Original Article

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Investigation of the Effect of Sodium Hypochlorite, EDTA, Propolis, Boric Acid and Citric Acid Irrigation Solutions on Push-out Bond Strengths of Root Canal Sealers

Sodyum Hipoklorit, EDTA, Propolis, Borik Asit ve Sitrik Asit Yıkama Solüsyonlarının Kök Kanal Patlarındaki Bağlanma Dayanımları Üzerine Etkisinin İncelenmesi

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ABSTRACT

Objective: The aim of this study is to investigate the effect of different root canal irrigation solutions, including propolis and boric acid (BA), on the bonding strengths of epoxy-resin-based AH Plus and bioceramic-based Bioserra root canal sealers on root dentin.

Methods: One hundred extracted teeth with single root-single canal were shaped and divided into 2 groups according to filling material (AH Plus and Bioserra) and each group was divided into 5 subgroups according to irrigation solution (5.25% NaOCl, 17% EDTA, 10% citric acid, 10% BA, 10% propolis). The teeth of which canals were filled were incubated at 37 °C for one week, then embedded in acrylic resin. Horizontal sections with thickness of 2 mm were taken from the middle level of the root of each tooth and pressing force was applied in vertical direction until a break occurred in the connection, POBS (push-out bond strength) values were calculated. Statistical analysis was performed using Kruskal-Wallis H and Mann-Whitney U tests. Finally samples were examined with binocular microscope.

Results: Regardless of the sealer used, mean POBS values of 5.25% NaOCl solution groups were found significantly higher than others ($p<0.05$). Also regardless of the irrigation solution used, mean POBS values of AH Plus groups were significantly higher than Bioserra groups ($p<0.05$). Among the experimental groups that

ÖZ

Amaç: Bu çalışmanın amacı, propolis ve borik asit (BA) dahil olmak üzere farklı kanal yıkama solüsyonlarının epoksi-rezin bazlı AH Plus ve biyoseramik bazlı Bioserra kanal patlarının kök dentini üzerindeki bağlanma dayanımlarına etkisini araştırmaktır.

Yöntemler: Tek kök-tek kanallı 100 adet çekilmiş insan dişi döner aletle şekillendirildikten sonra kanal dolum malzemesine (AH Plus ve Bioserra) göre 2 gruba ayrılmış ve her grup yıkama solüsyonuna (%5,25 NaOCl, %17 EDTA, %10 sitrik asit, %10 BA, %10 propolis) göre 10 örnek içeren 5 alt gruba ayrılmıştır. Kanalları doldurulan dişler bir hafta 37 °C'de etüvlendikten sonra akrilik reçineye gömülmüştür. Her bir dişin kökünün orta hizasından 2 mm kalınlığında horizontal kesitler alınmış ve bağlantıda kopma oluşana kadar dikey yönde basma kuvveti uygulanmıştır, bağlanma dayanım değerleri hesaplanmıştır. Ayrıca numuneler binoküler mikroskopla incelenmiştir. Değerlerin istatistiksel analizleri Kruskal-Wallis H ve Mann-Whitney U testleri kullanılarak yapılmıştır.

Bulgular: Kullanılan kanal patından bağımsız olarak, %5,25 NaOCl yıkama solüsyonu gruplarının ortalama bağlanma dayanım değerleri diğerlerine göre anlamlı derecede yüksek bulunmuştur ($p<0,05$). Ayrıca kullanılan yıkama solüsyonundan bağımsız olarak, AH Plus kullanılan grupların bağlanma dayanımlarının ortalaması, Bioserra kullanılan gruplardan anlamlı derecede yüksektir ($p<0,05$).

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used Bioserra, 5.25% NaOCl irrigation group had significantly higher POBS value than other solution groups. Meanwhile, there was no difference between POBS values of irrigation solution groups when AH Plus was used. In addition, in 17% EDTA and 10% citric acid groups, the mean POBS values of the samples using AH Plus were found significantly higher according to Bioserra samples ($p<0.05$). When mode of failures were examined; cohesive failure was mostly observed in NaOCl-AH Plus group, adhesive failure was mostly in BA-AH Plus group, mixed failure was mostly in Propolis-Bioserra group.

Conclusion: The bonding strength is significantly affected by the sealer used and the sealer/irrigation solution interaction. The bonding strength of AH Plus is superior to Bioserra. If 17% EDTA or 10% citric acid is to be used as irrigation solution, then AH Plus should be preferred instead of Bioserra sealer.

Keywords: Push-out bond strength test, propolis, boric acid, root canal sealer, root canal irrigation

ÖZ

Bioserra'yı kanal dolum patı olarak kullanan deney grupları arasında %5,25 NaOCl ile irrigasyon yapılan grup, diğer yıkama solüsyon gruplarına göre anlamlı derecede daha yüksek bağlanma dayanımı değerine sahiptir. Bu arada kök kanal patı olarak AH Plus kullanıldığında yıkama solüsyon gruplarının bağlanma dayanım değerleri arasında fark görülmemiştir. Ayrıca %17 EDTA ve %10 sitrik asit yıkama solüsyonu gruplarında, kanal patı olarak AH Plus kullanılan numunelerin bağlanma dayanımlarının ortalaması, Bioserra kullanılan numunelerin ortalamasına göre anlamlı olarak daha yüksek bulunmuştur ($p<0,05$). Bağlantı başarısızlıkları incelendiğinde; koheziv kopma en sık NaOCl-AH Plus grubunda, adeziv kopma en sık BA-AH Plus grubunda, karışık kopma en sık Propolis-Bioserra grubunda görülmüştür.

