

Original Article

Bond Strength of AH26 to Human Dentin Following Treatment with Dimethyl Sulfoxide (DMSO)

Maria Christou^{1*}

¹Department of Endodontology, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece.

*E-mail ✉ maria.christou.pro@gmail.com

Received: 12 January 2023; Revised: 28 March 2023; Accepted: 01 April 2023

ABSTRACT

This study investigated whether treating human coronal dentin with DMSO influences the adhesion of AH26 sealer. Seventy dentin samples were prepared and split evenly into two groups. All specimens underwent surface conditioning with 2 mL of 2.5 percent NaOCl, 3 mL of 17% EDTA, and a distilled water rinse. One group received an additional final rinse with 50% DMSO before AH26 application. Shear bond strength was then assessed using a universal testing machine at a crosshead speed of 0.5 mm/min. Statistical analysis using a paired samples t-test showed no significant difference between the groups, demonstrating that DMSO treatment did not affect AH26 bonding to dentin.

Keywords: Dimethyl sulfoxide, Dentistry, Bond strength, AH26, Sealer

How to Cite This Article: Christou M. Bond Strength of AH26 to Human Dentin Following Treatment with Dimethyl Sulfoxide (DMSO). *Int J Dent Res Allied Sci.* 2023;3(1):57-64. <https://doi.org/10.51847/DCI2pv2oU0>

Introduction

Achieving a long-lasting successful endodontic treatment relies heavily on creating a tight seal of the root filling material that prevents bacterial penetration. Gutta-percha is the most widely used core filling material [1]; however, it does not inherently bond to dentin, making the use of a root canal sealer crucial for improving the adaptation of the filling material [1]. Bond failure of endodontic sealers remains a clinical challenge and a potential cause of treatment failure [2, 3]. Therefore, an ideal sealer must adhere effectively to both dentin and gutta-percha [3]. Strong adhesion is beneficial for two reasons: it prevents fluid infiltration between the canal wall and gutta-percha in a static state, and it resists dislodgement of the filling under functional or manipulative forces [4].

Bonding between the filling material and canal walls can occur through chemical interaction or micromechanical retention. The bond quality is critical for resisting dislodgment and preserving the integrity of the core-dentin interface. Epoxy resin-based sealers

have demonstrated strong performance in this regard across multiple studies [5–9]. Their reactive epoxide rings form chemical bonds with dentin during polymerization, while mechanical interlocking is achieved as the sealer penetrates dentinal tubules and surface irregularities [10]. AH26, an epoxy-resin-based sealer, was selected for use in this study.

Dimethyl sulfoxide (DMSO; $(\text{CH}_3)_2\text{SO}$) is a polar aprotic solvent composed of a polar S=O group and two hydrophobic CH_3 groups [11]. Its amphiphilic nature, small molecular size, and dipolar aprotic properties make it an effective penetration enhancer for medical applications [12]. In adhesive dentistry, DMSO can disrupt the highly cross-linked collagen network in dentin by weakening hydrogen-bond-mediated forces, potentially improving material penetration and bond strength [13]. Studies have shown that DMSO treatment of acid-etched dentin may enhance long-term bond stability by inhibiting collagen-degrading enzymes [12] and increase immediate bond strength through better adhesive infiltration into collagen fibrils [13].

The use of a DMSO wet-bonding approach has been reported to enhance collagen encapsulation and improve resin–dentin bond quality [12–14]. A 50% DMSO solution is considered an effective concentration to enhance bonding, particularly for water-based etch-and-rinse adhesives [13, 14]. However, no studies have explored its effect on the adhesion of endodontic sealers to dentin. Given DMSO's ability to disrupt the dense collagen network into a more dispersed fibrillar structure, this study aimed to evaluate whether this modification could improve bonding of epoxy-resin-based sealers, which form chemical bonds between their epoxide rings and dentinal collagen amino groups [15].

