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Effect of Propylene Glycol on the Bond Strength of Two Endodontic Cements

Fereshte Sobhnamayan [a], **Alireza Adl** [b*], **Somaye Farmani** [c], **Nooshin Sadat Shojaee** [a]

a Department of Endodontics, Dental School, Shiraz University of Medical Sciences, Shiraz, Iran; b Department of Endodontics, Oral and Dental Disease Research Center, Dental School, Shiraz University of Medical Sciences, Shiraz, Iran; c Department of Orthodontics, Dental School, Shiraz University of Medical Science, Shiraz, Iran

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**Corresponding author*: Alireza Adl, Department of Endodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

Tel: +98-713 6263193
E-mail: adla@sums.ac.ir

ABSTRACT

Introduction: This study evaluated the effect of propylene glycol (PG) on the push-out bond strength of calcium-enriched mixture (CEM) cement compared to mineral trioxide aggregate (MTA). **Methods and Materials**: The lumens of two hundred 2±0.2 mm-thick root sections from human extracted teeth were prepared to achieve a diameter of 1.3 mm. The samples were then allocated into eight groups of 25 on the basis of the materials used (MTA or CEM cement) and different proportions of PG (0%, 20%, 505, and 100%). In each group, 0.4 mL of the liquid was mixed with 1 g MTA or CEM cement. After incubation, the push-out strength of the samples was measured using a universal testing machine. Data were analyzed using the two-way ANOVA followed by one-way ANOVA and student's *t*-test. **Results**: The MTA group showed significantly higher bond strength in comparison with CEM group ($P \leq 0.001$). Also 100% and 20% PG increased the bond strength of MTA ($P \leq 0.001$). For CEM cement, 100% and 50% PG decreased the bond strength ($P \leq 0.001$). **Conclusion**: This *in vitro* study demonstrated that while PG increased the push-out bond strength of MTA, it is not recommended for mixing with CEM cement.

Keywords: Bond Strength; Calcium-Enriched Mixture; Mineral Trioxide Aggregate; Propylene Glycol

Introduction

Propylene glycol (PG) is a clear, colorless and odorless viscous alcoholic compound with no evidence of carcinogenicity or genotoxicity, and it has been approved by the Food and Drug Administration as a safe food additive [1]. This substance has been used in the composition of many topical preparations [2] and some systemic medicaments like phenytoin and diazepam [1, 3]. In endodontics, PG has been used as a vehicle for calcium hydroxide because of its antimicrobial effect on the microorganisms commonly found in infected root canals [4]. The combination of calcium hydroxide with PG has been shown to be more effective in inhibiting the growth of bacteria compared with calcium hydroxide combined with other vehicles [5, 6]. Another advantage of PG is its consistency, which improves the handling qualities of the calcium hydroxide paste [7]. Moreover, increased diffusion of hydroxyl and calcium ions through the dentin and cementum has been reported when calcium hydroxide is mixed with PG [8, 9]. This diffusion of ions is important for periapical healing.

PG, in different proportions, has also been employed to improve the handling and physical and chemical properties of mineral trioxide aggregate (MTA) [1, 10-12]. Holland *et al.* [10] showed that PG facilitates the placement of MTA into the root canal with no influence on its biocompatibility. The addition of PG to MTA has also been shown to improve its sealing ability [11], flowability, pH, and calcium ion release [1]. Furthermore, mixing PG with MTA increases its push-out strength to dentin [12]. However, conflicting results have been reported regarding the effect of PG on the compressive strength of MTA [13, 14].

Calcium-enriched mixture (CEM) is a tooth-colored, water-based endodontic cement. The chemical composition of CEM cement is different from that of MTA [15]; however, they have similar clinical applications [16-20]. This endodontic cement has good sealing ability [21], excellent biocompatibility [22, 23], low cytotoxicity [24] and acceptable antibacterial effects [25]. However, a major weakness of CEM cement is its low bond strength to dentin [26, 27]. Previous studies have shown that mixing with PG improves compressive strength [13] and microhardness [28] of CEM cement but has no effect on its sealing ability [29]. Considering the promising effect of PG on the compressive strength and microhardness of CEM cement and also on the bond strength of MTA to dentin [12], this study was designed to evaluate the effect of different proportions of PG on the push-out bond strength of CEM cement compared to MTA.

