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Research Article

THE EFFECT OF DIFFERENT IRRIGATING SOLUTIONS AND LASER IRRADIATION ON PUSH OUT BOND STRENGTH OF PROSTHETIC POSTS: AN IN VITRO STUDY

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ABSTRACT

Fibre reinforced composite posts, in combination with resin cements have been widely used to restore teeth. Retention of fibre posts in roots depends upon adhesion between resin cement and the dentin as well as adhesion between resin cement and posts. After post space preparation dentin walls are covered with heavy smear layer. To create a hybrid layer it is necessary to remove the smear layer and debris from the dentin canal walls and the initial part of dentinal tubules to increase the retention when resin cement is used. Various chemical agents such as physiologic saline, Sodium hypochlorite (NaOCl) irrigation, Sodium hypochlorite (NaOCl) followed by 17% Ethylenediaminetetraacetic acid (EDTA), Chlorhexidine irrigation are used to remove smear layer efficiently. Recently lasers with wide range of chacteristics Niodymium-doped yttrium aluminium garnet (Nd:YAG), diode laser, Erbium-doped yttrium aluminium garnet (Er:YAG) have been evaluated for smear layer removal.

Keywords: Fiber post, NaOCl/EDTA, Laser and Bond strength

INTRODUCTION

Restoration of structurally damaged and endodontically treated teeth is important for the long-term clinical success of maintaining tooth function and esthetics. Fiber posts are being widely used to regain the functional requirements of the tooth. For the longevity of the restorations cementation and bonding of dentine to fiber posts is important. Retention of post to dentine surface is affected by several factors. Gutta-percha and sealer remnants, dentine debris, and a smear layer on the root canal dentine may reduce the bonding area, which can result in weakening of the adhesive bonding of the fiber post. The presence of smear layer on root canal walls can lead to undesirable effects on bonding at the adhesive material–dentine interface. Removal of the hybridized smear layer after post-space preparation helps to avoid a weakened area in the bonding interface and introduces the possibility of increasing fiber post retention. The effects of irrigants such as sodium hypochlorite (NaOCl), hydrogen peroxide (H_2O_2), and EDTA on dentin collagen depend on the particular conditions of hydration in root canal dentin resulting from pulp removal, the type of agent used for substrate conditioning, the polymerization stress of resin cement in root canals with unfavorable cavity configuration, and the chemical and physical properties of the posts. During the preparation of the post space, drills create a new smear layer that is rich in sealer and gutta-percha remnants and is plasticized by the heat of friction of the drill. The complete removal of the smear layer, which contains microorganisms, infectious deteriorated dentin, canal sealer remnants, and which can influence the polymerization of resin luting cements, is essential to the bonding of post to dentin with resin. Chemicalagents such as NaOCl, H_2O_2, EDTA, chlorhexidinedigluconate, citric acid (10%, 20%, and 50%), orthophosphoric acid (H_3PO_4), and their combinations are used to increase the micromechanical retention of the cement by removing the smear layer. As a result, the cement can penetrate into the dentinal tubules. Thus, the smear layer on root canal walls needs to be removed effectively before fiber post cementation. In recent years, one of the current approaches in endodontic practice involves laser devices.

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The near-infrared lasers diode (805 and 810 nm) and neodymium: yttrium–aluminum-garnet (Nd: YAG; 1064 nm) lasers and the mid-infrared erbium: yttrium–aluminum garnet (Er: YAG) (2940 nm) laser have been investigated for potential application in the removal of debris and smear layers by the shear stress created by acoustic streaming of the irrigation solution. Er:YAG present a resonance interaction with water and hydroxyapatite, the main components of dentin and enamel. During the ablation process, laser photons are absorbed by water on dental tissue, quickly increasing the temperature above the water evaporation temperature at the focal area. This process elevates the interstitial water pressure. It consequently breaks down adjacent tissue on an explosive process, removing all tissue and contaminants attached to it (e.g., smear layer). Moreover, Er:YAG laser irradiation on dentin surface is very safe and provides the exposure of dental tubules above the ablation threshold and a better adherence of cement. The ablation process also promotes bacterial removal, increasing the success of the procedure.

