ORIGINAL RESEARCH

Evaluation of the Bond Strength of Epoxy Resin-based Sealer Following Different Calcium Hydroxide Paste Removal Methods in Oval-shaped Root Canal

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Abstract

Aim: The study aimed to investigate the bond strength of epoxy resin-based sealer following five different calcium hydroxide paste removal methods in oval-shaped root canals.

Materials and methods: Sixty single-rooted human mandibular premolars having an oval-shaped root canal as evidenced by radiographs were decoronated and instrumented to size 40/0.04, medicated with calcium hydroxide paste for 7 days, before being randomly assigned to the conventional needle irrigation (CNI), manual dynamic agitation (MDA), sonic irrigation (SI), passive ultrasonic irrigation (PUI), and XP-endo Finisher (XP) groups to be irrigated using different irrigation systems. All specimens were then obturated using an epoxy resin-based root canal sealer and warm vertical compaction obturation technique. After 7 days, each specimen was sectioned into 1 mm root slices at the coronal, middle, and apical third of the root canal and tested for the push-out bond strength using a universal testing machine.

Results: The XP group was the only group that had comparable bond strength to the control group at every level of the root canal following removal of calcium hydroxide medicament ($p > 0.05$). The control group had higher bond strength than the CNI group at every level of the root canal ($p < 0.05$).

Conclusion: Calcium hydroxide interfered with the bonding of epoxy resin-based sealer to root canal walls. Irrigation with the XP increased the bonding sealer at every level of the root canal.

Clinical significance: The XP was efficacious as a final rinse agitation technique to promote the bonding of the epoxy resin-based sealer at every level of the root canal following calcium hydroxide medication.

Keywords: AH plus, Calcium hydroxide, Irrigation, Push-out bond strength.

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Introduction

Root canal disinfection is one of the crucial steps in endodontic treatment because it reduces the microbial load in the root canal system.[1] Mechanical debridement can remove most of the root canal infections, but those remaining still require attention.[2,3]

Root canal medications further disinfect the root canal. Calcium hydroxide paste is widely used for disinfection. However, it can be difficult to remove from root canals with complex anatomies,[4,5] curved canals,[6] and oval-shaped canals.[7] The remaining medicament could affect the quality and sealing ability of obturation materials.[8,9] Therefore, intracanal medicaments should be completely removed before obturation to obtain a good seal between the root canal sealer and the root canal wall.[10]

Conventional needle irrigation is a technique frequently used to irrigate root canals but its efficacy to remove medicament is limited.[11] Irrigant activation techniques can promote propagation of irrigants into the root canal complexities. Those techniques include MDA in which a gutta-percha cone is moved vertically at the working length (WL) 100 times per minute. Sonic irrigation such as the EndoActivator is an oscillating instrument that is used at sonic frequencies. These two techniques can adequately activate irrigants to remove intracanal medicaments.[12] An irrigation technique employing an ultrasonic instrument, namely the PUI technique, activates irrigants by creating acoustic microstreaming, which pushes irrigants into complex anatomies of the root canal system. This resulted in a canal better cleaned from intracanal calcium hydroxide than the CNI technique.[13,14]

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The new XP (FKG Dentaire, La Chaux de Fonds, Switzerland) is a rotary instrument developed using nickel–titanium alloy. It has an ISO 25 diameter without tapering and can expand 3 mm while rotating inside the root canal. Its high flexibility allows it to clean areas of the root canal system inaccessible by other instruments.[15] Studies have shown the high efficacy of the XP in removing calcium hydroxide medicament from the root canal.[15–17]

Removal of calcium hydroxide medicament is a crucial factor to a high-quality root canal filling. Therefore, this study aimed to investigate the bond strength of epoxy resin-based sealer following different calcium hydroxide paste removal methods (CNI, MDA, SI, PUI, and XP) in the oval-shaped root canal.

