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Effect of Different Post Space Irrigation Regimens on The Cleaning Efficacy and Pushout Bond Strength of The Fibre Post Attached with Self- Adhesive Resin Cement: An in-Vitro Study

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Abstract

Background: This study investigates the cleaning efficacy of post space and its impact on the bond strength between fiber posts and self-adhesive resin cements applied to radicular dentin.

Aim: The aim of the study was to evaluate and compare the effectiveness of different irrigation regimen on the Cleaning Efficacy of post space and Push-Out Bond Strength of fibre post luted with self-adhesive resin cement.

Materials and Methods: Eighty mandibular premolars were prepared using Protaper Gold system and irrigation was done with sodium hypochlorite. Four groups of teeth samples were considered for post space preparation and irrigated with different solutions: Group 1: 5ml of Distilled water (control group); Group 2: 5.25% Sodium hypochlorite + 17% EDTA; Group 3: 1% Phytic acid; Group 4: 0.2% Chitosan nanoparticle using scanning electron microscope (SEM). This was followed by the luting the posts with RelyX U200. After a week, from each sample, 1 mm thick slices were obtained from each third of the root and subjected to push-out bond strength testing using universal testing machine (UTM).

Results: One-way analysis of variance and Bonferroni's *Post hoc* analysis was used for assessing the results. The cleaning efficacy of the post space were better with phytic acid and chitosan nanoparticle. Bond strength values were improved with phytic acid and chitosan nanoparticle.

Conclusions: The results showed that Phytic acid and Chitosan nanoparticle could be advantageous for post

space irrigation when fiber posts are bonded with a self-adhesive resin cement.

Keywords: Bond strength, EDTA, Fiber post, Resin cement, Self-adhesive, Sodium hypochlorite (NaOCl)

Clinical Relevance: This study highlights the importance of selecting appropriate irrigation regimens for effective post space cleaning and optimal bond strength in Endodontically treated teeth. By ensuring better retention and longevity of fiber posts, these findings support restorative and prosthodontic outcomes, ultimately enhancing interdisciplinary treatment planning and patient care in complex tooth rehabilitations.

Introduction

The success of endodontic treatment depends largely on the eradication of microbes from the root canal system, aided with profuse irrigation and medicament, meanwhile, the longevity of the tooth hinges on the restoration following endodontic treatment.[2] One essential aspect of dental treatment is the restoration of teeth that have undergone endodontic treatment, encompassing various treatment modalities of varying complexity.[1]

The increasing preference for tooth-colored posts has driven the adoption of non-metallic alternatives. FRC (fiber-reinforced composite) posts were initially introduced into clinical practice in France in 1989, as stated by their manufacturers. [2]

The first research article on dental fiber posts was published by Duret in 1990.[4]

Since their introduction, fiber posts have become increasingly popular among clinicians due to their consistent clinical performance and a range of advantages. These include their mechanical strength, esthetic appeal, and elastic properties.[4] This material brought about a revolution in dentistry by offering an effective alternative to metal posts, with its modulus of elasticity closely resembling that of dentin.[3]

In fiber posts, carbon, quartz, glass, or silica fibers are incorporated into an epoxy or methacrylate resin matrix for better strength, modulus of elasticity and bonding. [5,6]

Numerous variables, including the condition of the dentin, the direction of the dentinal tubules, the kind of adhesive system used, the depth of the intraradicular region, irrigation solutions, and endodontic sealers, might affect this interface.[8]

The emergence of self-adhesive resin cements has led to widespread and growing use due to their time-saving and simplified application techniques. Introduced in 2002, self-adhesive resin cement (SARC) eliminates the need for pretreatment of the tooth surface, unlike conventional adhesives.[7,8] Moreover, because of its chemical or micromechanical adherence to the tooth surface, it has no negative effects on the root canal. They are now commonly employed for cementing resin fiber posts in contemporary practice.[9]

The dentin-resin cement interface's bond strength is directly impacted by this smear layer, which covers the dentin surface of the root canal.[10,11] Due to the smear layer, self-adhesive resin cements (SARC) are unable to etch the root canal dentin, nor are they able to produce a hybrid layer and resin tags. Their adherence is dependent on micromechanical retention in along with chemical interactions between monomeric acidic groups and hydroxyapatite.[14,15] Therefore, in order to facilitate the penetration of a self-etching adhesive, it is imperative that the dentin surface within the root canal be sufficiently cleaned before cementing the fiber post. It is difficult to completely remove the smear layer, particularly in the post space's deep and narrow apical region.[12,13]

