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# Effects of Calcium Hypochlorite and Sodium Hypochlorite, as Root Canal Irrigants, on the Bond Strength of Glass Fiber Posts Cemented with Self-Adhesive Resin Cement

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**ABSTRACT**

**Objectives:** Calcium hypochlorite ($Ca(OCl)_2$) is currently used as a root canal irrigant. The aim of this study was to compare the effects of calcium hypochlorite and sodium hypochlorite (NaOCl), as root canal irrigants, on the bond strength of posts cemented with a self-adhesive resin cement.

**Materials and Methods:** In this in-vitro study, 40 maxillary central incisors with similar root lengths were decoronated. The teeth were randomly divided into five groups based on the irrigant used: Group 1: normal saline (control), Group 2: 2.5% sodium hypochlorite, Group 3: 5.25% sodium hypochlorite, Group 4: 2.5% calcium hypochlorite, and Group 5: 5% calcium hypochlorite. Root canal treatments were performed with Gates-Glidden drills and the irrigant corresponding to each group was used upon changing the file and for irrigating the post space. Then, glass fiber posts were cemented by BisCem self-adhesive cement. After applying 1,000 thermocycles at 5-55°C, three samples of the mid-section of each root were prepared: one for scanning electron microscopy (SEM), and the rest for push-out testing. Data were analyzed with SPSS 23 software using one-way analysis of variance and post-hoc Tukey's test.

**Results:** The highest and lowest mean bond strengths were recorded in groups 5 and 1, respectively. There was a significant difference between the 5% calcium hypochlorite group and the other groups ($P<0.001$). The difference between the other groups was not significant.

**Conclusion:** The use of 5% calcium hypochlorite with self-adhesive cements increases the push-out bond strength of fiber posts to radicular dentin.

**Keywords:** Dental Bonding; Dental Adhesives; Post and Core Technique; Sodium Hypochlorite; Calcium Hypochlorite

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## INTRODUCTION

A common finding in daily dental treatments is a tooth with a minimal coronal structure in need of a dental post for retention inside the canal, for better distribution of functional forces, and for the support of future prostheses [1-3].

Disadvantages of metal posts, such as root fracture, weak aesthetics, and corrosion, and advantages of fiber posts, such as having an elastic modulus similar to that of dentin [4], reducing the rate of vertical root fractures [3,5,6] as a result of equal distribution of forces on the walls of the root canal [7], bonding to resin core materials, suitable aesthetics [6], and the possibility of root retreatment because of their easy retrieval from the root canal, have increased the use of fiber posts [8].

The adhesion between the tooth structure and adhesive cements is the result of physical and chemical interactions at the dentin-cement interface [9]. Various chemical substances are used as irrigants for chemical-mechanical preparation of root canals, aiming at disinfection, dissolving of pulp tissues, and smear layer removal [9].

Sodium hypochlorite (NaOCl) is a commonly used irrigant in root canal treatment due to its wide-spectrum antibacterial effect and its potential to dissolve necrotic tissue remnants [10]. In addition to its strong antibacterial effect which depends on the concentration of the available chlorine [10,11], sodium hypochlorite has the ability to remove organic contents, especially collagen. Sodium hypochlorite breaks down into sodium chloride (NaCl) and oxygen; the oxygen-rich layer is a strong inhibitor of the bond of resin cements to dentin [12,13]. Oxygen bubbles on the surface of cement and dentin interfere with the penetration of resin cements into dentinal tubules [14].

Sodium hypochlorite is thought to cause the oxidation of a number of compounds in the dentin matrix, especially collagen [12,15]. Radicals derived from dentinal proteins compete with vinyl free radicals produced by light activation of resins, leaving the end of the chain incomplete and the polymerization unfinished [13], thus compromising the bond strength of the adhesive system [16]; this also reduces the dentinal calcium and phosphate content [17], weakens the mechanical properties of dentin, such as the elastic modulus, bending strength, and hardness [18], and reduces the micro-mechanical interactions between adhesive resins and the root canal dentin after irrigation with sodium hypochlorite [19].

The search for a new irrigant has led to experimental studies on the use of calcium hypochlorite ($Ca(OCl)_2$). Dutta and Saunders [20] have recently introduced calcium hypochlorite as a root canal irrigant.