Materials and Methods

Sample Preparation

The ethical approval of this study was done by the human experimentation committee (Certificate of ethical clearance No. 43/2020, approved on June 19, 2020). The study was conducted at the Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand, from July 2021 to March 2022. Sixty human mandibular premolars single-rooted were collected randomly from a collection of extracted teeth due to orthodontic reasons. Teeth were kept in a 0.1% thymol solution. Teeth with a carious lesion, restoration, crack or fracture, and open apex were excluded from the study. The oval shape of the canal was determined using two conventional radiographs of buccolingual and mesiodistal aspects, and teeth with a maximum diameter 1.5 times larger than the minimum diameter 5 mm from the apex were included in the study.[18] Teeth were decoronated using a diamond disk (Intensiv SA, Montagnola, Switzerland) to a standardized tooth length of 16 mm. The root was then coated with two layers of nail polish and embedded in putty silicone to simulate a closed system and ease of handling. Canals were enlarged up to size 40/0.04 using rotary instruments (Mtwo, VDW GmbH, Munich, Germany) to a WL of 15 mm. During instrumentation, canals were irrigated with 20 mL of sodium hypochlorite (2.5% NaOCl) (Sigma-Aldrich, St. Louis, MO, USA) using a side-vented needle (gauge 27) and recapitulated using a K-file (ISO #10). The smear layer was then removed using 5 mL of 2.5% NaOCl solution and 2 mL of ethylenediaminetetraacetic acid (17% EDTA) for 1 minute. A flush was performed using distilled water (5 mL), and canals were dried using sterile paper points. Ten teeth were randomized into the negative control group, where they were not medicated with calcium hydroxide. The remaining 50 teeth were medicated with a premixed calcium hydroxide paste (UltraCal; Ultradent, South Jordan, USA) using a lentulo spiral to ensure that the medicament filled the root canal to the WL. The orifice was then sealed using a temporary restoration (Cavit; 3M ESPE, Seefeld, Germany), and all specimens were kept in 100% humidity at 37°C for 7 days.

Experimental Groups

Following the incubation period, the temporary restoration was removed using a round bur and a high-speed handpiece. The specimens were then assigned to 5 experimental groups (n = 10) as follows:

Group I (CNI): Canals were irrigated with 4 mL of 2.5% NaOCl for 3 minutes using a side-vented 27-gauge needle placed 2 mm short of the WL, and the irrigant was left inside the canal for another minute. Then, 2 mL of 17% EDTA was used to irrigate for 1 minute, followed by another 2 mL of 2.5% NaOCl for 1 minute, and the irrigant was left in the canal for another minute.

Group II (MDA): Canals were irrigated using the same irrigant, volume, and irrigation time as the previous group. EDTA and the subsequent NaOCl were activated using a gutta-percha main cone moving vertically at the WL level 100 times per minute.

Group III (SI): Canals were irrigated using the same irrigant, volume, and irrigation time as previous groups. EDTA and the subsequent NaOCl were activated using the EndoActivator® (6000 cycles per minute; medium power setting) together with a red tip (25/04). The instrument was placed 2 mm short of the WL and moved vertically with an amplitude of 2–3 mm.

Group IV (PUI): Canals were irrigated using the same irrigant, volume, and irrigation time as previous groups. EDTA and the subsequent NaOCl were activated using an ultrasonic generator (NEWTRON P5, Acteon) at the setting of 28,000 Hz as recommended by the manufacturer together with an IrriSafe tip #25IRR (Satelec Acteon Group, Merignac, France). The instrument was placed 2 mm short of the WL and moved vertically with an amplitude of 2–3 mm.

Group V (XP): Canals were irrigated using the same irrigant, volume, and irrigation time as previous groups. EDTA and the subsequent NaOCl were activated using XP together with a rotary motor (800 rpm and 1 Ncm). The instrument was placed at the WL and moved vertically with an amplitude of 7–8 mm.

Root Canal Filling

After irrigation, canals were dried using paper points and obturated using the warm vertical compaction technique. A gutta-percha cone with 4% tapering (Dentsply Sirona, Ballaigues, Vaud, Switzerland) was inserted into the WL. AH Plus (Dentsply Sirona) was used as a root canal sealer. The Gutta-percha was downpacked and backfilled to the level of the canal orifice using an obturation gun (B&L Biotech, Gyeonggi-do, South Korea). The access was sealed with a temporary restoration, and specimens were kept in 100% humidity at 37°C for 7 days.

