Journal of Dental Sciences 18 (2023) 129—134

Available online at www.sciencedirect.com

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journal homepage: www.e-jds.com

Original Article

Effect of different dentin moisture on the push-out strength of bioceramic root canal sealer

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Received 12 April 2022; Final revision received 27 June 2022
Available online 12 July 2022

KEYWORDS
Dentin moisture;
Push-out strength;
Root canal sealer

Abstract *Background/purpose:* Different moisture condition may affect the adhesion between obturation materials and root canal walls, thus further affect the quality of root canal obturation. The aim of this study was to evaluate the influence of dentin moisture conditions after different root canal drying protocols on the push-out strength of bioceramic root canal sealer.

Materials and methods: Twenty root canals from extracted human decoronated premolars were prepared in vitro to #30/0.09 taper and assigned to 4 moisture condition groups after using different root canal drying protocols: normal moisture (paper point) group: the canals were blot dried with paper points until the last one appeared dry. Ethanol dry group: the canals were dried with paper points followed by dehydration with 95% ethanol. Isopropanol dry group: the canals were dried with paper points followed by dehydration with 70% isopropanol. Complete dry group: the canals were dried in an air-blowing thermostatic oven for at least 6 h until there was no change in weight at an interval of 1 h. After drying, the canals were obturated with bioceramic sealer iRoot SP. Then, each root was sectioned into eight slices with 1-mm-thick using a diamond saw (40 slices each group). The push-out strength was tested for each slice between the sealer and dentin wall using a universal testing machine at a crosshead speed

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https://doi.org/10.1016/j.jds.2022.06.025

of 0.5 mm/min, and failure modes were recorded. Two-way analysis of variance and Tukey test were used to analyze the push-out strength. Logarithmic linear regression analysis was used to compare the failure modes.

Results: Push-out strength was statistically different in different moisture groups ($P < 0.05$). After drying using paper point, iRoot SP specimens showed the highest push-out strength (2.04 $\pm$ 0.03 MPa), followed by 95% ethanol, 70% isopropanol. The lowest push-out strength (0.68 $\pm$ 0.04 MPa) was observed under complete dry. For the failure modes, the majority were cohesive failures in the coronal and middle thirds of the root; while in the apical third, mixed failure was common.

Conclusion: Different drying protocols influenced the push-out strength between bioceramic sealer and canal wall.

Introduction

It has been demonstrated that the quality of root canal obturation is an influence factor for endodontic outcome.[1,2] The objective of obturation is to seal the root canal system and prevent reinfection from periapical tissue.[3] Therefore, the material should have an excellent apical fit, and the sealer itself should bond to the canal wall, which is called "monoblock".[4] One of the influence factors in obturation is moisture that exists in the root canal or dentinal tubules, which could occupy the space and inhibit filling material from entering the root canal. Furthermore, the remaining moisture could also occupy physical space in the canals, then negatively affect the interface between the material and dentin, thus breaking the "monoblock".[5,6]

Paper point is the most commonly used drying protocol in the practice. However, Nagas found that moisture remained in the irregular region of the canal and lateral canal after drying the root canal with paper points.[7] To improve the results of drying, organic solvent,[7–12] heat source and other protocols have also been introduced in some studies.[13,14]

Push-out strength has been widely used to represent the adhesion between obturation materials and root canal walls because of its simplicity and reproducibility.[12,18–22] It indicates a combination of friction between the materials and root canal walls, bonding force between molecules and chemical adhesion between materials and root dentin walls.[23]

With the advances in root canal filling materials, different kinds of sealers are used in clinic. For example, iRoot SP, a new hydrophilic calcium silicate–based sealer, is an insoluble, radiopaque, and aluminum-free material based on a calcium silicate composition, which requires the presence of water during the setting process.[15] However, the clinician may find it difficult to choose the drying protocol most suitable for an individual sealer.

Therefore, the aim of this study was to examine the influence of different root canal dentin moisture conditions on the push-out strength of bioceramic-based sealer. The null hypothesis was that the moisture condition of root dentin would not affect the push-out strength for bioceramic-based sealer.

