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Effect of Diamond Bur and Root Canal Irrigants on Retention of Fiber Posts

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Effect of Diamond Bur and Root Canal Irrigants on Retention of Fiber Posts

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree
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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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DEDICATION

This project is dedicated to my parents who have been my constant source of inspiration, to my wife and my daughter for being supportive during the hard times.

Without their love and support this project would not have been made possible.

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CONTENT

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ABBREVIATIONS

SEM	Scanning Electron Microscopy
NaOCl	Sodium hypochlorite
EDTA	Ethylene-diamine-tetracetic acid
MTAD	Mixture of Tetracycline, an Acid and a Detergent
NaCl	Sodium Chloride (Saline)
ITR	Intelligent Torque Reduction
LED	Light Emitting Diode

ABSTRACT OF THE THESIS

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Fiber Posts

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Esthetic glass fiber-reinforced posts are being used more often. The most commonly reported complication associated with these posts is debonding. Dentine conditioning with solutions such as EDTA or MTAD results in removal of smear layer and might improve the retention of posts to root canal dentin. Therefore, the purpose of this study was to investigate the effect of cleansing the post space with MTAD or EDTA on the bond strength of glass fiber-reinforced posts, when a diamond roughening instrument is used prior to cementation with self-adhesive resin cement.

Forty-five (n=15) extracted human premolar teeth were sectioned at the cemento-enamel junction to obtain root length of fifteen millimeters. Endodontic instrumentation and obturation was performed. Post space was prepared to a length of ten millimeters. Preparation first started with the rotary carbide drill followed by diamond roughening instrument. Then canals were irrigated using one of two solutions: MTAD for five minutes and 17% EDTA for one minute. No irrigation was used in the control group. After irrigation, excess moisture was removed and posts were cemented with RelyX Unicem. Retention of posts was evaluated with pull-out test using universal testing machine (0.5 mm/min) to pull the posts from the teeth. Maximum load-to-failure was

recorded. One-way analysis of variance was used for the statistical analysis ($\alpha=.05$). Dislodged posts were examined at 8X magnification to determine the mode of failure.

Mean bond strength (N) for the MTAD, EDTA and control group were 178.33, 201.07 and 167.00 respectively. The difference among the groups was not statistically significant ($\alpha>.05$). Most dislodged posts exhibited mixed mode of failure.

Based on these observations, it was concluded that the use of either EDTA or MTAD as a final rinse prior to post cementation does not influence the retention of glass fiber-reinforced posts, when cemented with self-adhesive resin cement.

CHAPTER ONE

INTRODUCTION

Background

Fiber-reinforced resin posts were introduced over 20 years ago.[1] In vitro studies have shown that these posts have high tensile strength, and a modulus of elasticity similar to that of dentin. [2, 3] In a Finite Element Analysis study, fiber posts were found to generate less stress concentration on the root and provided wider and more uniform stress distribution when compared with metal posts. This is thought to contribute to the reduced incidence of root fractures when fiber posts are used.

Fiber posts were initially reinforced with carbon which produced dark posts. The black carbon fiber posts were rapidly replaced by quartz or glass fibers, which7 exhibit translucency that improves optical properties, facilitating the fabrication of natural looking restorations. [1, 2] Overall, the excellent biocompatibility, superior esthetic appearance and mechanical properties of glass fiber-reinforced posts have contributed to their wide use among clinicians. [1]

Fiber-reinforced posts also present some limitations. These posts tend to undergo resin matrix degradation when subject to conditions simulating clinical environment, such as cyclic loading and thermocycling. This in turn results in decreased flexural strength and produces micromovements. These micromovements may lead to coronal leakage, caries and loss of the restoration. In addition, the drawback of any prefabricated post is the additional removal of sound tooth structure during post space preparation. [4, 5]

Post loosening is the most frequent complication with post and core restorations. [1, 5, 6] Moreover, several investigations reported that most of these adhesive failures occurred at the resin cement-dentin interface. [7]

Bonding to Dentin in the Root Canal System

In addition to the difficult access to the deeper portion of the canal, and the number of dentinal tubules that decreases towards the apical portion of the tooth, resin bonding in the root canal system is challenging due to the unfavorable geometry of the canal. [4, 1] The configuration factor (C-factor) is the ratio of bonded to unbonded resin surfaces. The higher the number of bonded surfaces; the more stresses will be placed on the surface due to polymerization shrinkage, in the post space, the stresses may exceed the bond strength of the bonding agent. [4] Theoretically, any ratio above 3 is considered unfavorable for resin bonding, in the root canal system, the ratio may reach 200 because there is only minimal unbonded dentin, which makes gap formation inevitable. [5]

The smear layer was first described in a Scanning Electron Microscope (SEM) study by Eick et al., who found that it is composed of small particles of dentin debris ranging in size between 0.5-15 μm. [8] In another SEM investigation [9], the smear layer was reported to be 2 to 5 μm thick, and that it extends a few micrometers into dentinal tubules. In the root canal system the smear layer is composed of, in addition to dentin debris, remnants of odontoblastic processes, pulp tissue and bacteria.[10] Moreover, the smear layer formed on dentin walls of the root canal system is denser and thicker than the one formed on coronal dentin.[11] Therefore, many reports indicated that the removal of the smear layer is essential to ensure removal of bacteria, proper penetration of disinfecting agents into dentinal tubules and, enhance dentin bonding. [12]

Early investigations evaluated the effect NaOCl on the smear layer, which has been shown to be capable of removing only portion of the smear layer. [13] Other methods evaluated for the removal of the smear layer include chlorhexidine, ethylene-diamine-tetracetic acid (EDTA), phosphoric acid, ultrasonic and laser techniques; no single technique was found to be effective to completely remove it.[12] However, the alternate use of 17% EDTA and NaOCl seems to be the most effective method.[14, 15]

