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EFFECT OF DIFFERENT GUTTA-PERCHA SOLVENTS ON THE BOND STRENGTH OF AH PLUS SEALER TO ROOT CANAL DENTIN FOLLOWING RETREATMENT

Adel AbdelWahed*

ABSTRACT

Aim: To evaluate the influence of solvents used in nonsurgical retreatment on the bond strength of AH Plus sealer to intraradicular dentin after reobturation of root canal.

Materials and Methods: Sixty mandibular premolars were employed in the study. Samples were endodontically treated using AH Plus sealer. Teeth were divided into four equal groups(n=15) according to the use and type of different gutta-percha solvents during retreatment;(Group A) PTR, (Group B) PTR& Chloroform, (Group C) PTR& Orange oil and (Group D):PTR& Endosolv. After retreatment, the teeth were re-oburated and cross sectionally cut in 1-mm-thick dentin slices, then subjected to the push-out test. Repeated measures ANOVA test was used to evaluate the effect of solvent, root level and their interactions on push-out bond strength. Pair-wise comparisons were performed with Bonferroni's post-hoc test when ANOVA test is significant.

Results: PTR group showed the highest statistically significantly mean push-out bond strength values. PTR &Orange oil group showed significantly lower mean push-out bond strength followed by PTR & Endosolv group. While, PTR &Chloroform group showed the lowest significant mean push-out bond strength.

Conclusion: The use of gutta-perch solvents had a negative impact on the bond strength values of AH Plus sealer to root canal dentin.

KEYWORDS: AH Plus, Chloroform, Endosolv, Orange oil, Retreatment.

INTRODUCTION

The success of root canal treatment depends entirely on achieving proper cleaning and shaping, followed by 3-D filling of the canal space. Failure of following this concept results in persistence of bacteria in the root canal space and occurrence of post-treatment disease [1]. Nonsurgical root canal retreatment is often considered the first line of

* Endodontic Department, Faculty of Oral and Dental Medicine, Future University.

treatment in the eradication of persistent infection. The concept of retreatment aims at full removal of the incompetent filling material from the canal space to allow for appropriate shaping, cleaning and refilling of the root canal [2].

Several techniques have been used in removing root canal filling materials including the use of hand and rotary files, ultrasonic devices, heat and solvents. However, researches have stated that none of the retreatment techniques allowed efficient removal of the obturating materials from the root canals, [3,4].

Nickel–titanium rotary files are more efficient than manual files in the removal of obturating materials, in terms of maintaining the canal shape and providing shorter working time [5,6]. The ProTaper Universal Retreatment system (PTR) (Dentsply, Maillefer, Ballaigues, Switzerland) is designed to remove the canal filling material using variable lengths, tapers, and tip diameters.

On the other hand, the efficacy of solvents in softening gutta-percha has been proven in previous studies[7,8]. Among the various solvents employed, chloroform is viewed as the most efficient, for the removal of canal filling material. However, it had been prohibited by the drug authority because of its carcinogenicity, shrinkage on evaporation and loss of apical seal. Essential oils such as orange oil were proven to be safe, biocompatible, non carcinogenic and has the ability to dissolve most of the root canal sealers [9,10].

Endosolv (Septodont, Cedex, France) is an efficient, biologically safe organic solvent applied for softening different obturating materials [11]. Endosolv R allows easy removal of fresh AH Plus after filling.

During the retreatment process, the contact between gutta-percha solvents and the tooth hard structure may cause chemical alterations in the coronal and radicular dentin [12,13].

The aim of this study was to compare the push-out bond strength of AH Plus sealer to root canal dentine exposed to different types of gutta-percha solvents. The null hypothesis is that different gutta-percha solvents would not significantly affect the bond strength of AH Plus sealer to root canal dentine.

MATERIALS AND METHODS

Samples selection and preparation

Sixty extracted human mandibular premolar teeth with single straight mature root canals were collected from the clinic of Oral Surgery Department, Faculty of Oral and Dental Medicine, Future University in Egypt. Teeth having fractures, resorptive defects or open apices in their roots were excluded from the study. Cleansing of teeth from soft tissue debris and calculus was performed with hand scalers, then the teeth were washed under running water.