The aim of this study was to assess the bond strength of AH26 to human coronal dentin treated with DMSO. The null hypothesis proposed that DMSO pre-treatment enhances the bond strength of AH26 to dentin.

Materials and Methods

This study adhered to the ethical principles outlined in the Declaration of Helsinki, and the protocol received approval from the institutional review board and ethics committee (protocol no. 107, 1 February 2022). The materials employed included AH26 sealer (AH26, Topseal; Dentsply, Konstanz, Switzerland) and dimethyl sulfoxide (DMSO) (Table 1).

Table 1. Materials used in this study.

Materials	Manufacturer	Composition
AH26 silver free (LOT: 1809000118)	Dentsply, Konstanz, Switzerland	Powder: bismuth oxide, methenamine Gel: epoxy resin
DMSO (LOT: E2119)	Santa Cruz Biotechnology, Heidelberg, Germany	C ₂ H ₆ OS

Specimen preparation

Thirty-five mandibular third molars from 18 patients aged 18–25 years, extracted within the past four months, were included in this study. Collection followed informed consent and approval from the Aristotle University of Thessaloniki Dental School Ethics Committee. Only teeth without caries, cracks, developmental defects, or previous restorations were selected. Teeth were stored at 4 °C in 0.2% thymol solution (Mallinckrodt Baker, Phillipsburg, NJ, USA) [16]. Each tooth was cleaned with an ultrasonic scaler (EMS Electro Medical Systems SA, Nyon, Switzerland) to remove calculus and periodontal ligament remnants, rinsed under running water to

eliminate thymol, and dried. Teeth were sectioned below the cemento-enamel junction using a diamond wafering blade (Isomet Blade, Buehler, Waukegan, IL, USA), and the crowns were split longitudinally in a buccolingual direction along mesial and distal surfaces using a low-speed diamond saw with water cooling (Buehler® Isomet™). Specimens were then divided into equal halves, and the mesial and distal surfaces were polished with 600-grit silicon carbide paper to obtain flat, smooth surfaces (Figure 1). Finally, all specimens were conditioned with 2 mL of 2.5 percent NaOCl, 17 percent EDTA, and rinsed with distilled water.

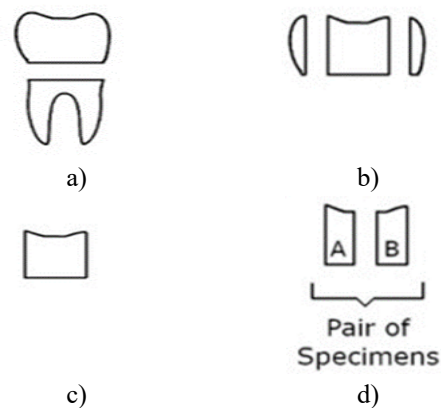


Figure 1. Specimen Preparation. (a) Teeth were first sectioned below the cemento-enamel junction, (b) then split longitudinally in the buccolingual direction along both mesial and distal surfaces, (c) the leftover portion of the specimen was retained, and (d) finally, this portion was cut centrally to yield two equal halves.

For testing, each dentin piece was mounted inside a copper ring on a glass plate, and the space around the specimen was filled with light-cured acrylic to hold it firmly. To standardize the bonding area, plastic cylinders (2 mm height × 2 mm diameter) were placed on the specimens using modified stationary clamps (Figures 2 and 3).

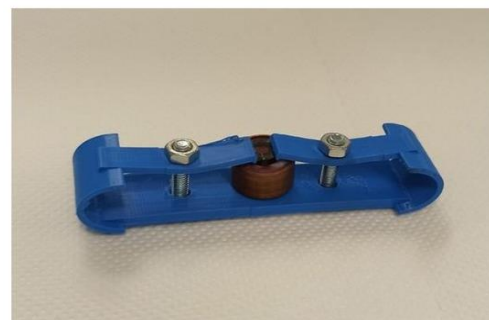


Figure 2. Modified clamp used to secure the plastic cylinders in place.

