ASSESSMENT OF HYBRIDIZATION AND PUSH OUT BOND STRENGTH OF FIBER POST AFTER ENDODONTIC RETREATMENT. AN INVITRO STUDY

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ABSTRACT

Statement of the problem: Bonding procedure of fiber post to root dentin after endodontic retreatment is a challenge using total etch cement.

Objective: The aim of this invitro study was to assess hybridization and push out bond strength of fiber post after endodontic retreatment.

Materials and methods: 10 freshly extracted human canines were collected having single root canal and with the same morphology and dimensions, samples were decoronated using diamond disc under wet condition 2mm above the CEJ. Endodontic treatment was then made to all samples. Samples were then inserted into resin blocks using cylinder block former and left till complete cure. Then they were randomly divided in to two groups: group I (control group) (5n) drilling was done to prepare post space followed by post cementation using total etch cement; while in group II (retreatment group) (5n) endodontic retreatment was made followed by drilling for post space preparation then post cementation was done like group one using the same cement. After post cementation samples were transversely sectioned into six sections of 1.5 mm thickness representing apical, middle and coronal root part. Push out test was performed using universal testing machine at 0.5 mm/min. Scanning of the root interface using SEM after bond strength test were made to detect the post cement/root interface.

Results: Regardless of the root level; Group I showed statistically significant higher mean push out bond strength (11.55 MPA) than Group II (7.93 MPA). **Regardless of groups;** there were no statistically significant difference between coronal (13.13 MPA) and middle root levels (9.62 MPA); both showed statistically significantly higher mean push out bond strength than apical root level (6.48 MPA). Comparing between groups at different root sections results showed; **as regards coronal root level;** Group I showed statistically significant higher mean push out bond strength (16.06 MPA) than Group II (10.19 MPA). **While at middle as well as apical root levels;** there were no statistically significant difference between mean push out bond strength values of the two groups. Scanning electron microscope revealed formation of resin tags and hybridization within the dentin in group one (GI) which was clearly found in the coronal section while in group two (GII) there was an ill-defined hybrid layer at interface. Interfacial gaps, void and remnants of resin sealer were found mainly in the apical section.

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Conclusions: Endodontic retreatment showed significant adverse effect on fiber post push out bond strength compared to endodontically treated teeth. In endodontically treated teeth root level affected fiber post push out bond strength mainly at the apical level while in endodontically retreated teeth there was no difference in push out bond strength mean value between the different root levels. Interface of the endodontically treated teeth showed hybrid layer formation and resin tags coronally while in endo retreatment gaps and void were seen at the interface.

KEY WORDS: Endodontic retreatment, Fiber post, Push out test.

INTRODUCTION

Restoration of endodontically treated teeth have been found to be one of the major concerns that affect the prognosis of the tooth. Post and core systems have been widely used nowadays in endodontically treated teeth with coronal tooth structure loss in order to improve the retention of the restoration [1,2]. Fiber posts have been widely used because of their advantages over the metal posts including the similar modulus of elasticity to dentine which decreases the stress on the root surface and allowing adequate distribution of the masticatory forces thus decreasing the possibility of root fracture as well as being a tooth colored post that can be bonded to tooth structure in addition to being a retrievable post helped in solving the unaesthetic problem of metal posts [3]. Uthappa et al in 2015[4] made a clinical comparative evaluation between metal and fiber posts in restoring endodontically treated teeth and found that metal post showed higher failure rates when compared to fiber post.

Adhesive resin cement have been used to cement glass fiber post because of its simplified technique and also as it decreases the nano-leakage through the demineralization of the smear layer. There are different types of adhesive resin cements that are used for fiber post cementation which include: total etch, self-etch and self-adhesive resin cements; studies have shown contradictory results about the adhesive capability of each system where some studies showed that self-adhesive system showed lowest adhesive capability when compared to total etch while others have shown that both had similar adhesive capability[7,8]. However a recent study done by Theodor, Koesmaningati and Gita in 2017[9] compared the adhesive capability of the three adhesive systems and stated that the total etch system showed significantly better adhesive capability than self-adhesive system and this was due to the acid etch that is applied in the total etch system which resulted in the demineralization of dentine and allowed the formation of a deeper hybrid layer and resin tag formation than self-adhesive; whereas the total etch showed a higher non-significant adhesive capability than self-etch and this was correlated to technique sensitivity of the total etch procedure.

