Available online at www.giornaleitalianoendodonzia.it

ORIGINAL ARTICLE

Influence of different root canal drying protocols on the bond strength of a bioceramic endodontic sealer

ABSTRACT

Aim: *This study aimed to evaluate the influence of different root canal drying protocols on the bond strength of a bioceramic sealer, in comparison with an epoxy resin-based sealer.*
Methodology: *Sixty-six mandibular premolar teeth had their crowns sectioned and their canals prepared with Reciproc (VDW GmbH). Next, the roots were randomly distributed into three groups (n=22), according to the different drying protocols: absorbent paper points (G_{PP}); irrigation with 95% ethanol and drying with paper points (G_{95E}); and irrigation with 70% ethanol and aspiration with a 30-gauge needle (G_{70E}). Each group was then redistributed into two subgroups (n=11), according to the sealer used in the single cone technique: Sealer Plus BC (MK Life) or AH Plus (Dentsply). After 7 days of obturation, the roots were sectioned into 1-mm thick slices and submitted to the push-out test. Bond strength was calculated (MPa) and data were analyzed by Kruskal-Wallis test, complemented by Games-Howell post-hoc test and Mann-Whitney U test (α=5%).*
Results: *There was no statistical difference among the drying protocols in the specimens filled with AH Plus, irrespective of the root third (P>0.05). For the Sealer Plus BC, no significant difference was observed for the drying protocols, however, there was statistical difference among the root thirds in G_{95E} (P=0.017). When the sealers were compared to each other, no statistical difference was observed, regardless of the drying protocol evaluated: G_{PP} (P=0.447), G_{95E} (P=0.687) and G_{70E} (P=0.132).*
Conclusions: *The different drying protocols of the root canal did not influence the bond strength of both endodontic sealers.*

Ihan Vitor Cardoso[1]

Maria Luisa Seixas-Silva[2]

Gabriela Rover[3]

Eduardo Antunes Bortoluzzi[1]

Lucas da Fonseca Roberti Garcia[1]

Cleonice Silveira Teixeira[1*]

[1]*Department of Dentistry, Endodontics Division, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil*

[2]*Clinical Practice, Florianópolis, Santa Catarina, Brazil*

[3]*Dentistry Division, Health Squad, Florianópolis Air Base, Brazilian Air Force, Santa Catarina, Brazil*

Received 2021, May 13

Accepted 2021, September 26

KEYWORDS *Bioceramics, bond strength, endodontic sealers, moisture, root canal filling*

Corresponding Author
Cleonice da Silveira Teixeira | Department of Dentistry, Health Sciences Center, Federal University of Santa Catarina, Campus João David Ferreira Lima, Rua Delfino Conti, s/n, Zip Code 88040-370, Florianópolis, Santa Catarina | Brazil
Tel.: +55 (048) 3721-5840; +55 (048) 3721-9520 | Email: cleotex@uol.com.br; cleonice.teixeira@ufsc.br

Peer review under responsibility of Società Italiana di Endodonzia

10.32067/GIE.2021.35.02.42

Introduction

In order to reestablish the health of the periapical tissues, it is necessary to effectively perform the cleaning, shaping and obturation of the root canal system (1). Ideally, the obturation should promote efficient filling and sealing along the entire root canal length, including the apical foramen, accessory canals, isthmus, voids and irregularities (2, 3). For this reason, it is essential that the sealers used in the root canal obturation have certain characteristics, such as insolubility to the tissue fluids, biocompatibility, flow ability, adequate setting-time, antimicrobial activity and adhesion to the dentine walls (4-6).

Among the root canal sealers disponible in the market, calcium silicate based-sealers, also called "bioceramic sealers" by most manufacturers for marketing purpose, have stood out mainly for their adequate physical, chemical and biological properties (7). One of them is the Sealer Plus BC (MK Life Medical and Dental Products, Porto Alegre, RS, Brazil), which is a material based on nanoparticulate di- and tricalcium silicate. This sealer has biocompatibility and bioactive potential (8, 9), in addition to antimicrobial activity (10). This activity has been associated with a large release of calcium hydroxide and an increase in the pH of the medium, when this sealer is used for root canal obturation (11). Unlike to conventional root canal sealers, calcium silicate-based sealers are hydraulic cements and need water to start their setting reaction. Under hydration conditions, would produce calcium silicate hydrate gel (C-S-H), which leads to calcium hydroxide formation, contributing to their biological properties (7).

Another sealer commonly used in endodontics, AH Plus (Dentsply De Trey, Konstanz, Germany), is an epoxy resin-based material and has been commonly used as gold standard sealer (12) due to its low solubility, adequate radiopacity, resistance and flow; besides having dimensional stability and high bond strength to dentine (2, 5, 8, 9, 11, 13).

