Push-out Bond Strength between Resin Core Material and Root Canal Dentin Contaminated by Different Types of Root Canal Sealers

Chamroonsri N Champirat T** Khongpreecha T***

Abstract

The aim of this study was to evaluate the effect of different root canal sealers contaminated in the root canal on the push-out bond strength between resin core material and root canal dentin. Forty-eight extracted single-rooted mandibular premolar teeth were randomly divided into four groups (n=12): group 1: control group, gutta-percha point only (no sealer); group 2: gutta-percha with zinc oxide eugenol-based sealer (MU sealer, M dent); group 3: gutta-percha with resin-based sealer (AH Plus®, Dentsply); group 4: gutta-percha with calcium hydroxide-based sealer (Apexit® Plus, Ivoclar Vivadent). The root canals were obturated with gutta-percha using warm vertical condensation technique and immediately restored with resin core material. The specimens were sectioned into 1 mm thick at the cervical and middle level of root canals. The push-out test was performed using a universal testing machine. The push-out pin diameter was 0.8 mm and 0.5 mm for testing at the coronal and the middle part of root. Failure mode was observed and classified into 3 types: adhesive, cohesive, and mixed failure. Data was statistically analysed by using Welch one-way ANOVA and Games-Howell test. There were significant differences of bond strength among most of the experimental groups at both cervical and middle levels (p<0.05). Except the coronal part, no significant difference was detected between AH Plus® - MU sealer groups and AH Plus® - Apexit® Plus sealer groups, and at the middle part, no significant difference was found between control - Apexit® Plus sealer groups and AH Plus® - MU sealer groups. The control group had the highest mean push-out bond strength at coronal and middle parts respectively (1.62±0.9, 1.43±0.74 MPa), followed by the Apexit® Plus sealer group (0.75±0.18, 0.97±0.50 MPa), AH Plus® sealer group (0.50±0.24, 0.38±0.18 MPa), and MU sealer group (0.27±0.09, 0.17±0.09 MPa). The predominant mode of failure was the adhesive failure while cohesive failure was not exhibited. It can be concluded that the contamination of different types of root canal sealers critically affected the push-out bond strength of resin core material in the root canal. The eugenol-based sealer had the strongest adverse effect on bond strength.

Keywords: *Push-out bond strength/ Root canal sealers/ Endodontically treated teeth/ Resin core material*

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Introduction

Considering the failure cause of endodontically treated teeth, it was found that the majority of the failure (59.4%) were prosthetic causes which were primarily from crown fracture, whereas only 8.6% were failure from endodontic causes.[1] Inappropriate restoration after root canal treatment was one of the causes of unrestorable crown fracture, especially at the cervical area of the tooth, resulting in the extraction of the damaged tooth.[2,3]

Restoration of root canal treated tooth should be appropriately achieved as soon as possible to enhance the strength of teeth and minimize the chance of cervical tooth fracture.[4] Factors associated with the strength of teeth are remaining tooth structure,[5] quality of organic and inorganic structure,[6] restoration method, and amount and direction of force that distributed through the teeth.[7] Moreover, another important factor to consider is bond strength between core material and dentin.[8]

Endodontically treated tooth can be restored through several methods, depending on the quality and quantity of the remaining tooth structure. Composite core with cuspal coverage should be considered in case of having less remaining cervical tooth structure in order to improve the strength of the tooth and reduce occurrence of cervical tooth fracture.[7, 9]

Nowadays, there are many types of core materials including amalgam, resin composite, and glass ionomer.

** Residency training program, General Dentistry, Faculty of Dentistry, Mahidol University, Bangkok*
*** Department of Advanced General Dentistry, Faculty of Dentistry, Mahidol University, Bangkok*

Resin composite is widely used as a core material due to its esthetic, favorable strength, and the ease of use.[10] However, the resin composite core materials need to be used in conjunction with dental adhesives which are technically sensitive.[11] Contamination of the adhesive layer will compromise the success of the restorations. Despite careful handling, contamination might inevitably occur at any step of the restoration procedure. One of the most common situations that causes unavoidable contamination is through residual root canal sealer on the dentin wall after the root canal treatment procedure.