Success rate of endodontic treatment have been reported to be from 80-85%[10]. Failure of endodontic treatment may be due to improper endodontic treatment, salivary or bacterial microleakage, improper cleaning or obturation or persistent root infection which will require further endodontic retreatment in order to be able to maintain the teeth in the dental arch. Endodontic retreatment should be done carefully with complete removal of the preexisting filling material to allow for proper instrumentation and effective disinfection but without excessive loss or damage to the dentine as studies have shown a direct relation between the strength of the root and the remaining amount of dentine [11,12]. Missau et al in 2017[13] studied the effect of endodontic treatment and retreatment on the fatigue failure load of human canine teeth and found that both endodontic treated canines and those with retreatment behaved the same in terms of fatigue failure loads and number of cycles to failure.

In endodontic retreatment the action of using drills to remove the gutta percha results in forming

a new smear layer in the canal rich with remnants of gutta percha and sealer which will be plasticized by heat obtained due to friction which in combination with inorganic components can occlude the dentinal tubules affecting the bonding of the fiber post[14,15]. Adequate and complete removal of this smear layer and these materials has not yet been established by any of the retreatment procedures [16,17].

A systematic review was done in 2019[18] to asses weather endodontic retreatment would affect the fracture strength of endodontically treated teeth and they stated that endodontic retreatment may affect the mechanical properties of endodontically treated teeth, however they declared that more studies are needed in this field to completely comprehend such matter.

So the aim of this study was to assess hybridization and push out bond strength of fiber post after endodontic retreatment.

The first null hypothesis was that endodontic retreatment would not affect the push out bond strength of fiber post and the second null hypothesis was that there would be no difference in the push out bond strength of fiber post at different root levels in both endodontically treated and retreated teeth.

MATERIALS AND METHODS

Specimen preparation

10 freshly extracted human maxillary canines were collected from oral surgery department in Faculty of dentistry; Cairo University. Teeth were selected according to inclusion criteria, having similar root morphology and dimension, with single root canal, free from internal resorption, caries, fracture, calcification or cracks. The dimensions were measured buccolingually and mesiodistally using digital caliper with accepted variation of 1-1.5mm [19] (Fig.1). The teeth collected had no previous endodontic treatment based on clinical and radiographic examination. The teeth were stored in saline solution at room temperature. Decoronation of teeth were made using diamond disc under wet condition 2mm above the CEJ. Endodontic treatment was made to all samples by the same operator and under the supervision of an endodontic expert. Working length was determined visually 1mm shorter than the length of the canal. Cleaning and shaping was done by protaper universal rotary system (Dentsply, Maillefer, Ballaigues, Switzerland) using the crown down technique in the following sequence: shaping files
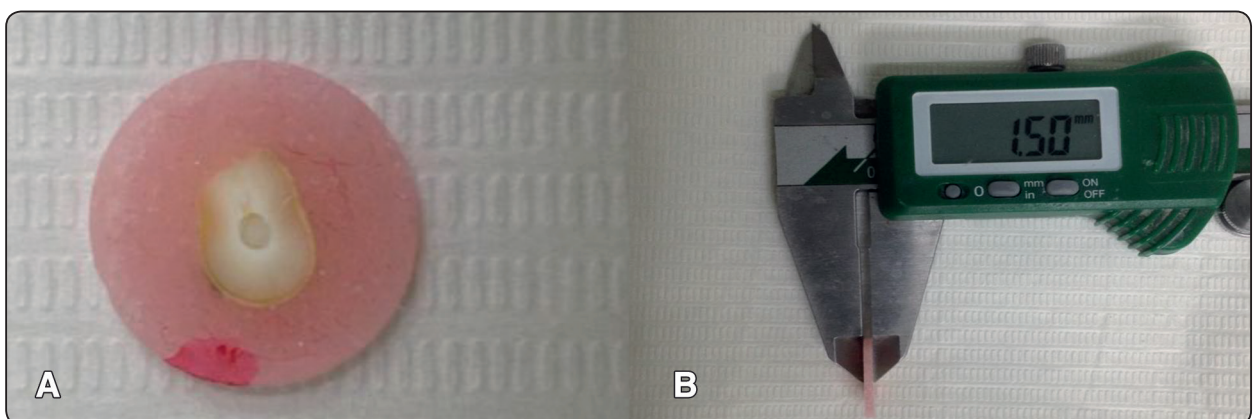