Materials and Methods

Two hundred single-rooted extracted human teeth including maxillary incisors and mandibular premolars were used in this study. The teeth were cleaned using a periodontal curette and stored in 0.5% chloramine-T until use. The middle-third of the roots was transversely sectioned under running water to obtain 2 mm-thick root slices using a diamond saw microtome (Persi; T180, France). The canal space of each slice was enlarged with #2 to #5 Gates Glidden burs (DentsplyMaillefer, Ballaigues, Switzerland) using light pressure to achieve a standard diameter of 1.3 mm. After preparation, the sections were immersed in 17% ethylenediaminetetraacetic acid (EDTA) (Ariadent, Tehran, Iran) for 3 min, followed by immersion in 2.5% sodium hypochlorite for 3 min, and then thoroughly washed in distilled water (DW) and dried. MTA (Angelus, Londrina, Brazil) and CEM cement (Biunique Dent, Tehran, Iran) were prepared by mixing 1 gr powder with 0.4 mL associated liquid of each material in combination with different proportion (0%, 20%, 50%, and 100%) of PG (Merk, Darmstadt, Germany); liquid/PG ratios were determined by volume. The slices were randomly divided into 8 groups (n=25). In groups 1 to 4, MTA, and in groups 5 to 8, CEM cement were placed into the lumen of the slices and compacted using a large amalgam condenser (Table 1). The extruded material was removed with a wet cotton pellet to provide a flat MTA or CEM cement surface. The samples were then wrapped in a piece of gauze soaked in synthetic tissue fluid (pH=7.4) and incubated at 37°C and 95% humidity for 96 h [12].

Table 1. Groups of materials used in the present study

Groups	Materials
1	MTA+100% MTA liquid
2	MTA+20% PG-80% MTA liquid
3	MTA+50% PG-50% MTA liquid
4	MTA+100% PG
5	CEM+100% CEM liquid
6	CEM+20% PG–80% CEM liquid
7	CEM+50% PG-50% CEM liquid
8	CEM+100% PG

Push-out test

A universal testing machine (Zwick/Roell, Z050; Zwick/Roell, Ulm, Germany) was used to measure the push out bond strength. The samples were placed on a metal slab with a 1.5 mm hole in the center to allow for free motion of the plunger. A cylindrical stainless steel plunger with a 1 mm diameter was used to apply force on MTA and CEM cement inside root slices at a speed of 1 mm/min. The maximum load applied to the cements before dislodgement occurred was recorded in Newtons. For bond strength to be expressed in megapascals (MPa), the recorded value in Newtons was divided by the adhesion surface area of the cement in mm^2, calculated according to the following formula: $2\pi r \times h$, where π is the constant 3.14, r is the root canal radius, and h is the thickness of the root slice in millimetres.

Statistical analysis

The data were statistically analyzed using SPSS software version 18 (SPSS Inc, Chicago, IL, USA). Two-way ANOVA was used to assess the interaction effects between the two factors. One-way ANOVA and student's t test were employed for sub-group analysis comparing the materials and different proportions of PG individually. The level of significance was set at 0.05.

Results

Logarithm transformation was performed to normalize data. There was an interaction effect between variables (P≤0.001). The results of subgroup analysis are shown in Table 2. The MTA groups showed significantly higher bond strength than the equivalent CEM cement groups (P≤0.001).

Compared to 0%, other proportions of PG increased the bond strength of MTA. This increase was significant for 100% and 20% PG (P≤0.001).