Push-out Bond-strength Analysis

The acrylic resin was used to embed the teeth along their long axis. Each root was sectioned perpendicular to the long axis using a precision cutter (IsoMet 1000: Buehler, Lake Bluff, IL, USA) to obtain three 1 mm thick, 13 mm (coronal), 8 mm (middle), and 3 mm (apical) from the WL. The sectioned root slices were verified with standardized thickness using a digital caliper. The push-out bond strength of all specimens was analyzed using a universal testing machine (Instron 5566 Universal Testing Machine, Instron Engineering Corporation, Norwood, MN, USA) at a crosshead speed of 0.5 mm per minute. The machine was used in conjunction with cylindrical plungers of 0.7 mm, 0.5 mm, and 0.3 mm diameters for specimens obtained from the coronal, middle, and apical thirds of the root canal, respectively. The maximum load given to the root canal fillings before failure was recorded. The bonded area of an oval-shaped canal was calculated as previously described.[19]

After the push-out test, the inverted phase-contrast microscope (Olympus, Tokyo, Japan) at 40× magnification was used to determine the mode of failure, which was classified into three modes: adhesive failure is those that failed at the sealer and root canal wall interface, cohesive failure is those that failed at the gutta-percha and sealer interface, and mixed failure is those that failed at both interfaces.

The bond strengths were statistically analyzed using one-way ANOVA and Duncan's post hoc tests using SPSS 17.0 (SPSS software, SPSS Inc., Chicago, IL, USA).

Results

At the coronal third, the control, SI, PUI, and XP groups had no significant difference ($p > 0.05$), but those groups demonstrated the higher bond strength than the CNI and MDA groups ($p < 0.05$). At the middle third, there were no statistical differences in bond strength between the control, MDA, SI, PUI, and XP groups ($p > 0.05$). At the apical third, MDA and XP groups had no significant difference in bond strength from the control group ($p > 0.05$). The SI and PUI groups had significantly lower bond strengths than the control group ($p < 0.05$), but the PUI group had no significant difference from the MDA group ($p > 0.05$). The control group had a higher bond strength than the CNI group at every level of the root canal ($p < 0.05$) (Table 1). Mixed failure predominated in every experimental group. Adhesive failure was most prominent in the CNI group (Fig. 1). It can be inferred from the study that calcium hydroxide interfered with the bonding of epoxy resin-based sealer to root canal walls and irrigation with the XP increased the bonding of the sealer at every level of the root canal.

Discussion

The bond strength of specimens irrigated using the CNI technique were significantly lower than the control at every level of the root canal. This could be because the resin-based sealer bonds to the root canal and creates a tag-like structure in the dentinal tubules, but were obstructed by the medicament on the root canal wall, as described by Uzunoglu-Özyürek et al.[20] Furthermore, calcium hydroxide may intervene in the reaction between the epoxide rings of the sealer and the exposed amino groups of dentinal collagens which promotes the formation of covalent bonds, resulting in poor bonding as described by Neelakantan et al.[21]

The MDA technique utilizes a close-fitting gutta-percha main cone in a short-stroke pumping action at the WL to create a hydraulic force that pushes irrigants into complex anatomies of the root canal. The MDA technique has been demonstrated to be efficacious in removing debris from the apical third of the root canal because it dislodges entrapped gases, as described by Jiang et al.[22] The result of Jiang et al. corresponded to the current study, which found the high bond strength at the apical third of the root canal. On the other hand, the gap (reflux space) between the root canal wall and the main cone, which was larger in the coronal third, resulted in a lower hydraulic force, leading to a lower bond strength, as reported by Bronnec et al.[23]

The debridement efficacy of the SI and PUI system is due to the transmission of energy from the oscillating instrument to the irrigant, creating cavitation and acoustic microstreaming in the root canal which pushes irrigants into areas that are difficult to clean as described by Blank-Gonçalves et al.[24] Donnermeyer et al.