Fig. (1) A: Transverse section of the sample to be to be tested, B: Caliber to check the thickness of the sample slice.

S1 and S2 in a brushing motion then the finishing files F1, F2, F3 up to finishing F4 file (size 40 with 6% apical taper) in picking motion using Xsmart plus endomotor (Dentsply, Maillefer, Ballaigues, Switzerland). Torque and speed were set according to the manufacturer instructions (2 N/cm torque and a constant speed of 300 rpm). Irrigation was done during treatment first by 5ml 2.5% sodium hypochlorite for one minute followed by 5ml 17 % EDTA for one minute then a final flush with saline for 1 min. Root canal was dried using paper points before obturation with gutta percha cones F4 (Dentsply, Maillefer, Ballaigues, Switzerland) using resin sealer (ADSEAL Meta, biomed, Korea) the access cavity was then sealed using temporary resin cement (Tempolink clear, Detax, Ettlingen, Germany). Teeth were stored for one week in saline solution at room temperature to allow complete setting of the sealer. All Samples were inserted into resin blocks using cylinder block former and left till complete cure.

Samples were then numbered from 1 to 10 and divided by www.random.org into two equal groups at allocation ratio 1:1 and sealed in a closed envelope to avoid selection bias and to allow samples to have equal chances to be in the control group or the retreatment group.

In group one (GI; control group) post space preparation was made one week after the endodontic treatment using peso drills size 2, 3, and 4 for partial removal of gutta percha leaving 5mm apical for apical seal and confirmed by radiograph. A post space was prepared with the calibration drill included in post kit corresponding to the post size, each canal was irrigated using 5ml 2.5% sodium hypochlorite for one minute followed by 5ml 17 % EDTA followed by a final flush with sodium hypochlorite and then dried using paper points.

Fiber post (GLASSIX plus, Nordin, Switzerland) cementation was done using total etch dual cure adhesive resin cement (Cement-it adhesive cement: Pentron, Batch no: 4717117, USA); first cleaning of fiber post was made using 70% alcohol this was followed by 37% phosphoric acid etching for 15 sec and then silanized with DentoBond Porcelain Fix (Itena, France) for 60 seconds then dried with a light jet of air, phosphoric acid etching 37% concentration was applied to the canal walls at post space using plastic needle for 15 sec. then irrigation with air water spray followed by dryness with paper point. Application of bonding agent single bond universal adhesive (3M GmbH, Neuss, Germany) for 20 sec using microbrush, removal of excess by paper point then air dried with gentle air pressure and light cured for 10 sec. Application of cement using lentulo spiral and also applied to the post using the supplied tips. The post was positioned in place by firm finger pressure, excess cement was removed by microbrush followed by light curing (LED) with light emitting of 1200 mw/cm^2 for 20 sec. in all directions using Woodpecker i-led (Woodpecker, China). Sealing of the access was done with flowable composite (Polofil NHT flow, Voco, Germany). Samples were preserved in saline solution at room temperature for one week till push out test.

In group two (GII; retreatment group) endodontic retreatment was made using D1, D2 and D3 files (Protaper Universal Retreatment; Dentsply Maillefer, Ballaigues, Switzerland) sequentially with the crown-down technique at torque and speed settings recommended by the manufacturer (2 N/cm torque and a constant speed of 300 rpm) until the required depth was achieved in all specimens, finishing was done by f4 protaper universal file; irrigation and filling of the root canal was made followed by post space preparation and fiber post cementation as in group I (GI). And then preserved in saline solution at room temperature for one week till push out test.