MATERIALS AND METHODS

Sixty extracted maxillary central incisor teeth devoid of caries were collected from The Department of Oral and Maxillofacial Surgery, The Oxford Dental College and Hospital, Bangalore. The present study was conducted in the Department of Prosthodontics, The Oxford Dental College and Hospital, Bangalore.

Sample selection

The teeth were collected on the basis of following inclusion and exclusion criteria as follows:

Inclusion criteria

Freshly extracted maxillary Central incisors of Inciso -apical length 22 ± 1mm
Central incisors extracted for periodontal reasons

Exclusion criteria

Fractured teeth
Internal/external resorption
Incompletely formed apices
Carious teeth
Failed root canal treated teeth
Samples which did not meet the inclusion criteria

Methodology

Sixty arbitrarily extracted straight single rooted human maxillary central incisors of approximately same dimension were selected and stored in 0.9% saline solution (Aculife) at room temperature until use. The anatomic crown of each tooth was cut off 2mm incisally from the cementoenamel junction. Following this the roots were endodontically instrumented and working length was established by the direct method by subtracting 1mm from the real root length determined by introducing a No.10k file until it was visible through apical foramen. Teeth were endodontically prepared using step back technique starting from 15K to a size 45K file and were obturated with gutta-percha(Pearl Dent Co.Ltd) and AH plus sealer(Shofu) using lateral compaction technique. During the biomechanical preparation irrigation of root canals was done with 0.9% saline solution preceding the use of each instrument and then dried with absorbent sterile paper points. Temporary sealing material was used to seal the canal orifice. The roots were then embedded in methacrylate resin(DPI-RR cold cureTMMumbai,India). After storage at 100% humidity for 24hrs at 37°C. The gutta-percha was removed and a post space was prepared with low speed post drills to a length of 10mm, leaving about 4mm of gutta-percha to preserve the apical seal. Following this the roots were randomly divided into 4 groups according to the post space treatment:

GROUP 1: was irrigated with 5ml of 0.9% normal saline(Aculife) for 1 minute.

GROUP 2: was irrigated with 5ml of 3% Sodium hypochlorite (NaOCl)(Vensions India) for 1 minute followed by irrigation with distilled water for 1 minute.

GROUP 3: was irrigated with 5ml of 3% Sodium hypochlorite (NaOCl) for 1 minute followed by 5ml 17%Ethylenediaminetetraacetic acid (EDTA) (DEOR) for 1 minute and final irrigation with distilled water for 1 minute.

GROUP 4: was irradiated with Er:YAG laser. The fibre optic tip was inserted into the post space for 5 seconds for 3 times in a circular motion according to the manufacturer's instruction.

After finishing the treatment post spaces were dried with paper points. Roots were etched with 37% phosphoric acid and glass fiber posts (GC India dental Pvt Ltd) were cemented into the post spaces with the resin cement. All samples were stored in saline solution. Three sections of root (apical, middle, coronal) were obtained by sectioning the root under distilled water coolant using low speed saw starting 1mm below the cementoenamel junction. The sections were stored in sterile saline solution until testing. Push out test was performed at a cross-head speed of 1mm/min using a Universal Testing Machine(Indian Institute of Science Bangalore). Center of the push out pin was on the center of post surface. The peak force which was applied at the point of extrusion of the post segment from the test specimen, was taken as the point of bond failure and will be recorded in Newton (N). Push-out bond strength values in MPa were then calculated by dividing this force by the bonded area of the post segment.

RESULTS

In the present study, the bond strength of fiber post was evaluated at three different levels after irrigating the post space with 4 different irrigants and bonding the post with resin cement followed by subjecting it to push out test.

Bond strength (Universal Testing machine):

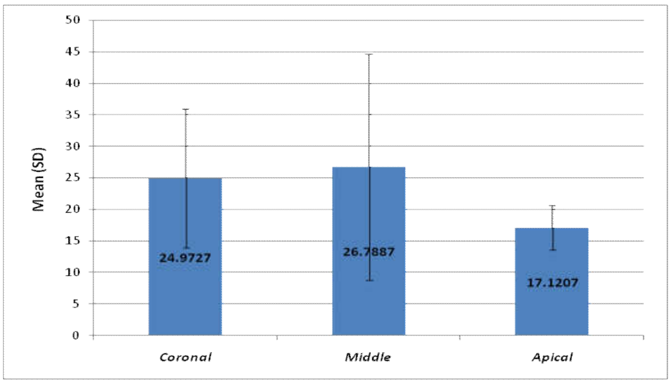
Statistical comparison of bond strength under loading in universal testing machine in terms of {mean (SD)} among all four groups using ANOVA test showed the highest bond strength group III with respect to coronal section followed by group II. (Table 1).