Compared to 0%, other proportions of PG decreased the bond strength of CEM cement. This decrease was significant for 100% and 50% PG (P≤0.001).

Table 2. Mean (SD) and subgroup comparison of push-out bond strength of experimental groups. Different superscript lowercase letters (rows) or uppercase letters (columns) are significantly different (P<0.05)

Proportion of PG	Push-out bond strength		P-value
	MTA	CEM	
0%	5.14 (2.78) $^{B, a}$	3.31 (1.03) $^{B, b}$	0.012
20%	9.21 (4.1) $^{A, a}$	3.1 (1.56) $^{AB, b}$	≤0.001
50%	6.05 (2.92) $^{B, a}$	1.6 (0.69) $^{C, b}$	≤0.001
100%	12.68 (4.88) $^{A, a}$	2.2 (0.91) $^{AC, b}$	≤0.001

Discussion

An ideal endodontic material should be resistant to dislodging forces induced by tooth function or operative procedures [30, 31]. Therefore, the bond strength of materials used for perforation repair, root-end filling and apical plug formation is an important factor.

Different techniques are available for evaluation of the adhesion strength of dental materials to dentin, including tensile, shear and push-out bond strength tests [32]. The push-out test used in this study has been shown to be efficient and reliable [33].

The results of this study revealed that with each proportion of PG (0%, 20%, 50%, and 100%), MTA Angelus had higher push-out bond strength than CEM cement. Similarly, in several separate studies MTA Angelus showed higher bond strength to dentin when compared to CEM cement [26, 27, 34]. The higher bond strength of MTA could be attributed to the incomplete setting of CEM cement, different chemical components, and potential difference in shape, size, and distribution of hydroxyapatite crystals that form during hydration of the two materials [26]. In contrast, Ertas *et al.* [35] found no significant difference between the bond strengths of MTA Angelus and CEM cement. Different experimental set up including keeping or removing smear layer may explain the contradictory results.

The results of the present study also showed that 100% PG and 20% PG increase the push-out bond strength of MTA Angelus. This finding is in agreement with the results of Milani *et al.*[12], who showed that mixing MTA with PG increased the bond strength of MTA to dentin. Our results also support the finding of Brito-Junior *et al.* [11], who showed that the use of PG as a vehicle for MTA increased its sealing ability in furcal perforations. In the present study, the highest bond strength of MTA was observed in the 100% PG group, followed by the 20% PG group. Interestingly, the bond strength of MTA in the 50% PG group was not statistically different from that of 0% PG group. The reason of this finding is unknown even for the authors. Duarte *et al.* [1] mixed MTA with different ratios of PG/distilled water and concluded that the addition of PG to MTA Angelus improved MTA's flow ability and increased the pH and calcium ion release during the initial post-mixing periods. They also observed a direct relationship between greater amounts of PG and increased setting time. Therefore, they recommended 80% DW-20% PG as the optimum ratio. Considering the longer setting time of MTA mixed with pure PG and similar push-out bond strength of the 100% PG and 20% PG groups in the present study, we also recommend this ratio.

In the current study, the highest bond strength of CEM cement was observed in the 0% PG group. Also 20% PG causes a decrease in the bond strength although not significant compared to 0% PG. Similar result was reported by Adl *et al.* [29] when the effect of 20% PG was evaluated on the sealing ability of CEM cement. On the other hand, our results revealed that the 50% and 100% PG significantly decreased the bond strength of CEM cement. Therefore, it seems that opposite to MTA, mixing with PG has no positive effect on the bond strength of CEM cement. The different behaviors of these two endodontic cements when mixed with PG may be attributed to the differences in their composition and/or hydration process upon setting.

It should be mentioned that a previous study [13] reported that PG in concentration of 20% increased the compressive strength of CEM cement, which is somehow in contrast with the results of the present study. This discrepancy can be attributed to the different natures of compressive strength and push-out bond strength tests.

Conclusion

Under the limitations of this study, PG increased the push-out bond strength of MTA. However, mixing CEM cement with PG is not recommended where bond strength is important.