Before push out test, samples from each group were sectioned transversely into slices of 1.5mm thickness each representing coronal, middle and apical third for each group leaving the last 6mm

from the apex using cutting machine under wet condition (Isomet; Buehler Ltda.). Each slice was marked for the detection of the coronal side during the pushout test.

Push out test was made using computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA). Each section was mounted on the instron and subjected to compressive loading in an apicocoronal direction at a crosshead speed of 0.5mm/min and a load cell of 5kN and the force required to debond the post was recorded in newton (N). The load cell is centered at the post away from dentine surface.

Push out bond strength was calculated using the following equation:

Push out bond strength = F/A where: A = π H (r1+r2)

Where π is the constant 3.14, H = 1.5mm which is the thickness of the slice, r1 is the coronal radius of the slice and r2 is the apical radius.

Both the statistician and the assessors were blinded in order to minimize the risk of bias.

Scanning electron microscope

Surface image interface was scanned using Quanta FEG 250 scanning electron microscope (FEI company, USA)*. Samples were mounted onto SEM stubs. SEM conditions were: 10.1mm working distance, with in-lens detector with an excitation voltage of 10 KV and 1000x magnification for studying the hybrid layer formation and root interface.

RESULTS

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values and 95% Confidence Interval (95% CI). Repeated measures Analysis of Variance (ANOVA) was used to study the effect of group, root level and their interaction on mean push out bond strength. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Repeated measures ANOVA results

The results showed that group regardless of root level had a statistically significant effect on mean push out bond strength. Root level regardless of group had a statistically significant effect on mean push out bond strength. The interaction between the variables had no statistically significant effect on mean push out bond strength. Since the interaction between the variables is non-statistically significant, so the variables are independent from each other. (Table 1)

TABLE (1) Repeated measures ANOVA results for the effect of different variables on mean push out bond strength

Source of variation	Type III Sum of Squares	Df	Mean Square	F-value	P-value	Effect size (Partial eta squared)
Group	98.468	1	98.468	11.843	0.009*	0.597
Root level	221.256	2	110.628	12.909	<0.001*	0.617
Group x Root level interaction	28.452	2	14.226	1.660	0.221	0.172

df: degrees of freedom = (n-1), *: Significant at P ≤ 0.05

Effect of group regardless of root level

Regardless of root level; Group I showed statistically significantly higher mean push out bond strength than Group II (*P*-value = 0.009, Effect size = 0.597). (Table 2)

TABLE (2) The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between push out bond strength (MPa) of the two groups regardless of root level

Group I		Group II		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD		
11.55	5	7.93	2.71	0.009*	0.597

*: Significant at P ≤ 0.05

Effect of root level regardless of group

Regardless of group; there was a statistically significant difference between mean push out bond strength at different root levels (*P*-value <0.001, Effect size = 0.617). Pair-wise comparisons revealed that there was no statistically significant difference between coronal and middle root levels; both showed statistically significantly higher mean push out bond strength than apical root level. (Table 3)

Interactions of variables:

Comparison between groups

As regards coronal root level; Group I showed statistically significantly higher mean push out bond strength than Group II (*P*-value = 0.018, Effect size = 0.526). **While at middle as well as apical root levels;** there was no statistically significant difference between mean push out bond strength values of the two groups (*P*-value = 0.094, Effect size = 0.310) and (*P*-value = 0.464, Effect size = 0.069), respectively. (Table 4)

TABLE (3) The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between push out bond strength values (MPa) at different root levels regardless of group

Coronal		Middle		Apical		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD	Mean	SD		
13.13 ᴬ	4.26	9.62 ᴬ	3.67	6.48 ᴮ	2.25	<0.001*	0.617

*: Significant at P ≤ 0.05, Different superscripts are statistically significantly different

TABLE (4) The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between push out bond strength values (MPa) of the two groups at each root level

Root level	Group I		Group II		*P*-value	Effect size *(Partial Eta Squared)*
	Mean	SD	Mean	SD		
Coronal	16.06	4	10.19	1.78	0.018*	0.526
Middle	11.56	3.88	7.68	2.42	0.094	0.310
Apical	7.04	2.34	5.92	2.27	0.464	0.069

*: Significant at P ≤ 0.05,

Comparison between root levels

As regards Group I; there was a statistically significant difference between mean push out bond strength values at different root levels (*P*-value = 0.001, Effect size = 0.846). Pair-wise comparisons revealed that there was no statistically significant difference between coronal and middle root levels; both showed statistically significantly higher mean push out bond strength than apical root level.