Root canal sealers are classified into several groups. There are three types of sealers that are widely used in Thailand. Zinc oxide eugenol-based sealer has been the most popular sealer with a long history of usage and success because of its ability to eliminate bacteria in the root canal and the ease of handling. Calcium hydroxide-based sealer has the effect of inhibiting bacterial growth in the root canal and promoting healing of periapical lesions.[12] Resin-based sealer has also become very popular because of its good properties such as the ease of usage, good flow, and adhesion ability to root canal dentin.[13]

Many investigators have compared the effects of various types of sealer contaminated root canal dentin on the retention of post luted with resin cements. It was found that the eugenol-containing sealer inhibits polymerization of the resin cements.[14-16] However, some studies have shown that the type of sealer did not affect the post retention.[17] In previous studies,[14,15] the teeth mostly used in the studies had been restored a week after root canal treatment to reduce the effect of sealer contamination on the root canal wall. However, in some clinical situations, restoration is needed to be done immediately after root canal treatment in order to increase the strength of the teeth, particularly immature permanent teeth with thin cervical dentine or the teeth presented with cervical root resorption. During immediate restorative procedure, it is often found that the root canal wall is inevitably contaminated with sealers. Therefore, it is necessary to be able to choose the types of endodontic sealers appropriately, in order to reduce the adverse effect of the sealer on the bond strength between the core build up material and dentin.

From the literature review, there was no study that evaluated the effect of the different types of root canal sealers on the push-out bond strength when restoration is done immediately. Therefore, the aim of this study was to compare the bond strength between resin core material and root canal dentin of the teeth that were immediately restored after root canal obturation with different types of root canal sealer.

Materials and Methods

The study was approved by the local ethics committee (Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board, COE. No. MU-DT/PY-IRB 2018/023.0106)

Sample selection Forty-eight extracted human single-rooted mandibular premolar teeth were selected in this study. Each tooth was visually examined to verify an absence of root caries, cracks, fracture or resorption. The selected teeth must be at least 14 mm of the root length. Preliminary radiographs were taken to determine root canal anatomy and to exclude any teeth with complex root canal anatomy or history of root canal treatment. The teeth were cleaned to remove calculus or soft tissue remnants with ultrasonic scaler and hand scaling instruments and stored in 0.1% thymol solution. Each tooth was decoronated perpendicularly to the long axis at the level below to cementoenamel junction using a slow speed saw, water-cooled diamond disc (Isomet® Low speed saw, Buehler Ltd., Lake Bluff, NY) to achieve a 14-mm root length.

Endodontic procedures All root canals were prepared by a single operator. Each root canal was firstly explored by using a size 8-10 K-files (SybronEndo, Kerr, Mexico) until the tip of file was visible through the apical foramen, the working length was determined by deducting 1 mm from the length at apical foramen. The root canal preparation was performed by using crown-down technique with rotary Ni-Ti instruments (ProTaper Next, Dentsply, Switzerland) from the X1. 17/04, X2. 25/06, X3. 30/07 up to X4. 40/06 files. During these steps, the root canal was irrigated with 1 ml of 2.5% sodium hypochlorite (M Dent, Mahidol University, Thailand) when changing the Ni-Ti instruments. After that, the root canal was flushed with 2 ml of 17% EDTA (M Dent, Mahidol University, Thailand), followed by 5 ml of 2.5% sodium hypochlorite. Finally, the canal was dried with match paper points (Absorbent Paper points, Dentsply, Switzerland).