In recent years, chitosan has seen widespread use in the health sector. It is a nontoxic cationic biopolymer that is usually produced by alkaline deacetylation of chitin, which is the main component of crab exoskeletons.[19]

Chitosan exhibits weaker chelating properties, resulting in less demineralization of dentin surfaces. The concentration 0.2% chitosan nanoparticles solution effectively removes the smear layer without inducing dentin demineralization.[20] In addition, chitosan is presumed to encourage the remineralization of demineralized dentin when it comes into contact with the dentin surface.[21]

Hence the aim of this in-vitro study was to evaluate the cleaning efficacy after irrigation with 5.25% sodium hypochlorite & 17% EDTA, 1% Phytic acid, 0.2% Chitosan nanoparticle following post space preparation and the impact they had on the push out bond strength of a fibre post luted using self-adhesive resin cement.

Materials and Methods

The study involved 45 human mandibular premolar teeth stored in 0.1% thymol solution. The study included intact premolars with minimal root curvature and absence from caries or restorations, extracted atraumatically. After decoronation, biomechanical preparation was done with Protaper Gold NiTi rotary instrumentation up to F2 file while rinsing with 5.25% NaOCl. Obturation was done using gutta-percha/AH Plus sealer. The samples were stored at 100% humidity.

Postspace preparation was done using peeso reamer (no. 4 = 1.3 mm tip diameter) leaving 4–5 mm of gutta-percha in the apical one-third. Later, the teeth were subdivided into 4 groups for final irrigation of postspace, using 27 gauge side vented needle.

Group I (n=20): 5ml of Distilled water (control group)

Group II (n=20): 5ml of 5.25% Sodium hypochlorite for 3 minutes + 17% EDTA for 1 minute

Group III (n=20): 5ml of 1% Phytic acid used for 3 minutes

Group IV (n=20): 0.2% Chitosan nanoparticle for 3 minutes

After completion of the experiments, two longitudinal grooves were prepared on each root’s palatal/lingual and buccal surfaces with a diamond bur used with a high-speed water-cooled handpiece to facilitate vertical splitting. Each sample was dipped in liquid nitrogen immediately after canal preparation and split longitudinally into two halves with a stainless-steel chisel. The sections were then prepared for SEM analysis: They were allowed to be air-dried overnight in a desiccator at room temperature. Then the specimens were sputter-coated using gold to be ready for SEM analysis.

SEM images were obtained at a magnification of ×1000, and photomicrographs were taken in three different areas in coronal, middle, and apical thirds of the post space. For the assessment of residual debris and smear layer, each specimen’s coronal, middle, and apical areas were chosen randomly. The areas were selected at low magnification by the SEM operator, who was blinded to the study’s aims and needed to be informed about the respective preparation technique. The images were captured at 5 kV.

Two operators performed the score evaluation with a study conducted in double-blind. So the results could not be influenced by the conscious or unconscious expectation effects that would lead to invalidation of the results. The evaluation was followed by a statistical analysis of the results obtained on the control sample and the experimental groups, in order to highlight any significant differences.

In order to score the presence or absence of debris and smear layer, three trained operators blindly assessed them on the surface of the post space preparation at each tooth's coronal, middle, and apical portions. The rating system applied in the current study was proposed by Hulsmann et al.[24], and the criteria for the scoring were reported as follows[25]

the evaluation was carried out of each group of samples, using the score according to Serafino et al.[21]

According to this evaluation method, the amount of debris is identified with a score between 0 and 2:

Score 0: no debris, patency of dentinal tubules.

Score 1: debris with a diameter smaller than 20 μm and in limited quantities.

Score 2: debris with a diameter greater than 20 μm and in high numbers, impossible to display the entrance of dentinal tubules

Scores of the smear layer

Score 1: No smear layer was detected, and the orifices of dentinal tubules were open.

Score 2: Small quantity of smear layer and some dentinal tubules were open.

Score 3: A homogenous smear layer covered the post space with just a few open dentinal tubules.

Score 4: A homogenous smear layer covered the entire post space wall, and no dentinal tubules were open.

Score 5: The heavy, homogenous smear layer covers the whole post space walls.