The effect of calcium hypochlorite, as a root canal irrigant, on the bond strength of fiber posts luted to radicular dentin with resin cements has not yet been investigated. Hence, the aim of the present study was to carry out a comparative investigation on the effects of calcium hypochlorite and sodium hypochlorite, as root canal irrigants, on the bond strength of posts cemented with a self-adhesive resin cement. The null hypothesis of this study was that 5.25% calcium hypochlorite irrigant could not have a significant effect on the push-out bond strength of fiber posts to dentin.

## MATERIALS AND METHODS

In this in-vitro experimental study, 40 single-canal premolars, recently extracted for orthodontic or periodontal reasons, without any cracks, root caries or curved canals, were selected. The teeth had similar mesiodistal and buccolingual diameters [1]. Surface debris was removed using periodontal scalers and hand instruments. The teeth were kept in 0.2% thymol solution [21] at room temperature. The teeth were decoronated perpendicular to the cementoenamel junction (CEJ) using a diamond disc (Skillbond, Jota, UK) such that 14 mm of the coronoapical length remained.

The specimens were randomly divided into five groups of eight samples each, and then, the canals were irrigated as follows: Group 1: 0.9% normal saline (control), Group 2: 2.5% sodium hypochlorite, Group 3: 5.25% sodium hypochlorite, Group 4: 2.5% calcium hypochlorite, and Group 5: 5% calcium hypochlorite.

The root canal was cleaned using the conventional step-back technique with a #35 K-file (Mani Inc., Tochigi-Ken, Japan) until reaching the working length, and then, the canal was shaped using #2 and #3 Gates-Glidden drills (Mani Inc., Tochigi-Ken, Japan). One ml of each irrigant was used for each sample in the corresponding study group using a 21-gauge syringe (Shafa Pharmaceuticals, Tehran, Iran) between changing the files and with Gates-Glidden drills. The irrigants were freshly prepared for each application. Next, the root canals were irrigated with distilled water and were dried with absorbent paper points (AriaDent, Tehran, Iran).

The root canals were obturated using the lateral condensation technique with gutta-percha cones (AriaDent, Tehran, Iran) of the same size, ProTaper files (Dentsply/Maillefer, Ballaigues, Switzerland), and a resin-based sealer (silver-free AH26, Dentsply DeTrey GmbH, Konstanz, Germany). Then, the coronal area was temporarily sealed with a composite resin (Denfil Flow, Vericom Co. Ltd., Gyeonggi-do, Korea).

The specimens were incubated (Behdad Digital Incubator, Tehran, Iran) at 37°C with 100% humidity for a week so that the sealer could be set. Then, 10 mm of the gutta-percha was removed from the root canal using #2 and #3 Peeso reamers (Mani Co., Tochigi-ken, Japan), while 4 mm of the gutta-percha was left at the end of the root canal to maintain the apical seal. Post spaces were prepared in all specimens using a special drill for the posts (Series 911, Conical Type 2°, Micro.Medica s.r.l., Robbio, PV, Italy).

In order to determine the effect of the irrigants, the post space was irrigated for 60 seconds with 5 ml of the irrigant corresponding to each group. Then, the teeth were irrigated with 5 ml of distilled water and were dried with absorbent paper points. Afterward, the posts (Micro.Medica s.r.l., Robbio, PV, Italy) were tested inside the canals to evaluate their fit, and they were cleaned with alcohol, dried, and cemented using BisCem self-adhesive cement (Bisco Inc., Schaumburg, IL, USA). The specifications of the materials used in the present study are listed in Table 1.

In order to cement the posts, the cement was placed inside the canal using special injection points that slowly moved backward while the canal was filled. The post was kept inside the canal for 30 seconds to ensure its complete seating. Next, light-curing (Optilux 501, Kerr Demetron, Orange, CA, USA) was performed for 40 seconds. After cementing and coating the coronal surfaces of the teeth with a liquid composite (Denfil Flow, Vericom Laboratories Ltd., Anyang, Korea), the teeth were incubated at 37°C with 100% humidity for 24 hours. Then, they underwent 1,000 thermocycles at 5-55°C with a dwell time of 30 seconds and a transfer time of 10 seconds. All the prepared roots were mounted in acrylic resin (Acropars, Marlic Medical Industries Co., Tehran, Iran), and three 1.1-mm-thick slices were obtained from the middle part of the root (n=24 in each group). The sections were cut perpendicular to the longitudinal axis of the root. No failure occurred during cutting, and all the pieces were selected for the push-out test.

