Push-Out Bond Strength of Calcium Silicate-Based Sealer to Root Canal Walls After Three Retreatment Techniques

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Abstract

Objective: To compare the push-out bond strength of calcium silicate-based sealer to root canal walls after three retreatment techniques in teeth with initial treatment with gutta-percha/AH plus.

Materials and methods: Forty human single-rooted maxillary anterior teeth were decoronated to standardize with a root length of 16 mm. The roots were randomly divided into four groups of 10 roots each. The control group was performed without retreatment. The experimental groups were obturated with AH Plus® followed by retreatment using three retreatment techniques as follows; Mtwo R®, Mtwo R® with GuttaClear, and Mtwo R® with Xylene after 7 days of initial treatment. All samples were re-obturated with iRoot SP®and were stored for 7 days. Sections of 2 mm thickness was performed perpendicularly to the long axis to obtain 3 slices per root, and then loaded by a Universal Testing Machine until dislodgement. The maximum load was recorded in MPa and specimens were inspected for failure mode. The data were analyzed by One-way ANOVA and Tukey's Test with a significance level of 0.05.

Results: The highest bond strength was expressed in non-retreatment group followed by retreatment groups. From statistical analysis, at the coronal and middle levels, the bond strength between control group and Mtwo R group did not show significant differences, however, the Mtwo R group was superior to Mtwo R with both gutta-percha solvents. At the apical level, no statistically significant difference was noticed. The pattern of filling dislodgement as cohesive failures was predominantly observed.

Conclusion: The use of rotary instrument to remove gutta-percha/AH plus is appropriate for retreatment gutta-percha/calcium silicate in term of push-out bond strength.

Keywords: Adhesiveness, Biocompatible materials, Endodontics, Epoxy resin-based root canal sealer

Received Date: May 30, 2025

Revised Date: Jul 15, 2025

Accepted Date: Jul 16, 2025

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Introduction

The removal of the existing root canal filling, which facilitates disinfection and instrumentation from the failed primary endodontic treatment, is one of the steps for non-surgical endodontic retreatment (1). Residual gutta-percha after root canal retreatment acts as a mechanical barrier to necrotic tissues or bacteria and to prevent irrigating solutions, intracanal dressings, and root canal filling material from attachment to the canal walls (2), The consequences may affect the success rate of root canal retreatment (3). Complete removal of root canal filling material appears to be essential role in retreatment procedures (4).

AH plus is one of the most common sealers used in the initial treatment. Although the treatment results of gutta-percha/AH plus are promising (5), some treated teeth need retreatment to correct the unsolved problems. Martins, et al. (6) demonstrated that either continuous or reciprocating rotary instruments were unable to clean the root filling of gutta-percha,/AH plus completely due to sealer penetration into dentinal tubules. This result was confirmed by the study of Simsek, et al.(7), which showed the number of debris free-dentinal tubules after retreatment in resin-based sealer group was still low due to presence of resin tag in dentinal tubules. These circumstances should be one of causes in failure of retreated cases, which imply the adaptation reduction of new root canal filling to dentinal walls.

Several reports showed that the quantity of the remaining root canal filling after filling removal varied from systems of NiTi rotary instruments used (8-10) and the size of the last instrument used (11). Madhu and his colleagues revealed that Mtwo R instruments had maximum efficacy for the removal of root filling materials over ProTaper® retreatment files, WaveOne® files, and Hedstrom files (12).NiTi rotary file selection, both type and size, may be the decisive factor for retreated canal preparation.

In retreatment procedure, the use of new endodontic sealer is aimed for the reconstruction the connection between root canal walls and root canal filling. Several endodontic sealers are used for endodontic retreatment such as zinc oxide eugenol sealer, epoxy resin sealer, calcium hydroxide-based sealer as well as calcium silicate-based sealer. Selection of appropriate root canal sealer may be one of important points for success rate increase (13-14), Veeramachaneni, et al (15) reported that push-out bond strength of bioceramic sealer is higher than epoxy sealer in various clinical situation. The results from previous studies showed good sealability in primary endodontic treatment, calcium silicate-based sealer may be the sealer of choice in retreatment. Push-out bond strength is generally used to evaluate interfacial bond strength between the materials and root canal walls (16-17) in the endodontic field. This method has the advantage of permitting the evaluation of low bond strength, even like root canal sealer (18).