For each canal, #10K-file tip (Dentsply, Maillefer, Ballaigues, Switzerland) was advanced till seen at the apical foramen, then the file was withdrawn and the length was measured. The working length was established by subtracting 1 mm from the previous length. Canals were shaped using ProTaper NEXT rotary files (Dentsply, Maillefer, Ballaigues, Switzerland) operated in brushing motion at (300 rpm/ 2.0N) using X-Smart Plus electric motor (Dentsply, Maillefer, Ballaigues, Switzerland), till reaching size X4 file (40/0.06). 3 mL of 2.5% NaOCl was used as an irrigant between successive file followed by 1 mL of 17% EDTA (MD-cleanser, Meta Biomed) for smear layer removal, then 5 mL distilled water was used as a final rinse. Canals were dried with paper points.

Protaper Next matching gutta percha cones (X4) and AH plus sealer were used to obturate the canals in modified lateral compaction technique. Then, the root canals were radiographed in bucco-lingual and mesio-distal directions in order to confirm the adequacy of the root canal filling. Glass ionomer cement (Fuji, GC, Tokyo, Japan) was used to seal the root canal orifices.

Samples were wrapped in sponge and stored at 37°C in 100% humidity for 2 weeks to allow for complete setting of sealer.

Preparation of orange oil

Orange oil used were prepared by hydro-distillation of 175gm fresh fruit peel using Clevenger's type of apparatus for 3 hours for isolation of orange oil which was directly measured in the extraction burette at the Faculty of pharmaceutical science and Pharmaceutical industry, Future University in Egypt.

Samples classification

Protaper Universal retreatment files (PTR) (Dentsply Maillefer, Ballaigues, Switzerland) were used to remove the root canal filling materials in addition to a solvent according to the following groups;

Group A: PTR (n=15),

Group B: PTR& Chloroform (n=15)

Group C: PTR& Orange oil (n=15)

Group D: PTR& Endosolv (Septodont, Cedex, France) (n=15).

For Group B, C and D: A total of 0.2 mL of each solvent was placed in the pulp chamber and left for 5 min prior to the use of the PTR.

Retreatment of root canal filling

Retreatment procedures were done using PTR in a crown-down technique. D1, D2, and D3 files were operated sequentially in a brushing motion till reaching the WL. The files were operated (X-Smart Plus electric motor) at speed of 500 rpm for D1 and 400 rpm for D2 and D3 and a torque of 3 N cm. 2.5 mL of 2.5% NaOCl was used for canal irrigation. Each file was used in three canals only. The procedure was considered complete when the files were able to reach the working length; remnants of the obturating material were not detected between the file flutes and clear irrigating solution was noted.

All samples (n = 60) were refilled with X4 gutta-percha points and accessories and AH Plus sealer in modified lateral compaction technique, and kept for 2 weeks at 37°C in 100% humidity.

Push-out bond strength Test

Samples were vertically positioned in chemically-cured acrylic resin. Roots were horizontally sectioned perpendicular to the long axis into three sections (coronal, middle, and apical) of 1 mm-thickness serial slices using low-speed precision diamond saw (IsoMet 4000, Buehler USA) of 0.6 mm thickness and 8inch diameter, rotating at speed of 2500 rpm under water cooling with a feeding rate of 10 mm/min. Digital caliper (Mituyoyo, Japan) of ± 0.02 mm accuracy was used to measure the thickness of the specimen. The coronal side of each root slice was marked to ensure proper alignment.

A custom-made metallic block was established to mountain each root slice with a circular cavity placed in the middle to allow for displacement of the obturating material. Then, compressive loading was applied on the specimens with a blunt stainless-steel plunger (0.5 mm in diameter) and cross-head speed of 1 mm/min using a 500N load cell till de-bonding occurred. The plunger tip was placed to contact the obturating material only without touching the radicular dentin. The plunger was mounted on a universal testing machine (Instron-model 3345-England) and computer software Bluehill 3 version 3.3 was used to record the data.