A pin with a diameter of 1 mm was used to exert the force on the posts. The pin was placed on the specimens such that it was completely in contact with the post during the

**Table 1:** The specifications and the composition of the materials used in the present study

| Product | Manufacturer | Composition |
|---|---|---|
| **BisCem self-adhesive resin cement (paste-paste dual syringe, automix)** | Bisco Inc., Schaumburg, IL, USA | Bis (hydroxy-ethyl metha-crylate) Phosphate (base), tetra-ethylene glycol dimethacrylate, dental glass |
| **Glass fiber post (90V; 011series)-conical type 2** | Micro.Medica s.r.l., Robbio, PV, Italy | Glass fiber post + epoxy resin |
| **AH26 silver-free powder AH resin** | Dentsply DeTrey, Konstanz, Germany | Bismuth oxide, Methenamine epoxy resin |
| **Calcium hypochlorite** | Merck KGaA, Darmstadt, Germany | 100% calcium hypochlorite |
| **Sodium hypochlorite** | Raga, Pakrood Co., Isfahan, Iran | 100% sodium hypochlorite |

test. The direction of force application was from the apical aspect toward the coronal aspect so that the post could move toward the larger zone. Then, a push-out test was carried out for each section at a crosshead speed of 0.5 mm/minute using a universal testing machine (Walter & Bai, K21046, Löhningen, Switzerland). The maximum force at the point where the post was dislodged from the root section was considered as the bond failure point and was recorded in Newton (N). Then, the push-out bond strengths were calculated in Megapascal (MPa) by dividing the force at the bond failure point by the area of the bonded cross-section according to the following formula [1]:

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

where "R" is the radius of the coronal third of the post, "r" represents the radius of the apical third of the post, and "h" shows the thickness of each specimen in millimeters (mm).

The failure type in each cross-section was evaluated using a stereomicroscope (MBC-10, SF-100, Lomo, St. Petersburg, Russia) at ×40 magnification. The failure patterns were classified as adhesive failure between cement and post, adhesive failure between cement and dentin, and mixed failure pattern.

***Scanning electron microscopy (SEM):***

One sample from each group was prepared for bonding interface analysis under an SEM (JSM-5410LV; JEOL, Tokyo, Japan) at ×2000 and ×5000 magnifications.

***Statistical analysis:***

The data were analyzed according to one-way analysis of variance (ANOVA) and Tukey's HSD (honestly significant difference) post-hoc test with the aid of SPSS 23 software (SPSS Inc., Chicago, IL, USA; $\alpha=0.05$).

## RESUTS

Values related to the mean and standard deviation (SD) of the bond strengths (MPa) are reported in Table 2 for all experimental groups. The lowest bond strength belonged to the control group, while the highest bond strength belonged to the 5% calcium hypochlorite group. There was a statistically significant difference between the 5% calcium hypochlorite group and the other groups ($P<0.001$); however, the difference between the other groups was not significant. The results of the SEM analysis showed the penetration of the cement into dentinal tubules and the presence of resin tags in the control group (Fig. 1); the length of the resin tags reached 30 to 50 micrometers (μm). In the 2.5% sodium hypochlorite group (Fig. 2), the cement was separated from dentin, and no cement penetration was detected in dentinal tubules.