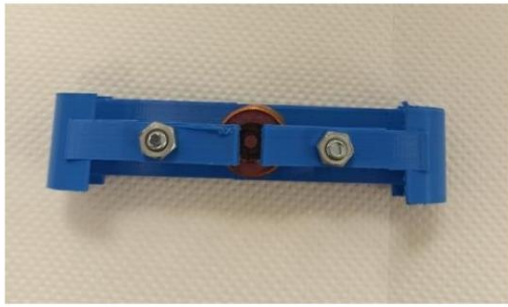


Figure 3. Alternative view of the modified clamp used to stabilize the plastic cylinders.

From each tooth, two dentin specimens were collected, with one assigned to group A and the other to group B, resulting in two equal groups of 35 samples each. The two groups underwent separate treatment protocols. In group A, specimens were first rinsed with 3 mL of 17% EDTA (Largal Ultra, Septodont, France) for two minutes, then briefly washed with distilled water for 10 seconds, and air-dried for 10 seconds prior to sealer placement. AH26 sealer was prepared according to the manufacturer's 2:1 powder-to-liquid ratio instructions and applied using a Buchanan Hand Plugger No. 2 (Kerr Endodontics). For group B, dentin surfaces were etched with 3 mL of 17% EDTA for 2 minutes, rinsed with distilled water for ten seconds, and air-dried for 10 seconds, followed by a careful application of 50 percent DMSO for 1 minute with a disposable brush, a protocol designed to preserve dentin collagen integrity. After a brief 5-second air-dry, AH26 sealer was applied in the same manner as group A. **Table 2** provides an overview of the groups, the respective dentin treatments, and the materials used.

Table 2. Dentin treatment amnnd materials.

Group	Dentin Treatment	Materials
A	3 mL EDTA 17%, 2 min	AH26
	Drying with air spray, 10 s	
B	3 mL EDTA 17%, 2 min	DMSO AH26
	Rinse with distilled water, 10 s	
	Drying with air spray, 10 s	
	DMSO, 60 s	
	Gently air dry, 5 s	
	AH26	

After the endodontic sealer was applied, all specimens, including both dentin and bonded materials, were initially left at room temperature for 4 hours and subsequently incubated at 37 °C with 100 percent humidity for one week. Following this period, the samples underwent shear bond strength testing and were examined under a stereomicroscope to identify the mode of failure.

Shear bond strength testing

Each specimen was positioned so that the applied load was parallel to the adhesive interface between the dentin and the sealer. Shear bond strength was measured using a universal testing machine (Ultratester™, Ultradent, South Jordan, UT, USA) at a crosshead speed of 0.5 mm/min, following established testing parameters [10]. The force required to separate the sealer from the dentin was recorded in kilograms using a Sentan kb3 device (Sentran, LLC, Ontario, CA, USA) attached to the testing machine, and the resulting bond strength was expressed in megapascals (MPa).

After testing, each specimen was evaluated under a stereomicroscope (Nikon SMZ10, Tokyo, Japan) at 20× magnification to determine the failure type. Failures were classified as adhesive if separation occurred at the dentin–sealer interface, cohesive if the break occurred within the sealer itself without affecting the interface, or mixed when both interface and sealer material were involved [10].

Statistical analysis

Sample size was estimated based on a prior pilot study, assuming an effect size of 0.5, a power of 0.95 (1–β), and a significance level of $\alpha = 0.05$. Statistical analysis was performed using a paired-samples t-test via G*Power 3.1 software (version 3.1.9.2, Franz Faul, Kiel University, Germany) [10, 13], which indicated that more than 35 pairs of specimens were sufficient.

Normality of the data was verified using both the Shapiro–Wilk and Kolmogorov–Smirnov tests, which confirmed a normal distribution ($p > 0.05$). Consequently, paired-samples t-tests were conducted to compare differences between groups. All analyses were performed using IBM SPSS version 25, applying a 5% significance threshold.