Materials and methods

Specimen preparation

Twenty freshly extracted discarded, straight and single-rooted human premolars were included. The teeth were decoronated at the cemento-enamel junction (CEJ) using a high-speed diamond bur with copious water coolant, leaving roots 14 mm in length. Patency was confirmed with a #15 K-file, and the root canals were enlarged using ProTaper Universal rotary instruments (Dentsply Sirona, Konstanz, Germany) until file F3 reached the working length (1 mm from the apical foramen). The root canals were irrigated by using 2 mL of 1.25% NaOCl between each instrument. Complete drying in an air-blowing thermostatic oven (BPG-9040A; Yiheng Scientific Instrument Co., Shanghai, China) at 58 °C for at least 6 h was confirmed by measurement at 1 h intervals until the weight was unchanged.

The roots were randomly assigned into 4 moisture condition groups according to different root canal drying protocols:[16]

Normal moisture (paper point) group: 10 μL of distilled water was injected into the canals. Then, the water was blot dried with paper points until dryness was confirmed by a stereoscopic microscope (CF-2000C; Changfang Optical Instrument Co., Shanghai, China) at a 45 $\times$ magnification.

Ethanol dry group: 10 μL of distilled water was injected into the canals. After the removal of excess distilled water with paper points, the canals were dried with 10 μL of 95% ethanol using a microsyringe. Ethanol was gently injected into the root canal while slowly withdrawing the syringe. After being left in the canal for 10 s, the ethanol was removed with paper points.

Isopropanol dry group: The same step as ethanol dry group (using 10 μL of 70% isopropanol).

Complete dry group: No further root canal drying protocol was used.

After drying, the bioceramic-based sealer iRoot SP (Innovative Co., Vancouver, Canada) was prepared and applied according to the manufacturer's recommendations. The EZ-Fill bi-directional spiral (EDS, Hackensack, NJ, USA) was coated with root canal sealer and placed in the canal twice approximately 5 s along the length of the canal at 300 rpm with a slow up and down and circular motion. The apical foramen was sealed by using 2-step self-etch adhesive (Clearfil SE Bond; Kuraray Medical Inc., Tokyo, Japan) and composite resin (3M Z350; 3M-ESPE, St. Paul, MN, USA). The orifice was sealed with GIC (Shangchi Dental Material Co., Jiangsu, China). Thereafter, the specimens were stored at 37 °C and 95% relative humidity for 48 h to ensure a complete set of the materials.[5]

Evaluation of push-out strength

Eight slices with 1-mm-thick (2 slices in the apical third, 3 slices in the middle third and 3 slices in the coronal third) were cut at intervals of 3, 5 and 9 mm from the apical to coronal third (40 slices each group) by using a water-cooled diamond saw (SYJ-150; Kejing Auto-Instrument Co., Shenyang, China). The push-out test was performed using a universal testing machine (Instron 3367; Instron Co., Canton, China) (Fig. 1) with a crosshead speed of 0.5 mm/min. Shafts with tip diameters of 0.4 mm, 0.8 mm and 1.0 mm were used for the apical, middle, and coronal sections. The push-out strength at failure was calculated in megapascals (MPa) by dividing the load in newtons (N) by the area of the bond interface:

$$\text{Bond area} = \pi\,(R + r)\,h$$

where $\pi = 3.14$, R = the radius of the sealer close to the crown, r = the radius of the sealer close to the apex, h = the height of the slice in mm.

Analysis of failure modes

The failure modes were observed under a stereoscopic microscope at a 30 × magnification. Failures were classified as follows (Fig. 1):

Adhesive failure: Failure occurred between the sealer and the inner wall of the root canal.

Cohesive failure: Failure occurred inside the sealer.