A mixture of doxycycline, citric acid, and a detergent (MTAD) was introduced in 2003,[16] as an aqueous solution of 3% doxycycline (a broad-spectrum antibiotic); 4.25% citric acid, (a demineralizing agent); and 0.5% polysorbate 80 (a detergent). The use of MTAD has been reported to be an effective antimicrobial agent, and also more efficient in removing smear layer as compared with the use of EDTA and NaOCl, especially from the apical third. [16, 17]

Effect of Root Canal Irrigants on Retention of Fiber Posts

Irrigation solutions used after post space preparation for removal of smear layer may affect the structural properties of dentin, and subsequently alter the bonding of fiber posts to radicular dentin.[18, 19] Several studies have been conducted to evaluate the effect of different intracanal irrigants, when used prior to post cementation, on bond strength of fiber-reinforced posts. However, again conflicting results have been reported.[12]

EDTA

EDTA has a low pH and acts a calcium-chelating agent, which tends to be effective in removing the smear layer.[12] In an in vitro study, Gu et al.[20] confirmed the opening of dentinal tubules after application of 14% EDTA for 60 seconds. Under SEM, resin tags were observed along the entire length of the canal most of these tags were 20-30 μm deep. This resulted in significantly higher bond strength, when compared to NaOCl or NaCl. However, Demiryurek et al.[21] reported the lowest bond strength among the test groups when 17% EDTA was used. In another study, Faria-e-Silva [22] evaluated two different self-adhesive resin cements, and found that irrigation with 17% EDTA after post space preparation resulted in higher bond strength when using one of the cements. He also demonstrated in the same study utilizing the same irrigation protocol, the lowest bond strength, when the other cement was used, thus creating contradictory results.

The use of EDTA seems to enhance the retention of fiber post. However, the current evidence is inconclusive, and using EDTA may actually reduce the bond strength of fiber posts.[23]

MTAD

Use of MTAD may be advantageous over other irrigation solutions since it seems to be effective in removing both organic and inorganic debris, in addition to the anti-microbial effect. The effect of MTAD on bond strength of fiber posts has never been studied. However, some investigations evaluated the effect of MTAD on the bond strength of resin endodontic sealers to radicular dentin. Kumar et al.[24] compared the effect different irrigation solutions on the push-out bond strength at the apical region. Bond strength was found to be higher on the teeth irrigated with MTAD or EDTA, however the difference was not statistically significant compared to NaOCl, Chlorhexidine or no-irrigation.

Statement of the Problem

Some endodontically treated teeth require a post and core prior to complete coverage restoration, which is frequently performed with fiber post systems. As stated above, there seems to be agreement in that the most commonly reported clinical failure with post and core restorations is post loosening, and several studies indicated that these failures were predominantly at the cement-dentin interface. Therefore, it is crucial to improve the bond strength at this interface.

Numerous studies have evaluated dentin conditioning and its effect upon the bond strength. However, no conclusive evidence on the best conditioning solution/technique was reached, and different cements exhibited different results with different irrigation solutions.

The purpose of this in vitro study was to investigate the effect of different irrigation solutions after the use of rotary diamond bur to prepare the post space, on the bond strength of glass fiber-reinforced posts cemented with self-adhesive resin cement.

The null hypothesis was that the irrigation solution used prior to post cementation does not increase the bond strength of glass fiber-reinforced posts to root dentin.

CHAPTER TWO

MATERIALS AND METHODS

Since this is a portion of a collaborative study, the methodology is the same as the one described in Faisal Al-Qarni's thesis. Both authors contributed equally to the study and the writing process.

Preparation of Specimens

Forty-five extracted human, caries free premolar teeth of approximately the same length were selected for this study and stored in saline solution. For each tooth a radiographs was taken to evaluate the morphology, number and size of the root canals to standardize all samples as best as possible. Premolars with fractures, more than one root canal, caries, or restorations were excluded.

The crowns of all teeth were sectioned at the cemento-enamel junction, perpendicular to the long axis of the teeth, to obtain a remaining root length of 15.0 mm. A diamond disc (365.11.220 HP, Brasseler USA Inc., Savannah, GA) was used at low speed with water spray.

Endodontic Instrumentation and Obturation

Root canal treatment performed on all of the teeth by two endodontists. A number 10 K-file (K-file; Dentsply Maillefer, Ballaigues, Switzerland) was first used to ensure canal patency. Instrumentation performed with Profile series 29 0.04 taper files (Dentsply, York, PA) in an Endo ITR – Intelligent Torque Reduction (AEU-20; Dentsply Tulsa Dental, Co., Tulsa, OK) handpiece at ratio 1:8, torque 2 and 350 rpm to achieve the required 0.04 mm taper. Throughout the instrumentation procedures, canals were alternatively rinsed with

2.6% sodium hypochlorite and 17% EDTA (Pulpdent, Watertown, MA) using a disposable 5 ml syringe (Ultradent Products, South Jordan, UT) and a 30-gauge needle (Endo Eze Tip; Ultradent Products, South Jordan, UT), followed by a final rinse with saline. Then, all root canals were dried with absorbent paper points (Henry Schein, Melville, NY).

Canals were fitted with MF – Medium Fine - Gutta percha master cone (Dentsply, Tulsa, OK) and a zinc oxide eugenol sealer (Roth Root Canal Cement, Roth International LTD, Chicago, IL) was used to seat the cone. The cone was seared off and down packed utilizing a System B to a depth of 10mm creating a post space. After obturation, all roots were stored in humid environment for one week to allow the sealer to set.