Results and Discussion

Table 3 presents the mean shear bond strength values (MPa) along with standard deviations, showing that the two groups had comparable bond strength measurements.

Table 3. Descriptive statistics of the involved variables.

Variable	Mean	Std Deviation	Minimum	Maximum
Group A	0.8924	0.3753	0.2256	1.7162
Group B	0.8927	0.4164	0.2157	2.0299

The paired-samples t-test results showed no statistically significant difference between the variables, with the p-value exceeding the 5% threshold ($p > 0.05$) (**Table 4**).

Table 4. Paired samples t-test results.

Pair of Variables	Mean Difference	Standard Error	t-Statistic	p-Value
Group A–Group B	-0.00028	0.07119	-0.004	0.997

Microscopic evaluation of all fractured surfaces demonstrated that bond failure was predominantly adhesive in the AH26 sealer group without DMSO (group A). Specifically, group A exhibited 77.1 percent adhesive, 14.3 percent cohesive, and 8.6 percent mixed failure modes, whereas group B (AH26 with DMSO) showed 71.5 percent adhesive, 17.1 percent cohesive, and 11.4 percent mixed failures. A 95% confidence interval was applied. The distribution of failure types for both groups is detailed in **Table 5**, and representative images of each failure type were captured during microscopic analysis (**Figures 4–9**).

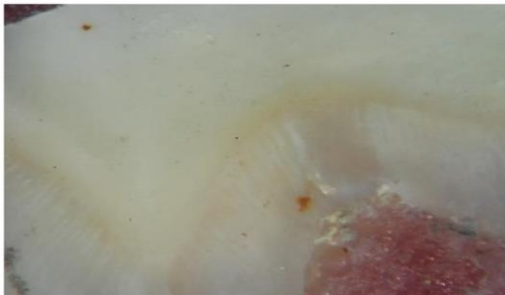


Figure 4. Adhesive-type failure observed in group A



Figure 5. Adhesive-type failure observed in group B.



Figure 6. Cohesive-type failure in group A.

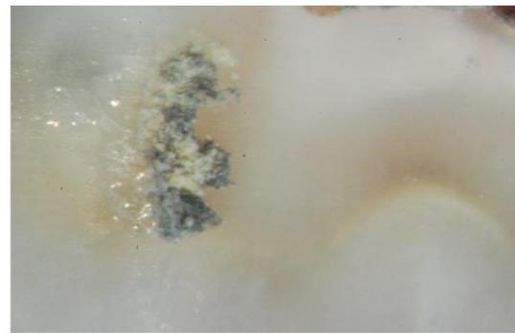


Figure 7. Cohesive-type failure in group B.



Figure 8. Mixed-mode failure observed in group A.



Figure 9. Mixed-mode failure observed in group B.

Table 5. Fracture models of the materials.

Material	Adhesive Failure	Cohesive Failure	Mixed Mode Failure	Confidence Interval
AH26	27 (77.1%)	5 (14.3%)	3 (8.6%)	95%
AH26 + DMSO	25 (71.5%)	6 (17.1%)	4 (11.4%)	95%

Discussion

Achieving a bacteria-tight seal remains one of the primary objectives of root canal obturation in endodontic treatment. To meet this goal, continuous research seeks to identify sealers with superior performance characteristics—particularly enhanced adhesion and deeper tubular penetration—and to determine the most effective dentin pretreatment protocols that optimize sealer adaptation. Among

various agents, 50% dimethyl sulfoxide (DMSO) has been extensively studied in adhesive dentistry. Evidence indicates that DMSO can disrupt the dense collagen structure within dentin by weakening hydrogen bonds, effectively transforming the cross-linked collagen matrix into a more dispersed fibrillar network [17]. Additionally, DMSO reduces dentin surface free energy, improving its wettability and facilitating deeper adhesive infiltration. These characteristics suggest that DMSO could improve the adhesive interface between sealers and dentin, warranting further exploration. In the current study, DMSO was applied with the aim of utilizing its chemical and surface-modifying properties to promote a more stable and durable bond between the root canal sealer and dentin [18]. However, the null hypothesis asserting that DMSO pretreatment would increase the bond strength of the AH26 root sealer was rejected, as the results revealed no significant enhancement in adhesion strength following its application.