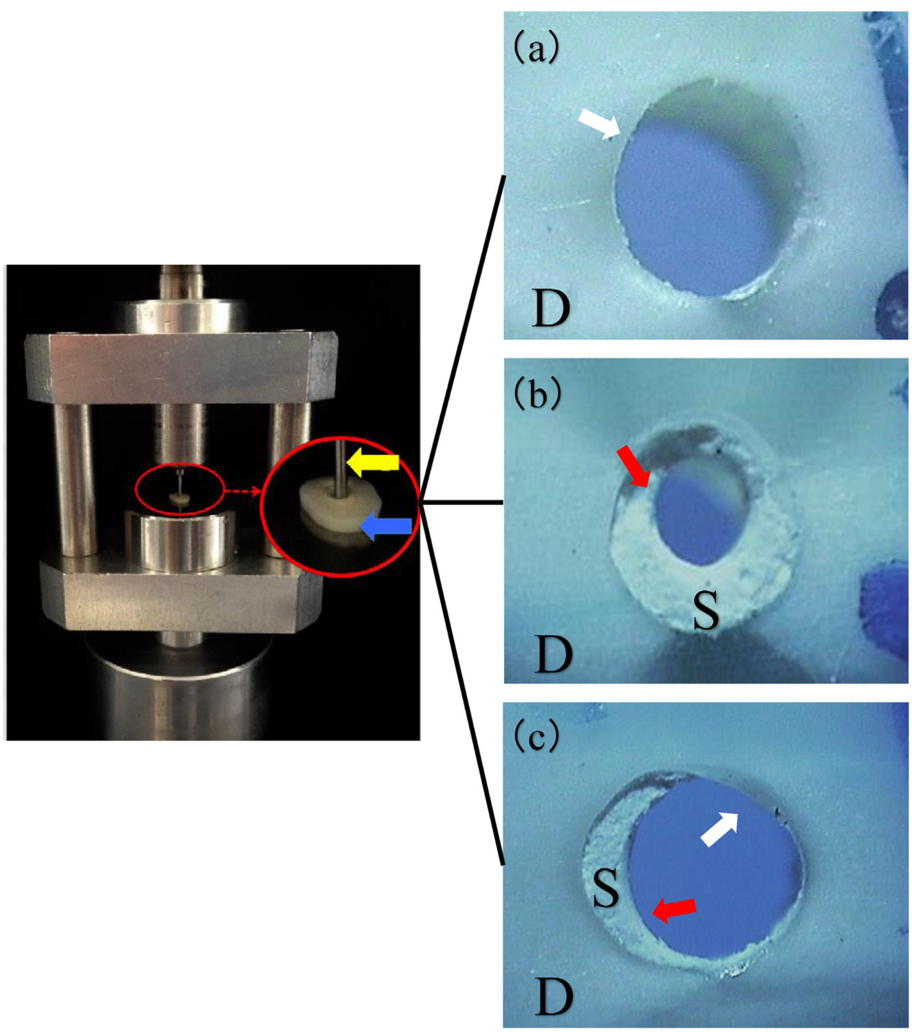

Figure 1 Universal testing machine for the push-out test (left) and representative failure mode images under a stereoscopic microscope (right). The shaft (yellow arrow) was placed over the tooth slice (blue arrow). (a) adhesive failure: failure occurred between the sealer and the inner wall of the root canal. (b) cohesive failure: failure occurred inside the sealer. (c) mixed failure: the above failure modes both occurred. Arrows indicate the interface after bond failure. D, dentin; S, Sealer.

Mixed failure: The above failure modes both occurred.

Statistical analysis

SPSS version 20.0 (IBM, Chicago, IL, USA) was used to analyze the data. Two-way analysis of variance (ANOVA) was performed to analyze the push-out strength. Logarithmic linear regression analysis was used to compare the failure modes. The statistical significance level was set at $\alpha = 0.05$.

Results

Push-out strength

There was a significant difference in push-out strength between the 4 moisture condition groups ($P < 0.05$) (Fig. 2). In complete dry group, bioceramic sealer iRoot SP demonstrated the lowest push-out strength (0.68 $\pm$ 0.04 MPa) ($P < 0.05$). Whereas in normal moisture (paper point) group, the push-out strength between the sealer and dentin wall showed the highest value (2.04 $\pm$ 0.03 MPa) ($P < 0.05$), followed by 95% ethanol group (1.95 $\pm$ 0.03 MPa) ($P < 0.05$), 70% isopropanol group (1.56 $\pm$ 0.03 MPa) ($P < 0.05$). There was no significant difference in the push-out strength between different sections of root ($P > 0.05$).