However, the least bond strength was seen with respect to group II in apical section. All the results with respect to coronal and apical section in intergroup analysis were statistically significant ($p < 0.05$). Intergroup analysis was done using Post hoc Tukey's test for all the groups.

(Group 1) (Irrigation done with 5ml of 0.9% normal saline)

Table 1: Comparison of push out bond strength in terms of {Mean (SD)} at different levels in group 1 using ANOVA test.

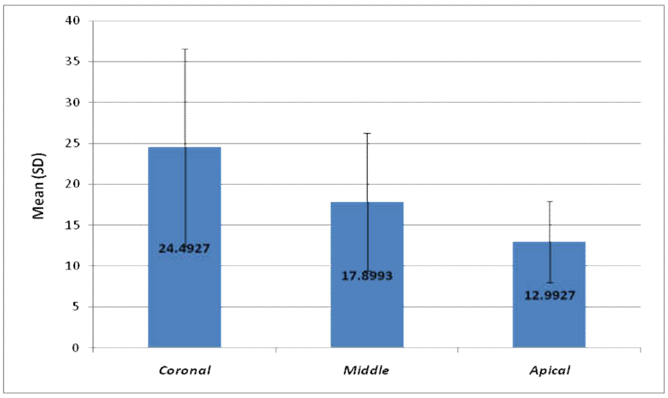
Group	N	Mean	Std. Deviation	F value	P value
Coronal	15	24.9727	10.98428	2.616	0.085
Middle	15	26.7887	17.90981		
Apical	15	17.1207	3.56577		
Total	45	22.9607	12.74749		



(Group 2) (Irrigated with 5ml 3% NaOCl followed by distilled water)

Table 2: Comparison of push out bond strength in terms of {Mean (SD)} at different levels in group 2 using ANOVA test

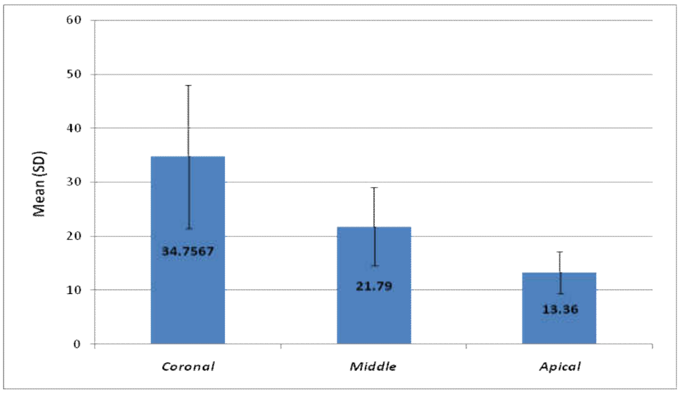
Group	N	Mean	Std. Deviation	F value	P value
Coronal	15	24.4927	12.06551	6.214	0.004*
Middle	15	17.8993	8.40302		
Apical	15	12.9927	4.99467		
Total	45	18.4616	9.97139		



(Group 3) (Irrigated with 5ml of 3% NaOCl followed by EDTA 17%)

Table 3: Comparison of push out bond strength in terms of {Mean (SD)} at different levels in group 3 using ANOVA test.