As mentioned earlier, various gutta-percha removal techniques resulted in different root canal surface and eventually different bond strength which vary to the type of initial sealer and retreated sealer. Yavari et al. (19) showed that AH plus used as a initial and retreated sealer exhibited higher bond strength than MTA-based sealer with same situation. Da Rosa et al. (11) demonstrated that additional apical enlargement from initial apical size may increase the root canal-free surface, which may create more bond strength of each sealer. Further studies are required to investigate the bond strength properties of calcium silicate-based sealer in retreatment in case of additional apical enlargement and gutta-percha solvent use.

The bond strength of calcium silicate sealer is generally created from the material reaction with humidity in dentinal tubules to form hydroxyapatite which grows both on the dentin sealer interface and deep inside the tubules (20). The study of Ersahan and Aydin (21) showed that iRoot SP® sealer had higher push-out strength than resilon/epiphany. Several studies showed that the use of gutta-percha solvent, both organic and inorganic solvent, led to more residual root filling or root canal walls than use of endodontic file only (12,22-23). No studies, involved additional apical enlargement combined with gutta-percha solvent, on push-out bond strength were performed. Thus the present study was intended to assess the push-out bond strength of calcium silicate-based sealer to the retreated root canal walls after three retreatment techniques in teeth with initial treatment with gutta-percha/AH plus.

Materials and Methods

The research was authorized by the Human and Research Ethics Committee of Srinakharinwirot University (SWUEC-661003). The study was conducted in accordance with the principles of the Declaration of Helsinki. A G*Power calculation (software version 3.1.9.4) was used to calculate the sample size based on a previous study done by Shokouhinejad et al. (24) using an effect size of 0.70 with a power of 0.80 at a statistical significance level of 0.05 to determine a minimum sample size of 10 in each group.

Forty extracted human single-rooted maxillary anterior teeth were chosen and kept in 0.1% thymol solution. Roots with an open apex, root curvature or root fracture were excluded. Digital periapical radiographs (Focus™ Intraoral x-ray, KaVo, Tuusula, Finland) were taken in buccolingual and mesiodistal views to confirm the presence of a single root canal with a normal root canal.

All of them had crown removed at or below CEJ to standardize a root length of 16 mm. The maximum diameter of the root canal at coronal end was measured using a digital vernier caliper (Mitutoyo; Absolute DIGIMAX, Kanagawa, Japan) and the initial apical file size (IAF) was confirmed by insertion 30 K-file (K-file: Dentsply Sirona, North Carolina, USA) to the apex. To standardize the size of the specimen, any root with a coronal diameter less than 1.40 mm or greater than 1.50 mm or IAF larger than size 30 K-file was excluded.

After selection, all of them were submerged in acrylic resin block and then established the working length at 1 mm short from the apex. The Mtwo rotary system (Mtwo® file, Vereinigte DentalWerke:VDW, Munich, Germany) was operated under torque control 2 N/cm torque. Sequentially, the Mtwo rotary system was used until apical size 40/.06 of the root canal was reached. The canals were irrigated between each instrument with 5 mL of 2.5% sodium hypochlorite (M-Dent, Mahidol University, Bangkok, Thailand).

All of them were randomly distributed into four groups of 10 roots each according to the retreatment techniques.

Group I: Control group (Root canal treated teeth without retreatment)

In the control group, the root canals were continuously instrumented to 45/.04 M two® file. and rinsed with 3 mL of 17% EDTA (M-Dent, Mahidol University, Bangkok, Thailand) for 1 minute, 5 mL of 2.5% sodium hypochlorite and finally irrigated with 5 mL of distilled water. The root canals were dried with paper point and then obturated with single-matched cone gutta-percha (VereinigteDentalWerke:VDW, Munich, Germany) with premixed calcium silicate-based sealer (iRoot SP®, Innovative BioCeramix Inc, Vancouver, Canada) by using a syringe with a suitable tip inserted into the canal and gently placed the sealer 2 millimeters far from the apex, followed by putting a sealer-coated gutta-percha cone into the canal. The periapical radiograph was taken in two directions, buccolingually and mesiodistally, to confirm the quality of root canal filling. end of the filling was heated to make 2 mm space and filled by Cavit-G® (3M ESPE, St. Paul, Minnesota, USA) and stored in the container at 37°C and 100% humidity for 7 The coronal days.