The bond strength of a sealer to the root dentin is an important property for maintaining the integrity of the filling material (14). The drying protocol performed prior to root canal obturation may directly influence the adhesion of the sealer to the dentinal walls and reflect on the success or failure of the endodontic treatment (15, 16). Several studies have reported that residual moisture in the root canal modify the sealing ability and the adhesion of endodontic sealers (15-17). On the other hand, the complete absence of moisture may also lead to unsatisfactory results (18). Moisture plays a fundamental role on the bioceramic endodontic sealers setting and hardening (19). The complete absence of moisture might be associated to alteration in setting reaction of this type of endodontic sealer (19). To the best of our knowledge, there is no scientific accordance regarding the most appropriate protocol for root canal drying prior to obturation with bioceramic sealers (16, 19-22).

Therefore, the present study evaluated the influence of different root canal drying protocols on the bond strength of a bioceramic endodontic sealer (Sealer Plus BC, MK Life), in comparison with an epoxy resin-based sealer (AH Plus, Dentsply De Trey). The null hypothesis tested was that the adhesion of both endodontic sealers to the root dentin would not be influenced by the different levels of moisture, irrespective of the root canal third.

Materials and Methods

Sample Size Calculation

The sample size was estimated based on previous studies comparing the bond strength of teeth filled with different endodontic sealers (17, 18). Accordingly, with the aid of the sealed Envelope software (Sealed Envelope Ltd., 2018, https://sealedenvelope.com), for the analysis with $\alpha=0.05$ and considering an effect size=0.80, at least 10 teeth should be allocated in each testing group.

Sample Selection and Preparation

After Institutional Ethics Committee approval, (Protocol no. 035475), sixty-six freshly extracted human mandibular premolars were selected for this study. To confirm the existence of a single and straight root canal with a fully formed apical foramen, the teeth were radiographed (Spectro 70X Selectronic X-ray machine, Dabi Atlante, Ribeirão Preto, São Paulo, Brazil) in both mesial-distal and buccal-lingual directions. The roots with large oval canals were substituted in order to provide canals with round section after endodontic preparation. After examination in stereoscopic lens under ×4 magnification (Illuminated Magnifying Glass, Tokyo, Japan), the teeth with caries, restorations and signs of cracks were discarded from the final sample. Then, the selected teeth were cleaned with periodontal curettes (SM 17/18, Hu-Friedy, Rio de Janeiro, RJ, Brazil), followed by disinfection in 0.5% chloramine T solution at a temperature of 4 °C for 48h, and washing under running water for 24h.

Next, the teeth were positioned, in their long axis, on a surface parallel to the ground and had their crowns sectioned below the cement-enamel junction by a double-sided diamond disc (Brasseler Dental Products, Savannah, GA, USA), under air/water spray copious cooling, in order to provide root length of approximately 16 mm. The root canal length was verified by introducing a size 15 Flexofile instrument (Dentsply Maillefer, Tulsa, OK, USA), until its tip reached the apical foramen.

Then, the working length (WL) was established by subtracting 1 mm from the root canal length.

All root canals were prepared with Reciproc R40 (40/0.06) instrument (VDW GmbH, Munich, Germany), driven by an electrical motor (VDW Silver, VDW GmbH), according to the manufacturer's instructions. At each removal of the instrument for cleaning, the root canals were irrigated with 2 mL of 1% sodium hypochlorite (NaOCl) solution using a syringe with NaviTip 30-gauge needle (Ultradent, South Jordan, UT, USA) inserted up to 2 mm from the apical foramen. As final irrigation, 3 mL of 2.5% NaOCl was also used for 3 minutes, followed by 3 mL of 17% EDTA and rinsing with 5 mL of distilled water.

Drying Protocols

The roots were randomly assigned to the following three experimental groups, according to the drying protocols performed (n=22).

G_{PP} (control group): root canals were dried with size 40 absorbent paper points (Dentsply Maillefer), until complete dryness of the last paper point used.

G_{95E} (lower moisture): the excess of distilled water was removed with size 40 absorbent paper points (Dentsply Maillefer). Root canals were then dried with the application of 3 mL of 95% ethanol using a syringe with a NaviTip 30-gauge needle inserted up to 2 mm from the apical foramen. Ethanol was left in the root canal for 10 seconds, and removed with absorbent paper points, as described in G_{PP}.

Table 1

Sealers used in the experimental procedures, with their respective composition and manufacturers

Sealer	Composition	Manufacturer
AH PlusTM	AH Plus Paste A: Epoxy Resin with Bisphenol-A, epoxy resin with bisphenol-F, calcium tungstate, zirconium oxide, silica, iron oxide pigments. AH Plus Paste B: Dibenzildiamina; aminoadamantane; triciclodecano diamine, calcium tungstate, zirconium oxide, silica, silicone oil.	Dentsply DeTrey, Konstanz, Alemanha
Sealer Plus BC	Zirconium oxide, tricalcium silicate, dicalcium silicate, calcium hydroxide, propylene glycol.	MK Life, Porto Alegre, RS, Brazil