After canal preparation, the teeth were randomly allocated into 4 groups of 12 teeth (n=12). Then, they undergone canal obturation as follows;

Group 1: The root canals were obturated with gutta-percha point only, served as a control group

Group 2: The root canals were obturated with gutta-percha point and zinc oxide eugenol-based sealer (MU sealer, M dent, Mahidol University, Thailand)

Group 3: The root canals were obturated with gutta-percha point and resin-based sealer (AH Plus®, Dentsply, USA)

Group 4: The root canals were obturated with gutta-percha point and calcium hydroxide-based sealer (Apexit® Plus, Ivoclar Vivadent, Liechtenstein)

Tested materials in this study were summarized in Table 1. Root canal obturation was performed with match cone gutta percha size 40, taper 0.06 (Gutta-Percha Point, Dentsply, Switzerland) using warm vertical condensation technique. In groups 2-4, the root canal sealers were prepared according to the manufacturers' instructions and applied to 3-mm tip of match cone gutta percha. The root canal dentin was coated with sealer prior to root canal obturation, by brushing of the matched cone gutta percha on circumferential dentin wall from apex to coronal direction. After root canal obturation was completed, the excessive sealer was removed with endodontic spoon excavator.

Table 1 Type, composition and manufacturer of tested materials

Material	Type	Composition		Manufacturer
MU sealer	Zinc oxide eugenol-based	Powder: - Zinc oxide - Resin - Bismuth subcarbonate - Barium sulfate - Sodium borate	Liquid: - Clove oil	M Dent, Mahidol University, Bangkok, Thailand Lot. 61009
AH Plus®	Epoxy resin-based	Paste 1: - Bisphenol-A epoxy resin - Bisphenol-F epoxy resin - Calcium tungstate - Zirconium oxide - Silica - Iron oxide pigments	Paste 2: - Dibenzyldiamine - Aminoadamantane - Tricyclodecane-diamine - Calcium tungstate - Zirconium oxide - Silica - Silicone oil	Dentsply-Maillefer, Tulsa, OK, USA Lot. 1803000355
Apexit® Plus	Calcium hydroxide- based	Base: - Calcium hydroxide / Calcium oxide 36.9 %wt - Hydrated collophonium 54.0 %wt - Fillers and other auxiliary materials 9.1 %wt (highly dispersed silicon dioxide, phosphoric acid alkyl ester) Catalyst: - Disalicylate 47.6 %wt - Bismuth hydroxide / Bismuth carbonate 36.4 %wt - Fillers and other auxiliary materials 16.0 %wt (highly dispersed silicon dioxide, phosphoric acid alkyl ester)		Ivoclar, Vivadent, Schaan, Liechtenstein Lot. X17592

Restorative procedures Immediately after each tooth has done the root canal obturation step, 7-mm depth of root canal filling materials was removed with heated instrument (SybronEndo, Kerr, USA) and, therefore, 6-mm gutta percha was preserved within the root canal. The canal was continuously prepared by etching with 37% phosphoric acid (Scotchbond™ Universal Etchant, 3M ESPE, USA) for 15 seconds, rinsing with normal saline for 30 seconds, and drying with paper point. The dried root canal was conditioned with dentin bonding agent. The dual cured adhesive (Excite® F DSC, Ivoclar Vivadent, Liechtenstein) was applied in the canal and agitated for 20 seconds, and excess adhesive was eliminated with paper points. Then, the specimen was cured for 10 seconds using LED light curing unit (Bluephase®, Ivoclar Vivadent, Liechtenstein). Core build up material (Multicore® Flow, Ivoclar Vivadent, Liechtenstein) was applied into the root canal with intra-oral tip from bottom to top of root canal, then light polymerization was carried out for 40 seconds using LED light curing unit. After restorative procedure was completed, post-operative radiograph was taken to evaluate the quality of endodontic and restorative treatment. The specimen with poor quality was excluded. Then, all teeth were stored in 100% humidity at 37 ºC environment at least 24 hours before the tested period.

Specimen preparation Each tooth was sectioned horizontally with a slow speed saw, water-cooled diamond disc (Isomet® Low speed saw, Buehler Ltd., Lake Bluff, NY) to create a 1-mm thick specimen at coronal and middle regions of the root. The specimens representing the coronal part and the middle part were prepared by creating cut line at 12 mm and 8 mm from the apex respectively (Figure 1). To focus on each specimen, the diameter of resin core material was measured on both coronal and apical faces sides under a measuring microscope[18] (Nikon, measurescope MM11-C) and the thickness of specimen was measured by a digital caliper.