The surfaces of the fiber posts were treated with silane coupling agent prior to luting them with self-adhesive resin cement. After storage in distilled water for a week, 2 mm thick slices were sectioned using a low speed diamond disc from coronal, middle and apical third of the postspace. The samples were subjected to push-out bond strength testing in the universal testing machine. The posts were dislodged by applying the load at a crosshead speed of 0.5 mm/min to arrive at the bond strength values (MPa).

Statistical Analysis

Data was tabulated in MS excel software and analyzed using SPSS v23 software. Level of significance was kept at 5%. Data was subjected to normality testing using Kolmogorov Smirnov test. Parametric tests were applied for normally distributed data and non-parametric tests were applied for skewed data. Comparisons of push out bond strength among four groups was performed using One-way ANOVA test followed by Post hoc Tukey test. Comparison of debris score and smear layer score among four groups and within each group were performed using either Kruskal Wallis test followed by post hoc pairwise comparisons.

Results

In control group, a thick smear layer (score 4) and more blocked tubules was observed in more samples compared to other groups. The most number of samples with complete smear layer removal was observed in 17% EDTA + 5.25% NaOCl group (totally in 9 surfaces). More and larger dentinal tubules were visible in coronal and middle thirds.

In other groups (17% EDTA, 17% EDTA + 5.25% NaOCl and 5.25%NaOCl) smear layer was removed partially in most cases especially in coronal and middle thirds compared to apical third.

The data on smear layer removal scores for each group at 3 levels of post space surfaces are presented in Table 1. According to *P*-values, no significant difference was found between different parts of post space levels within one experimental group (*P*>0.05), except 17% EDTA + 2% CHX group (*P*<0.05).

Significant difference was found among different groups at coronal third (*P*=0.001) and also in middle and apical thirds (*P*=0.000). When experimental groups were compared statistical analyses in Mann-Whitney U test revealed significant differences between EDTA + NaOCl group and EDTA and also between EDTA + NaOCl group and saline samples, in coronal third (*P*<0.05). Statistical difference was found between samples in saline groups and NaOCl and saline and EDTA + NaOCl samples, in middle third. The same difference was found between groups EDTA + NaOCl and EDTA, EDTA + NaOCl, EDTA + CHX and EDTA + NaOCl and saline in apical third. There were no significant differences among other groups in each level.

Because no statistically significant differences were found among the regions (P=.583), the mean of the 3 regions of each tooth was calculated and tested for differences with 1-way ANOVA. Data Table 1 are means ±SD. Significant differences among the PSI procedures were found (between groups df=3, F=5.532, P=.003). The NaOCl+EDTA treatment yielded a significantly higher bond strength than those in the other 3 groups. No significant differences were found in the mean bond strength among the CHX, PA, and DW groups (P>.05).

Different root regions (coronaasal, middle, apical) showed similar bond strength values (P>.05) (Table 2).

The frequency of each type of bond failure mode is given in Table 3. The most common failure mode was mixed, followed by adhesive failure between the dentin and resin cement and cohesive failure in the resin cement. No cohesive failures were found in the post or within the dentin. In addition, no failure was observed at the resin-post interface.

Table 1: Comparison of debris score between coronal, middle and apical section of each group

Group	Coronal	Middle	Apical	p-value	Pairwise comparison
Group 1	1.60 ± 0.52	1.90 ± 0.32	2.00 ± 0.00	0.342	--
Group 2	0.90 ± 0.57	1.30 ± 0.48	1.50 ± 0.53	0.050*	Coronal vs Apical: S
Group 3	0.20 ± 0.42	0.70 ± 0.48	0.80 ± 0.42	0.017*	Coronal vs Apical: S
Group 4	0.20 ± 0.42	0.70 ± 0.48	0.90 ± 0.57	0.015*	Coronal vs Apical: S

Kruskal Wallis test; Post hoc Bonferroni test; * indicates a significant difference at p≤0.05; S: Significant difference between two groups

Table 2: Comparison of smear layer removal score between coronal,middle and apical section of each group

Group	Coronal	Middle	Apical	p-value	Pairwise comparison
Group 1	4.10 ± 0.32	4.60 ± 0.52	5.00 ± 0.00	<0.001*	Coronal vs Apical: S
Group 2	2.50 ± 0.53	3.00 ± 0.67	3.50 ± 0.53	0.006*	Coronal vs Apical: S
Group 3	1.10 ± 0.32	1.40 ± 0.52	2.10 ± 0.57	0.027*	Coronal vs Apical: S
Group 4	1.20 ± 0.42	1.50 ± 0.53	2.10 ± 0.32	0.031*	Coronal vs Apical: S