Group	N	Mean	Std. Deviation	F value	P value
Coronal	15	34.7567	13.24159	21.546	<0.001**
Middle	15	21.7900	7.24530		
Apical	15	13.3600	3.84627		
Total	45	23.3022	12.50625		



(Group 4) (Irrigated with Er:YAG laser)

Table 4: Comparison of push out bond strength in terms of {Mean (SD)} at different levels in group 4 using ANOVA test

Group	N	Mean	Std. Deviation	F value	P value
Coronal	15	16.8587	8.08154	1.520	0.231
Middle	15	20.0793	12.31877		
Apical	15	14.5387	3.49371		
Total	45	17.1589	8.84467		

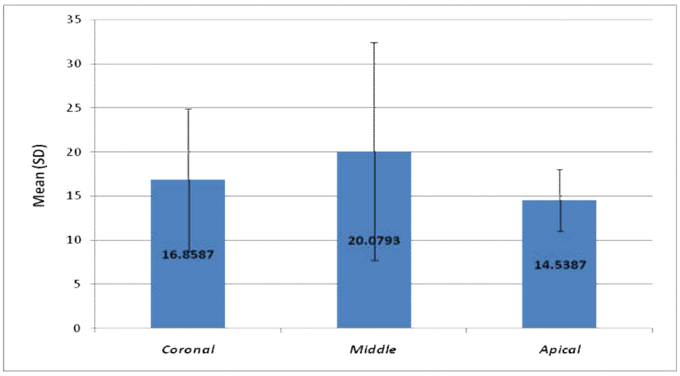


Table 5. Comparison of push out bond strength in terms of {Mean (SD)} at coronal level among all the 4 groups using ANOVA test

Group	N	Mean	Std. Deviation	F value	P value
Group 1	15	24.9727	10.98428	6.370	<0.001**
Group 2	15	24.4927	12.06551		
Group 3	15	34.7567	13.24159		
Group 4	15	16.8587	8.08154		
Total	60	25.2702	12.70123		

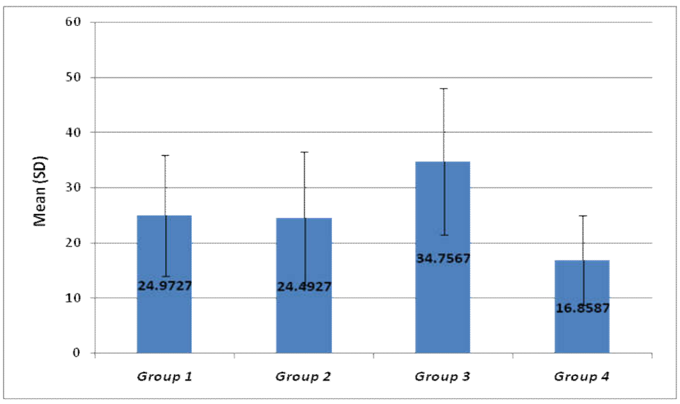


Table 6. Comparison of push out bond strength in terms of {Mean (SD)} at Middle level among all the 4 groups using ANOVA test

Group	N	Mean	Std. Deviation	F value	P value
Group 1	15	26.7887	17.90981	1.443	0.240
Group 2	15	17.8993	8.40302		
Group 3	15	21.7900	7.24530		
Group 4	15	20.0793	12.31877		
Total	60	21.6393	12.33917		

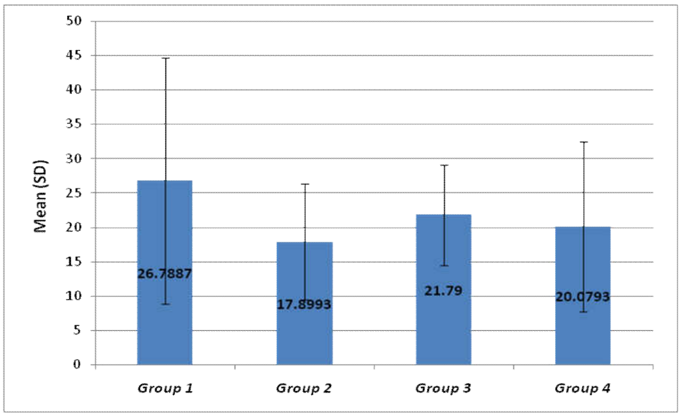
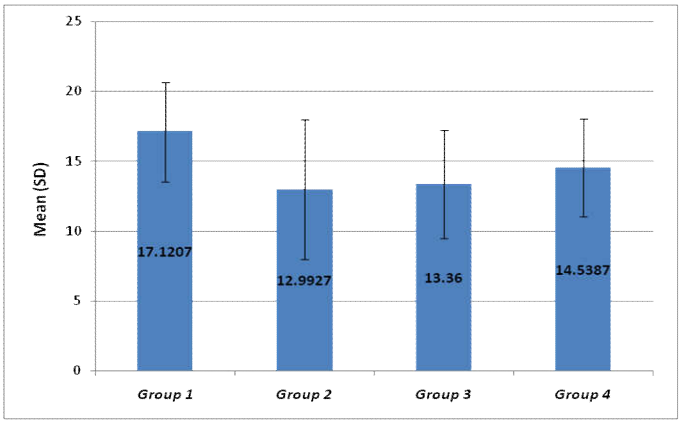