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Conflict of Interest: 'None declared'.

References

1. Duarte M, Alves de Aguiar K, Zeferino M, Vivan R, Ordinola-Zapata R, Tanomaru-Filho M, Weckwerth P, Kuga MC. Evaluation of the propylene glycol association on some physical and chemical properties of mineral trioxide aggregate. Int Endod J. 2012;45(6):565-70.
2. Hannuksela M, Salo H. The repeated open application test (ROAT). Contact Dermatitis. 1986;14(4):221-7.
3. Ishiwata H, Sugita T, Kawasaki Y, Takeda Y, Yamada T, Nishijima M, Fukasawa Y. Estimation of inorganic food additive (nitrite, nitrate, and sulfur dioxide) concentrations in foods and their daily intake based on official inspection results in Japan in fiscal year 1996. Shokuhin Eiseigaku Zasshi. 2000;41(1):79-85_1.
4. Fava L, Saunders W. Calcium hydroxide pastes: classification and clinical indications. Int Endod J. 1999;32(4):257-82.

5. Vaghela DJ, Kandaswamy D, Venkateshbabu N, Jamini N, Arathi G. Disinfection of dentinal tubules with two different formulations of calcium hydroxide as compared to 2% chlorhexidine: As intracanal medicaments against Enterococcus faecalis and Candida albicans: An in vitro study. J Conserv Dent. 2011;14(2):182.
6. de Magalhães Silveira CF, Cunha RS, Fontana CE, de Martin AS, de Almeida Gomes BPF, Motta RHL, da Silveira Bueno CE. Assessment of the antibacterial activity of calcium hydroxide combined with chlorhexidine paste and other intracanal medications against bacterial pathogens. Eur J Dent. 2011;5(1):1.
7. Pacios MG, de la Casa ML, de los Angeles Bulacio M, López ME. Calcium hydroxide's association with different vehicles: in vitro action on some dentinal components. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003;96(1):96-101.
8. Nunes ACGP, Rocha MJdC. Hydroxyl and calcium ions diffusion from endodontic materials through roots of primary teeth-in vitro study. J Appl Oral Sci. 2005;13(2):187-92.
9. Ximenes M, Cardoso M. Assessment of diffusion of hydroxyl and calcium ions of root canal filling materials in primary teeth. Pediatr Dent. 2012;34(2):122-6.
10. Holland R, Mazuqueli L, de Souza V, Murata SS, Júnior ED, Suzuki P. Influence of the type of vehicle and limit of obturation on apical and periapical tissue response in dogs' teeth after root canal filling with mineral trioxide aggregate. J Endod. 2007;33(6):693-7.
11. Brito-Júnior M, Viana F, Pereira R, Nobre S, Soares J, Camilo C, Faria-e-Silva A. Sealing ability of MTA-Angelus with propyleneglycol in furcal perforations. Acta Odontol Latinoam. 2009;23(2):124-8.
12. Milani AS, Froughreyhani M, Aghdam SC, Pournaghiazar F, Jafarabadi MA. Mixing with propylene glycol enhances the bond strength of mineral trioxide aggregate to dentin. J Endod. 2013;39(11):1452-5.
13. Sobhnamayan F, Adl A, Shojaee NS, Sedigh-Shams M, Zarghami E. Compressive Strength of Mineral Trioxide Aggregate and Calcium-enriched Mixture Cement Mixed with Propylene Glycol. Iran Endod J. 2017;12(4):493.
14. Ghasemi N, Rahimi S, Shahi S, Milani AS, Rezaei Y, Nobakht M. Compressive strength of mineral trioxide aggregate with propylene glycol. Iran Endod J. 2016;11(4):325.
15. Asgary S, Shahabi S, Jafarzadeh T, Amini S, Kheirieh S. The properties of a new endodontic material. J Endod. 2008;34(8):990-3.
16. Asgary S, Nosrat A, Seifi A. Management of inflammatory external root resorption by using calcium-enriched mixture cement: a case report. J Endod. 2011;37(3):411-3.
