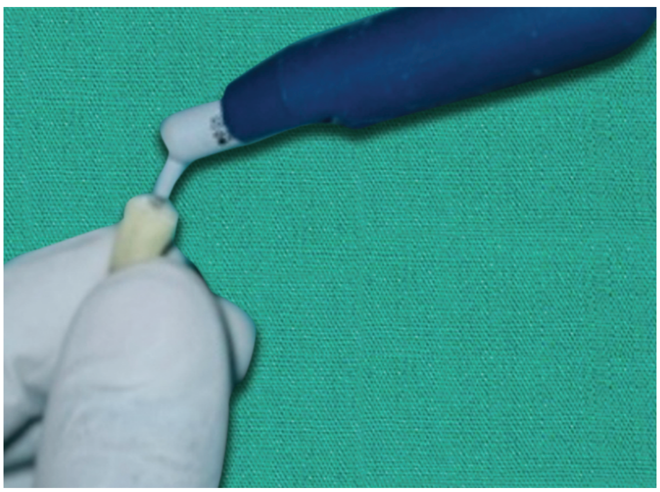


Fig. 3: Injection of SDR compule into the canal with special dispensing gun in a sample of group III

Custom-made rolled cone gutta-percha points were prepared. After radiographic verification, 4 mm of the apical segment was cut with heated instrument. Sectional obturation was performed with custom-made rolled cone gutta-percha (Prime Dental, India) and AH Plus sealer (Dentsply) and randomly divided into three groups using random.org, for different intracanal rehabilitation techniques.

Group I—Fiber post + flowable composite.

Group II—Biological post + Rely X cement.

Group III—SDR as post material.

In group I, first, the canal spaces of the specimen were etched with 37% phosphoric acid (N etch gel, Ivoclar Vivadent, USA) for 15 seconds rinsed with water using an endodontic needle and gently air-dried. The bonding agent (Tetric N Bond, Ivoclar) was applied to the canal walls with micro brush and excess was removed with gentle air blow and light cured for 10 seconds. DT light post was cut with diamond disk to resultant length of 10 mm prior to cementation. Flowable composite (Tetric N Flow, Ivoclar) was injected into the canal, and the post with a coating of flowable composite was placed into the canal (Fig. 1). Ultrasonic activation was performed for uniform flow of composite resin by activating the tip of post which was placed in the canal. Then, it was photopolymerized with intensity of 800 mW/cm^2 for 40 seconds with a light cure gun (Woodpecker 586, China).[4] The posts were sealed with nanohybrid composite resin (Tetric N Ceram, Ivoclar).

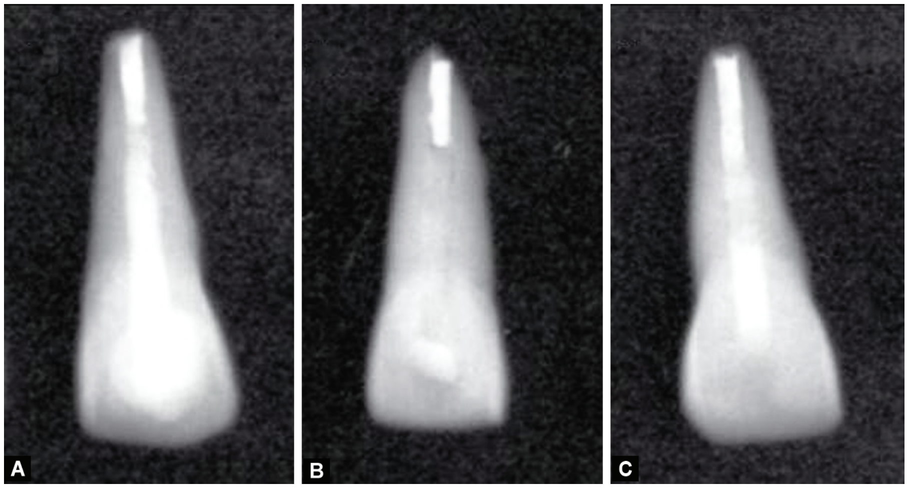
In group II, pattern of prepared canals was fabricated with inlay wax, which acted as 3-dimensional guide for the preparation of biological posts. Freshly extracted human canines were taken and sterilized by autoclaving at 121°C for 15 minutes. They were split mesiodistally with diamond disk under continuous water spray. These split canines were shaped accordingly to fit into the post space (Fig. 2). After preparation of biological posts, the fit was verified with radiographs. The biological posts and canal walls were etched (N etch gel, Ivoclar Vivadent, USA) for 15 seconds, rinsed, and bonding agent (Tetric N Bond, Ivoclar) was applied and light cured for 10 seconds. Then, biological post was trimmed with diamond disk resulting in 10 mm post. They were coated with Rely X (3M, USA), dual-cure resin cement and placed into the root canal and held with constant digital pressure for 10 seconds and light cured for 40 seconds.