The formation of a smear layer is an unavoidable consequence of mechanical instrumentation on hard tissues, whether using hand files or rotary systems. Eldarrata *et al.* [19] reported that this layer, typically around 0.5 μm thick, is composed of organic and inorganic materials such as hydroxyapatite debris, saliva, microorganisms, and blood remnants. Structurally, it consists of a superficial amorphous coating and a deeper component extending up to 110 μm into the dentinal tubules, known as a smear plug. This layer can act as a physical barrier at the adhesive interface, hindering effective bonding between adhesive agents and dentin. Therefore, it is widely accepted that dentin conditioning using chelating agents enhances sealer adhesion [20]. In this study, dentin was pretreated with 17% EDTA to eliminate the smear layer, thereby improving the sealer's adaptation and bonding performance. Smear layer removal not only facilitates more efficient cleaning and disinfection of the canal walls but also promotes both chemical and micromechanical adhesion. While a smooth dentin surface favors chemical bonding, micromechanical retention occurs when the sealer penetrates into surface irregularities and dentinal tubules. Consequently, removing the smear layer has been demonstrated to improve the bonding interface and increase the bond strength compared to untreated dentin [20].

Among various endodontic sealers, AH26 has consistently shown superior bond strength in multiple investigations [6-9]. Its selection in this study was based on its unique molecular adhesion mechanism. The epoxy-resin-based AH26 interacts with the amino groups of collagen through covalent bonding, which occurs when the epoxide ring opens and binds to the

exposed collagen on the dentin surface [1]. It was hypothesized that DMSO, by breaking down cross-linked collagen into individual fibrils, might facilitate greater interaction between the epoxide rings of AH26 and the available amino groups of collagen, thereby enhancing the overall adhesive performance. Although this theoretical mechanism suggests an improvement in bonding potential, previous studies already indicate that AH26 demonstrates strong adhesion to dentin even without DMSO treatment. Comparative analyses have shown that AH26 exhibits significantly higher bond strength than other sealers such as Diaket and Ketac-Endo. Furthermore, pretreating dentin with a chelating agent has been shown to further augment AH26's adhesive capacity [21].

Several studies have consistently demonstrated the beneficial influence of DMSO on dentin adhesion. Mehtälä *et al.* reported that pretreating wet dentin with DMSO enhanced the adhesive bond by increasing the exposure of collagen fibrils within the dentin matrix [14]. Similar findings from other investigations confirmed that DMSO application improved the quality of the collagen-resin hybrid layer at the bonded interface by limiting the exposure of the densely cross-linked collagen structure, suggesting that a 50% DMSO solution could serve as an effective approach to strengthen the resin-dentin bond, particularly when using water-based etch-and-rinse adhesive systems [13, 14]. Nevertheless, previous research examining DMSO's impact has primarily focused on its interaction with dentin bonding agents. Because this solvent can expand the collagen matrix, dissolve adhesive components, permeate dentinal collagen, exhibits low toxicity, and enhances both short-term and long-term bond durability, it has been proposed as a potential additive for improving the adhesive performance of epoxy resin sealers on dentin surfaces. In the present study, the effect of DMSO pretreatment on the bonding behavior of the AH26 sealer was assessed. Contrary to earlier findings supporting DMSO's positive role with bonding agents, the current results indicated that its application did not significantly influence AH26's adhesion to dentin. Thus, both chemical and micromechanical bonding mechanisms of the AH26 sealer remained unaffected. This outcome may be attributed to the fundamental differences in bonding mechanisms between conventional dentin bonding agents and epoxy resin-based sealers. The distinct chemical makeup of self-etch adhesive monomers and the structural characteristics of their resulting collagen-resin matrices differ substantially from those of epoxy resin sealers, particularly concerning the interaction between the epoxy ring and dentin's amino groups.