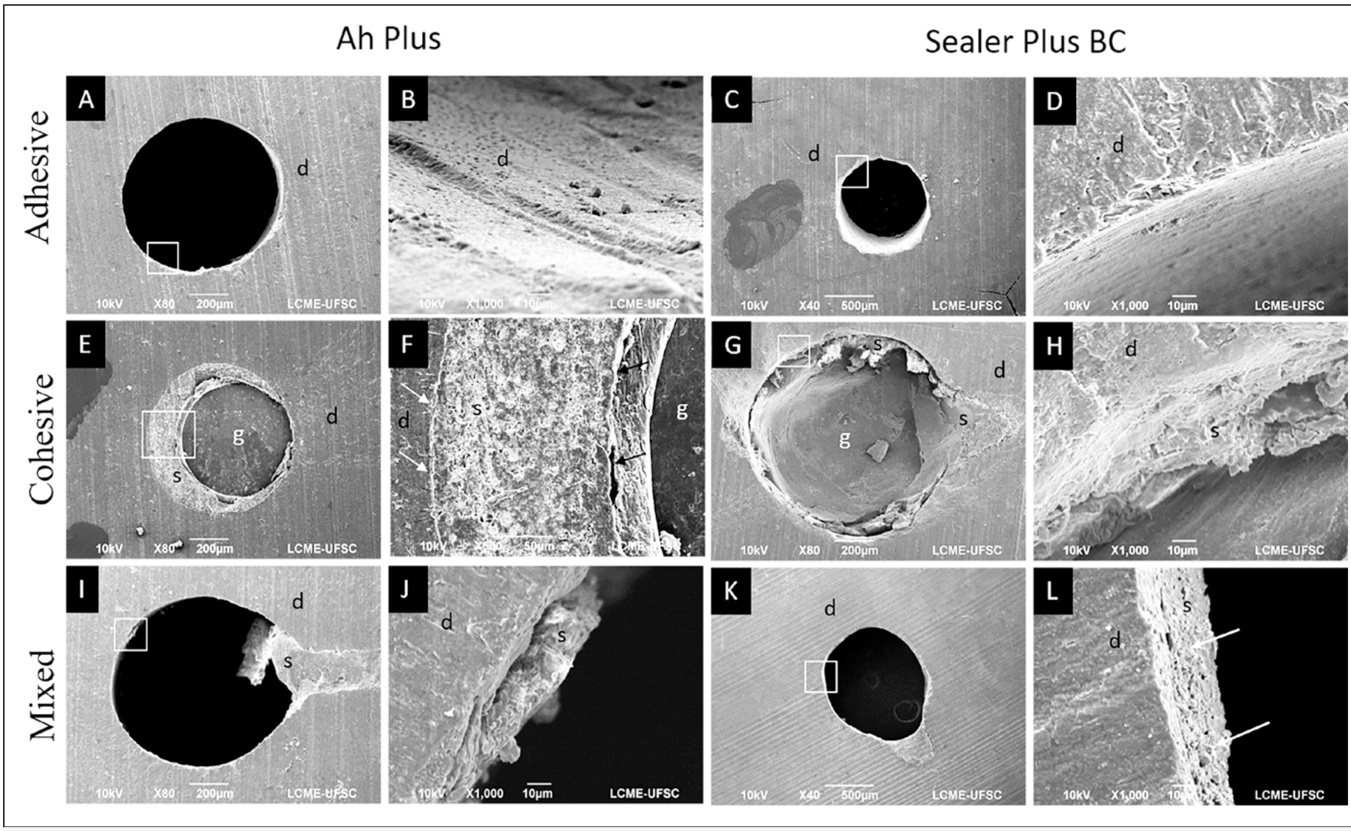

Figure 1
Representative SEM images of the failure mode analysis for the AH Plus (A-B, E-F, I-J) and Sealer Plus BC Groups (C-D, G-H, K-L). Adhesive-type failures in low magnification (A, C). Note in higher magnification the dentine surface free of sealer and the exposure of dentinal tubules after displacement of the filling material, specially at the AH Plus group (B). In the group filled with the calcium silicate-based sealer, a white surface with a lesser number of open dentinal tubules was observed (D). Low magnifications of cohesive-type failures showing the fracture of the filling material (E, G). Details of the cohesive failures in higher magnification (F, H). In the AH Plus group, it is possible to observe the sealer still adhered to the dentine surface (white arrows) and fractured inside material (black arrows) (F). Higher magnification of the area demarcated in G showing the calcium silicate-based sealer fractured and partially adhered to the dentine (H). Mixed-type failures showing the simultaneous occurrence of adhesive failure at the dentine and cohesive failure of the filling material in both groups (I, K). Higher magnification showing details of the mixed failure mode, with the presence of the epoxy-resin based sealer fractured and adhered to the dentine (J), and the presence of sealer's particles adhered to the dentine surface showing structural cohesive failure of the calcium silicate-based sealer (L).
d: dentin; g: gutta-percha; s: sealer.

G_{70E} (higher moisture): the excess of distilled water was removed with size 40 absorbent paper points (Dentsply Maillefer). Root canals were dried with the application of 3 mL of 70% ethanol using a syringe with a NaviTip 30-gauge needle inserted up to 2 mm from the apical foramen. Ethanol was left in the root canal for 1 minute, and then, it was aspirated using a syringe with Capillary tip (Purple, Ultradent, South Jordan, UT, USA).
Each group was then randomly redistributed into 2 subgroups (n=11), according to the endodontic sealer used, as follows: Sealer Plus BC (MK Life) and AH Plus (Dentsply De Trey). Each sealer used in the experimental procedures, with the respective composition and manufacturers are shown in Table 1.