In group III, the prepared root canals were filled with SDR material using a special gun (Fig. 3). Initially, canals were filled up to 4 mm and light cured for 20 seconds with intensity of 800 mW/cm^2, followed by injection of next increment and curing. Similar to the previous group, access cavity was sealed with nanohybrid composite. Radiographic evaluation of all the specimens was performed (Fig. 4).

All the specimens were stored in 0.9% saline for 1 week, and they were subjected to thermocycling. Thermocycling procedure consisted of 3,000 cycles between water baths at 5°C and 55°C, with a dwell time of 30 seconds. After thermocycling, the samples were sectioned with a new diamond disk.

Two transverse sections of thickness of 1 mm were obtained, one from the coronal third and the other from the middle third of the canal from each sample. Thickness was measured with digital caliper with 0.01 mm accuracy.

Coronal section was obtained at 11 mm from the apex, and the middle section was obtained at 6 mm from the apex. The apical surfaces of the slices were marked with a permanent blue-ink dot. The apical surface displaying the ink dot was placed facing the plunger tip ensuring that loading forces were introduced in an apical to coronal direction. The pushout bond strengths were measured using a universal testing machine (Instron, Norwood,



Figs 4A to C: Radiograph of each sample from groups I, II, and III after intracanal rehabilitation

Fig. 5: Pushout bond strength test with UTM using a custom made jig

USA). The fillings were loaded with a 1 mm diameter cylindrical stainless steel plunger at a speed of 1 mm/minute, ensuring that the plunger touches the post only (Fig. 5). Pushout bond strength data were converted to MPa by dividing the load in Newton by the bonded surface area (SL) in mm^2. SL was calculated as the lateral surface area of a truncated cone using the formula:

$$S_L = \pi(R+r)\left[\left(h^2+R+r\right)^2\right]^{0.5}$$

R is the coronal post radius, *r* the apical post radius measured on stereomicroscopic images, and *h* the thickness of the slice. Results were subjected for statistical analysis.

Results

Mean and standard deviation of groups I, II, and III (in MPa) are tabulated in Table 1.

The values obtained after pushout bond strength were subjected to one-way ANOVA test and significance level was set to 0.05. Group III (11.65 MPa at coronal section and 10.05 at middle section) scored the highest mean value, followed by group II (8.47 MPa at coronal section and 7.76 at middle section). The least mean value was with group I (8.04 MPa at coronal section and 7.22 at middle section). However, there was no statistical significant difference in mean values among groups except for group III.

Table 1: Mean and standard deviation of groups I, II, and III (in MPa)

Groups		*Coronal*	*Middle*
I (DT light post)	*n*	10	10
	Standard deviation	2.41	1.86
	Mean	8.04	7.22
II (biological post)	*n*	10	10
	Standard deviation	2.06	1.87
	Mean	8.47	7.76
III (SDR as post)	*n*	10	10
	Standard deviation	2.36	2.14
	Mean	11.65	10.05
Total	*n*	30	30
	Standard deviation	2.74	2.27
	Mean	9.39	8.34

Mean values of pushout bond strength in MPa of the three groups in decreasing order are as follows: group III (SDR) > group II (biological post) > group I (DT light post).

Mean values: (in MPa).

Coronal 11.65 > 8.47 > 8.04 (group III > II > I).