Post Space Preparation

A post space was prepared in each tooth to a standardized length of 10 mm length, leaving 5 mm of gutta percha to maintain the apical seal. Size number 3 Gates Glidden drills (L.D. Caulk/Dentsply International hie, Milford, DE) with endodontic reference stop were utilized to remove gutta percha to the desired length. The length of the post space was verified using a periodontal probe (Hu-Friedy Inc, Chicago, IL) fitted with an endodontic reference stop. Then, a post space was prepared with a matching carbide drill of the fiber-reinforced post size 50 (ER DentinPost, Komet USA, Rock Hill, SC) to the depth of 10 mm. Then a matching diamond roughening instrument (196D, KometUSA, Rock Hill, SC) were manually twisted five times in the canal. The fiber reinforced post, matching carbide drill and the manual diamond roughening instrument are shown in Figure 1.

Figure 1. ER DentinPost (epoxy resin matrix with 60% glass fiber proportion) size 50 with the matching carbide drill and diamond roughening instrument.

Irrigation Protocols

The specimens were randomly divided into 3 groups:

Group 1: MTAD (BioPure MTAD, Dentsply Tulsa, Johnson City TN) was used to rinse the root canal prior to post cementation following the manufacturer's instructions; the liquid was injected into the powder and mixed for 60 seconds, drawn with the 5 ml syringe provided with the system. 1 ml of MTAD was injected into the post space, and left for 5 minutes, then withdrawn with another syringe. The remaining 4 ml was used to rinse the post space, followed by drying with paper points.

Group 2: 17% ETDA solution was injected into the canal space, left for one minute, and the canals were then dried with paper points.

Group 3: was the control group, no final rinse was used in the post space. Groups and irrigation solutions tested are listed in Table 1.

Table 1.

List of different groups and irrigation solutions tested

Group	Irrigation solution	Lot number
Bio Pure MTAD (Dentsply)	A mixture of: • 3% Doxycycline • 4.25% Citric acid • 0.5% Polysorbate 80	131029
EDTA (Pulpdent)	17 % Ethylen-ediamine-tetracetic acid	130913
Control	None	None

Post Cementation

Fiber-reinforced epoxy resin posts (ER DentinPost, Komet USA, Rock Hill, SC) of the same size 50 were used for all groups. The posts were tried in the post space to verify their fit then cleaned with alcohol prior to cementation. A self-adhesive resin cement (RelyX Unicem Clicker, 3M ESPE, St Paul, MN) was used to cement the posts of all groups. Two clicks of cement were dispensed onto a mixing pad (3M ESPE, St Paul, MN) and mixed for 20 seconds with a plastic cement spatula (Hu-Friedy Inc, Chicago, IL) and applied directly on the post. Then the post was gently placed into the standardized 10 mm post space and stabilized with finger pressure. Excess cement was removed with a microbrush (Plasdent, Pomona, CA) prior to light polymerizing for 40 seconds with a Light Emitting Diode (LED) polymerization light (3M ESPE, St Paul, MN) at a distance of approximately 2 mm. Composition of the fiber post and resin cement used for this study are shown in Table 2.

Pull-out Test

A mold formed by milling a Teflon block (Figures 2 and 3) was used to make a composite resin grip (4.0 mm deep x 3.5 mm diameter) in order to prevent post fractures during the pull-out test. Prior to cementation, the post was placed into the mold, the composite resin (Vitalescence, Ultradent, South Jordan, UT) was packed to form the composite resin grip, and light polymerized for 40 seconds (Figure 4). The completed specimen prior to pull-out testing is illustrated in Figure 5.

Table 2

Compositions of the post and cement used in the study

Material	Composition	Lot number
ER DentinPost (Komet)	60% glass fibers embedded in epoxy resin matrix	423356
RelyX Unicem Clicker (3M ESPE)	Base: methacrylate monomers containing phosphoric acid groups, methacrylate monomers, silanated fillers, initiator components, stabilizers Catalyst: methacrylate monomers, alkaline fillers, silanated fillers, initiator components, stabilizers, pigments	538320