Root Canal Obturation
The endodontic sealers were manipulated according to the recommendations of their respective manufacturers. Root canal obturation was performed by the single cone technique, using a master gutta-percha cone of the Reciproc system (R40, VDW GmbH). The sealer was applied to canal walls using a lentulo spiral (Dentsply, Maillefer). The master cone was coated

with sealer and placed within the canal up to the WL. After gutta-percha excess removal with a heated plugger (Odous de Deus, Belo Horizonte, MG, Brazil) and vertical compaction, the root canal entrance was restored with a temporary restorative material (Citodur, Dorident, Austria) and the specimens were stored in an oven at 37 °C and 100% relative humidity for 7 days, to allow sealers setting.

Push-Out Test

The roots were transversely sectioned in relation to their long axis with a diamond saw blade (South Bay Technology, San Clement, CA, USA), coupled to a metallographic cutter (Isomet 1000, Buehler, Lake Forest, IL, USA), obtaining 1 mm-thick slices. The first and last slices were discarded from the final sample. Six slices per root were selected to perform the push-out test.

The root slices were individually attached to the lower portion of the Universal Testing Machine (Model 4444, Instron, Canton, OH, USA). A compressive load was applied by a cylindrical plunger (0.6-1.0 mm in diameter) attached to the upper portion of the Universal Testing Machine. A cross-head speed of 0.5 mm/min was applied, until bond failure has occurred.

The maximum force required for the filling material displacement was measured in Kilonewtons (KN), transformed into Newtons (N) and converted into Megapascal (MPa) by force division by the lateral area (SL) of the obturation. SL was calculated by the following formula:

$$SL= \pi(R+r)\sqrt{(h^2+(R-r)^2}$$

where SL=lateral bonded surface area, R=measure of the radius of the root canal in its coronal portion, r=measure of the radius of the root canal in its apical portion, h=height/thickness of the root cross section.

Failure Mode Analysis

After the push-out test, the fractured slices were submitted to a careful visual examination in a stereomicroscope (SteREO Discovery V12, Carl Zeiss, Jena, Germany) at ×50 magnification. The failure mode was classified, according to the following criteria: adhesive failure (dentine surface free of sealer); cohesive failure (filling material fracture, with the dentine surface covered by sealer); or mixed failure (part of the dentine surface covered by sealer and another free).

Representative samples of each group were selected and prepared for analysis under Scanning Electron Microscope (SEM) (JEOL JSM 6390 LV, Peabody, MA, USA). The samples were dried, mounted on aluminum stubs, placed in a vacuum chamber and sputter-coated with a gold layer of 300

Table 2

Bond strength Mean Values (MPa) and Standard Deviation for AH Plus, considering the different root canal thirds and drying protocols (G_{PP}, G_{95E} and G_{70E})

Drying Protocol	AH Plus		
	Cervical	Medium	Apical
G_{PP}	0.69 ±1.21^{Aa}	0.87±1.29^{Aa}	0.97±1.28^{Aa}
G_{95E}	0.79 ±1.07^{Aa}	0.91±1.18^{Aa}	1.06±0.90^{Aa}
G_{70E}	1.19 ±1.49^{Aa}	0.71±0.89^{Aa}	1.16±0.91^{Aa}

**Equal uppercase letters in the lines indicate no significant statistical difference among the root thirds (Kruskal-Wallis test, p>0.05).*
**Equal lowercase letters in the columns indicate no significant statistical difference among the drying protocols (Kruskal-Wallis test, p>0.05).*
G_{PP}: control group, drying protocol with paper points; G_{95E}: 95% ethanol and paper points; and G_{70E}: 70% ethanol and aspiration.

Table 3

Bond strength Mean Values (MPa) and Standard Deviation for Sealer Plus BC, considering the different root canal thirds and drying protocols (G_{PP}, G_{95E} and G_{70E})

Drying Protocol	Sealer Plus BC		
	Cervical	Medium	Apical
GPP	0.65 ± 0.71^{Aa}	0.47 ± 0.43^{Aa}	1.08 ± 0.87^{Aa}
G95E	0.50 ± 0.54^{Aa}	1.04 ± 1.55^{ABa}	1.06 ± 0.59^{Ba}
G70E	1.24 ± 1.61^{Aa}	1.21 ± 1.72^{Aa}	1.51 ± 1.23^{Aa}

Different uppercase letters in the lines indicate statistical difference among the root thirds (Kruskal-Wallis test and Games-Howell post-hoc, p<0.05).
Equal lowercase letters in the columns indicate no significant statistical difference among the drying protocols (Kruskal-Wallis test, p>0.05).
GPP: control group, drying protocol with paper points; G95E: 95% ethanol and paper points; and G70E: 70% ethanol and aspiration.