Middle 10.05 > 7.76 > 7.22 (group III > II > I)

Discussion

Trauma to develop anterior teeth is common in patients between the ages of 8 years and 12 years and might lead to pulpal necrosis with subsequent halted development of the root.[5] The resultant divergent dentinal walls and open apices render these teeth more susceptible to fracture, especially in the cervical area.[5] In some situations, root canals can become weakened and flared because of the progression of caries on the root canals along with endodontic access. Because of this process, the resultant flared root canals have thin inner dentin, which may be too weak to resist physiological occlusal loading, thus becoming more susceptible to the fatigue process and fractures. Loss of anterior teeth can affect esthetics and function of teeth, which include mastication, phonetics, and perception.

Various treatment modalities available in this condition are, retaining teeth by endodontic treatment, extraction followed by fixed partial denture (FPD) or implant. Extraction has adverse effects, such as loss of periodontal ligament (PDL), alveolar bone height, and proprioception. Data from the literature suggest that the modeling of alveolar bone following extraction was uninfluenced by the presence of a dental implant.[6] So, preserving tooth is the most beneficial option for the patient rather than implant or FPD. Retention of these teeth, however, remains critically essential because other alternatives, such as implant-supported restorations or fixed prostheses, require completion of craniofacial growth in younger patients for acceptable outcomes.[5] The flared and weakened canals make the restorative procedure of these teeth more difficult. Therefore, the rehabilitation of weakened root-filled teeth has been recognized as a challenge by several authors.[7] Several studies have shown that bonded composite resin seems to provide the most significant potential to strengthen and reinforce the thin dentinal walls of immature teeth.[5]

Traditionally, flared canals have been restored using cast metal posts and are often unsuccessful because of lack of retention.[7] Thus, fiberglass posts have substantially replaced metallic posts for intraradicular retainers, as they have a modulus of elasticity similar to dentin, reducing the number of root failures. Reinforcement of fiber post with composite resins is one of the methods to reinforce the weakened root canals.

Another approach is the biological post. “Biological post or dentinal post” is a post made of a human extracted tooth to provide resilience compared to the natural tooth. Different materials and various post systems are available in the market, but none of them are proved to be equally effective as natural teeth considering mechanical and biological properties.[8]

Smart dentin replacement is the first bulk-fill flowable composite base material. On the basis of its properties, such as lower polymerization shrinkage, greater depth of cure, and self-leveling feature, it was tried as post material to rehabilitate the weakened root canals.[9] The results of the study are as follows:

Mean values (pushout bond strength) of the three groups in decreasing order are as follows: group III (SDR) > group II (biological post) > group I (DT light post).

Coronal sections had more significant pushout bond strength than the middle parts for all the samples but not statistically significant. Literature suggests that adhesion to coronal dentin is better or more predictable than adherence to radicular dentin, because the number and density of dentinal tubules decreases from the cervical to the apical region. Additionally, it is challenging to achieve adhesion protocol (including etching, priming, and bonding) in the apical third. Also, there can be remnants of gutta-percha and sealer, weakening the bonding procedure. Moreover, the effectiveness of light-curing diminishes in deeper regions.[10] However, this issue is still controversial because some authors have reported increased or similar bond strength values closer to the apical region.[10]

But the point to be noted is that most of the pushout bond strength studies available in the literature are not of structurally compromised roots. This study tries to fill the lacunae by comparing the pushout bond strength of different comprehensive techniques in structurally compromised roots.

In group III, SDR as post achieved the highest pushout bond strength value, i.e., 11.65 MPa in coronal third sections and 10.05 MPa in middle third sections.

The superior results of group III (SDR) among the other groups might be due to less interphases as it is a single material. That is there were no interfaces among the post and core materials. The degree of conversion could have been better as the material was placed in two increments and cured separately. The whole restorative complex worked like a single unit.

Other reasons might be 60–70% reduction in shrinkage stress when compared to conventional methacrylate-based resins. These resins are patent registered as being based on the SDR™ technology (=stress decreasing resin). The chemistry of SDR is designed to slow the polymerization rate, which helps in reducing polymerization shrinkage stress without affecting polymerization shrinkage levels.

Only one research article is available, which shows superior fracture resistance of teeth restored with SDR compared to teeth restored with fiber post and flowable composite resin. The values obtained for the SDR group (739.15 N) was superior with statistical significance to fiber post and flowable composite resin (510.29 N).[10] It is a smart dentine replacement used in bulk fill technique. It has a self-leveling property and minimal polymerization shrinkage coupled by polymerization stress relieving properties. This may lead to minimal shrinkage.