Kruskal Wallis test; Post hoc Bonferroni test; * indicates a significant difference at p≤0.05; S: Significant difference between two groups

Table 3: Comparison of push-out bond strength between coronal, middle,and apical sections of each group

Group	Coronal		Middle		Apical		p-value
	Mean	SD	Mean	SD	Mean	SD	
Group 1	6.05	0.44	5.94	0.45	5.66	0.35	0.117
Group 2	6.62	0.31	6.53	0.23	5.93	0.20	<0.001*
Group 3	7.44	0.64	7.32	0.56	6.62	0.38	0.004*
Group 4	7.22	0.37	7.12	0.42	6.55	0.31	0.001*

One-way ANOVA test; * indicates a significant difference at $p \leq 0.05$

Table 4: Pairwise comparison of push-out bond strength between coronal, middle, and apical sections of each group

Group	Coronal vs Middle		Coronal vs Apical		Middle vs Apical	
	Mean difference	p- value	Mean difference	p-value	Mean difference	p-value
Group 1	0.12	0.811	0.39	0.109	0.28	0.317
Group 2	0.25	0.123	0.69	<0.001*	0.44	0.004*
Group 3	0.12	0.870	0.82	0.006	0.70	0.019*
Group 4	0.10	0.807	0.67	0.001*	0.56	0.006*

Post hoc Tukey test; #Mann Whitney test; * indicates a significant difference at $p \leq 0.05$

Discussion

After using a self-adhesive resin cement, the significance of various post space irrigation techniques in assessing fiber post-bond strength was assessed. The findings showed that the strength of the fiber post bond is impacted by various irrigation techniques.[15]

Scanning electron microscopy was used to detect the presence of a layer containing gutta percha remnants, sealer, and other debris in the root canal dentin following post space preparation.[16] Prior studies have demonstrated the efficacy of EDTA in conjunction with NaOCl irrigation for the elimination of smear layers. Adequate removal of the smear layer was assured by a 1-minute irrigation with 17% EDTA; however, prolonged use of EDTA may cause severe dentinal erosion. EDTA was only used for a one-minute application in this study.[22]

The primary phosphorus storage form present in plant seeds and grains is phytotic acid (IP6). It can be extracted cheaply and easily. Because of its high negative charge density, phytic acid can form a chelation bond with cations.[17] Consequently, IP6 has been suggested as a potential replacement chelating agent for root canal therapy that can remove the smear layer. Phytic acid works by etching the dentin, strengthening the dentin-resin bond, and acting as a natural cross-linker to maintain the demineralized dentin matrix.[26]

Chitosan has been used extensively in the medical field in recent years. The main constituent is of crab exoskeletons, chitin, is typically synthesized via alkaline deacetylation to create this harmless cationic biopolymer.[18,20] The smear layer is successfully removed by the concentration 0.2% chitosan nanoparticle solution without causing dentin demineralization. Additionally, when chitosan comes into touch with the dentin surface, it is thought to promote the remineralization of demineralized dentin.[22]

Group 1 (Distilled water) had the highest debris and smear layer scores as compared to Group 2(5% NaOCl + 17% EDTA), Group 3 (1% Phytic acid), Group 4 (0.2% Chitosan nanoparticle) In Group 1 (Distilled water) as the post space irrigant used was distilled water which is the control group it resulted in the highest mean debris and smear layer score and this was significantly different from other treatment groups.[23]

This result was expected as distilled water has no chelating effects and is incapable of removing smear layer. The results of this study showed that the distilled water cleaned the post space least compared to all the other groups because the smear layer covered the dentinal wall almost completely in coronal, middle and apical.[24]

The higher debris and smear layer scores observed when using 5% NaOCl + 17% EDTA compared to 1% Phytic acid and 0.2% chitosan in post space irrigation of root canal may be attributed to the different properties and mechanisms of action of these irrigants.5% NaOCl is a commonly used irrigant in endodontics due to its strong antimicrobial properties and ability to dissolve organic tissue.[25,26]

For pushout bond strength,

Push out bond strength for all sections Group 2 (5% NaOCl + 17% EDTA), Group 3 (1% Phytic acid), Group 4 (0.2%chitosan nanoparticle) > Group 1 (Distilled water)

All the other Groups had higher pushout bond strength when compared to Group 1(control) Soares CJ et al (2012)[31] reported that the bond strength level may depend on the compatibility between the luting agent and adhesive system, the way in which the luting agent was polymerized, the root canal anatomy, the moisture within the canal and the density and orientation of root dentinal tubules.