Table 1: Mean (standard deviation) of the push-out bond strength values (MPa) of all experimental groups obtained from different levels of the root canal

		Experimental groups				
	Control	*CNI*	*MDA*	*SI*	*PUI*	*XP*
Coronal	2.44 (0.59)[a]	1.13 (0.54)[c]	1.29 (0.42)[bc]	2.13 (1.68)[ab]	2.11 (1.11)[ab]	2.28 (1.07)[a]
Middle	4.50 (1.56)[a]	1.86 (0.78)[b]	3.36 (1.06)[a]	3.56 (1.67)[a]	3.97 (1.70)[a]	4.04 (1.65)[a]
Apical	6.61 (2.10)[a]	2.60 (0.62)[c]	5.53 (1.94)[ab]	3.24 (0.87)[c]	4.72 (1.82)[b]	6.60 (1.17)[a]

CNI, conventional needle irrigation; MDA, manual dynamic agitation; SI, sonic irrigation; PUI, passive ultrasonic irrigation; XP, XP-endo Finisher
Different superscript letters indicate a statistically significant difference between the mean value of specimens obtained from the same level of the root canal (p < 0.05)

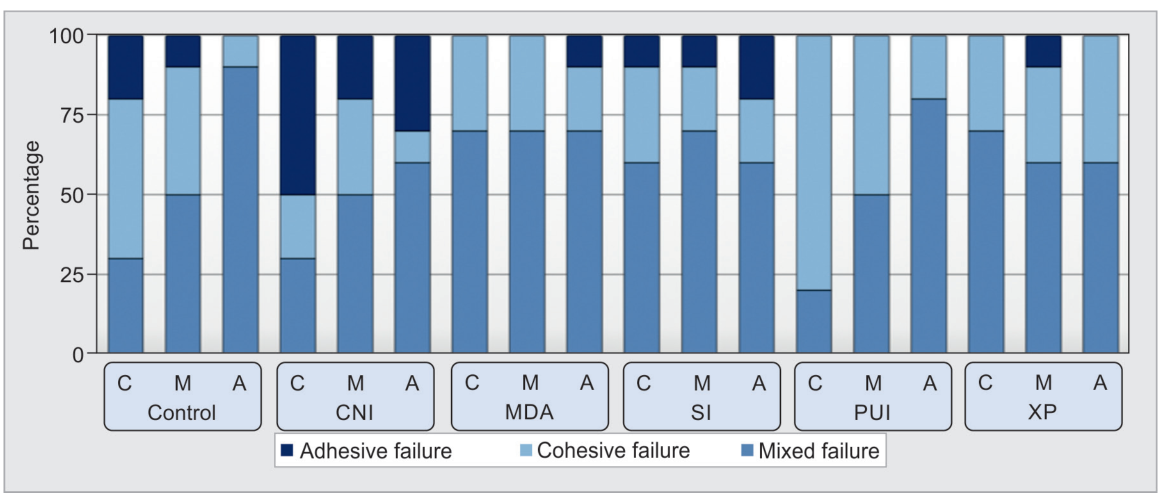

Fig. 1: Stacked bar chart showing the percentage distribution of failure mode of all experimental groups obtained from different levels of the root canal (C, coronal; M, middle; A, apical; CNI, conventional needle irrigation; MDA, manual dynamic agitation; SI, sonic irrigation; PUI, passive ultrasonic irrigation; XP, XP-endo Finisher)

and Alturaiki et al. have demonstrated that the SI and PUI systems were both efficacious at removing calcium hydroxide from the coronal third of the root canal.[4,25] Their results corresponded to our study, which found that both the SI and PUI groups had a high bond strength and were not different from the control and XP groups. On the other hand, a study also reported that in the apical third of the root canal, the PUI was more efficacious than the XP system at removing calcium hydroxide medicament as reported by Donnermeyer et al.[4] Their results contradicted ours and could be due to the methodologies, and the selection and preparation of specimens. Furthermore, one of the factors influencing the efficacy of the PUI system is a fresh replacement of irrigants. In our study, losing the reservoir of the irrigant was limited because the teeth were decoronated.

Donnermeyer et al. and Leoni et al. have shown the efficacy of the XP in removing hard-tissue debris or root canal medicaments.[4,26] The findings of those studies corresponded to the current study, where the XP group had similar bond strength to the control group at every level of the root canal. The XP can effectively remove medicaments from the root canal, especially canals that are not ideally round because the instrument has high flexibility. When it rotates, it physically contacts and debrides the root canal wall. It can also reach areas that are inaccessible to other instruments such as the buccal or lingual recesses of oval canals, which may have some remaining calcium hydroxide medicament as reported by Denna et al.[27]

Our results showed that mixed failure and cohesive failure were the most common failure mode, which corresponds to Prado et al.[28] This could be due to the sealer and gutta-percha cone not bonded together when the failure occurs. On the contrary, adhesive failure was observed mostly in the CNI group. This may be due to the remaining calcium hydroxide medicament obstructing the bond of the sealer and root canal surface.