A° (Bal-Tec SCD 005, Bal-Tec Co., Balzers, Liechtenstein). The failure mode analysis was performed under SEM operated at accelerating voltage of 15 kV, at ×20, ×40, ×80, ×500 and ×1000 magnifications (Figure 1).

Statistical Analysis
The normality of the data was verified by the Kolmogorov Smirnov test ($p<0.05$) and non-parametric tests were used in the data analysis ($\alpha=5\%$). When the drying protocols and different root canal thirds were considered in the analysis, the bond strength data were submitted to Kruskal-Wallis test, complemented by the Games-Howell post-hoc test. The comparison between the endodontic sealers was performed by the Mann-Whitney U test, when the root canal thirds were not considered. The statistical tests were performed with the aid of the GraphPad Prism 4.0 Software program (GraphPad Software, La Jolla, CA, USA).

Results

Table 2 and 3 show the bond strength mean values of AH Plus and Sealer Plus BC, respectively, considering the different root canal thirds. In samples obturated with AH Plus, there was no significant difference between the experimental groups (drying protocols), irrespective of the root canal third assessed ($P>0.05$). For Sealer Plus BC, no significant difference between

Table 4

Bond strength Mean Values (MPa) and Standard Deviation for AH Plus and Sealer Plus BC considering the drying protocols (G_{PP}, G_{95E} and G_{70E})

Drying Protocol	Sealer	
	AH Plus	Sealer Plus BC
G_{PP}	0.84 ± 1.23^{Aa}	0.71 ± 0.65^{Aa}
G_{95E}	1.24 ± 0.94^{Aa}	0.85 ± 0.69^{Aa}
G_{70E}	1.16 ± 1.25^{Aa}	1.34 ± 1.38^{Aa}

Equal uppercase letters in the lines indicate no significant statistical difference between the sealers (Mann-Whitney U test, p>0.05).
Equal lowercase letters in the columns indicate no significant statistical difference among the drying protocols (Kruskal-Wallis test, p>0.05).
G_{PP}: control group, drying protocol with paper points; G_{95E}: 95% ethanol and paper points; and G_{70E}: 70% ethanol and aspiration.

Table 5

Distribution of Failure Modes (%) according to the sealers and drying protocols

Drying Protocol	Sealer					
	AH Plus			Sealer Plus BC		
	Adhesive	Cohesive	Mixed	Adhesive	Cohesive	Mixed
G_{PP}	22.23	44.44	33.33	17.16	31.42	51.42
G_{95E}	22.23	41.66	36.11	20.58	29.41	50.01
G_{70E}	48.49	12.12	39.39	21.42	39.30	39.28

G_{PP}: control group, drying protocol with paper points; G_{95E}: 95% ethanol and paper points; and G_{70E}: 70% ethanol and aspiration.

the drying protocols was observed (P>0.05), however, there was statistical difference between the cervical and apical root canal thirds for G_{95E} (P=0.017). When the root canal thirds were not considered in the analysis, no statistically significant difference was observed between the drying protocols for AH Plus (P=0.446) and Sealer Plus BC (P=0.497) (Table 4).

Table 5 shows the distribution of the failure modes (adhesive, cohesive or mixed). AH Plus presented predominantly cohesive failures for G_{PP} (44.44%) and G_{95E} (41.16%), and adhesive failure for G_{70E} (48.49%). For the Sealer Plus BC, the majority of specimens presented mixed failure (G_{PP} 51.42% and G_{95E} 50.01%). G_{70E} presented similar percentages of cohesive (39.30%) and mixed (39.28%) failures.

Discussion

The integrity of root canal sealing after obturation is directly related to the bond strength of the endodontic sealer to the dentinal walls (23). However, the moisture and the presence of fluids prior to this clinical step may influence the adhesiveness of sealers (21, 22). Other studies also have showed the effect of intracanal moisture on the bond strength of endodontic sealers to root canal dentin (16, 17, 20, 21, 24, 25). On the other hand, until now, no studies have evaluated the influence of different drying protocols on the bond strength of Sealer Plus BC (bioceramic endodontic sealer) to the root canal walls. Therefore, the purpose of the present study was to evaluate the influence of different root canal drying protocols on the bond strength of a bioceramic endodontic sealer, in comparison with an epoxy resin-based sealer. Based on the results obtained, the null hypothesis was accepted, as none of the assessed drying protocols affected the bond strength of the endodontic sealers to the root dentin, when root canals were obturated with the single cone technique.