While in Group II; there was no statistically significant difference between mean push out bond strength values at different root levels (*P*-value = 0.082, Effect size = 0.511). (Table 5)

Scanning electron microscope:

Scanning electron microscope revealed formation of resin tags and hybridization within the dentine in group one (G1) which was clearly found in the coronal section however in the apical section resin tag formation was found but with decreased density and ill-defined hybrid layer (Fig.2). In group two (G2) there was an ill-defined hybrid layer and resin cement was not well adapted to

dentine at interface where interfacial gaps, voids and remnants of resin sealer in addition to multiple smear plugs were found which was clearly identified mainly in the apical section. (Fig.3)

TABLE (5) The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between push out bond strength values (MPa) at different root levels within each group

Root level	Group I		Group II	
	Mean	SD	Mean	SD
Coronal	16.06 [A]	4	10.19	1.78
Middle	11.56 [A]	3.88	7.68	2.42
Apical	7.04 [B]	2.34	5.92	2.27
P-value	0.001*		0.082	
Effect size *(Partial Eta Squared)*	0.846		0.511	

*: Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically significant difference between root levels
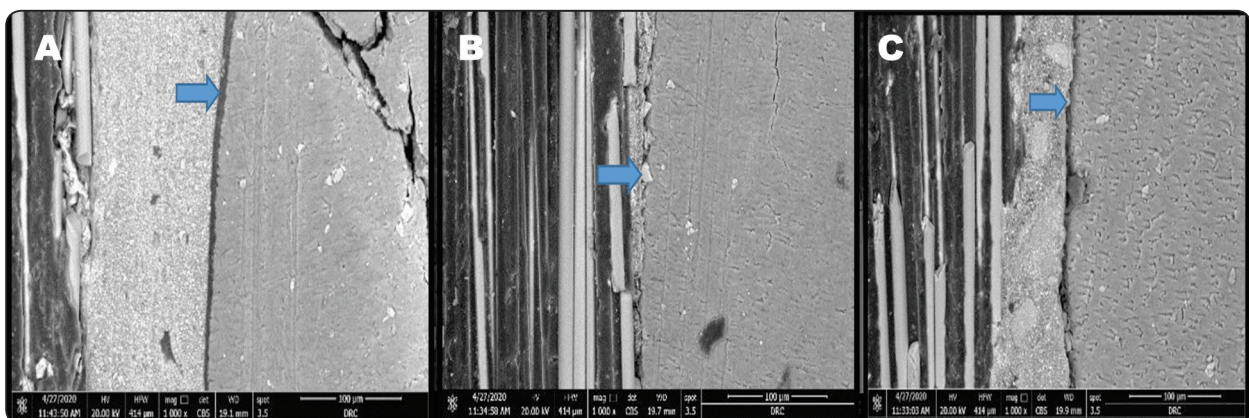