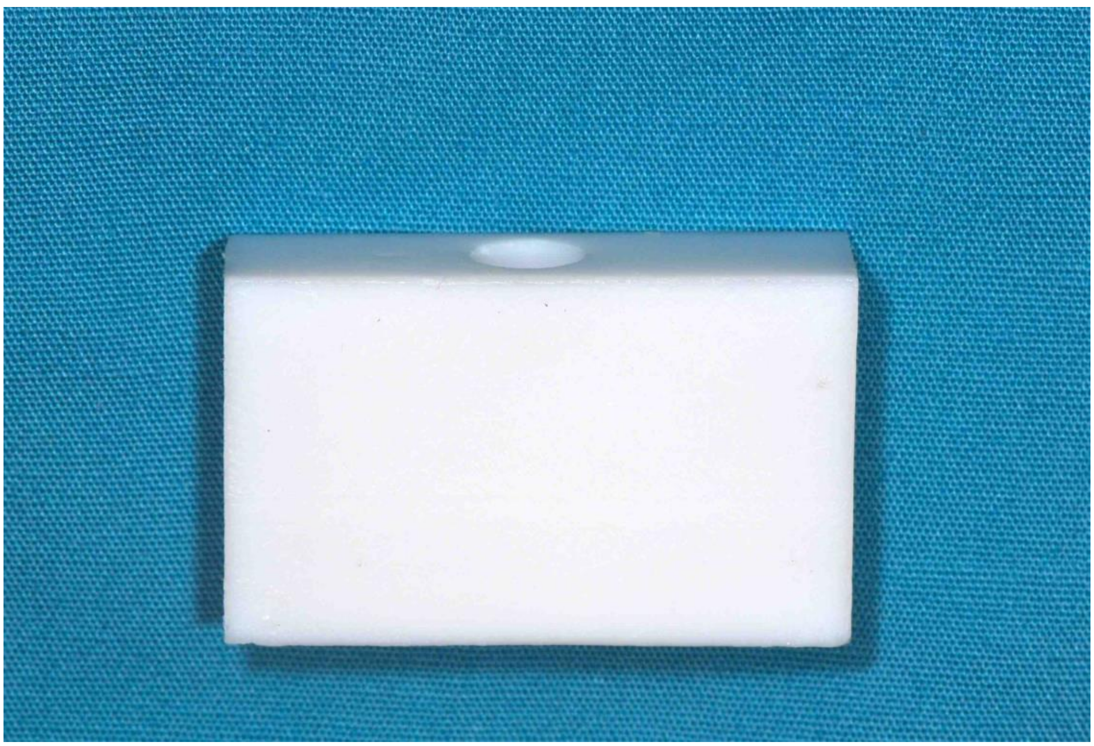

Figure 2. Teflon mold used to fabricate the composite resin grips

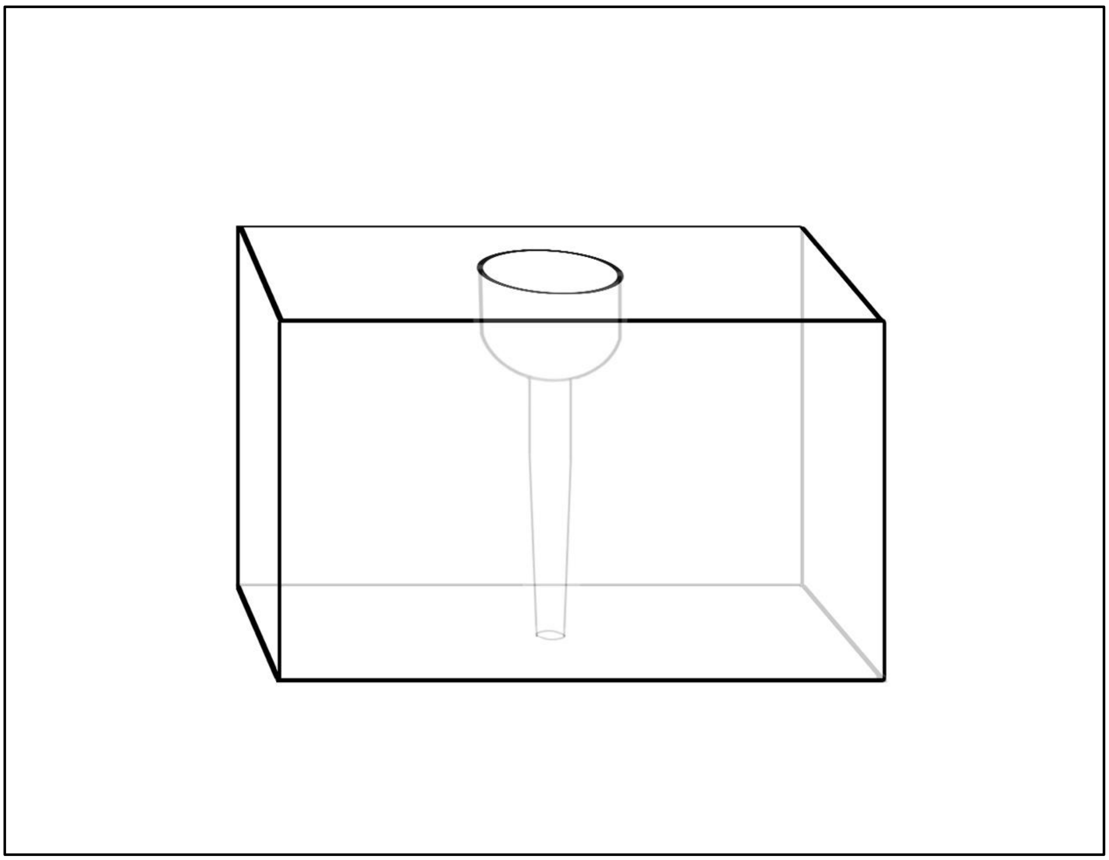

Figure 3. Illustration of the Teflon mold

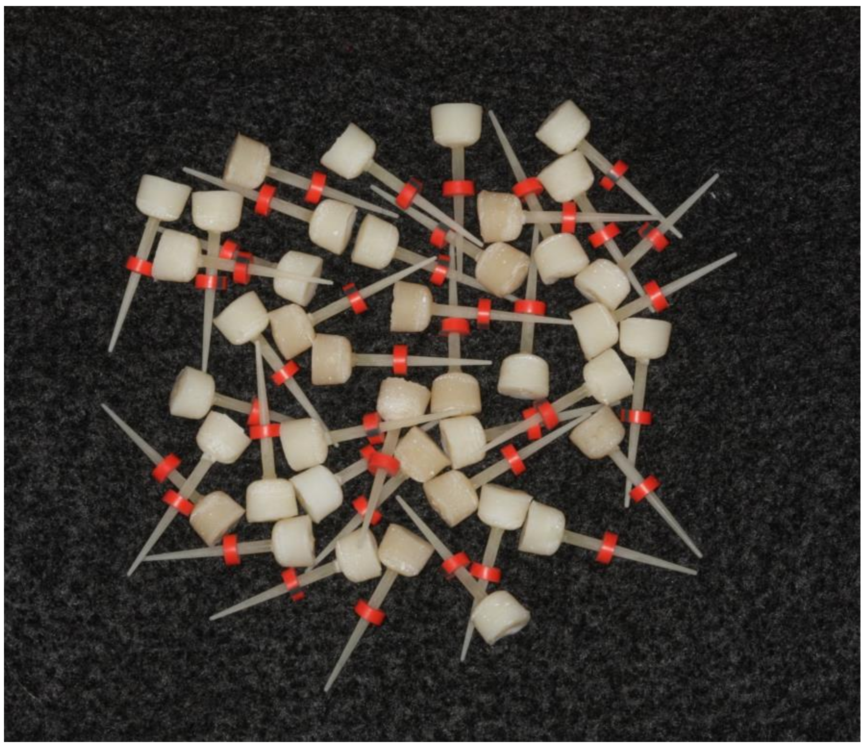

Figure 4. Fiber reinforced posts with the composite resin grips

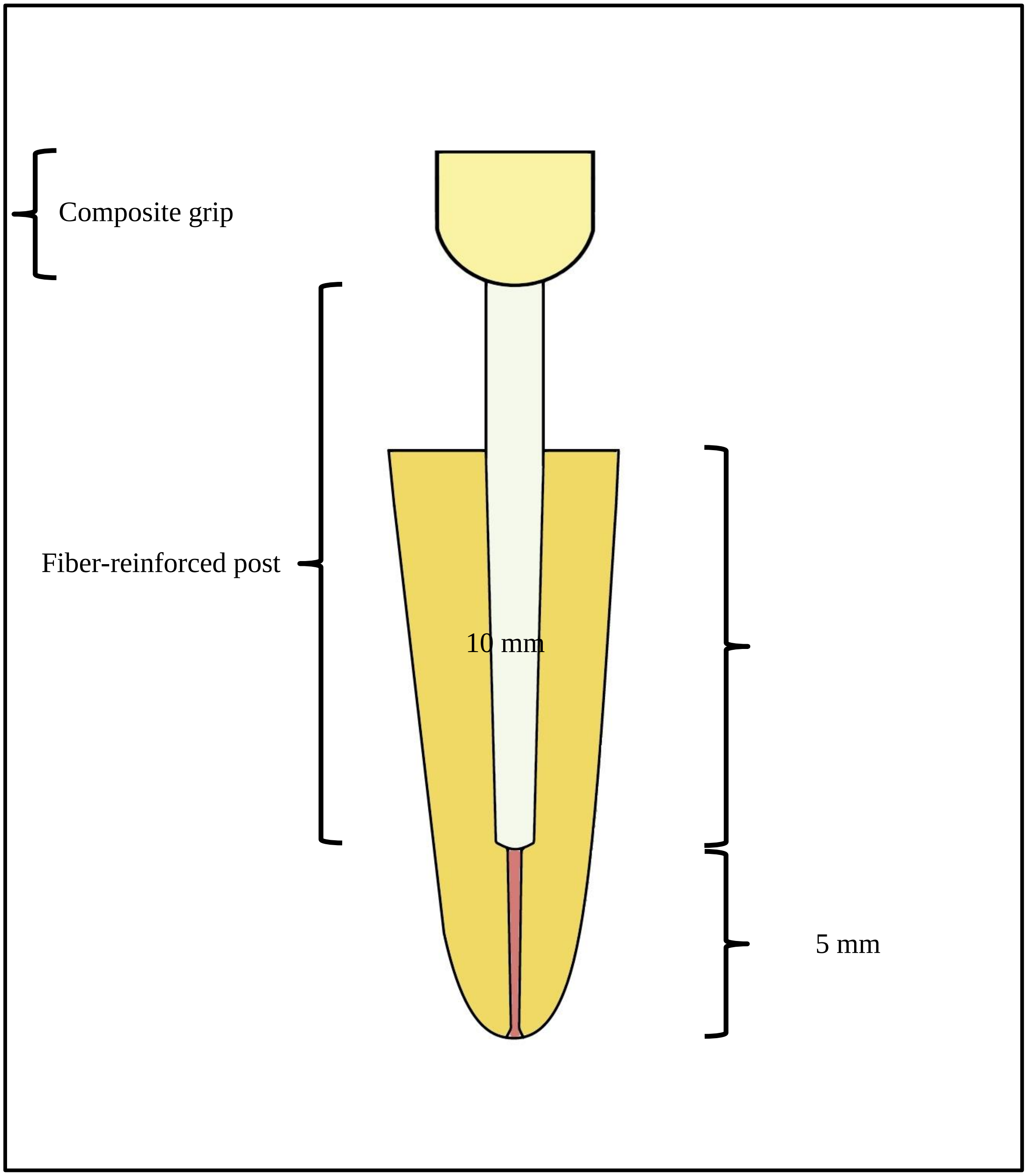

Figure 5. Illustration of the premolar tooth with the composite grip and the cemented glass fiber-reinforced post

A special holding device, similar to the devices used previously [25, 26] was made and used for this study (Figures 6-8). The device was composed of two members; the upper member held the root and contained a 3 mm-wide groove in the middle to accommodate the post, while the lower member held the composite resin grip. An internal round slot was made in the lower member, using the same bur that was used to mill the Teflon block, therefore creating close adaptation between the composite resin grip and the testing jig, avoiding stress concentration. A universal testing machine (ElectroPlus E10000, Instron, Norwood, MA) was used to separate the post from the tooth by applying a tensile force at a crosshead speed of 0.5 mm/min until failure. The point of failure was defined as the maximum tensile force recorded by the machine. Since all of the posts used were placed in the canal with the same length, the force was expressed in Newton rather than Megapascal.

The dislodged posts were examined at x8 magnification to determine the type of failure. The type of failure was classified into one of three categories: (1) adhesive between post and resin cement (no resin cement visible around the post); (2) mixed, (with resin cement partially covering the post surface); (3) adhesive between resin cement and root dentin (post completely covered by resin cement). The percentage of each type of failure within each group was calculated.