The maximum load applied on the specimens was recorded in Newton (N) at the time of dislodgment by a computer and converted to mega pascal (MPa).

The value detected was divided by the adhesion surface area of the filling material as follow:

Push-out bond strength (MPa) = Maximum load (N) / Adhesion area (mm^2)

Adhesion area= $2\Pi rh$

$\Pi = 3.14$.

r = Root canal radius in millimetres

h = Root dentin specimen thickness in millimetres

Values of each group were recorded, and the mean and standard deviation values were calculated.

Statistical analysis

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

RESULTS

Repeated measures ANOVA results

Repeated measures ANOVA results for the effect of different variables on mean push-out bond strength presented in table (1). The results showed that solvent (regardless of root level) showed a statistically significant effect on the mean push-out bond strength (*P*-value <0.001). Root level (regardless of solvent) had a statistically significant effect on mean push-out bond strength (*P*-value <0.001). The interaction between the two variables had no statistically significant effect on mean push-out bond strength (*P*-value = 0.887). Since the interaction between the variables is non-statistically significant, so the variables are independent from each other.

Effect of solvent regardless of root level

The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between push-out bond strength (MPa) with different solvents regardless of root level presented in table(2).

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)*
Solvent	59.545	3	19.848	160.357	<0.001*	0.945
Root level	42.886	2	21.443	161.749	<0.001*	0.852
Solvent x Root level interaction	0.304	6	0.051	0.382	0.887	0.039

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

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

PTR		PTR& Chloroform		PTR& Orange oil		PTR& Endosolv		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD	Mean	SD	Mean	SD		
5.73^{A}	0.8	3.58^{D}	0.66	5.15^{B}	0.76	4.77^{C}	0.83	<0.001*	0.945

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

Regardless of root level; there was a significant difference between solvents (*P*-value <0.001). Pair-wise comparisons among solvents revealed that PTR showed the highest significant mean push-out bond strength. Orange oil showed significantly lower mean push-out bond strength followed by Endosolv. Chloroform showed the lowest significant mean push-out bond strength.

Effect of root level regardless of solvent

Regardless of solvent; there was a statistically significant difference between root levels (*P*-value <0.001). Pair-wise comparisons between levels revealed that coronal root level showed the statistically significantly highest mean push-out bond strength. Middle root level showed statistically significantly lower mean push-out bond strength. Apical root level showed the statistically significantly lowest mean push-out bond strength. Table (3)

Effect of different interactions on push-out bond strength

a) Comparison between solvents:

At the coronal as well as middle root levels; there was a statistically significant difference between root levels (*P*-value <0.001) and (*P*-value <0.001), respectively. Pair-wise comparisons between techniques revealed that PTR showed the statistically significantly highest mean push-out bond strength. There was no statistically significant difference between orange oil and Endosolv; both showed statistically significantly lower mean values. Chloroform showed the statistically significantly lowest mean push-out bond strength.

At the apical root level; there was a statistically significant difference between solvents (*P*-value <0.001). Pair-wise comparisons between solvents revealed that control showed the statistically significantly highest mean push-out bond strength. Orange oil showed statistically significantly lower mean push-out bond strength followed by Endosolv. Chloroform showed the statistically significantly lowest mean push-out bond strength.

b) Comparison between root levels:

As regards control, orange oil as well as Endosolv; there was a statistically significant difference between root levels (*P*-value <0.001), (*P*-value <0.001) and (*P*-value <0.001), respectively. Pair-wise comparisons between levels revealed that coronal root level showed the statistically significantly highest mean push-out bond strength. Middle root level showed statistically significantly lower mean push-out bond strength. Apical root level showed the statistically significantly lowest mean push-out bond strength.