Mechanical testing The push-out test was performed with a universal testing machine (Shimadsu: EZ-S, 500N, 50N) by applying cross head speed at 0.5 mm/min from the apical to coronal direction until the dislodgement of resin core from the root section occured (Figure 2). The push-out pin was used as 0.8 and 0.5 mm in diameters, for testing the coronal and middle part respectively. The maximum failure load (N) that can push the resin core out of the root section was recorded for all specimens, then it was converted to the bond strength in MPa with the following formula:

$$P = \frac{F}{\pi(r_1+r_2)\sqrt{(r_1-r_2)^2+h^2}}$$

In this formula, F is the maximum failure load (N), π is the constant 3.14, r_1 is the apical part radius (mm), r_2 is the coronal part radius (mm) and h is the specimen thickness (mm) (Figure 3).

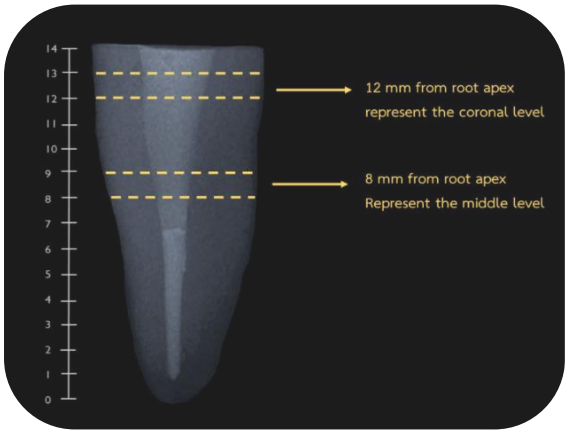

Figure 1 Demonstration of sectioning the root to produce specimens

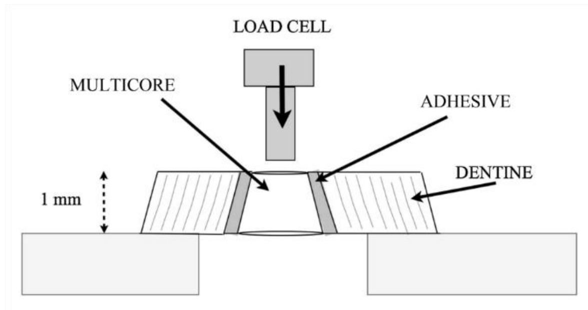

Figure 2 Demonstration of loading push-out test

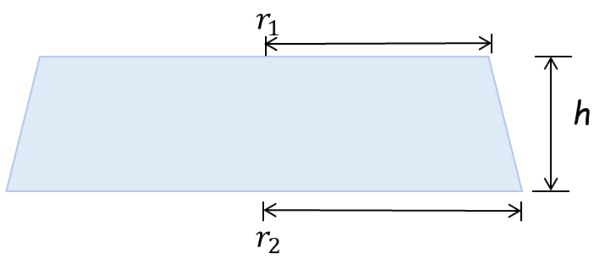

Figure 3 Demonstration of radius and thickness of specimen

Classification of failure mode The specimens were examined under a dental operating microscope (ZEISS, OPMI pico). Then, mode of failure was classified with image J (version k 1.45).

Statistical analysis The data was analysed using statistical software (SPSS Statistics 18.0, SPSS Inc, Illinois, USA). Shapiro-Wilks test and the Levene test were chosen to explore the normality of data and verify the homogeneity of variances respectively. Welch one-way analysis of variance (Welch one-way ANOVA) was used to determine any significant differences among all experimental groups (α=0.05), followed by Games-Howell test. Finally, mode of failure of each group was reported in percentage.