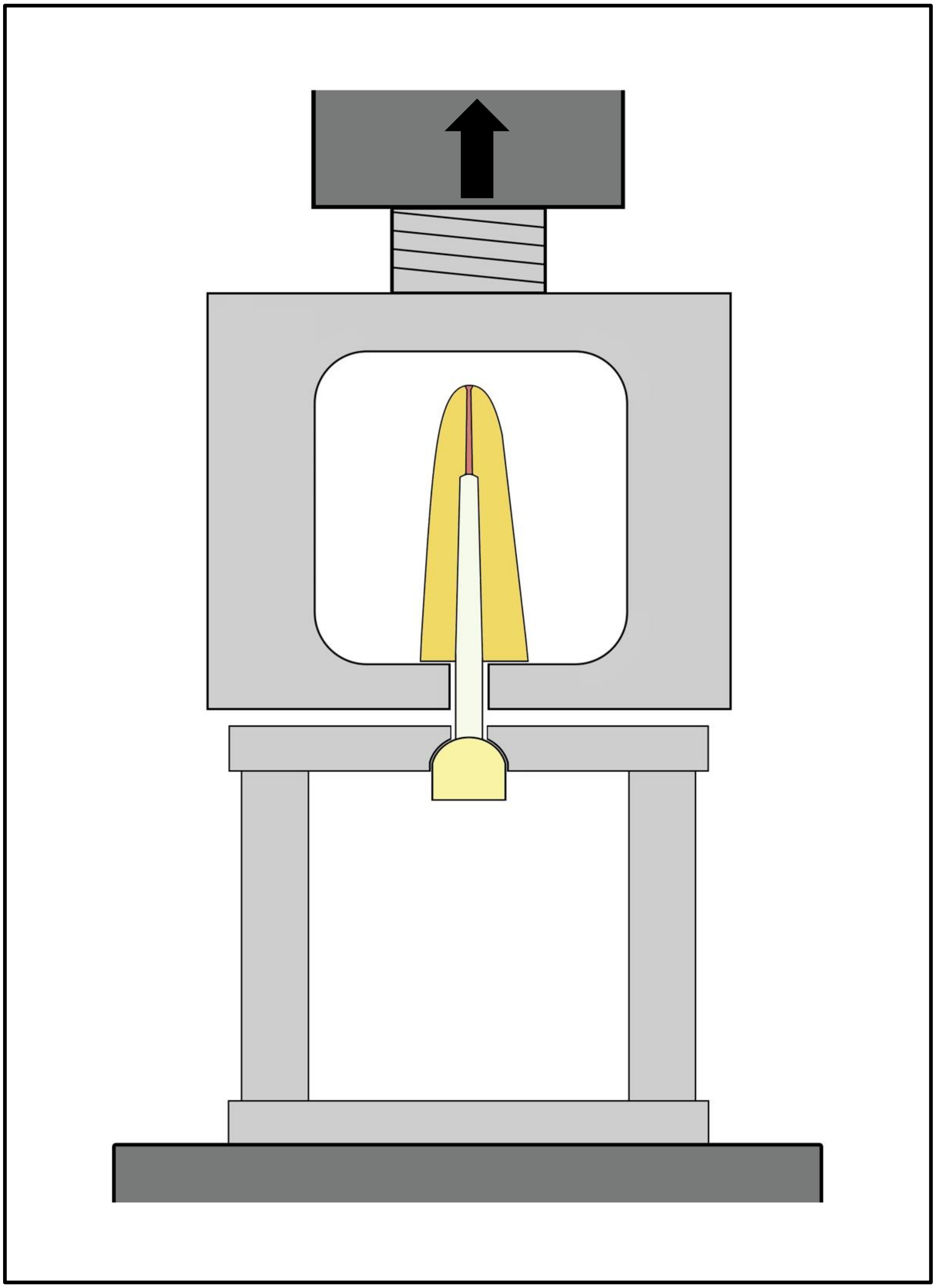

Figure 6. Illustration of the testing apparatus used to apply upward tensile force