Table 7. Comparison of push out bond strength in terms of {Mean (SD)} at Apical level among all the 4 groups using ANOVA test

Group	N	Mean	Std. Deviation	F value	P value
Group 1	15	17.1207	3.56577	3.229	0.029*
Group 2	15	12.9927	4.99467		
Group 3	15	13.3600	3.84627		
Group 4	15	14.5387	3.49371		
Total	60	14.5030	4.24239		



DISCUSSION

After post space preparation, cleaning the root canal dentinal walls is a critical procedure for optimal post retention. Because several factors may impede this retention, such as the presence of fluid, the odontoblastic process within the tubules, dentin humidity and the smear layer formation. Among these factors, the smear layer must be considered before post cementation, bearing in mind that there is little interaction between this layer and the close dentin and that it must be removed or modified with different methods (e.g. irrigation regimes, sonic/ ultrasonic systems, lasers). Also, it contains gutta-percha and sealer remnants and dentin components. Removal of this layer before the post cementation has been advocated to allow better adhesive penetration into dentinal tubules and enhance the micromechanical adhesion of the resin cements. Dentin surface treatment with the abovementioned methods causes alterations in the chemical and structural composition of dentin; the permeability and solubility characteristics of dentin may change and hence affect the adhesion of resin cements to dentin surfaces. Fiber posts have been recommended to restore structurally damaged and endodontically treated teeth because of their dentine-matched mechanical characteristics. Effective bonding between dentine and resin for luting a fiber post and its durability are crucial for the longevity of restorations. Previous investigations by Pashley et al have reported that the efficacy of post luting cements depends mostly on smear layer removal and resindentine inter-diffusion zone formation. A study done by Boone et al suggested that the NaOCl/EDTA combination can effectively remove the smear layer from the post space, and irrigant activation techniques can increase post retention. This was in accordance with the current study where the bond strength of fiber post was highest when the post space was irrigated with NaOCl/EDTA combination. When fiber posts and resin luting systems are used to restore endodontically treated teeth, the adhesive bonding to dentin is based on micromechanical retention created by demineralized surface and resin tag formation. Cleaning surfaces of canal walls after post space preparation is a critical procedure for optimal post retention. Previous studies on endodontic treatment showed that EDTA and NaOCl irrigating alternatively could remove the smear layer effectively. However, such usage of irrigation or even EDTA alone for 5 minutes would lead to severe erosion on the radicular dentin surface. Saito et al found that shortened irrigation time with EDTA less than 1 minute could significantly decrease smear layer removal. Thus, in our study, EDTA and NaOCl were used for irrigation separately with a 1-minute irrigating time. The results of the current study showed that EDTA could effectively remove the smear layer and debris both on the dentin surface and in the dentinal tubules along the entire post space, whereas NaOCl could remove the smear layer on most dentin surfaces except for the apical portion. This finding may be mainly attributed to the low pH of EDTA, which acts as a calcium chelator and dissolves the smear layer.Da Silva et al showed that irrigation with EDTA could effectively remove the smear layer, which is in agreement with the findings of our study. Surface tension of the irrigating solutions might contribute to this result. EDTA and NaOCl, which have relatively lower surface tension values compared with saline, might improve the dentin wettability and therefore improve the flow of the irrigating solution into the root canal and its contact with the smear layer and the underlying dentin.