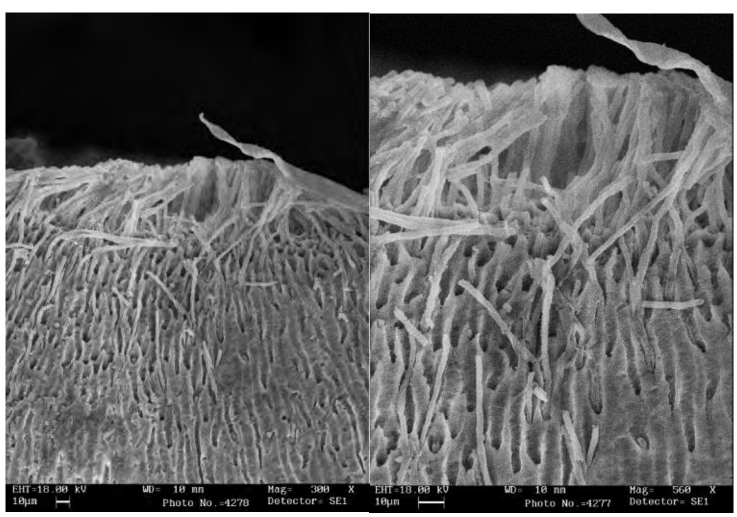

**Fig. 1.** A scanning electron microscopic (SEM) image of a specimen in the normal saline group.

**Table 2:** Mean and standard deviation (SD) of bond strength (MPa) in the tested groups

| Group Number | Group definition | Mean | SD | SE | 95% Confidence Interval | | Min | Max |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| **1** | NS(control) | 7.28[a] | 2.66 | 0.54 | 6.15 | 8.41 | 4.64 | 15.9 |
| **2** | 2.5% SH | 8.15[a] | 2.51 | 0.51 | 7.09 | 9.21 | 3.85 | 11.8 |
| **3** | 5.25% SH | 8.38[a] | 3.76 | 0.77 | 6.79 | 9.97 | 3.27 | 20.5 |
| **4** | 2.5% CH | 8.9[a] | 3.13 | 0.64 | 7.58 | 10.22 | 3.8 | 14 |
| **5** | 5% CH | 11.84[b] | 2.04 | 0.42 | 10.98 | 12.7 | 7.2 | 15.5 |
| **Total** | | 9 | 3.22 | 0.29 | 8.32 | 9.49 | 3.27 | 20.5 |

NS: Normal Saline, SH: Sodium Hypochlorite, CH: Calcium Hypochlorite, SD: Standard Deviation; SE: Standard Error; Min: Minimum; Max: Maximum; Data with different lowercase letters indicate significant differences ($P<0.05$, Tukey's test)

Resin tags and the penetration of the cement into dentinal tubules can be seen in the SEM images of the 5.25% sodium hypochlorite group (Fig. 3); the length of the resin tags reached 30 to 60 µm. Resin tags and the penetration of the cement into dentinal tubules can also be seen in the SEM images of the 2.5% calcium hypochlorite group (Fig. 4); the length of the resin tags reached 40 to 90 µm.

Figure 5 shows resin tags and the penetration of the cement into dentinal tubules in the 5% calcium hypochlorite group; the length of the resin tags reached 60 to 100 µm. The failure pattern frequency in each group is reported in Table 3. In group 1, adhesive failure at the post-luting agent interface was reported as the most frequent type of failure. In group 2, no adhesive failure at the dentine-luting agent interface was reported.