Results

Regarding the coronal part, the highest mean bond strength value was recorded in the control group (1.62±0.9 MPa). Among the three sealer groups, Apexit® Plus sealer group (0.75±0.18 MPa) displayed the highest mean bond strength, followed by AH Plus® sealer group (0.50±0.24 MPa), while the lowest mean bond strength was detected in MU sealer group (0.27±0.09 MPa) as shown in Table 2. Welch one-way ANOVA revealed significant differences among most of the groups (P<0.05). No significant difference was detected between the AH Plus® group - MU sealer group and AH Plus® group - Apexit® Plus sealer group (P>0.05).

Similarly, at the middle part, the control group had the highest mean push-out bond strength (1.43±0.74 MPa), followed by the Apexit® Plus sealer group (0.97±0.50 MPa), AH Plus® sealer group (0.38±0.18 MPa), and MU sealer group (0.17±0.09 MPa) respectively. No significant difference was found between the control group - Apexit® Plus sealer group and AH Plus® group - MU sealer group (P>0.05).

Table 2 Means push-out bond strength and standard deviations (SD) at coronal and middle parts of different groups (MPa)

Group (N=12)	Mean ± SD	
	Coronal Part	Middle Part
Control	1.62 ± 0.9	1.43 ± 0.74
MU sealer	0.27^{b} ± 0.09	0.17^{c} ± 0.09
AH Plus®	0.50^{ab} ± 0.24	0.38^{c} ± 0.18
Apexit® Plus	0.75^{a} ± 0.18	0.97 ± 0.50

Mean values designated with the same superscript are not significantly different (P>0.05)

The mode of failure was analyzed in each group and adhesive failure was found to be a majority among the groups. Interestingly, there was no cohesive failure detected as shown in Table 3. At the coronal part, there were 4 samples (33.33%) of the control group and 2 samples (16.67%) of the AH Plus® group presented with mixed type of failure respectively. Whereas, there were only adhesive failure in all experimental groups at the middle part.

Table 3 Mode of failure for each group

Group (N=24)			Mode of failure		
			Cohesive	Mixed	Adhesive
Control	Coronal	Count	-	4	8
		%	-	33.33	66.67
	Middle	Count	-	-	12
		%	-	-	100
MU sealer	Coronal	Count	-	-	12
		%	-	-	100
	Middle	Count	-	-	12
		%	-	-	100
AH Plus®	Coronal	Count	-	2	10
		%	-	16.67	83.33
	Middle	Count	-	-	12
		%		-	100
Apexit® Plus	Coronal	Count	-	-	12
		%	-	-	100
	Middle	Count	-	-	12
		%	-	-	100

Discussion

This study was designed to simulate the actual situation of clinical endodontic treatment, in which contamination of the sealer at the dentin wall after root canal filling is often found. Contamination of the sealer may affect the adhesion of restorative material to tooth structure, especially in case wherein immediate restoration after root canal fillings is required.

Micro-push out bond strength test has been modified from shear punch test, in order to evaluate the bond strength in root canal. The load is directly applied on the tested material in root canal and fracture is occurred parallel to the bonded interface, resulting in a true shear strength outcome.[19, 20] Therefore, the micro push-out bond strength has the ability to better closely simulate the clinical conditions.

This method provides uniform stress distribution, low percentage of premature failure, and enables to test for regional difference in the root canals.[21] The low level of bond strength can be effectively recorded and reproducible. Therefore, micro-push out bond strength test was selected to be used in this study to evaluate the bond strength between the core material and the root canal wall as in previous studies.[14,15,17,22,23]

The push-out bond strength between the resin core material and the root canal wall after completing root canal obturation with gutta percha and calcium hydroxide-based sealer showed the highest number in this experimental sealer groups. This can be explained by the process of acid etching and rinsing before applying the resin core material to the root canal. Calcium hydroxide-based sealer, which has high water and acid solubility properties,[24, 25] could be washed off easily. Lesser sealer contaminated on the dentin wall could help increase bond strength in this group. However, the surface of the calcium hydroxide was eroded when exposed to the dentin primers,[23,26] which might cause accidental contamination during the bonding technique and affect adhesion. Thus, the mean push-out bond strength of this group was lower than that in the control group. Similar finding was reported by Demiryürek EÖ et al.,[23] who studied the effects of different endodontic sealers on the bond strength of fiber post cemented with adhesive resin cement. The results showed that the calcium hydroxide group had significantly higher push-out bond strength than the eugenol and resin-based sealer groups. In contrast, other researchers[14,15] have observed that no significant differences were found between calcium hydroxide and resin-based group when the posts were luted with adhesive resin cement. Nevertheless, unlike the present study, almost previous studies have investigated the push-out bond strength of post within root canal when the sealer was completely set.