Fig. (2) SEM for the control group (G1), A: Coronal section **Arrow:** hybrid layer and resin tag. B: Middle section; **Arrow:** resin. C: Apical section; **Arrow:** ill-defined hybrid layer
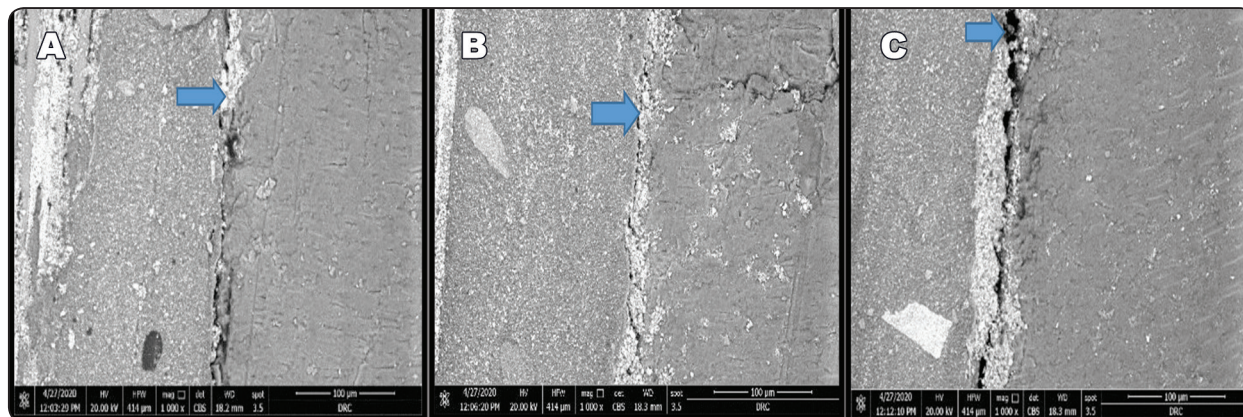
Fig. (3): SEM for retreatment group A: Coronal section; **Arrow**: remnants of resin sealer, B: Middle section **Arrow**: ill-defined hybrid layer .C: apical section; **Arrow**: Void

DISCUSSION

The purpose of this study was to assess hybridization and push out bond strength of fiber post after endodontic retreatment.

Endodontic treatment requires complete and efficient removal of necrotic pulp tissues, cleansing efficacy depends on multiple things one of which is the instrumentation procedure; in this study protaper system was used for removal of pulpal tissues; a study done by Elnagar MH, Ghoname NA and Ghoneim WM in 2018[20] stated that a better cleanliness was achieved when rotary system was used when compared to manual instrumentation technique. Also a systematic review done by Peralta-Mamani et al in 2019[21] stated that rotary instrumentation showed better centralization, less alterations in working length and canal curvatures, better cleaning ability and debris removal in addition to better attaining of regular canal shape than manual instrumentation. Endodontic retreatment is required in cases where previous endodontic treatment failed, in order to maintain the tooth in the dental arch. Endodontic retreatment has been reported to be a treatment of predictable prognosis with a success rate of 80% to 88% when well performed, thus becoming a prior treatment option to tooth extraction [22].

In this study protaper universal retreatment kit (D1, D2 and D3 files (Protaper Universal Retreatment; Dentsply Maillefer, Ballaigues, Switzerland)) was used for endodontic retreatment as studies have shown its effectiveness in removal of the filling material as well as being faster and easier in penetration which facilitates the removal of gutta percha and sealer[23-26]. Solvents was not used in removal of the gutta percha as studies showed that using solvents will result in a layer of gutta percha and sealer at root canal walls that may not be easily removed or even detected[27,28].

Restoration of endodontically treated teeth may require post placement to provide retention for the core. There are many types of posts available nowadays; however glass fiber post have gained popularity due to its modulus of elasticity being close to that of dentine and the ease of being adhesively bonded to dentine using adhesive resin cement thus allowing a more homogenous stress distribution and decreasing the possibility of catastrophic root fracture[29,30]. Bonding mechanism depend on hybrid layer formation and resin tag which offers bonding to dentin. Cleaning of fiber post was made using 70% alcohol to remove any contaminants during try in procedure this was followed by 37% phosphoric acid etching for 15 sec and then silanized with ceramic primer (3M ESPE, St. Paul) for 60 seconds to increase the bond between the cement and the post.

Irrigation regimen is known to affect the canal surface characteristics and failure of removal of the smear layer will result in formation of a deficient hybrid layer and consequently poor adhesion and apparent interfacial gap [31]. In this study Irrigation was done first with 5ml 2.5% sodium hypochlorite for one minute to dissolve organic material and smear layer in addition to its antimicrobial action[32], followed by 5ml 17 % EDTA which is responsible for removal of the inorganic component of the smear layer due to its chelating powder [33]. This was followed with a final flush using sodium hypochlorite to remove residual of EDTA and stop its chelating action.