Failure mode

In the present experimental groups, the most common type of failure mode was cohesive failure, which occurred inside the sealer ($P < 0.05$) (Table 1). However, there was no significant difference in the failure mode between the experimental groups ($P > 0.05$). For different levels of root, there was a significant difference ($P < 0.05$) (Fig. 3): in the coronal and middle thirds of the root, the majority of failures were cohesive failures (66.7%, 65%); while in the apical third, mixed failure was common (47.5%).

Table 1 Distribution of failure mode in different groups (%).

Moisture condition group	Failure mode		
	Adhesive	Cohesive	Mixed
Normal paper point[a]	0	77.5	22.5
Dry (Ethanol)[a]	7.5	67.5	25
Dry (Isopropanol)[a]	5	62.5	32.5
Complete dry[a]	0	92.5	7.5

Groups marked with the same superscript letter did not differ significantly with respect to failure mode distribution ($P > 0.05$).

Discussion

The push-out test was first applied in the field of prosthetic dentistry in 2002 to measure the bond strength of fiber posts luted into prepared root canals.[17] Since then, push-out strength has been widely used to represent the adhesion between obturation materials and root canal walls because of its simplicity and reproducibility.[12,18–22] The value of push-out strength indicates a combination of friction between the materials and root canal walls, bonding force between molecules and chemical adhesion between materials and root dentin walls.[23] It is also affected by friction,[24] C factor[25,26] and different root canal treatment protocols.[27]

With novel endodontic sealers being successively developed and commercialized by manufacturers, it has been important for the clinician to understand the

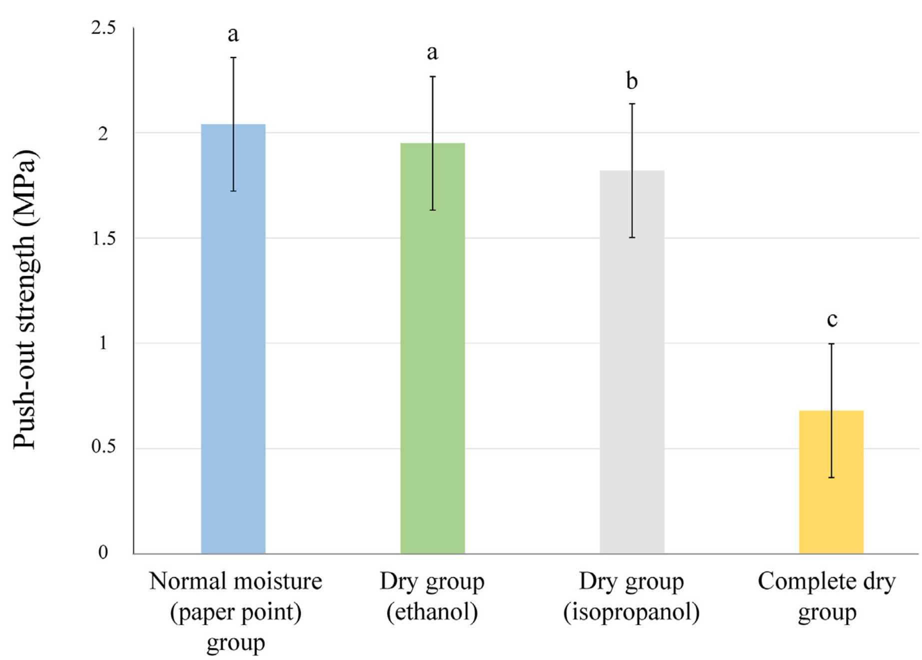

Figure 2 Push-out strength (MPa) of iRoot SP with respect to the experimental dentin moisture conditions. Different letters represent statistically significant differences between groups ($P < 0.05$).