This study revealed the bond strength of an epoxy resin-based root canal sealer following different strategies for a final rinse protocol to remove calcium hydroxide medicament from an oval-shaped root canal, in which its anatomy was obtained as indirect information. Our findings demonstrated that irrigant activation using different methods after calcium hydroxide medication increased the bond strength of the root-filling material. Despite the results, root canals have numerous complex anatomies, such as lateral canals, isthmuses, and apical ramifications, that were not investigated in this study. These could be studied further as well as other types of medicaments and root canal sealers.

Conclusion

Within the limitation of this study, it may be concluded that calcium hydroxide medicament had a negative effect on the bonding between the sealer and the root canal surface. The bond strength of the root-filling material was different among the irrigation protocols. The XP was efficacious as a final rinse agitation technique to promote the bonding of the epoxy resin-based sealer at every level of the root canal following calcium hydroxide medication.

References

1. Siqueira JF Jr, de Uzeda M. Disinfection by calcium hydroxide pastes of dentinal tubules infected with two obligate and one facultative anaerobic bacteria. J Endod 1996;22(12):674–676. DOI: 10.1016/S0099-2399(96)80062-8.
2. Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: Shaping goals, techniques and means. Endod Topics 2005;10(1):30–76. DOI: 10.1111/j.1601-1546.2005.00152.x.
3. Siqueira JF Jr, Rôças IN, Santos SRLD, et al. Efficacy of instrumentation techniques and irrigation regimens in reducing the bacterial population within root canals. J Endod 2002;28(3):181–184. DOI: 10.1097/00004770-200203000-00009.
4. Donnermeyer D, Wyrsch H, Bürklein S, et al. Removal of calcium hydroxide from artificial Grooves in straight root canals: Sonic activation using EDDY versus passive ultrasonic irrigation and XPendo Finisher. J Endod 2019;45(3):322–326. DOI: 10.1016/j.joen.2018.11.001.
5. Ma JZ, Shen Y, Al-Ashaw AJ, et al. Micro-computed tomography evaluation of the removal of calcium hydroxide medicament from C-shaped root canals of mandibular second molars. Int Endod J 2015;48(4):333–341. DOI: 10.1111/iej.12319.
6. Wang Y, Guo LY, Fang HZ, et al. An in vitro study on the efficacy of removing calcium hydroxide from curved root canal systems in root canal therapy. Int J Oral Sci 2017;9(2):110–116. DOI: 10.1038/ijos.2017.14.
7. de Oliveira RL, Guerisoli DMZ, Duque JA, et al. Computed micro-tomography evaluation of calcium hydroxide-based root canal dressing removal from oval root canals by different methods of irrigation. Microsc Res Tech 2019;82(3):232–237. DOI: 10.1002/jemt.23164.
8. Barbizam JV, Trope M, Teixeira EC, et al. Effect of calcium hydroxide intracanal dressing on the bond strength of a resin-based endodontic sealer. Braz Dent J 2008;19(3):224–227. DOI: 10.1590/s0103-64402008000300009.
9. Kim SK, Kim YO. Influence of calcium hydroxide intracanal medication on apical seal. Int Endod J 2002;35(7):623–628. DOI: 10.1046/j.1365-2591.2002.00539.x.
10. Guiotti FA, Kuga MC, Duarte MAH, et al. Effect of calcium hydroxide dressing on push-out bond strength of endodontic sealers to root canal dentin. Braz Oral Res 2014;28. DOI: 10.1590/S1806-83242014.50000002.
11. Rödig T, Vogel S, Zapf A, et al. Efficacy of different irrigants in the removal of calcium hydroxide from root canals. Int Endod J 2010;43(6):519–527. DOI: 10.1111/j.1365-2591.2010.01709.x.
12. Kirar DS, Jain P, Patni P. Comparison of different irrigation and agitation methods for the removal of two types of calcium hydroxide medicaments from the root canal wall: An in-vitro study. Clujul Med 2017;90(3):327–332. DOI: 10.15386/cjmed-737.
13. Pabel AK, Hülsmann M. Comparison of different techniques for removal of calcium hydroxide from straight root canals: An in vitro study. Odontology 2017;105(4):453–459. DOI: 10.1007/s10266-017-0293-6.
14. Yaylali IE, Kececi AD, Ureyen Kaya B. Ultrasonically activated irrigation to remove calcium hydroxide from apical third of human root canal system: A systematic review of in vitro studies. J Endod 2015;41(10):1589–1599. DOI: 10.1016/j.joen.2015.06.006.
15. Wigler R, Dvir R, Weisman A, et al. Efficacy of XP-endo finisher files in the removal of calcium hydroxide paste from artificial standardized grooves in the apical third of oval root canals. Int Endod J 2017;50(7):700–705. DOI: 10.1111/iej.12668.
16. Hamdan R, Michetti J, Pinchon D, et al. The XP-Endo Finisher for the removal of calcium hydroxide paste from root canals and from the apical third. J Clin Exp Dent 2017;9(7):e855–e860. DOI: 10.4317/jced.53962.
17. Kfir A, Blau-Venezia N, Goldberger T, et al. Efficacy of self-adjusting file, XP-endo finisher and passive ultrasonic irrigation on the removal of calcium hydroxide paste from an artificial standardized groove. Aust Endod J 2018;44(1):26–31. DOI: 10.1111/aej.12204.
18. Wu MK, R'oris A, Barkis D, et al. Prevalence and extent of long oval canals in the apical third. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89(6):739–743. DOI: 10.1067/moe.2000.106344.
19. Coniglio I, Magni E, Cantoro A, et al. Push-out bond strength of circular and oval-shaped fiber posts. Clin Oral Investig 2011;15(5):667–672. DOI: 10.1007/s00784-010-0448-0.