Microscopic analysis of the fractured specimens showed that adhesive failure was the predominant mode of bond failure. Because the sealer was used independently, cohesive failure was unlikely to occur. Previous research has shown that the bond between epoxy resin sealers and gutta-percha is weaker than the bond between sealers and dentin, which tends to result in cohesive failure during push-out bond strength tests [22-24]. Therefore, in the absence of a gutta-percha–sealer interface and depending on the testing method used, adhesive failure becomes more prevalent. Other studies employing the push-out test have also reported adhesive failure as the dominant pattern in epoxy resin sealers [25, 26].

Comparative analyses between the shear bond strength (SBS) and push-out testing methods have indicated that SBS testing is simpler, more efficient, and yields highly reproducible results when applied to both gutta-percha and dentin specimens [27]. It offers more uniform data with lower variability in bond strength values [28]. The SBS test is also considered more appropriate for materials exhibiting high plasticity, such as gutta-percha, for which the push-out method is less suitable. Furthermore, the use of flat dentin surfaces in SBS testing facilitates standardization and allows for more consistent comparisons between different filling materials. In this investigation, flat coronal dentin surfaces were used to evaluate the shear bond strength of AH26, minimizing sample variability. This choice was based on the structural differences between coronal and root dentin; the latter presents irregular canal walls and a non-uniform tubular structure. Moreover, the density of dentinal tubules decreases progressively from the coronal to the apical region, a factor that can influence specimen homogeneity and ultimately affect test outcomes [29]. Additional factors not examined in this study may influence bond strength, including contamination by fluids. Charuphan Oonsombat *et al.* demonstrated that blood contamination at any stage of bonding with a self-etch primer markedly reduces the shear bond strength of orthodontic brackets to enamel [30]. Another variable affecting adhesion is fluoride application, which, when performed before conditioning or bonding, significantly decreases bond strength values [31]. These potential influences merit examination in future *in vitro* and *in vivo* research.

Several investigations have explored how different dentin pre-treatment agents impact the bonding performance of endodontic sealers. Saleh *et al.* assessed the adhesion of multiple sealers—such as Grossman’s sealer, Apexit, Ketac-Endo, AH Plus, and RoekoSeal Automix—to dentin surfaces treated with 37% phosphoric acid, 17% EDTA, or 25% citric acid.

Their findings revealed that EDTA pretreatment either had no impact or led to weaker adhesion compared to controls, whereas phosphoric and citric acid pretreatment enhanced bonding only for Grossman’s sealer [7]. Similarly, another investigation evaluated the influence of MTAD and EDTA as final irrigants on the shear bond strength of Kerr, Apexit, and AH Plus sealers. The results showed that AH Plus demonstrated the highest bond strength when EDTA was applied, whereas MTAD negatively affected the adhesion of both AH Plus and Apexit [32]. These observations reinforce the idea that the effectiveness of dentin pretreatment varies depending on the chemical composition and bonding mechanism of each sealer type [7].

Although the shear bond strength test provides reliable and reproducible outcomes within uniform sample groups by minimizing structural and morphological inconsistencies, it has certain drawbacks. One major limitation lies in the difficulty of precisely aligning the shear-loading apparatus with the adhesive interface, while another is the inability to fully replicate clinical conditions; specifically, the direction of load application does not mimic the natural forces within the root canal since it is not perpendicular to the dentinal tubules [33]. Another limitation of the present research is the exclusive use of AH26 as the test sealer. This material was chosen due to its strong molecular bonding characteristics and consistently higher bond strength compared to other sealers. However, further investigations are required to better understand how DMSO interacts with dentin and how this interaction may enhance the adhesion of various endodontic sealers, including AH26. The current findings serve as an initial step toward clarifying the relationship between DMSO and endodontic sealers and should encourage future studies to refine and expand upon the existing experimental framework. Subsequent research should assess the impact of varying DMSO concentrations and application durations, as these factors are likely to influence its chemical activity and bonding efficacy.