Specimen prepared after complete root canal obturation with zinc oxide eugenol sealer had the lowest mean push-out bond strength as assumed in the research hypothesis and as reported in several studies.[14,17,23] Zinc oxide eugenol sealer consisted of zinc oxide powder and eugenol. When sealer was prepared, they form a zinc eugenolate matrix with unreacted eugenol molecules trapped inside. Because of reversible reaction, the entrapped eugenol molecules were released again when the set sealer contacted the fluid in the dentinal tubule, and the released eugenol could then penetrate into smear layer and dentinal tubules.[27] Eugenol may react with free radicals by seizing free radicals that occur during polymerization process of the resin material,[28] resulting in incomplete polymerization and low bond strength between the resin core material and dentin wall.

The group using resin-based sealer in the root canal obturation process showed high push-out bond strength between resin core material and root canal dentin, however, the bond strength was lower than the group using calcium hydroxide-based sealer. AH Plus® possesses good physical properties such as great stability, low shrinkage,[29] and good flow.[30] Its flow ability allowed the sealer to penetrate well into the dentinal tubule that may interfere with the binding of resin core material to dentin.

The specimens were prepared from both coronal segment and middle segment of the roots in this experiment. Though, the coronal part of root canal seems to be more clinically relevant than the middle part, with the purposed of studying bond strength between core material and dentin. Due to the limitation of testing machine, round-shaped head pin does not match to coronal root canal morphology which is naturally oval. This might affect transmission of force during the experiment and accuracy in measuring the push-out bond strength. Whereas, the middle part is rounder because it was being shaped by rotary instrument in the process of root canal preparation.

In this study, the mean push-out bond strength between resin core material and root dentin in cervical region was higher than that of the middle region of root. Adhesion of the resin material in the root canal depends primarily on the quality of the hybrid layer.[31] For this reason, surface cleaning and moisture control in the root canal should be considered as a major factor in achieving good quality of hybrid layer. The middle level of the root canal was anatomically smaller and narrower than the cervical region.

Thus, removal of residual sealers and control of moisture in the root canal could be hardly achieved. Hence, the push-out bond strength between resin core material and the root dentin at the middle level was lower than that in the cervical level. On the other hand, water is crucial for complete setting reaction of Apexit® Plus sealer. During this reaction, higher temperature and relative humidity can accelerate the reaction and there would be no by product that prevents polymerization of core material.[32] Therefore, the greater residual moisture in root canal can bring about higher push-out bond strength at the middle level in Apexit® Plus sealer group. For this reason, a significant difference of bond strength was detected between calcium hydroxide-based sealer and resin-based sealer group at the middle part of root canal.

However, the mean push-out bond strength in this study was relatively low in all experimental groups compared to many previous studies. Unlike many previous studies,[14,15,17,23] the restoration method used in this study was designed to restore the teeth with resin core material without using the post. According to previous studies, the bond strength between resin cement retained post and the root canal wall was tested. The teeth must be drilled to create the post space, causing partial removal of the contaminated sealer on the root canal wall. In addition to the setting time of endodontic sealers that were about 1-3 weeks and fully set at the end of 4 weeks,[33] the immediate restoration of the teeth with remaining unset sealers on the root canal wall might get worse bonding because unset sealers may contaminate to root canal dentin, which result in lower bond strength.

According to the physicochemical properties[24] and adverse effects of endodontic sealers,[23,26,27] resin-based restoration should not be an appropriate method to use immediately. Nevertheless, the immediate restoration may be required continuously in some clinical situations, in order to enhance the strength of the immature or weakened teeth, reduce possibility of teeth fracture, and save overall treatment time.