One of the most important factors affecting the bond strength of the fiber post to root dentine is the adhesive cement used; in this study total etch system have been used as studies have shown that it had better adhesive capability than other adhesive systems. This may be due to the acid etch applied which resulted in the demineralization of dentine and allowed for the formation of a deeper hybrid layer and resin tag formation, etching also removes the smear layer, demineralize hydroxyapatite matrix exposing the collagen and dentinal tubule so allow good bonding when the monomer in the bonding agent penetrate the dentin and collagen fibers forming hybrid layer and resin tags [9].

Push out test was done in this study to determine the adhesive capability for the adhesively cemented fiber post as researchers have found it to be a more effective and reliable method than microtensile test as the later showed a higher risk of specimens destruction [34-37].

Results of the current study showed that endodontic retreatment adversely affect fiber post bond strength, thus the null hypothesis that endodontic retreatment would not affect fiber post push out bond strength was rejected.

Results of this study showed that Group I (endodontic treatment) showed statistically significantly higher mean push out bond strength (11.55 MPA) than Group II (endodontic retreatment) (7.93 MPA) and this may be due to the inability to ensure the complete removal of the filling material from the root canal as several studies have stated that regardless the technique used for retreatment and the use of solvent, it is difficult to completely remove the resin sealer tags from the root canal as it is deeply penetrated into the dentinal tubules [38,39].

The results of this study were in agreement with other studies as Pelegrine et al in 2016 [40] who performed a study to determine the bond strength of fiber post in endodontically retreated teeth, and found that endodontic retreatment had an adverse effect on the push out bond strength of fiber post when compared to endodontically treated teeth; a study done by Pereira et al in 2019 [41] who found that endodontic retreatment negatively affected the cement penetration and also the fiber post bond strength. Also a systematic review that was done by Schestatsky et al in 2019 [18] which concluded that endodontic retreatment showed a lower mechanical performance than endodontically treated teeth.

Regarding the post push out bond strength at different root levels; there was a statistically significant difference between mean push out bond strength at different root levels. In group I there was no statistically significant difference between coronal and middle root levels; both showed statistically significantly higher mean push out bond strength than apical root level while in group II there was no statistically significant difference between mean shear bond strength values at different root levels. Thus the second null hypothesis was partially rejected.

The difference in the fiber post bond strength at different root levels with higher bond strength at the coronal part have been attributed due to many reasons as the coronal dentine showed a more dense and wider diameter tubules than the middle and apical root level allowing for a stronger adhesion and more penetration of the resin into the tubules[42,43].

In addition to other methodological factors which may also affect the bond strength as the accessibility of the coronal portion making the application of the etch and adhesive more easier in addition to proper light transmission which ensure complete resin polymerization, while at the middle and apical regions there is a decrease in the light energy transmission which will affect the resin polymerization in these regions, in addition to the effect of moisture contamination and over drying after etching [39,41,42]. The results were in agreement with other studies which attributed a higher bond strength of fiber post at the coronal dentin [46-53].

Scanning electron microscope was done in this study to determine the bonding surface quality and it revealed resin tag formation and hybrid layer which was clearly identified in the coronal sample of group one, while differences of resin tag density were found in middle and apical parts of group one while in group two there was few resin tags at the coronal area with evidence of remnants of resin sealer on the root dentine at middle and apical areas, and this may be attributed to the decrease in diameter and quantity of the dentine as we move apically resulting in difficult accessibility and ineffective cleaning in addition to smear layer on dentine surface which is not cleaned completely resulting in a more superficial hybrid layer and resin tags [54-57]. This was observed by other authors who found that specimens from endodontically retreated teeth showed remnants of filling material of primary treatment mainly in the apical region [23,38,58].

The limitations of this study include being an invitro study in addition to not applying fatigue loading and thermocycling to simulate clinical conditions.

CONCLUSIONS

Within the limitations of this study the following conclusions could be drawn:

1. Endodontic retreatment showed an adverse effect on fiber post push out bond strength compared to endodontic treatment.

2. In endodontically treated teeth root level affected fiber post push out bond strength mainly at the apical level.

3. Different root levels in endodontically retreated teeth showed no difference in push out bond strength mean value.

4. Interface of the endodontically treated teeth showed hybrid layer formation and resin tags while in endo retreatment, gaps and voids were clearly seen at the interface.

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