Group II: Mtwo® (Retreatment with rotary Niti files)

Firstly, specimens in this group were rinsed with 3 mL of 17% EDTA for 1 minute followed by 5 mL of 2.5% sodium hypochlorite. The root canals were dried with paper points and initially obturated with single-matched cone with Epoxy resin-based sealer (AH Plus®, Dentsply DE Trey, Konstanz, Germany) under a warm vertical technique. The specimens were verified the quality of obturation and stored as group I.

After that period, the temporary stop was removed and gutta-percha underneath was removed using 25/.05 Mtwo® R instruments until reach the working length. To complete instrumentation, an additional 45/.04 Mtwo® file was used to remove residual materials. All of these procedures were performed under a dental operating microscope (Carl Zeiss OPMI ProErgo; Carl Zeiss Meditec AG, Jena, Germany) at 10x magnification to prove no filling remnant inside the root canal. All of the prepared root canals were rinsed with 3 mL of 17% EDTA for 1 minute, 5 mL of 2.5% sodium hypochlorite and finally irrigated with 5 mL of distilled water.

Group III: Mtwo® plus organic solvent (Retreatment with rotary Niti files and D-limonene)

The root canals were obturated as described in group II. After 7 days of storage, the gutta-percha was removed by Mtwo® instruments in conjunction with 0.5 mL of D-limonene (GuttaClear, M-Dent, Mahidol University, Bangkok, Thailand). Final instrumentation was performed to remove residual materials with 45/.04 Mtwo® file. All of these procedures were performed under a dental operating microscope at 10x magnification to prove no filling remnant visible inside the root canal.

Group IV: Mtwo® plus inorganic solvent (Retreatment with rotary Niti files and xylene)

All procedures were done as described in group III and were prove under microscope at 10x magnification, but 0.5 mL of xylene (M-Dent, Mahidol University, Bangkok, Thailand) was used as gutta-percha solvent.

Finally, specimens in the group II, III, and IV were obturated with gutta-percha and iRoot SP® and kept as the protocol presented in group I.

Push-out bond strength testing procedures

Each obturated retreated root was sectioned with the precision saw (IsoMet 1000 Precision Saw, Buehler Ltd, Lake Bluff, Illinois, USA) into three 2 mm-thick root slices, representing the coronal, middle, and apical levels. The sections were performed as shown in Fig 1. Each slice was examined for the completeness of the obturating material and measured the diameter of the lumen as shown in representative image (Fig 2).

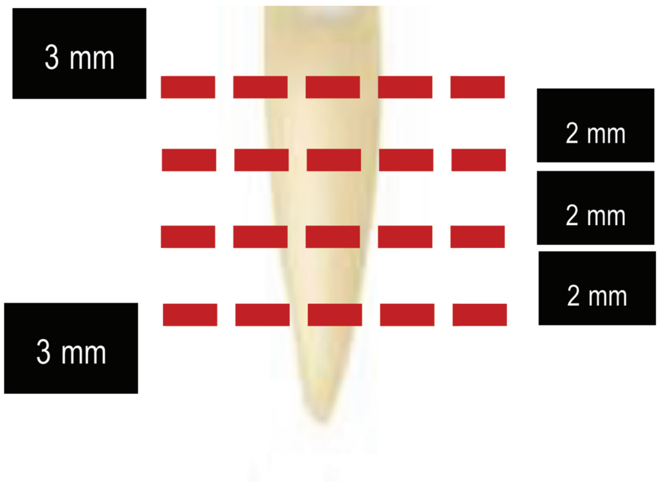

Fig 1. Slicing dentin thickness of the sample.