20. Uzunoglu-Özyürek E, Erdoan Ö, Aktemur Türker S. Effect of calcium hydroxide dressing on the dentinal tubule penetration of 2 different root canal sealers: A confocal laser scanning microscopic study. J Endod 2018;44(6):1018–1023. DOI: 10.1016/j.joen.2018.02.016.
21. Neelakantan P, Sharma S, Shemesh H, et al. Influence of irrigation sequence on the adhesion of root canal sealers to dentin: A fourier transform infrared spectroscopy and push-out bond strength analysis. J Endod 2015;41(7):1108–1011. DOI: 10.1016/j.joen.2015.02.001.
22. Jiang L-M, Lak B, Eijsvogels LM, et al. Comparison of the cleaning efficacy of different final irrigation techniques. J Endod 2012;38(6): 838–841. DOI: 10.1016/j.joen.2012.03.002.
23. Bronnec F, Bouillaguet S, Machtou P. *Ex vivo* assessment of irrigant penetration and renewal during the final irrigation regimen. Int Endod J 2010;43(8):663–672. DOI: 10.1111/j.1365-2591.2010.01723.x.
24. Blank-Gonçalves LM, Nabeshima CK, Martins GHR, et al. Qualitative analysis of the removal of the smear layer in the apical third of curved roots: Conventional irrigation versus activation systems. J Endod 2011;37(9):1268–1271. DOI: 10.1016/j.joen.2011.06.009.
25. Alturaiki S, Lamphon H, Edrees H, et al. Efficacy of 3 different irrigation systems on removal of calcium hydroxide from the root canal: A scanning electron microscopic study. J Endod 2015;41(1):97–101. DOI: 10.1016/j.joen.2014.07.033.
26. Leoni GB, Versiani MA, Silva-Sousa YT, et al. Ex vivo evaluation of four final irrigation protocols on the removal of hard-tissue debris from the mesial root canal system of mandibular first molars. Int Endod J 2017;50(4):398–406. DOI: 10.1111/iej.12630.
27. Denna J, Shafie LA, Alsofi L, et al. Efficacy of the rotary instrument XP-Endo Finisher in the removal of calcium hydroxide intracanal medicament in combination with different irrigation techniques: A microtomographic study. Materials (Basel) 2020;13(10):2222. DOI: 10.3390/ma13102222.
28. Prado M, Simão RA, Gomes BP. Effect of different irrigation protocols on resin sealer bond strength to dentin. J Endod 2013;39(5):689–692. DOI: 10.1016/j.joen.2012.12.009.