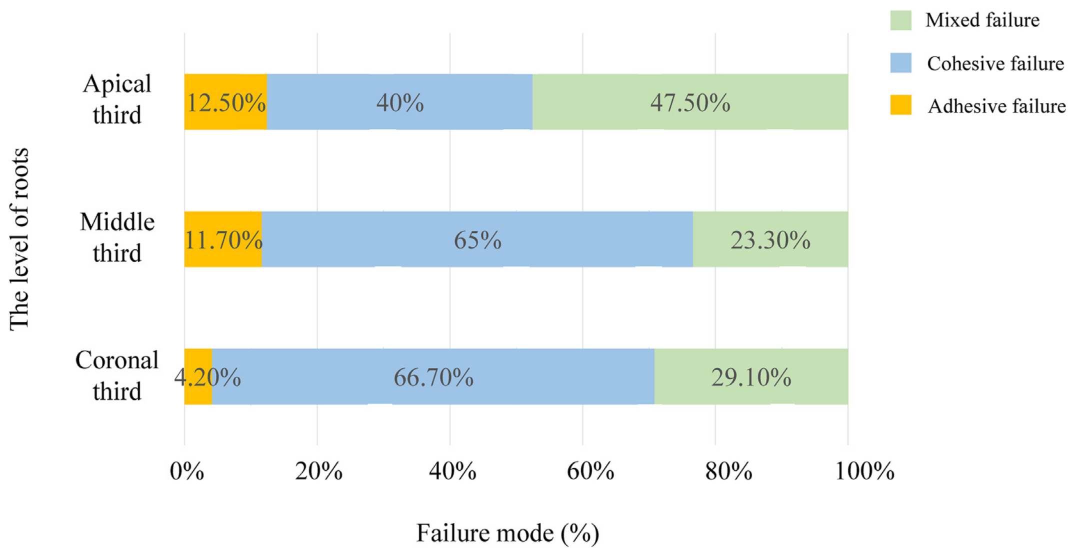

Figure 3 Failure mode percentage distribution (%) in different root regions. There was a significant difference between the different root regions ($P < 0.05$).

physicochemical properties of endodontic sealers. The properties of endodontic sealers, which are mainly determined by the type and proportions of the main components, can enable them to function adequately under different clinical dentin moisture conditions. Laboratory studies on the physicochemical properties could contribute to a better understanding of the clinical behavior and handling performance of endodontic sealers. A recent study has shown the apical sealing ability of iRoot SP to be equivalent to that of AH Plus.[8] However, there is limited information available regarding the push-out strength of iRoot SP under different dentin moisture conditions. Therefore, this study aimed to evaluate the influence of dentin moisture conditions after different root canal drying protocols on the push-out strength of bioceramic root canal sealer iRoot SP.

In our study and other previous studies,[7–12,30] different canal drying protocols could result in different dentin moisture levels: normal, dry and complete dry. According to Nagas' and Zmener's studies,[7,16] the effect of drying with paper points was defined as "normal moisture" and using of isopropanol solvent drying was defined as "dry moisture". In the present study, it was found that for iRoot SP, higher push-out strength was observed in normal moisture group (paper point group) among the four different moisture condition groups. This finding indicates that after drying by paper points, the canal dentin moisture for iRoot SP is optimal. iRoot SP is a hydrophilic material, it can hydrate with the water in dentinal tubules and play its biological characteristic to deposit apatite minerals on the surface, thus enhancing the chemical combination of the sealer and root canal dentin, which might be the explanation for why "normal moisture" was optimal for the hydration reaction of iRoot SP.[28,29]

Interestingly, the lowest push-out strength value was detected in the complete drying condition for iRoot SP. It was found that in a totally dry root canal, the water was not sufficient for the hydration reaction process, thus compromising the combination between the material and the canal dentin wall.[16]

In our present study, the predominant fracture mode was cohesive failure inside the sealer in all groups, which was as same as Dias' study.[12] In the normal moisture (paper point) group, there was no adhesive failure along the sealer and inner wall of the root canal, which could be partly explained by the bonding force with the canal wall.[7] While under complete drying condition, a relatively high cohesive mode was observed, which may indicate that hydrophilic iRoot SP has better combination with canal dentin wall.[34] It was showed that mixed failure was common in the apical third. It may be speculated that the anatomy of the apical region was complicated, such as the existence of lateral canals, which made the solidification of the sealer itself and the combination with the canal wall uncertain, thus the predominant fracture mode was mixed (adhesive/cohesive) failure. While in the coronal and middle thirds of the root, modes of failure were consistent with other studies that showed the majority of failures were cohesive failures.[35,36]

In conclusion, within the limitations of this in vitro study, we conclude that when using bioceramic sealer iRoot SP, the optimal moisture condition to achieve ideal push-out strength is normal moisture.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article

Acknowledgments

The work was supported by Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology, China.

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