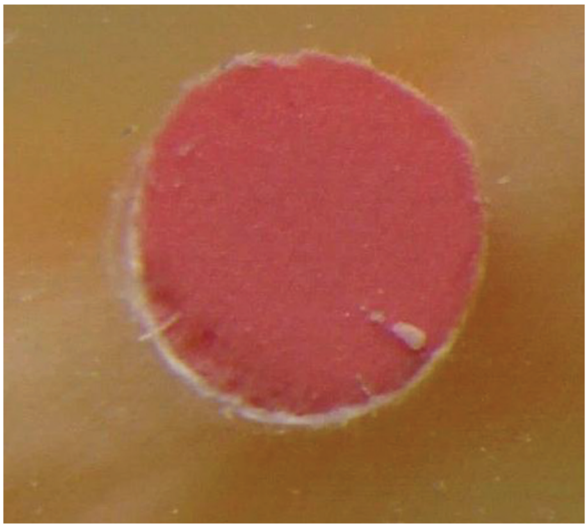

Fig 2. Representative images of root sliced specimens (x50).

Push-out test was performed by vertical loading with a Universal Testing Machine (EZ-Test; Shimadzu, Kyoto, Japan) at a crosshead speed of 0.5 mm/min as presented in Fig 3. The plunger sizes 1.0 mm, 0.8 mm, or 0.6 mm were assigned to different levels of slice to match the lumen diameter. The maximum load was recorded (N) and calculated into MPa.

$$\text{Push-out bond strength (MPa)} = \frac{\text{Maximum load (N)}}{\text{Area (mm}^2\text{)}}$$

$$\text{Push-out bond strength (MPa)} = \frac{\text{Maximum load (N)}}{\pi(R+r)h}$$

R = Mean radius of the coronal part in millimeter.

r = Mean radius of the apical part in millimeter.

h = Height relative to the tapered inverted cone in millimeter.

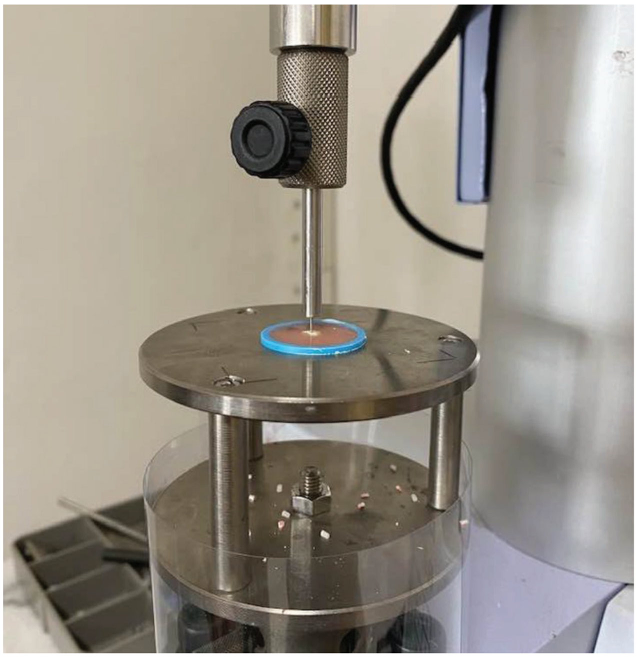

Fig 3. A vertical loading was delivered to the specimen using a Universal Testing Machine.

Determination of the mode of failure, the sample was examined under stereomicroscopy (Olympus EP50, Olympus optical Co., Tokyo, Japan) at x50 magnification as follows: adhesive failure, cohesive failure within the sealer, and mixed failure (25).

Statistical analysis

Statistical analysis of the push-out bond strength was performed using IBM SPSS Statistics 20 (SPSS Inc, Chicago, Illinois, USA), Normal distribution was determined using the Shapiro-Wilk test. Homogeneity of variance was checked using the Levene test and used one-way ANOVA and Multiple comparison test (Tukey's Test) for comparing the statistically significant difference with a 95% confidence interval.