While with Chloroform; there was a statistically significant difference between root levels (*P*-value <0.001). Pair-wise comparisons between levels revealed that coronal root level showed the statistically significantly highest mean push-out bond strength. There was no statistically significant difference between middle and apical root levels; both showed the statistically significantly lowest mean push-out bond strength values. Table 4

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

Coronal		Middle		Apical		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD	Mean	SD		
5.72 ^{A}	0.92	4.56 ^{B}	0.88	4.14 ^{C}	0.81	<0.001*	0.852

: 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 (MPa) values with different interactions of variables

Root level	PTR		PTR& Chloroform		PTR& Orange oil		PTR& Endosolv		*P*-value (Between solvents)	Effect size *(Partial eta squared)*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Coronal	6.7 [AE]	0.5	4.42 [CE]	0.33	6.02 [BE]	0.47	5.75 [BE]	0.14	<0.001*	0.839
Middle	5.47 [AF]	0.36	3.3 [CF]	0.28	4.93 [BF]	0.46	4.55 [BF]	0.38	<0.001*	0.838
Apical	5.04 [AG]	0.18	3.02 [DF]	0.15	4.5 [BG]	0.24	4.01 [CG]	0.52	<0.001*	0.865
P-value (Between root levels)	<0.001*		<0.001*		<0.001*		<0.001*			
Effect size *(Partial eta squared)*	0.783		0.72		0.752		0.796			

: Significant at $P \leq 0.05$,

A,B,C,D superscripts in the same row indicate statistically significant difference between solvents

E,F,G superscripts in the same column indicate statistically significant difference between root levels

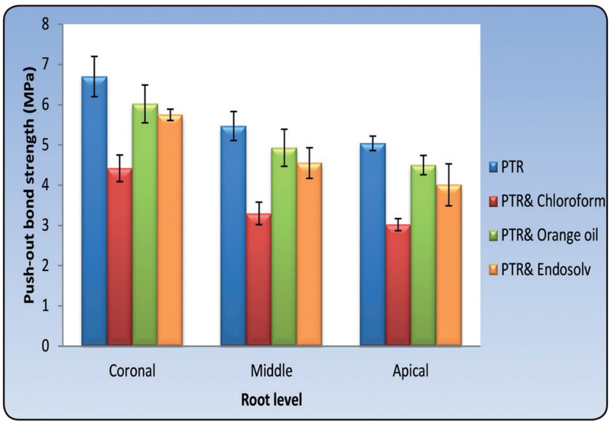

Fig. (1) Bar chart representing mean and standard deviation values for push-out bond strength

DISCUSSION

Non-surgical retreatment has been considered the first choice in treating failed endodontic cases. Removal of gutta-percha and sealer from root canal is essential to ensure complete removal of preexisting bacteria, thereby, enhancing the chances of healing and success of the retreatment procedure. The success rate of non-surgical retreatment has been reported to vary from 50- 90% [14, 15]. This was attributed to the fact that none of the present techniques is capable of providing completely clean canal walls [16]. Removal of existing filling can be done by various ways solely or by a combination of two or more methods, mechanical, chemical, or thermal methods are the common methods. Many studies have reported the efficacy and safety of rotary nickel–titanium retreatment files in filling removal [17], Thus, PTR system used in this study.

One of various techniques for facilitating removal of primary endodontic obturation is chemical dissolution of gutta-percha using solvents [18].

One of the most commonly solvents is chloroform which proven its ability in removing root canal filling materials, ceramic and epoxy resin sealers 19, 20. However, there have been controversies about its use in the practice of dentistry because of its cytotoxic effect [21].

Orange oil had drawn attention and was considered a good alternative to chloroform with close results of efficacy in dissolving root canal obturating material. It was proven to be safe, biocompatible and non-carcinogenic [22].

Endosolv R has been recommended in the removal of resin-based sealers (AH Plus), which creates a great challenge due to the difficulty in the removal of deeply penetrating resin tags in the dentinal tubules [23]. It contains co-solvents as formamide and 2-phenylethanol, designed for softening Resorcinol-formaldehyde resin [24]. Recently, Endosolv has been introduced to the market to replace two Endosolv E and Endosolv R; thereby, providing one product capable of removing both eugenol and resin based root canal sealer.