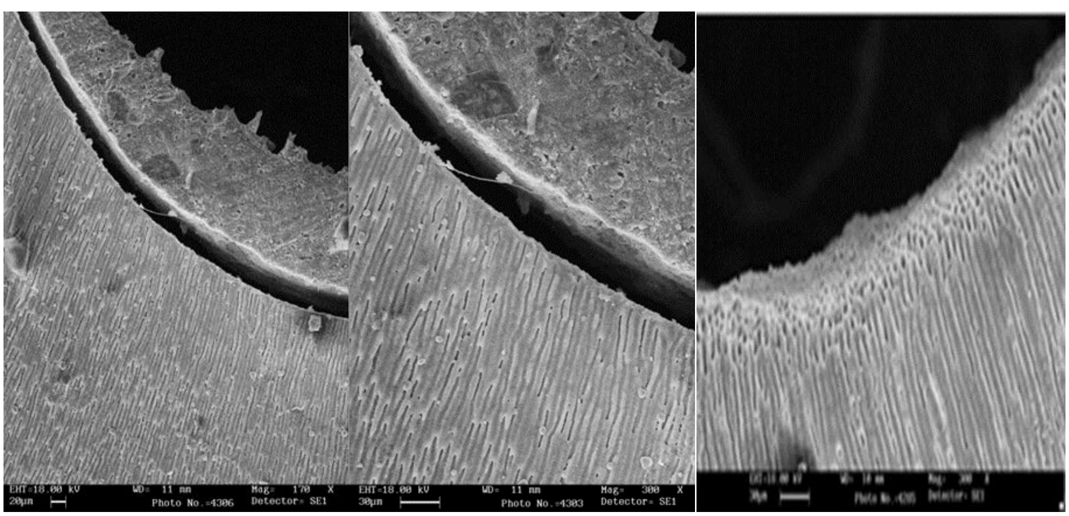

**Fig. 2.** A scanning electron microscopic image of a specimen in the 2.5% sodium hypochlorite group

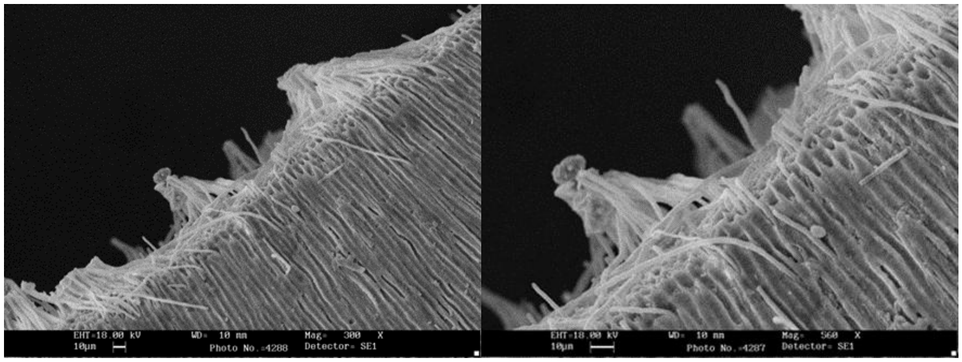

**Fig. 3.** A scanning electron microscopic image of a specimen in the 5.25% sodium hypochlorite group.

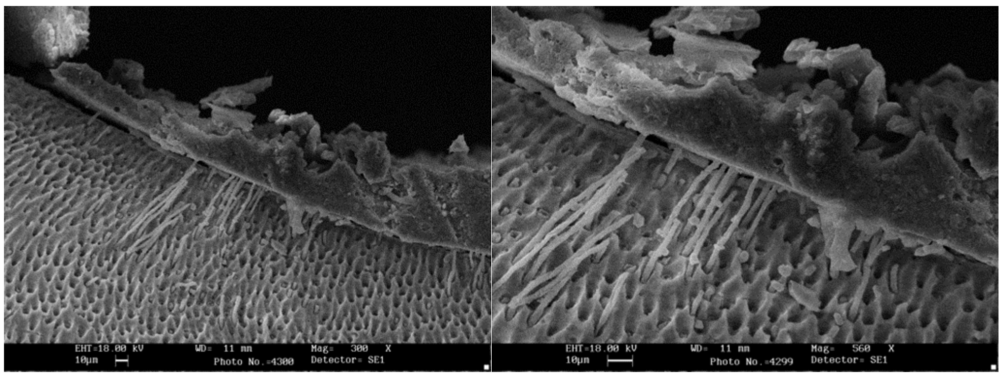

**Fig 4:** A scanning electron microscopic image of a specimen in the 2.5% calcium hypochlorite group.

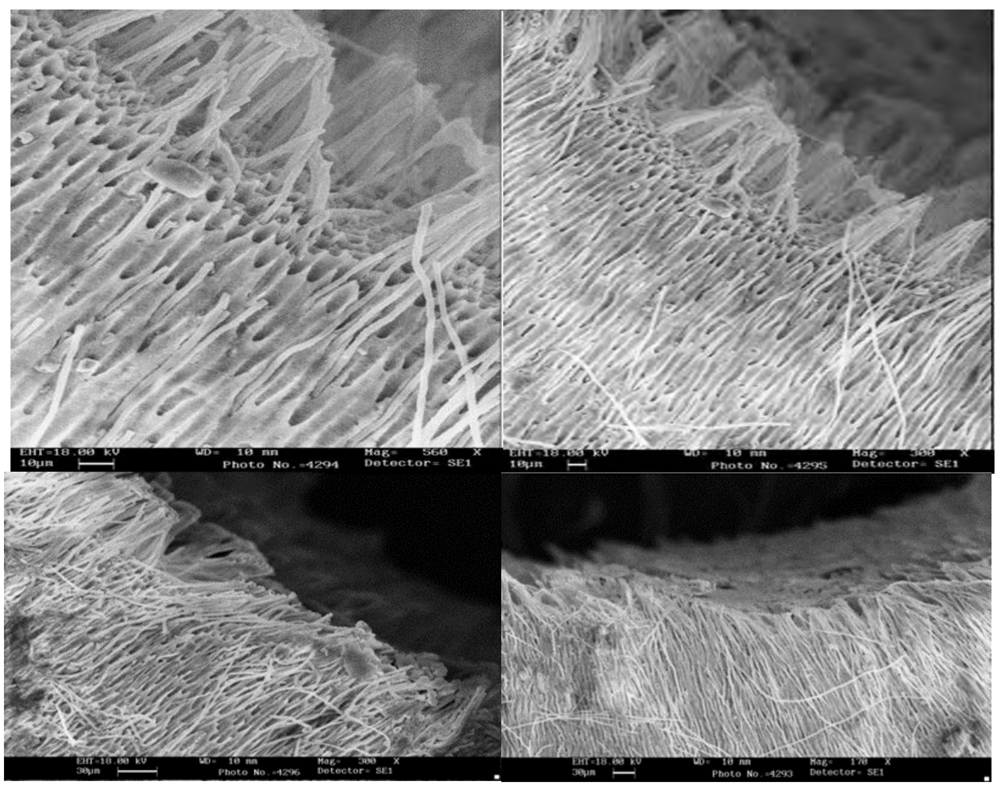

**Fig. 5:** A scanning electron microscopic image of a specimen in the 5% calcium hypochlorite group.
c=cement, d=root canal dentin, r=resin tag)

**Table 3:** Frequency (%) of different failure modes in the tested groups

| GN | Group | AP | AD | M |
|---|---|---|---|---|
| **1** | NS | 50 | 4.1 | 45.9 |
| **2** | 2.5% SH | 50 | 0 | 50 |
| **3** | 5.25% SH | 33.34 | 8.32 | 58.34 |
| **4** | 2.5% CH | 41.67 | 0 | 58.34 |
| **5** | 5% CH | 41.66 | 0 | 58.34 |

GN: Group Number; NS: Normal Saline; SH: Sodium Hypochlorite; CH: Calcium Hypochlorite; AP: Adhesive: post-luting agent interface; AD: Adhesive: dentin-luting agent interface; M: Mixed failure pattern

In groups 3, 4, and 5, mixed failure pattern was reported as the most frequent type of failure.

## DISCUSSION

In the present study, we carried out a comparative investigation on the effects of calcium hypochlorite and sodium hypochlorite, as root canal irrigants, on the bond strength of posts luted with a self-adhesive resin cement. When analyzing the obtained results, the null hypothesis of this study was rejected as the 5.25% calcium hypochlorite irrigant had a significant effect on the increase in the push-out bond strength. Chemical solutions used for disinfection, cleaning, and completing the mechanical process of instrumentation during root canal treatment cause physical and chemical changes, such as decreased microhardness and increased permeability of the root canal dentin [22,23]. The severity of the effects of these solutions is directly correlated with the concentration of their compounds and changes in the dentin layer [24]. Due to its antibacterial properties and tissue solving ability, sodium hypochlorite is used as a common irrigant in root treatment [25].