Skupien et al (2015)[32] has reported that various factors such as length, diameter, shape, surface structure, type of post, thickness of cement layer between post dentine, applied surface treatment, and roughness of root canal dentin surface affect the retention of post.

A study by Kul et al.[33] reported positive effects of irrigation with a combination of 5.25% NaOCl/17% EDTA, which can be explained using the irrigant improving the penetration of the resin monomers into the dentinal tubules by removal of the smear layer and promotion of resin tag formation.

Group 3 (1% Phytic acid), Group 4 (0.2% chitosan nanoparticle) > Group 2 (5% NaOCl + 17% EDTA) The pushout bond strength of Group 3 (phytic acid) and Group 4 (0.2% chitosan nanoparticle) were found to be higher than group 2 (5% NaOCl + 17% EDTA) The pushout bond strength of a fibre post was lower in the sodium hypochlorite and EDTA group compared to phytic acid and chitosan nanoparticle the reason is that they promoted dentin alterations that provided a negative influence on adhesion, independent of their concentrations.[26]

The reduced bond strength in Group 2 (5% NaOCl + 17% EDTA) could be because of multiple factors. Different mechanisms have been proposed to explain this adverse effect, one of which is the removal of the organic matrix of the treated dentin resulting from cleavage of the carbon bonds in collagen.[28] This leads to changes in the dentinal substrate and reduces the effective infiltration of the adhesive system into the interfibrillar spaces, resulting in a weak hybrid layer.[27]

When NaOCl comes into contact with organic tissue, it acts as a solvent and releases chlorine, which combines with amino groups to form chloramines. The chloramines, in turn, reduce diffusion of the adhesive resin into the underlying tissue.[29]

Moreover, NaOCl acts as a pro oxidant agent, limiting the polymerisation of resin cement at the adhesive interface. The deleterious effects of NaOCl on mineralised dentin have been related to collagen loss from the apatite-rich dentin matrix that remains after treatment with NaOCl, which has been associated with a reduction in the elastic modulus, the flexural strength of dentin and the bond strength.[30]

IP6 has a better ability to open dentinal tubules, a property that may be important in root canal treatment as it may allow for superior penetration of the resin cement.[19]

Nevertheless, compared to the control and EDTA-treated groups, the production of resin tags using IP6 did not provide a stronger bond, which may indicate that resin tags only slightly contributed to the adherence of resindents with self-etch adhesive.[28] The use of 0.2% chitosan positively affected the adhesive strength, especially in the cervical region.[15]

It is essential to highlight that the cement's ability to adhere to intrarradicular dentin is influenced by the chosen cleaning technique.[18] However, it is essential to take into account the fact that a higher concentration of the chelating agent can lead to increased demineralization of the dentin matrix, exposing the collagen and causing a series of inconveniences, including the reduction of microhardness and notably higher incidences of adhesion failures.[24]

The improved push-out bond strength of fiber posts when treated with chitosan nanoparticles post-space irrigation can be attributed to several factors. Chitosan nanoparticles have been shown to possess antimicrobial properties and promote adhesion, which can enhance the bond between the post and the root canal dentin.[23] Additionally, chitosan nanoparticles can penetrate into dentinal tubules, forming a stable interaction with the dentin matrix, thus increasing the mechanical retention of the fiber post.[21]

In a study it was found that chitosan nanoparticle treatment significantly improved the bond strength compared to conventional irrigation solutions.[22] They suggested that the interaction between chitosan nanoparticles and dentin promoted better adhesion and sealing of the post space interface, leading to enhanced mechanical retention. Chitosan is an oligosaccharide that has multiple functional properties. [24]

This substance has a high chelating capacity for different metallic ions, being extensively explored by the industry. Adsorption, ionic exchange, and chelation are probably responsible for forming complexes between chitosan and metal ions. Silva et al.[10] evaluated the efficacy of smear layer removal using chitosan compared with different chelating agents

Conclusion

It was concluded that

- For smear layer and debris score chitosan nanoparticle and phytic acid had lower scores when compared to distilled water and sodium hypochlorite plus EDTA in all sections.
- Between phytic acid and chitosan nanoparticle there was no statistical difference between the two in debris score and smear layer.

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