On the other hand, gutta-percha solvents can inevitably alter the histochemical composition of the dentin surface when comes in contact with the canal walls for a period of time during the retreatment process[7, 12]. Thus, the impact of chemical solvents on the bond strength of AH Plus sealer to the root canal dentin following retreatment was evaluated using the push-out test.

Despite, the use of solvents enhanced the removal of the filling material they were associated with lower bond strength values. In this study, the tested solvents negatively affected the bond strength to root canal dentin. The results were in accordance with Erdemir et al [7] and Palhais et al [25]. Even though, the solvents enabled the removal of the obturating materials, they created a layer on the root canal walls [26] that affected the sealer penetration into the dentinal tubules and reduced its bond strength. Several gutta-percha solvents alter the chemical structure of dentine. Changes in the original Calcium/Phosphorous ratio between organic and inorganic components cause variation in the permeability and solubility of root canal dentine and affect the adhesion quality of different dental materials to dentine [27-29].

Regarding the bond strength of different solvents to root canal dentin, there was a significant difference between Endosolv, orange oil on one side and chloroform on the other side. This could be attributed to the similar dissolution capacity of Orange oil and Endosolv as both have a softening action on the gutta-percha rather than dissolving action of chloroform hence gutta-percha became easier to be removed using the rotary files.

Also, the dissolving action of chloroform leads to leaving more residues on the canal walls. It shows fast evaporation, causing the use of more solvent, creating a messy and inconvenient treatment procedure [20]. Erdemir et al. [30] found a significant decrease in the magnesium levels after the use of chloroform and halothane. Topcuoglu et al. [31] stated that the use of chloroform in the root canal decreased the bond strength of all sealers including epoxy resin-based (AH Plus). While, the use of orange oil and eucalyptol did not have an impact on the bond strength of the root canal sealers. Roberts et al, [32] showed the efficiency of Endosolv R in removing AH Plus sealer from the pulp chamber.

The results of the present study showed that that root canal filling materials removed using PTR system without solvent recorded the highest bond strength scores in all tested root levels. This may be attributed to the ability of rotary files to produce heat via torque and frictional forces which facilitates removal of softened gutta-percha [33].

Additionally, PTR system is able to remove large amounts of guttapercha through the instrument spirals, which provides both cutting and softening actions. Moreover, the rotary file design provides negative cutting angle and absence of radial land exert a cutting not a planning action on gutta-percha, this cutting action may facilitate removal of gutta-percha [34]. The current study revealed that using PTR system with solvent recorded lower scores of bond strength for all tested root sections. This might be related to that the use of solvents with rotary system causes more soften gutta-percha which make the dentinal tubules more prone to be blocked by the softened filling [35]. This might be explained by the fact that solvents softens obturation materials, breaking it into small fragments and makes it more flowable 36, this softened obturation materials can be easily packed into dentinal tubules and irregularities from where they can no longer be reached; thus, the removal of filling material become extremely difficult and time consuming [18]. This finding is in accordance with the results obtained by several authors [3, 18, 35, 37, 38] as they concluded that solvents leave a thin film of softened gutta-percha, residual filling materials on root canal walls.

Thereby, the mechanical removal of AH plus sealer without using solvent is considered an appropriate retreatment technique in terms of the bond strength of refilling materials. When the root canal sections were compared, the present results revealed that the lower scores of bond strength were found in the apical third than in the middle and coronal thirds, irrespective of the type of solvent used. This may be attributed to the variable progressive taper of PTR system resulting in cutting the superficial layer of coronal dentine [38], and greater anatomical variations in the apical third [33], which is a critical zone, demanding a considerable enlargement for the cleaning and shaping procedure, and difficulty of instrumentation in this area. Paque et al,[39] stated that the decrease in the bond strength in the corono-apical direction can be explained by the reduction of the tubule density in an apical direction, which decrease the sealer penetration into the smaller tubules in the apical third.

CONCLUSION

Different gutta-perch solvents had a negative impact on the bond strength of AH Plus sealer to root canal dentin.

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