Use of this substance at 5% concentration reduces the dentinal calcium and phosphate content [17] and weakens the mechanical properties of dentin, such as the elastic modulus, bending strength, and hardness [18]. According to some studies, this solution reduces the bond strength of the post to radicular dentin [26,27], whereas some other studies have shown no decrease in bond strength after using this solution [28,29]. In the present study, no decrease was observed in bond strength after using sodium hypochlorite. This non-decrease in bond strength can be due to the final irrigation of root canal and post space with distilled water. In the present study, a self-adhesive cement was used to cement the post to radicular dentin. According to some researchers, self-adhesive resin cements do not have enough etching potential to remove the smear layer inside the root canal after preparation of the post space [29,30], while some other studies have reported better results about self-adhesive cements in this respect [3,31,32]. Nonetheless, it should be noted that these studies lacked a thermocycling/aging procedure and could not simulate the clinical conditions. The bonding mechanism of self-adhesive cements is based on micromechanical retention and chemical bonding. BisCem cement contains acidic phosphate monomers which establish chemical bonds to calcium hydroxyapatite [12,14]. In the present study, the bond strength in the control group was not significantly different than that in the 2.5% sodium hypochlorite, 5% sodium hypochlorite, and 2.5% calcium hypochlorite groups. Likewise, there was no significant difference between the 2.5% sodium hypochlorite and 5.25% sodium hypochlorite groups. It has been stated that the use of calcium hypochlorite solution on dentin increases the amount of calcium while decreasing the amount of carbon [33]. This finding suggests that the use of a calcium hypochlorite solution can result in changes in the chemical composition of the dentin surface by removing organic materials. In addition, the amount of calcium and phosphorus ions increases, which can be beneficial for mineralization process and formation of amorphous calcium phosphate phase in the hybrid layer; calcium and phosphorus ions are the mineral components of the primary dentin. New apatite crystals and calcium phosphate and calcium carbonate crystals may also form. These crystals may be attached