In the current study, the total irrigation times were limited at 60 s for each irrigation solution and laser activation cycles were applied with a standardized protocol using a 5-s rest time in all root canals. This timing protocol can help to prevent severe peritubular erosion, as well as the possible hazardous effects of temperature rise on the dentine surface, depending on the use of lasers in the root canal. Moreover, study by Yasar et al have reported that NaOCl irrigation had an adverse effect on adhesion at the resin cementdentine interface. NaOCl decomposes to sodium chloride (NaCl) and oxygen (O_2).The release of O_2 can inhibit the polymerization process of adhesive systems. In this study, because of the possible negative effects of NaOCl or EDTA solutions on adhesion, distilled water was used after irrigation protocols to eliminate the undesirable effects of residual irrigation solutions and their products on the root canal walls. Recently, the self-etch adhesive systems have been suggested for the cementation of fiber posts. Problems associated with the moist application technique can be solved with the advantage that they can be applied on wet and dry dentin surfaces.Self-etch adhesive systems bond to the superior layer of dentine and removing smear plugs may not be achieved completely, their bonding efficacy may depend more on the formation of the hybrid layer than on resin tags. Consequently, regional differences in the push-out strength of fiber posts may be eliminated. It has also been reported that previous treatment with EDTA increased the bondstrength of self-etch adhesive systems. Thus, a self-etch adhesive system was chosen for the luting cement in the present study.The effectiveness of the NaOCl-EDTA combination in removing the smear layer from the root canal walls is well documented in endodontics. Kambara et al. demonstrated that NaOCl, EDTA affected the bond strength between the cement and dentin interface because of the material's hydrophobic/hydrophilic properties.To date,various types of the lasers (diode,Nd:YAG, and erbium lasers) have been used to increase the bond strength of FRC posts to the root canal dentin. Ghiggi et al stated that

Nd:YAG and Er:YAG lasers changed the adhesive–dentin interface. Arslan et al. found that Er:YAG laser irradiation with/ without EDTA increased the bond strength of the fiberposts.

Among the various laser types, the use of an Er,Cr: YSGG laser on the tooth structure is lately recommended. Erbium lasers act on tissues by thermomechanical ablation and vaporize any water, causing an expansion followed by micro-explosions that eject both organic and inorganic tissue to provide a surface with open dentinal tubules and no smear layer. Yamazaki et al. irradiated the dentin surface with Er,Cr:YSGG laser and recommended this laser for the removal of the smear layer and debris from root canals. According to the studies, researchers have reported different results about the effects of this laser on the radicular dentin. Mohammadi et al. demonstrated that the bond strength values after Er,Cr:YSGG laser irradiation (0.5–2.5W) were significantly higher than those for the untreated group. Bond strength of dental material with dentin is an important factor for the success of root canal treatment procedures. Consequently, mechanical testing of bonded interfaces can provide important insights into material selection and outcome prediction. Several test methods are used to measure the adhesion of numerous materials including tensile, shear and push-out strength tests. Out of them, the push-out test, has been frequently used. It has been suggested that the push-out test provides better evaluation results than the shear test because, using the push-out test, the fracture occurs parallel to the dentin-bonding interface, which makes it a true shear test for parallel-sided samples. Besides, the tensile test is not appropriate for use with intracanal fillings because of the high percentage of premature bond failures and the large variation in test results. For these reasons, for FRC posts, the push-out test has been considered a more reliable test method. Limitations of the study being that it's an in vitro study so all the oral conditions could not be simulated during the study and only tapered fibre posts were used.

Conclusion

Within the limitations of the study, the following conclusions were drawn:

Statistical difference ($p < 0.05$) was seen in the bond strength values of coronal and apical section of teeth irrigated with different irrigants. On Intragroup bond strength analysis of Group I the middle section showed highest bond strength, in Group II coronal section showed highest bond strength, in Group III the coronal section and in Group IV middle section showed highest bond strength. On Intergroup bond strength analysis the results showed variation with respect to different sections. The Group III showed highest bond strength in middle section of all the groups and the least bond strength was seen in apical third of Group II. It was concluded that the type of irrigant used during removal of guttapercha,smear layer and post space preparation does has an effect on the bond strength of fiber post. The bond strength also varies with respect to different sections of root when irrigated with single irrigant.

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