Regarding the fracture analysis, adhesive failure was displayed as predominant type in all groups. The mixed failure was indicated in a minority, only at coronal part of the control group and resin-based sealer group, and there was no cohesive failure exhibition (Table3). Thus, it was represented that the occurrence of weak bond was mostly seen between the resin core and root dentin, inferring some interferences might have been occurred during bonding process as a result of sealer characteristics. It was noticed that the higher push-out bond strength obtained may related to more prevalence of mixed failure.

From the present study, it was revealed that every type of sealer had adverse effect on the bond strength of resin core material to the root dentin. Owing to the well controlling throughout the experimental process, which was done by one operator, it could be indicated that the type of sealer was the important related factor to concern. Besides the proper selection of the type of sealer in case of immediate restoration, it is necessary to consider how to minimize the contamination of the sealer in the root canal before restoring the tooth which will be an interesting issue for further study.

Conclusion

Within the limitations of this study, it was determined that endodontic sealers significantly decrease the push-out bond strength of resin core material in the root canal. Among the sealer groups, the push-out bond strength between resin core material and root canal dentin was adversely affected when eugenol-based sealer was used, while calcium hydroxide-based sealer had the least interference to the push-out bond strength.

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Corresponding Author

Thanawut Khongpreecha

Department of Advanced General Dentistry,

Faculty of Dentistry, Mahidol University,

Phayathai, Bangkok 10400.

Tel.: +66 2200 7853 4

Fax.: +66 2200 7852

Email: thanawut.kho@mahidol.ac.th

ความแข็งแรงกดออกของวัสดุสร้างแกนฟันชนิดเรซินกับผนังคลองรากฟันที่ปนเปื้อนด้วยซีลเลอร์ชนิดต่างๆ