to the surface through ionic bonds or may be surrounded by the adhesive [33].
According to the present study, the use of calcium hypochlorite, as a root canal irrigant, increases the bond strength of calcium groups. Because of the presence of calcium sediments in the environment and their probable entrance into the radicular dentin structure, and since the self-adhesive cement increases the bond strength through chemical bonding to these substances, BisCem self-adhesive cement resulted in the increased bond strength with chemical bonding to calcium hydroxyapatite, calcium phosphate crystals, and apatite crystals ;however, this increase was not significant. This can be due to root canal irrigation after cleaning and shaping as well as post space irrigation with distilled water, which removes calcium sediments inside dentinal tubules resulting from the irrigant. Since this substance has been used at a low concentration, the volume of its sediments has been reduced by irrigation with distilled water; therefore, it was not able to significantly increase the bond strength. This difference may also become significant in case of an increase in the number of specimens and a change in the status and the concentration of the substance. Nonetheless, the 2.5% calcium hypochlorite group was significantly different than the 5% calcium hypochlorite group in this respect. In this study, the 5% calcium hypochlorite group showed the highest bond strength (11.84±2.04 MPa), which was significantly different than that of the rest of the groups. This may be due to the chemical bonding of BisCem cement to newly-formed apatite crystals or calcium phosphate crystals. Since the concentration of the calcium hypochlorite solution was appropriate and it was not removed by irrigation, the formation of apatite crystals or calcium phosphate crystals increased, resulting in a dramatic increase in bond strength. When analyzing the results of the present study, in the 2.5% sodium hypochlorite group, the lowest failure rate belonged to the failure at the adhesive cement-dentin interface, which was consistent with some similar studies [34,35] while contrasting some other studies [36,37].
In the 5.25% sodium hypochlorite group, the highest failure rate belonged to the mixed failure pattern, which was consistent with a study conducted by Bitter et al [28].
No failure at the adhesive cement-dentin interface was reported in the 2.5% calcium hypochlorite and 5% calcium hypochlorite groups, and most of the failures were mixed failures, which is consistent with the higher bond strengths in these two groups compared to the other groups. The lower rate of failure at the adhesive cement-dentin interface can be due to the absence of thermomechanical loading, which has been shown to effectively change the percentage of the predominant failure pattern before and after loading [38].
In addition, in the present study, a jig was designed for the push-out test such that its bar was only in contact with the post surface, while the cement-dentin interface was supported by a stainless steel table that had a hole with a diameter similar to that of the post. This causes a more favorable failure pattern at the interface area while performing the test and prevents excess pressure on dentin.
An SEM evaluation was also carried out in the present study. The SEM images were consistent with the results obtained in the groups. Resin tags were obviously more frequent in group 5, where the bond strength increased dramatically. It has been shown recently that the thickness of the hybrid layer and the morphology of resin tags have only a small effect on the bond strength [39]. The decrease in the intraradicular dentin bond strength is probably due to factors other than substrate morphology and can be due to clinical problems resulting from limited endodontic space and high C-factor [39].
The limitations of this in-vitro study included the small sample size and the inability to thoroughly simulate the clinical conditions.

## CONCLUSION

Considering the limitations of the present study, it seems that the use of calcium hypochlorite solutions at an appropriate concentration increases the bond strength of fiber posts cemented with self-adhesive resin cements.

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## CONFLICT OF INTEREST STATEMENT

None declared.

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