Results

From Shapiro-Wilk's test and Levene test, they showed normal distribution and homogeneity of variance, respectively. Considering the level, no significant difference was found between only the control group and Mtwo R group in the coronal and middle level. However, push out bond strength in the apical level did not present significant difference among all experimental groups.

Considering the effect of solvents, the Mtwo R with both solvents group exhibited less bond strength compared to the group not use of solvents, control and Mtwo R group. Moreover, no statistically significant difference in bond strength could be observed between the two solvent groups.

At the middle level, the control group and Mtwo R alone group showed no significant difference in push-out bond strength, nevertheless, both groups surpassed observed in the Mtwo R with solvents groups. At the apical level, no significant difference was observed among all experimental groups.

The mean and standard deviation of the push-out bond strength of various retreatment techniques are presented in Table 1. The highest mean push-out bond strength was observed in the no retreatment group (group I).

Table 1. The push-out bond strength of the experimental groups

Experimental groups	Push-out bond strength (MPa, mean ± SD)		
	Coronal level	Middle level	Apical level
Group I	4.57 ± 0.82^{a}	3.47 ± 0.40*	2.12 ± 0.57$^{\alpha}$
Group II	4.01 ± 0.83^{ab}	3.02 ± 0.62*	2.00 ± 0.40$^{\alpha}$
Group III	3.56 ± 0.65bc	2.26 ± 0.54**	1.90 ± 0.66$^{\alpha}$
Group IV	3.31 ± 0.48c	2.12 ± 0.61**	1.75 ± 0.28$^{\alpha}$

Different superscript letters indicate a significant difference in the columns ($p < .05$).

All failure modes of all slices were presented in Fig 4. The majority type of failure was a cohesive failure which demonstrated some part of material remnants on the root canal wall.

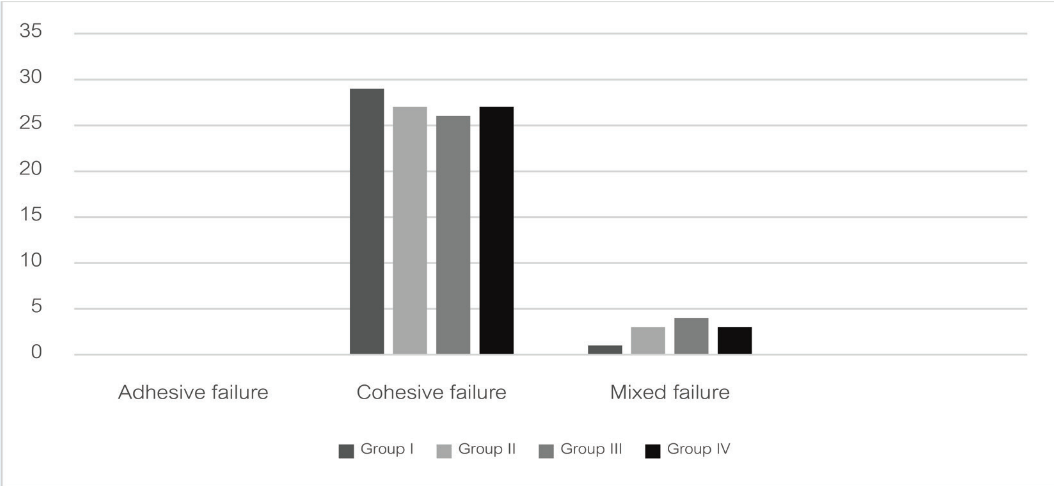

Fig 4. Graph presenting the analysis of failure modes for the experimented groups.

Discussion

Use of AH plus in initial treatment seem to have no effect on the push-pout bond strength of calcium silicate sealer (i rootSP) as a retreated sealer. One of these explanations is no interaction between both sealers while the other is effect of additional enlargement which made the close surface character between group I and group II in term of either smear layer or surface topography. Additional enlargement in group II should remove more resin tag extension in dentinal tubules as a described in Simsek, et al 's study (7).