Conclusion

Based on the findings of this study, DMSO did not significantly affect the bond strength of the AH26 root canal sealer to dentin. Further research is necessary to determine the optimal concentration and application conditions of DMSO that could potentially enhance dentin adhesion and improve the sealing efficiency of obturation materials.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Lee KW, Williams MC, Camps JJ, Pashley DH. Adhesion of endodontic sealers to dentin and gutta-percha. *J Endod.* 2002;28(10):684-8.
2. Gogos C, Economides N, Stavrianos C, Kolokouris I, Kokorikos I. Adhesion of a new methacrylate resin-based sealer to human dentin. *J Endod.* 2004;30(4):238-40.
3. Dovt R, Methad ND. Isotope determination of root canal failure. *Oral Surg Oral Med Oral Pathol.* 1955;8(10):1100-4.
4. Ørstavik D, Eriksen HM, Beyer-Olsen EM. Adhesive properties and leakage of root canal sealers in vitro. *Int Endod J.* 1983;16(2):59-63.
5. George G, Stewart AB. A comparative study of three root canal sealing agents. *Oral Surg Oral Med Oral Pathol.* 1958;11(10):1174-8.
6. Tagger M, Tagger E, Tjan AH, Bakland LK. Measurement of adhesion of endodontic sealers to dentin. *J Endod.* 2002;28(5):351-4.
7. Saleh IM, Ruyter IE, Haapasalo MP, Ørstavik D. Adhesion of endodontic sealers: scanning electron microscopy and energy dispersive spectroscopy. *J Endod.* 2003;29(9):595-601.
8. Assmann E, Scarparo RK, Böttcher DE, Grecca FS. Dentin bond strength of two mineral trioxide aggregate-based and one epoxy resin-based sealers. *J Endod.* 2012;38(2):219-21.
9. de Gee AJ, Wu MK, Wesselink PR. Sealing properties of Ketac-Endo glass ionomer cement and AH26 root canal sealers. *Int Endod J.* 1994;27(5):239-44.
10. Gogos C, Stavrianos C, Kolokouris I, Papadoyannis I, Economides N. Shear bond strength of AH-26 root canal sealer to dentine using three dentine bonding agents. *J Dent.* 2003;31(5):321-6.
11. Budeanu MM, Dumitrescu V. Densities, viscosities and excess properties for dimethyl sulfoxide with diethylene glycol and methyldiethanolamine at different temperatures. *Appl Sci.* 2022;12(1):116.
12. Tjäderhane L, Mehtälä P, Scaffa P, Vidal C, Pääkkönen V, Breschi L, et al. The effect of dimethyl sulfoxide (DMSO) on dentin bonding and nanoleakage of etch-and-rinse adhesives. *Dent Mater.* 2013;29(10):1055-62.
13. Scarabello STH, Leo T, Rocha MM, Baggio AFH, Marcondes MLR. Effect of dimethyl sulfoxide wet-bonding technique on hybrid layer quality and dentin bond strength. *Dent Mater.* 2015;31(6):676-83.
14. Mehtälä P, Pashley DH, Tjäderhane L. Effect of dimethyl sulfoxide on dentin collagen. *Dent Mater.* 2017;33(8):915-22.
15. Maxwell Z, Anthony MR, Bernard C, Olaf PE. Following dimethyl sulfoxide skin optical clearing dynamics with quantitative nonlinear multimodal microscopy. *Appl Opt.* 2009;48(1):79-87.
16. Goodis HE, Marshall GW Jr, White JM, Hornberger B, Marshall SJ. Storage effects on dentin permeability and shear bond strengths. *Dent Mater.* 1993;9(2):79-84.
17. Scarabello STH, Arzu TM, Murat MM, Martins LRM, do Prado RL, Pizi ECG, et al. Influence of dimethyl sulfoxide used as a solvent on the physical properties and long-term dentin bonding of hydrophilic resins. *J Mech Behav Biomed Mater.* 2016;64:220-8.
18. Hebling J, Bianchi L, Basso FG, Scheffel DL, Soares DG, Carrilho MRO, et al. Cytotoxicity of dimethyl sulfoxide (DMSO) in direct contact with odontoblast-like cells. *Dent Mater.* 2015;31(4):399-405.
19. Eldarrat AH, High AS, Kale GM. In vitro analysis of 'smear layer' on human dentine using ac impedance spectroscopy. *J Dent.* 2004;32(7):547-54.
20. Eldeniz AU, Erdemir A, Shear SB. Bond strength of three resin based sealers to dentine with and without the smear layer. *J Endod.* 2005;31(4):293-6.
21. Salman R, Behnam I. Shear bond strength measurement of three different adhesive sealers to dentin & gutta-percha (in vitro study). *J Med Sci.* 2018;14(3):151-60.
22. Donnermeyer D, Dornseifer P, Schäfer E, Dammaschke T. The push-out bond strength of calcium silicate-based endodontic sealers. *Head Face Med.* 2018;14(1):13.
23. Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Shamshiri AR. 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(3):102-6.
24. Carvalho CN, Graziotin-Soares R, de Melo Candeiro GT, Martinez LG, de Sousa JP, de Sousa PO, et al. Micro push-out bond strength and bioactivity analysis of a bioceramic root canal sealer. *Iran Endod J.* 2017;12(3):343-8.