Figure 7. Testing apparatus attached to Instron E10000 machine

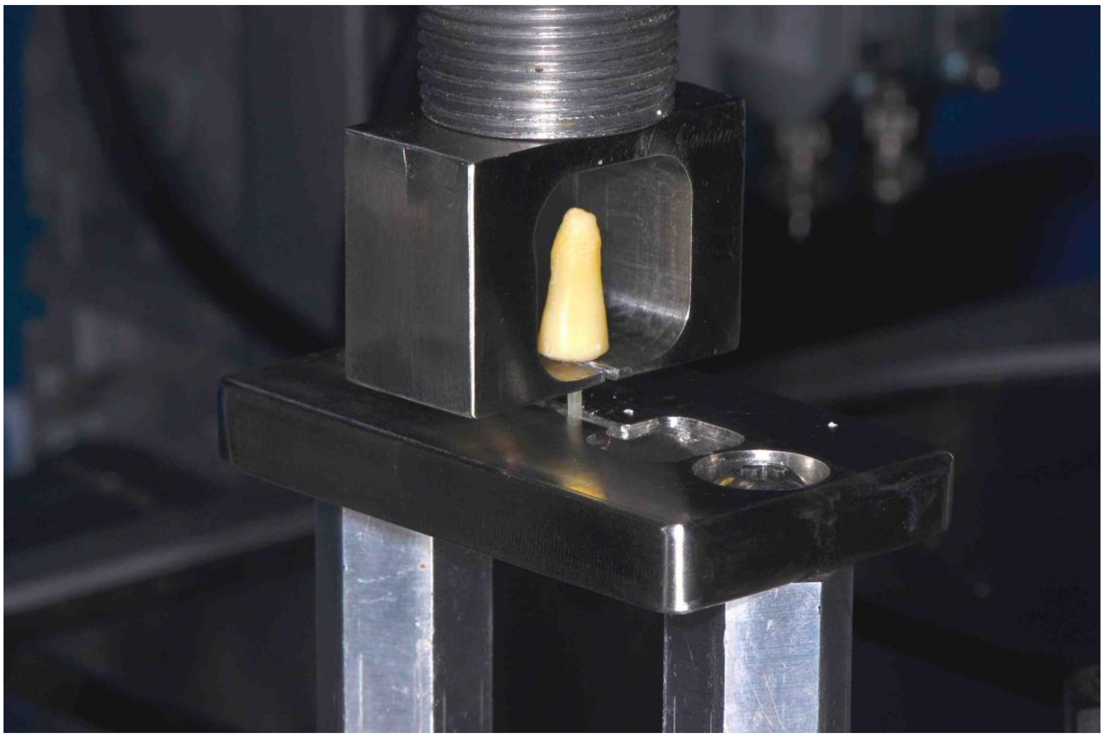

Figure 8. Close-up photograph of the testing apparatus with one of the specimens

Statistical Analysis

One-way ANOVA procedure was used to determine if there was a difference in dislodgement load between the three groups. The α-level of significance was set at 0.05. Descriptive statistics were given as mean and standard deviation for quantitative variables (Table-3). All statistical analyses were performed using IBM SPSS Statistics (Version 20; IBM Corporation 1989, 2011).

CHAPTER THREE

RESULTS

The control group achieved the highest and lowest bond strength (252.79 N), (73.48 N). The highest mean bond strength was found in the EDTA group (201.07 N) followed by the MTAD group (178.33 N) then the control group (167.00 N). A summary of the means and standard deviations for the recorded pull-out bond strength are provided in Table 3 and in Figure 9, while the bond strength of individual specimens are listed in Tables 4 – 6.

One-way ANOVA showed no statistically significant difference in bond strengths among the irrigation solutions tested. Irrigating the post space with EDTA or MTAD did not improve the retention of glass fiber reinforced posts (P=0.458).

Table 3

Mean pull-out bond strength (N) and standard deviation (SD) for the tested groups

Group	Mean ± SD	P-value
Control	167.00 ± 54.50 N	
EDTA	201.07 ± 49.84 N	0.458
MTAD	178.33 ± 42.67 N	

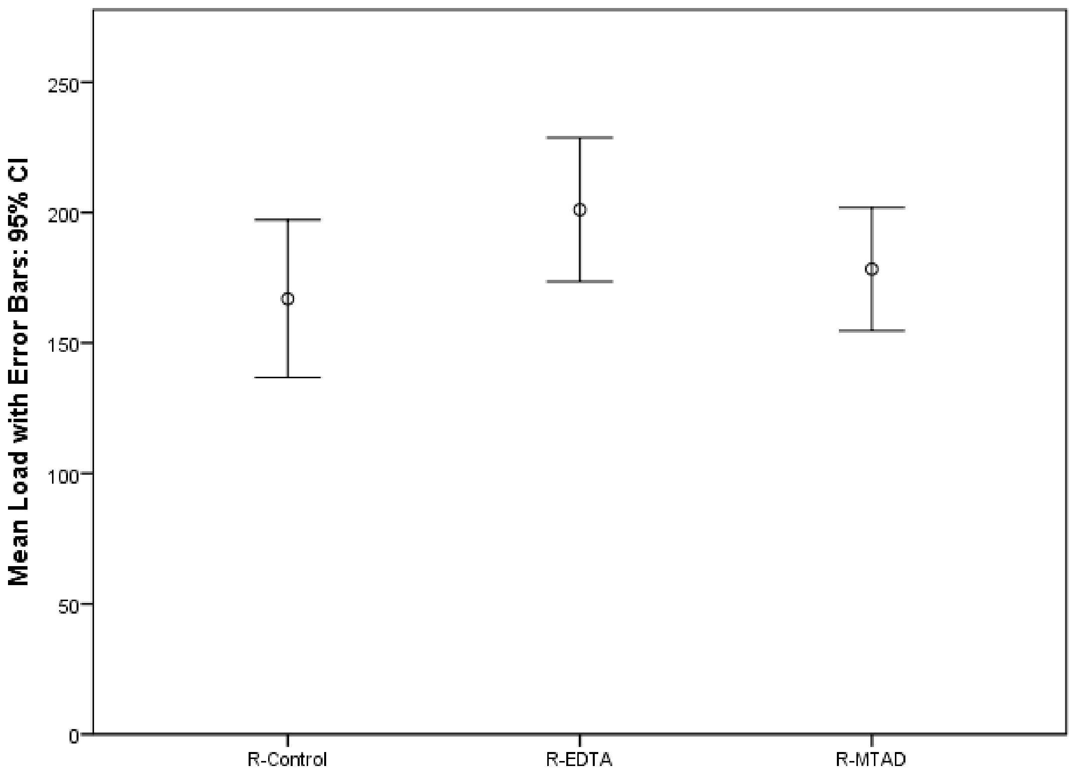

Figure 9. Graphic illustration of the bond strengths (N) for the different groups

Table 4

Bond strength values (N) of the control group

Specimen	Bond strength
1	88.1
2	235.0
3	194.9
4	171.7
5	199.4
6	185.9
7	154.3
8	150.9
9	248.8
10	252.8
11	110.1
12	73.6
13	139.5
14	168.7
15	129.9
Mean	167.0
Standard deviation	54.5
Upper bound (95% CI)	197.2
Lower bound (95% CI)	136.8

Table 5

Bond strength values (N) of the EDTA group

Specimen	Bond strength
1	87.8
2	131.9
3	246.9
4	238.1
5	185.5
6	223.1
7	207.2
8	222.4
9	222.8
10	252.4
11	252.3
12	140.9
13	242.8
14	161.5
15	199.8
Mean	201.1
Standard deviation	49.8
Upper bound (95% CI)	228.7
Lower bound (95% CI)	173.5