In brief, advantages of SDR include, it allows light penetration for curing up to 4 mm at a time, less polymerization shrinkage which is 3.5% comparable to other flowable composites but less than many hybrid composites. Most flowable composites have an average volume polymerization shrinkage rate of 5%.[11,12] Dentsply claims that the marginal stress caused by polymerization shrinkage of SDR is around 1.5 MPa—substantially less than other composites.

In group II, biological post achieved the pushout bond strength of 8.47 MPa in the coronal third and 7.76 MPa in the middle third section. There was no statistical difference between groups II and I, but significantly less than that of group III.

In group II, biological post was used as a post. The first report in the literature about the use of fragments of extracted teeth as dental restorative materials was published in 1964 and the expression “biological restoration” was first coined by authors.[13]

In 2010, authors reported a clinical case performed utilizing biological restoration using homogeneous fragment bonding associated with biological posts to restore an extensively fractured central maxillary incisor and after 1 year follow-up demonstrated excellent results. In 2014, authors reported a clinical case where biological dentin post was used for intraradicular rehabilitation of a fractured anterior. The case was followed up for 1 year, which revealed the satisfactory functional, esthetic, and structural performance of the tooth, with regular clinical and radiographic findings.[14] A dentine post is a feasible option for the strengthening of the weakened root canal, because it diminishes radicular dentin stress, is biocompatible, preserves the internal dentin walls, adapts to canal configuration. Biological post favors greater tooth strength and higher retention of the posts as compared to metal, glass fiber premanufactured posts.[15] In an *in vitro* study, it was concluded that dentine posts have higher fracture resistance as compared to carbon and glass fiber post system.[16–18]

Disadvantages of the biological post include non-availability of the tooth fragment and non-acceptance by the patient.

In group I, DT light post relined with flowable composite achieved pushout bond strength of 8.04 MPa in coronal third and 7.22 MPa in the middle third section. There was no statistical difference between groups I and II but significantly less than that of group III.

DT light post is commercially available prefabricated quartz post which is translucent and radiopaque. Its translucency enhances the esthetics and its light-transmitting properties. Its double taper design conforms to the prepared canal to minimize the dentin removal and also minimize the amount of luting media around the post.[19] DT light post illusion (Bisco, USA) was selected in this study because of its many advantages. Flowable composite is used along with DT light post as flowable composite has a similar elastic modulus of dentine.

Different techniques and materials are proposed to minimize the discrepancy between standard post and flared canal by reconstructing the inner walls of the root canals. The primary objective of such reinforcement is the formation of an ideal "monoblock" restoration that creates a single biomechanical complex between the tooth structure and the prosthetic components (dowel, cement, restorative material). This can be achieved by bonding and using materials with mechanical properties similar to those of the remaining root structure. One of the proposed solutions is to reline fiber-reinforced dowels with composite resin.[20]

The clinical success of fiber-reinforced dowels had been attributed to their modulus of elasticity, which matches that of dentin and resin luting cements. This reduces stress transmission to root canal walls and decreases the risk of vertical root fractures. Moreover, fiber-reinforced dowels allow the construction of highly esthetic restorations when combined with all-ceramic extracoronal restorations.[20]

Post fabrication with SDR can be a better option in rehabilitating weakened root canals. Fiber-reinforced post, and flowable composite and biological posts can be the next choice.

Conclusion

Within the limitations of the present study, SDR resulted in highest pushout bond strength both in coronal and middle sections with statistical significance. Smart dentin replacement is a better material for intracanal rehabilitation of teeth with flared canals in terms of pushout bond strength when compared with other groups. DT light post + flowable composite could be used to reinforce weakened roots and is least technique sensitive. Depending on the clinical situation and the availability of doomed tooth, biological post may be preferred.

Future Studies

Results of the present study showed promising results with SDR. So, further studies are required with more samples. And other factors to simulate oral condition must be considered, such as long-term artificial aging with thermocycling, mechanical load simulation with cycling loading along with pH changes to the sample.

In group II, i.e., biological post, there is no available literature to date signifying the rehydration effect of the post before luting. Further studies are required with various periods of rehydration for biological post before cementation.

Clinical Significance

Traumatized doomed young permanent teeth can be salvaged with newer material like SDR, which is easy to use with better results.

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