25. Kcay M, Arslan H, Topcuoglu HS, Tuncay O. Effect of calcium hydroxide and double and triple antibiotic pastes on the bond strength of epoxy resin-based sealer to root canal dentin. *J Endod.* 2014;40(10):1663-7.
26. Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LVJ, et al. Dentin moisture conditions affect the adhesion of root canal sealers. *J Endod.* 2012;38(2):240-4.
27. Bojar W, Czarnecka B, Pryliński M, Walory J. Shear bond strength of epoxy resin-based endodontic sealers to bovine dentin after ozone application. *Acta Bioeng Biomech.* 2009;11(3):41-5.
28. Tagger M, Tagger E, Tjan AHL, Bakland LK. Shearing bond strength of endodontic sealers to gutta-percha. *J Endod.* 2003;29(3):191-3.
29. Kadhim Hasan R, Al-Hashimi Majida K. Shear bond strength of endodontic sealers to dentin with and without smear layer and gutta percha: an in vitro study. *J Baghdad Coll Dent.* 2014;26(2):86-9.
30. Oonsombat C, Bishara SE, Ajlouni R. The effect of blood contamination on the shear bond strength of orthodontic brackets with the use of a new self-etch primer. *Am J Orthod Dentofacial Orthop.* 2003;123(5):547-50.
31. Cacciafesta V, Sfondrini MF, Calvi D, Scribante A. Effect of fluoride application on shear bond strength of brackets bonded with a resin-modified glass-ionomer. *Am J Orthod Dentofacial Orthop.* 2005;127(5):580-3.
32. Gopikrishna V, Venkateshababu N, Krithikadatta J, Kandaswamy D. Evaluation of the effect of MTAD in comparison with EDTA when employed as the final rinse on the shear bond strength of three endodontic sealers to dentine. *Aust Endod J.* 2011;37(1):12-7.
33. Silveira Teixeira C, Alfredo E, Thomé LHC, Gariba-Silva R, Silva-Sousa YTC, Sousa-Neto MD. Adhesion of an endodontic sealer to dentin and gutta-percha: shear and push-out bond strength measurements and SEM analysis. *J Appl Oral Sci.* 2009;17(2):129-35.