Table 6

Bond strength values (N) of the MTAD group

Specimen	Bond strength
1	215.3
2	227.1
3	220.4
4	169.9
5	170.2
6	169.8
7	208.1
8	180.8
9	194.2
10	226.2
11	86.7
12	142.4
13	163.1
14	101.8
15	200.7
Mean	178.3
Standard deviation	42.7
Upper bound (95% CI)	201.9
Lower bound (95% CI)	154.7

The examination of dislodged posts under a light microscope revealed that for the EDTA and MTAD groups, 53.3% of the dislodged posts were partially covered with cement and therefore had a mixed failure mode. On the remaining 46.7%, no visible cement was observed on the post, indicating an adhesive failure at the cement-to-post interface. While in the control group 46.7% of the posts were partially covered with resin cement, indicating a mixed mode of failure. None of the posts were completely covered with resin cement (Table 7).

Table 7

Failure modes (as percentage) of the dislodged posts

Failure mode	Control	EDTA	MTAD
Adhesive (cement-post)	53.3	46.7	46.7
Mixed	46.7	53.3	53.3
Adhesive (cement-dentin)	-	-	-

CHAPTER FOUR

DISCUSSION

The results from this study showed that the use of MTAD and EDTA did not improve the bond strength of fiber-reinforced posts to dentin when self-adhesive resin cement was used. Therefore this study fails to reject the null hypothesis.

Several studies have pointed out that the most frequent failure mode of post-retained restorations is post debonding.[1, 5, 6] Multiple dentin conditioning techniques were investigated in an attempt to enhance the bond at the cement-to-dentin interface. Several studies have evaluated the influence of solutions such as sodium hypochlorite, chlorhexidine, 17% EDTA, citric acid, MTAD, and 37% phosphoric acid on the bond strength of resin to dentin walls. Devices such as lasers and ultrasonic devices have also been reported. However, conflicting results were found. Dentin conditioning may affect the bond strength, and this effect greatly varies depending on the resin cement used.[23] The irrigation solutions tested for this study were EDTA and MTAD.

EDTA

17% EDTA has been reported to remove smear layer in multiple studies when used in the canal for 1 minute.[27] Shorter irrigation times could significantly decrease smear layer removal.[28] In contrast, using EDTA for periods longer than 1 minute could lead to severe erosion of the radicular dentin surface.[16] Thus in this study, EDTA was used for 1 minute.

Several in vitro investigations tested the effect of EDTA on bond strength of endodontic posts to root dentin, which was reported to be significantly improved.[20, 23] In this study, the use of EDTA resulted in slightly higher tensile bond strength compared to the other groups, though this difference did not reach statistical significance.

However, results reported by Faria-e-Silva [22] showed that the use of EDTA prior to cementation with RelyX Unicem resulted in significantly lower bond strength, when compared to the control group, where post space was irrigated with distilled water. This might be attributed to the strong demineralizing effect of EDTA on root dentin, which causes enlargement of the dentinal tubules, softening of the dentin, and denaturation of the collagen fibers.[29] These effects may subsequently influence the bonding to dentin in the root canal system.[27]

MTAD

Although smear layer removal remains a controversial issue, it is generally believed to enhance the bond strength to radicular dentin. MTAD is an acidic solution with a pH of 2.15 that is able to dissolve inorganic substance.[30] Torabinejad et al. showed that MTAD is an effective solution for the removal of the smear layer and does not significantly change the structure of the dentinal tubules when used as a final rinse.[16] MTAD used in this study resulted in lowest bond strength when compared to EDTA but higher bond strength than using no irrigation. Statistical analysis revealed however that these differences were not significant.

Self-adhesive Resin Cements

Self-adhesive resin cements have been introduced in the past decade, which eliminated the need for an extra clinical step for bonding. The presence of water as a component in self-adhesive resin cements provides them with hydrophilic characteristics.

The acid component will demineralize the smear layer and the underlying dentin. In addition, water and methacrylate monomer will lead to infiltration of resin into the porous dentin surface. However, insufficient demineralization and limited resin infiltration have been reported, which has been attributed to a slightly higher pH, which is 1.5 to 3.0, when compared to self-etching cements with a pH range of 0 to 1.5.[31] In the present study, EDTA and MTAD were used to verify whether they would provide further demineralization to enhance bonding. Although results of this study show that the EDTA group performed better compared to the MTAD group, the use of either solution as a final rinse did not significantly improve bond strength when compared to the control group.

Pull-out Test

In vitro evaluation of the bond strength of endodontic posts can be performed using one of three common methods; pull-out, push-out and micro-tensile tests. The push-out and micro-tensile tests allow the measurement of bond strength at different regions of the root canal system; apical, middle or coronal thirds. However, sectioning procedure can alter and negatively influence the bond strength of the posts to be tested.[32] On the other hand, the pull-out test is a simple alternative for testing higher specimen amounts. In addition, reported clinical failures of fiber posts usually occur with the entire post being debonded from the post space. Therefore, the pull-out testing may simulate clinical conditions more closely, when compared to the other two testing methods,[33] and thus was used for this study.

Study Limitations

This in vitro study has some limitations. The reported results only true for the fiber posts system used when cemented with RelyX Unicem. The effect of different irrigation solutions with different resin cement brands and types requires further research. It is suggested that future studies should use fatigue loading and thermocycling, as they may better simulate clinical environment and might alter the reported results. Also. More studies are required to evaluate the effect of MTAD on bond strength of different fiber post systems.

Conclusions

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

1. Removal of smear layer does not necessarily influence bond strength when self-adhesive resin cements are used to cement fiber-reinforced posts.
2. The use of MTAD or EDTA as a final rinse did not have a significant impact on the retention of glass fiber-reinforced posts cemented with RelyX Unicem.

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