The bond strength of the endodontic sealers may be measured by several methods, and the push-out test is one of the most used due to its easy reproducibility and interpretation of the results (26). In the present study, the resistance of the filling material to displacement was evaluated using tips with different diameters (0.6 to 1.0mm), specifically selected for use according to the diameter of the root canal in each root portion. The use of this apparatus allowed the force to be applied to the material in a more homogeneous way, making the results more reliable (27). The epoxy-resin based sealer chosen for comparison to the bioceramic has been widely used in previous studies and is consid-

ered a gold-standard sealer, since it has excellent physicochemical properties (28) and adequate bond strength to dentin (4).
In this study, to perform different moisture conditions of the root dentine, the canals were irrigated with different concentrations of alcohol and the content was dried with absorbent paper points or aspirated using a syringe with Capillary tip. This protocol has already been used in previous studies, with the aim of evaluating the influence of different moisture conditions on dentine and its relationship with different types of endodontic sealers (15, 17, 20).
Our results shows that the presence of greater or lesser moisture in the root canal, after the use of the different drying protocols, did not interfere in the bond strength of the tested sealers to root dentin. In addition, there was no statistically significant difference between both endodontic sealers, regardless of the drying protocol evaluated. These results differ from the literature, which has shown significant difference with the use of different root canal drying protocols, especially with respect to bioceramic sealers (18, 20-22, 24). It is important to point out that in our study we performed root canal filling simulating what happens in clinical reality, in which the endodontic sealers are used in conjunction with gutta percha cones for root canal filling. Many studies use only sealers to check the influence of moisture on its bond strength to root canal dentin (16-20). However, it is necessary to check the behavior of these sealers according to their clinical application, regardless of existing laboratory results.
The use of the single cone technique may be associated with the low bond strength values exhibited by the AH Plus sealer in our experiment. While some studies have shown higher bond strength values with the use of the single cone in root canal filling, others have observed lower adhesion to dentin with the use of this technique (26, 29), mainly in the obturation of oval root canals (27).
In another study, Araújo et al. (29) obtained results of bond strength to dentin (0.77 MPa), after root canal preparation with a reciprocating system and obturation with AH Plus by the single-cone technique, lower than the group in which the specimens were obturated by the lateral condensation technique.
These results are similar to the bond strength values obtained in the present study (0.84 MPa, Table 4), in the experimental group where the root canals were dried with paper points and sealed with epoxy-resin sealer.
According to Rached-Júnior et al. (26), during the execution of the single cone technique, the sealing forces are exerted mainly in the apical direction, which may reduce the frictional resistance of the filling material against the root canal walls and decrease the bond strength to dentin. In addition, the anatomic variations of the root canal may increase the occurrence of non-touched areas by the instruments during preparation, which may negatively affect the adaptation of the master cone (26). Also, according to the study of Pereira et al. (27), root canals with circular section have higher bond strength in the cervical and middle thirds than those with more oval section. The latter have 3 to 4 times more sealer in the cervical and middle thirds than circular canals, making these areas more susceptible to failure, due to larger sealer accumulation (27). In the apical third, the presence of less sealer may explain similar values of bond strength in all groups, including in the bioceramic sealer groups (27). However, the assessment of this condition was not included in the present study and should be evaluated in the future studies with the use of other methodologies.
The most appropriate dimensional stability of calcium silicate-based sealer is often highlighted as the main reason for allowing their use with the cold hydraulic condensation, especially the single-cone technique (7). In the single-cone technique, greater emphasis is placed on the sealer used than on gutta-percha (concept of sealer-based filling) (7). Thus, especially in non-vital teeth, the use of a calcium silicate-based sealer, such as Sealer BC, due to its more adequate biological properties, may induce a mild

inflammatory reaction and favor repair when in close contact with the periapical tissue (9).

Several studies have shown that the level of root canal moisture may affect the adhesiveness of the endodontic sealers, and that their composition also influences their behavior in the presence of higher or lower moisture (16, 17, 20, 22, 30). Nagas et al. (17) evaluated the bond strength of the iRoot SP, AH Plus and MTA Fillapex sealers inserted in root canals with different levels of residual moisture. These authors observed that, regardless of the moisture level, the bioceramic iRoot SP demonstrated the highest adhesive potential, which may be explained by the material composition. This class of sealer have particles of reduced size, which allows better flow between the gutta-percha cones and possible irregularities inherent to the root canal (30).

Paula et al. (20) assessed different drying protocols (70% isopropyl alcohol, paper points, EndoVac and 95% ethanol) prior to obturation with MTA Fillapex, AH Plus and Sealapex, and correlated the high polarity of the ethanol molecules with the canal dehydration, and consequent decrease of the adhesive potential of the sealers. In another study (25), the authors found that the iRoot SP sealer presented lower bond strength when the root canals were dried with paper points (3 to 4 units) and ethyl alcohol. This result might be explained by the fact that this material, similarly to other bioceramic sealers, has in its composition calcium silicate and calcium phosphate, whose main compounds require moisture to carry out the hydration reaction, allowing the sealer setting and hardening (31). Furthermore, the excessive drying promoted by the mentioned protocols removed the water present in the dentinal tubules, which may hinder the penetration of hydrophilic sealers and compromise the adhesion quality of them (15).

Such evidence corroborates with a recent study (16), which concludes that maintaining moist dentin, but not dry or wet dentin, may be advantageous before the filling root canals with bioactive sealers. However, in our study, there was no significant difference among the tested drying protocols when Sealer Plus BC was used for root canal filling. The methodological differences of the studies may have contributed to the achievement of different results, since in the study by Tasdemir et al. (24), for instance, the obturation was performed only with the iRoot sealer, without the presence of gutta-percha cones.