These results confirmed the effect of additional enlargement of root canals, as shown in group II, which may allow more removal of both root canal dentin walls and residual root canal filling (26-28). This procedure resulted in the exposure more dentinal tubules and more cleaning of dentin (29), which facilitated the sealer penetration as presented in group I (30). These more intimacies in group I and II elevate the push-out bond strength by increasing frictional forces between the sealer and the root canal walls by ingrowth of hydroxyapatite crystal in the dentinal tubules (31). The results of the present study differ from Palhais and his colleagues' study (32), which showed a higher push-out bond strength in the no retreatment group. These differences could be attributed to the presence of additional root canal enlargement in our study. Although the AH Plus sealer exhibits variable penetration depth into dentinal tubules (33). The additional enlargement just one size allows greater contact of the instrument and dentin walls reducing residual filling not only in the apical level but also in the middle and coronal levels (11,34). It confirmed by the observational study that success rate of 90.4% after 2 years was observed after apical enlargement from size 40 to 60 (35).

A reduction in push-out bond strength of retreatment with both organic and inorganic solvents was aligned with the outcomes of several studies (24,32). They have highlighted the solvent-induced formation of a thin layer of softened gutta-percha covered the root canal walls and dentinal tubules, which reduces the adaptability of calcium silicate sealer to root canal walls, which is difficult to remove even in additional apical enlargement condition, thus impeding effective sealer penetration (22) and finally reduced reaction of calcium silicate with humidity in dentin. In addition, the complex and variable anatomy of the root canal system also significantly impacts the effectiveness of removing root filling and cleaning during root canal retreatment (28). Moreover, the smear of softened gutta-percha should be covered the dentin wall during the treatment, These situations impeded both material adaptability and product reaction with root canal (22,30).

The decreasing bond strength from the coronal to apical direction in all specimens was observed. It could be explained by the higher number and the larger diameter of dentinal tubules presented in the cervical area than middle and apical areas, respectively. These characteristics facilitated penetration enhancement of the new filling material into the dentinal tubules (36-37), which accomplished mechanical lock, potentially augmenting the retention of the root filling (38). Additionally, the lowest bond strength in the apical level may be from dentin composition, the least number and also the least opening of dentinal tubules in apical third of root canal. The dentin in these situations is difficult to make dentin surface improvement and good bond as well (39).

The pattern of filling dislodgement as cohesive failure was predominantly observed in specimens following the push-out bond test to all experimental groups, which is similar to the results of various studies (24,32,36). The explanation of the cohesive failures within the sealer in the control group was the strong adhesion of the calcium silicate-based sealer to radicular dentin. Similarly, the retreatment specimens, it can be attributed to the weak interaction between the two different sealers (AH Plus and calcium silicate-based sealers) (40). Moreover, the occluded remnants of initial root canal filling materials did not affect to the refilling materials (32).

In surrogate outcome, several techniques have been proved to be an importance to reflect the ongoing success of the treatment, sealability or leakage studies frequently was studied, nowadays, the results varied due to many affected factors. The push-out test measures the shear stress between the sealer and the root canal walls which is similar to the stress produced under clinical circumstances (41). This method is efficient and reproducible, and also measurable even in conditions where the bond strength is low (42). Moreover, it is possible to evaluate the different adhesion values for each level of the root canal. Thereby, this study was selected to test the push-out bond strength of sealer due to its reliability and accuracy by applying a force parallel to the bonding surface causing failure from the actual shear test, as well as simulating clinical scenarios closely (17). The major drawback of push-out bond test is difficult to control either geometric form or diameter, which can lead to inaccurate results and to standardize test (43-44). However, in this study, the size and geometry of each slice would be measured and confirmed before the test started.

This study focused on the impact of apical enlargement and use of different retreatment techniques on bondability of calcium silicate sealer in retreatment. Further research should be performed with new techniques for cleaning the retreated root canal walls, where difference in cleanliness was exhibited the bond strength may be increase and new protocol of retreated root canal cleaning may be developed.

Conclusion

The push-out bond strength between calcium silicate-based sealer and the root canal walls using various retreatment techniques was significantly different. The highest push-out bond strength was observed in the case of retreatment without solvent when using calcium silicate-based sealer.

Acknowledgement

No conflicts of interest

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