ณัฐวรา จำรูญศรี ธารี จำปีรัตน์** ฐานวุฒิ คงปรีชา***

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบผลของซีลเลอร์ต่างชนิดที่ปนเปื้อนในคลองรากฟันต่อความแข็งแรงกดออกของวัสดุสร้างแกนฟันชนิดเรซินกับผนังคลองรากฟัน โดยทำการศึกษาในฟันกรามน้อยล่างที่ถูกถอน จำนวน 48 ซี่ แบ่งด้วยวิธีสุ่มออกเป็น 4 กลุ่ม (n=12) กลุ่มที่ 1 เป็นกลุ่มควบคุมซึ่งอุดคลองรากฟันด้วยกัตทาเพอร์ชาเพียงอย่างเดียวโดยไม่ใช้ซีลเลอร์ กลุ่มที่ 2 อุดคลองรากฟันด้วยกัตทาเพอร์ชาร่วมกับซิงค์ออกไซด์ยูจินอลซีลเลอร์ (MU sealer, M dent) กลุ่มที่ 3 อุดคลองรากฟันด้วยกัตทาเพอร์ชาร่วมกับเรซินซีลเลอร์ (AH Plus®, Dentsply) และกลุ่มที่ 4 อุดคลองรากฟันด้วยกัตทาเพอร์ชาร่วมกับแคลเซียมไฮดรอกไซด์ซีลเลอร์ (Apexit® Plus, Ivoclar Vivadent) จากนั้นทำการบูรณะฟันด้วยวัสดุสร้างแกนฟันชนิดเรซินทันทีหลังจากอุดคลองรากฟันเสร็จ เตรียมชิ้นตัวอย่างด้วยเครื่องตัดฟันกรอช้าให้มีความหนา 1 มิลลิเมตร ที่ตำแหน่งกลางฟันและคอฟัน นำชิ้นตัวอย่างไปทดสอบค่าความแข็งแรงกดออกด้วยเครื่องทดสอบแรงดึงแรงอัด ใช้หัวกดขนาดเส้นผ่านศูนย์กลาง 0.8 มิลลิเมตร สำหรับชิ้นตัวอย่างตำแหน่งคอฟัน และขนาดเส้นผ่านศูนย์กลาง 0.5 มิลลิเมตร สำหรับชิ้นตัวอย่างตำแหน่งกลางฟัน กดด้วยความเร็ว 0.5 มิลลิเมตร/นาที และจำแนกความล้มเหลวการแตกหักออกเป็น ความล้มเหลวแตกหักในวัสดุสร้างแกนฟันชนิดเรซินหรือในเนื้อฟัน ความล้มเหลวแตกหักระหว่างวัสดุสร้างแกนฟันและเนื้อฟัน และความล้มเหลวแตกหักร่วมกันทั้งสองแบบ ทำการวิเคราะห์ข้อมูลโดยใช้สถิติทดสอบของเวลช์ และ เจมส์ โฮเวลล์ (Welch one-way ANOVA, Games-Howell test) จากการศึกษาพบว่าค่าเฉลี่ยความแข็งแรงกดออกในแต่ละกลุ่มมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ยกเว้น ระหว่างกลุ่มเรซินซีลเลอร์ กับกลุ่มซิงค์ออกไซด์ยูจินอลซีลเลอร์และแคลเซียมไฮดรอกไซด์ซีลเลอร์ที่ระดับคอฟัน และระหว่างกลุ่มควบคุมกับกลุ่มแคลเซียมไฮดรอกไซด์ซีลเลอร์ และกลุ่มเรซินซีลเลอร์กับกลุ่มซิงค์ออกไซด์ยูจินอลซีลเลอร์ที่ระดับกลางฟัน ที่ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ พบว่า กลุ่มควบคุมมีค่าเฉลี่ยความแข็งแรงกดออกสูงที่สุดทั้งที่ระดับคอฟันและกลางฟัน (1.62±0.9, 1.43±0.74 MPa) ตามมาด้วยกลุ่มแคลเซียมไฮดรอกไซด์ซีลเลอร์ (0.75±0.18, 0.97±0.50 MPa) กลุ่มเรซินซีลเลอร์ (0.50±0.24, 0.38±0.18 MPa) และกลุ่มซิงค์ออกไซด์ยูจินอลซีลเลอร์ (0.27±0.09, 0.17±0.09 MPa) ตามลำดับ โดยทุกกลุ่มการทดลองพบการแตกหักระหว่างวัสดุสร้างแกนฟันและเนื้อฟันเป็นส่วนใหญ่ และไม่พบความล้มเหลวแตกหักในวัสดุสร้างแกนฟันชนิดเรซินหรือในเนื้อฟันเลย จากการศึกษานี้สรุปได้ว่าการปนเปื้อนของซีลเลอร์ที่แตกต่างกันในการอุดคลองรากฟันมีผลต่อค่าความแข็งแรงกดออกของวัสดุสร้างแกนฟันชนิดเรซินกับผนังคลองรากฟัน โดยที่ซีลเลอร์ชนิดที่มียูจินอลเป็นส่วนประกอบจะมีผลลดค่าแรงยึดมากที่สุด

คำไขรหัส*: ความแข็งแรงกดออก/ ซีลเลอร์อุดคลองรากฟัน/ ฟันที่ผ่านการรักษาคลองรากฟัน/ วัสดุสร้างแกนฟัน*

ผู้รับผิดชอบบทความ

ฐานวุฒิ คงปรีชา
ภาควิชาทันตกรรมทั่วไปขั้นสูง
คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล
เขตพญาไท กรุงเทพฯ 10400
โทรศัพท์: 0 2200 7853 4
โทรสาร: 0 2200 7852
จดหมายอิเล็กทรอนิกส์: thanawut.kho@mahidol.ac.th

* นักศึกษาหลักสูตรทันตแพทย์ประจำบ้าน ระดับวุฒิบัตร สาขาทันตกรรมทั่วไป คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล กรุงเทพฯ
** ภาควิชาทันตกรรมทั่วไปขั้นสูง คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล กรุงเทพฯ