In the present study, Sealer Plus BC presented significant difference among the root canal thirds in G_{95E} (drying with 95% ethyl alcohol and paper points, lower moisture). The apical third had significant difference when compared to the middle and cervical thirds. In a study conducted by Dias et al. (18), the residual moisture was evaluated after root canals drying with paper points or paper points associated with irrigation with 70% isopropyl alcohol. The authors also reported differences in bond strength values among the root canal thirds, and related their results to the difficulty in standardizing the moisture along the root canal, due to the difference in density of the dentinal tubules and the difficulty of accessing and drying the solutions in the more apical portions (32). According to the manufacturer of the Sealer Plus BC, this sealer is an insoluble, radiopaque and non-aluminum compound, which contains calcium silicate and requires the presence of moisture to set. It may be assumed that in the groups obturated with Sealer Plus BC, the apical third presented a greater content of residual moisture than the cervical and middle thirds, optimizing the setting reaction of the sealer. However, new studies need to be performed to assess other obturation techniques associated to other drying protocols.

Studies have reported that water removal almost completely decreases the bond strength of calcium silicate-based endodontic sealers to root dentine (17,20,24). However, the excess of water may also be a detrimental factor for this class of materials (21). In a study conducted by Razmi et al. (21), the decrease of bond strength to dentin was verified when the sealer EndoSequence was inserted in an intracanal environment with presence of excessive humidity. The hydrophilic characteristics of the sealing materials will never be sufficient to displace the water in a fully wet root canal, leading to a trap of water droplets at the dentine-cement interface, which results in a decrease in adhesiveness (15).

Despite the results presented in other studies, the occurrence of extreme situations, which include dehydrated or excessively hydrated root canals, negatively interferes with the quality of sealer adhesion to the dentinal walls (17, 21). Sealer Plus BC and AH Plus, did not show significant statistical difference in relation to the drying protocols performed. Sealer Plus BC has good physicochemical properties, such as pH, calcium ion release, flow, radiopacity and setting-time, however, this new calcium silicate-based endodontic sealer showed higher solubility than recommended by ISO 6876:2012 (11). Also, as it is a premixed bioceramic sealer, it has some advantages, such as the reduced working time, and it is not influenced by manual mixing and any change in the powder-liquid ratio that may affect its physicochemical properties (33-35). When compared to the powder-liquid presentation form, this sealer may have better physicochemical properties, such as viscosity, solubility and bond strength to root dentine, however, as it was not the objective of the present study, further studies are needed to evaluate this comparison.

It is important to highlight that the present study has some limitations, such as the non-comparison with other bioceramic sealers and the non-use of a wet chamber to simulate a wet root canal, which would be more similar to the clinical situation than the use of an oven in this experiment. Therefore, it is necessary to carry out further laboratory and clinical studies in order to verify the physicochemical and biological properties of this sealer, comparing it with other calcium silicate-based endodontic sealers (premixed or not) and its use with different techniques of root canal filling.

Conclusions

The different levels of moisture did not influence the bond strength of the tested endodontic sealers to the root canal walls, when the single cone technique was used to perform the root canal filling. The bioceramic and the epoxy resin-based sealers presented similar results regarding bond strength, except for the apical third, when the root canal was dried with absorbent paper points and 95% ethanol prior to obturation with the bioceramic sealer.

Clinical Relevance

Moisture has a fundamental role in the hydration kinetics of bioceramic sealers. It is important that clinicians know the most appropriate root canal drying protocols when using bioceramic sealers for root canal obturation.

Conflict of Interest

None.

Acknowledgements

This research was supported in part by National Council for Scientific and Technological Development (CNPq).

References

1 *Pedro FM, Marques A, Pereira TM et al. Status of endodontic treatment and the correlations to the quality of root canal filling and coronal restoration. J Contemp Dent Pract 2016;17:830-6.*

2 *Asawaworarit W, Pinyosopon T, Kijsamanmith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. J Dent Sci 2020;15:186-192.*

3 *Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16:498-504.*

4 *Zhou HM, Shen Y, Zheng W et al. Physical properties of 5 root canal sealers. J Endod 2013;39:1281-6.*

5 *Lee JK, Kwak SW, Ha JH et al. Physicochemical properties of epoxy resin-based and bioceramic-based root canal sealers. Bioinorg Chem Appl 2017;2017:2582849.*

6 *Long J, Kreft JU, Camilleri J. Antimicrobial and ultrastructural properties of root canal filling materials exposed to bacterial challenge. J Dent 2020;93:e103283.*