17. Asgary S. Furcal perforation repair using calcium enriched mixture cement. J Conserv Dent. 2010;13(3):156.
18. Asgary S, Ehsani S. Permanent molar pulpotomy with a new endodontic cement: A case series. J Conserv Dent. 2009;12(1):31.
19. Malekafzali B, Shekarchi F, Asgary S. Treatment outcomes of pulpotomy in primary molars using two endodontic biomaterials. A 2-year randomised clinical trial. Eur J Paediatr Dent. 2011;12(3):189-93.
20. Baek S-H, Lee WC, Setzer FC, Kim S. Periapical bone regeneration after endodontic microsurgery with three different root-end filling materials: amalgam, SuperEBA, and mineral trioxide aggregate. J Endod. 2010;36(8):1323-5.
21. Asgary S, Eghbal MJ, Parirokh M. Sealing ability of a novel endodontic cement as a root-end filling material. J Biomed Mater Res A. 2008;87(3):706-9.
22. Asgary S, Eghbal MJ, Parirokh M, Ghanavati F, Rahimi H. A comparative study of histologic response to different pulp capping materials and a novel endodontic cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106(4):609-14.
23. Asgary S, Eghbal MJ, Ehsani S. Periradicular regeneration after endodontic surgery with calcium-enriched mixture cement in dogs. J Endod. 2010;36(5):837-41.
24. Mozayeni MA, Milani AS, Marvasti LA, Asgary S. Cytotoxicity of calcium enriched mixture cement compared with mineral trioxide aggregate and intermediate restorative material. Aust Endod J. 2012;38(2):70-5.
25. Asgary S, Kamrani FA. Antibacterial effects of five different root canal sealing materials. J Oral Sci. 2008;50(4):469-74.
26. Adl A, Sobhnamayan F, Kazemi O. Comparison of push-out bond strength of mineral trioxide aggregate and calcium enriched mixture cement as root end filling materials. Dent Res J. 2014;11(5):564.
27. Adl A, Sobhnamayan F, Sadatshojaee N, Azadeh N. Effect of blood contamination on the push-out bond strength of two endodontic biomaterials. J Restor Dent. 2016;4(2):59.
28. Sobhnamayan F, Adl A, Shojaee NS, Zarei Z, Emkani A. Physical and Chemical Properties of CEM Cement Mixed with Propylene Glycol. Iran Endod J. 2017;12(4):474.
29. Adl A, Sobhnamayan F, Shojaee NS, Azad FT, Bahmani M. Effect of Propylene Glycol on the Sealing Ability of Mineral Trioxide Aggregate and Calcium-Enriched Mixture Cement Apical Barriers. Iran Endod J. 2017;12(3):318.
30. Reyes-Carmona JF, Felippe MS, Felippe WT. Biomineralization ability and interaction of mineral trioxide aggregate and white portland cement with dentin in a phosphate-containing fluid. J Endod. 2009;35(5):731-6.
31. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part I: chemical, physical, and antibacterial properties. J Endod. 2010;36(1):16-27.
32. Loxley EC, Liewehr FR, Buxton T, McPherson J. The effect of various intracanal oxidizing agents on the push-out strength of various perforation repair materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003;95(4):490-4.
33. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, Tay F, Ferrari M. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci. 2004;112(4):353-61.
34. Shokouhi MM, Abbaszadegan A, Ameri A, Sharifian SM, Nabavizadeh M. The effect of calcium chloride on push-out bond strength of calcium-enriched mixture cement and mineral trioxide aggregate. Iran Endod J. 2017;12(3):334.
35. Ertas H, Kucukyilmaz E, Ok E, Uysal B. Push-out bond strength of different mineral trioxide aggregates. Eur J Dent. 2014;8(3):348.

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