7 *Sfeir G, Zogheib C, Patel S et al. Calcium Sili-*

cate-Based Root Canal Sealers: A Narrative Review and Clinical Perspectives. Materials (Basel) 2021;14(14):3965.
8 Benetti F, de Azevedo Queiroz ÍO, Oliveira PHC et al. Cytotoxicity and biocompatibility of a new bioceramic endodontic sealer containing calcium hydroxide. Braz Oral Res 2019;33:e042.
9 Alves Silva EC, Tanomaru-Filho M, da Silva GF et al. Biocompatibility and Bioactive Potential of New Calcium Silicate-based Endodontic Sealers: Bio-C Sealer and Sealer Plus BC. J Endod 2020;46(10):1470-7.
10 Viana FLP, Vivan RR, Pinheiro ET et al. Antimicrobial activity of new bioceramic endodontic sealers. RSD [Internet]. 2021J;10(8):e52910817593.
11 Mendes AT, Silva PBD, Só BB et al. Evaluation of physicochemical properties of new calcium silicate-based sealer. Braz Dent J 2018;29:536-40.
12 Torres FFE, Zordan-Bronzel CL, Guerreiro-Tanomaru JM et al. Effect of immersion in distilled water or phosphate-buffered saline on the solubility, volumetric change and presence of voids within new calcium silicate-based root canal sealers. Int Endod J 2020;53(3):385-91.
13 De Bem IA, de Oliveira RA, Weissheimer T et al. Effect of Ultrasonic Activation of Endodontic Sealers on Intratubular Penetration and Bond Strength to Root Dentin. J Endod 2020;46(9):1302-8.
14 Tagger M, Tagger E, Tjan AH, Bakland LK. Measurement of adhesion of endodontic sealers to dentin. J Endod 2002;28:351-4.
15 Zmener O, Pameijer CH, Serrano AS et al. Significance of moist root canal dentin with the use of methacrylate-based endodontic sealers: an in vitro coronal dye leakage study. J Endod 2008;34:76-9.
16 Ozlek E, Gündüz H, Akkol E, Neelakantan P. Dentin moisture conditions strongly influence its interactions with bioactive root canal sealers. Restor Dent Endod. 2020 Mar 24;45:e24.
17 Nagas E, Uyanik MO, Eymirli A et al. Dentin moisture conditions affect the adhesion of root canal sealers. J Endod 2012;38:240-4.
18 Dias KC, Soares CJ, Steier L et al. Influence of drying protocol with isopropyl alcohol on the bond strength of resin-based sealers to the root dentin. J Endod 2014;40:1454-8.
19 Al-Haddad AY, Kutty MG, Abu Kasim NH et al. The effect of moisture conditions on the constitution of two bioceramic-based root canal sealers. J Dent Sci 2017;12:340-346.
20 Paula AC, Brito-Júnior M, Araújo CC et al. Drying protocol influence on the bond strength and apical sealing of three different endodontic sealers. Braz Oral Res 2016; 30:e50.
21 Razmi H, Bolhari B, Karamzadehdashti N, Fazlyab M. The effect of canal dryness on bond strength of bioceramic and epoxy-resin sealers after irrigation with sodium hypochlorite or chlorhexidine. Iran Endod J 2016;11:129-33.
22 Khurana N, Chourasia HR, Singh G et al. Effect of Drying Protocols on the Bond Strength of Bioceramic, MTA and Resin-based Sealer Obturated Teeth. Int J Clin Pediatr Dent 2019;12:33-36.
23 Ungor M, Onay EO, Orucoglu H. Push-out bond strengths: The Epiphany-Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha. Int Endod J 2006;39:643-7.
24 Tasdemir T, Er K, Çelik D et al. Bond strength of calcium silicate-based sealers to dentine dried with different technique. Med Princ Pract 2014;23:373-6.
25 Kapur I, Malhotra A, Makkar S et al. Effect of Distinctive Moisture Conditions on Push-out Bond Strength of Three Root Canal Sealers-An In-Vitro Study. J Int Soc Prev Community Dent 2019;9:492-498.
26 Rached-Júnior FJ, Souza AM, Macedo LM et al. Effect of root canal filling techniques in the bond strength of epoxy resin-based sealers. Braz Oral Res 2016;30:e24.
27 Pereira RD, Brito-Júnior M, Leoni GB et al. Evaluation of bond strength in single-cone fillings of canals with different cross-sections. Int Endod J 2017;50:177-183.
28 Flores DSH, Rached-Júnior FJA, Versiani MA et al. Evaluation of physicochemical properties of four root canal sealers. Int Endod J 2011;44:126-35.
29 Araújo CC, Brito-Júnior M, Faria-e-Silva AL. Root filling bond strength using reciprocating file-matched singles-cones with different sealers. Braz Oral Res 2016;30:e53.
30 Shokouhinejad N, Gorjestani H., Nasseh AA et al. Push-out bond strength of gutta- percha with a new bioceramic sealer in the presence or absence of smear layer. Aust Endod J 2013;39:102-6.
31 Zhang W, Li Z, Peng B. Assessment of a new root canal sealer's apical sealing ability. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e79-82.
32 Tay FR, Loushine RJ, Lambrechts P et al. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. J Endod 2005; 31:584–9.
33 Kharouf N, Arntz Y, Eid A, et al. Physicochemical and Antibacterial Properties of Novel, Premixed Calcium Silicate-Based Sealer Compared to Powder-Liquid Bioceramic Sealer. J Clin Med 2020;9(10):3096.