Sonuç: Bağlanma dayanım gücü; kullanılan kök kanal patından ve kanal patı/yıkama solüsyonu etkileşiminden önemli ölçüde etkilenmektedir. AH Plus'ın bağlanma dayanımı, Bioserra'dan üstündür. İrrigasyon solüsyonu olarak %17'lik EDTA veya %10'luk sitrik asit kullanılacak ise ardından dolumda Bioserra yerine AH Plus patı tercih edilmelidir.

Anahtar Sözcükler: Basma dayanım testi, propolis, borik asit, kök kanal patı, kök kanal irrigasyonu

Introduction

The aim of a successful root canal treatment is to clean and shape the root canals and then fill them in a three-dimensional hermetic way (1). Gutta percha, which is a root canal filling material, should be used together with a sealer because it does not have the ability to bind to the root canal walls alone (2). The task of the sealer is to ensure the adhesion of the gutta percha to the root canal walls and also to fill the gaps between the master apical file and the other gutta percha points during the lateral condensation technique (3). An effective irrigation can ensure that even the lateral canals, isthmus, apical deltas that cannot be reached by the gutta percha are filled with root canal sealer.

There are some agents such as Sodium hypochlorite (NaOCl), EDTA, citric acid, which have been used for a long time as an irrigation solution in endodontic treatments and have proven many benefits. NaOCl exhibits strong antibacterial properties, dissolves organic substances and removes necrotic tissue. Some clinicians work by filling the pulp chamber with NaOCl during the entire root canal preparation process to maximize the lubrication, antibiofilm and proteolytic effects (4). EDTA is a chelating agent used to dissolve inorganic components. It acts on calcium ions in the content of hydroxyapatite, the main inorganic compound of dentin, and accelerates the removal of smear layer by demineralizing its' inorganic components (5). Qian et al. (6) concluded in a study that EDTA and citric acid led to negative features such as intertubular and peritubular dentin erosion. Although there are studies like these in the literature, these two solutions are the most commonly used irrigation solutions for complete removal of the smear layer; it is recommended to use citric acid at a concentration of 10% and EDTA at a concentration of 17% (7). The use of boric acid (BA), which has antifungal, antiseptic, strong antibacterial properties and has proven biocompatibility with tissue, as an endodontic irrigation agent is also on the agenda and represents an ideal irrigant (8,9). A limited number of studies have been conducted on the use of BA in dentistry (10). Apart from these, when we examine the literature, we see that propolis, which is a natural and easy-to-obtain material that is already used in different areas of daily life and has many different biological properties, is also used in dentistry and researches on it are increasing (11).

AH Plus (Dentsply Sirona, Germany), one of the root canal sealers to be used, is an epoxy-resin based root canal filling material whose superior physical properties have been demonstrated many times (12). The other root canal sealer Bioserra (Meta Biomed Co. Ltd., Korea) is one of the calcium-silicate-based materials of which use has increased especially in recent years due to its' superior biocompatibility and sealing properties.

The interaction of all these irrigation solutions with the root canal filling materials is inevitable. Irrigation solutions should not negatively affect the bonding properties of the root canal sealer to the root dentin. For this purpose, it is important to know the effect of irrigation solutions on the push-out bond strengths of root canal sealers. "Push-out bond strength", also called dislodgement resistance, is considered as the determining factor in evaluating the connection of a root canal sealer to the root canal dentin and core material (13). Instead of shear and tensile tests, push-out test has been advocated as a more appropriate test to evaluate the bonding resistance of intra-canal filling materials (14).

In our research, we aim to make useful contributions to the endodontic literature by keeping the diversity range of the

materials wide. In this study, it was aimed to investigate the effects of some root canal irrigaiton solutions, including propolis and BA, on the bond strength of epoxy resin-based AH Plus and bioceramic-based Bioserra sealers on root dentin.

Methods

In our study, 100 human teeth with single root-single canal extracted for caries, orthodontic or periodontal reasons and did not have any cracks/fractures on the root surface and also did not have any anomalies in the root canal morphologies were used. Because of human tissues were utilized for this *in vitro* study, the ethics committee approval of this study was obtained from the Clinical Research Ethics Committee of the Faculty of Dentistry of Marmara University under decision number 2022/91, dated September 29, 2022. All procedures of the study were carried out by the same operator. Organic and inorganic tissue residues on the root surfaces of the teeth that complied with the criteria and were included in the study were cleaned with the help of periodontal curettes and cavitron. Then, all the teeth were kept in 10% NaOCl for 1 and a half hours and disinfected; at the end of this time, the teeth were washed under running water and kept in 10% formalin solution until the experiment started. The crowns of the teeth were removed with a diamond fissure burr. The working length was determined with a 15 K-file to be 1 mm behind the root canal length and the root canals were shaped with a Protaper Next X3 (Dentsply Maillefer, Ballaigues, Switzerland) rotary file. One hundred teeth with shaped root canals were randomly distributed to 10 experimental groups containing 10 samples each. A total of 5 mL of irrigation solution was applied to each tooth in the experimental groups with an endodontic irrigation needle for 4 minutes. Then, the root canals were dried with paper-points and root canals were filled. According to this:

- Group 1A: irrigation with 5.25% NaOCl, cold lateral condensation with AH Plus sealer (n=10).

- Group 1B: irrigation with 5.25% NaOCl, single cone technique with Bioserra sealer (n=10).

- Group 2A: irrigation with 17% EDTA, cold lateral condensation with AH Plus sealer (n=10).

- Group 2B: irrigation with 17% EDTA, single cone technique with Bioserra sealer (n=10).

- Group 3A: irrigation with 10% citric acid, cold lateral condensation with AH Plus sealer (n=10).

- Group 3B: irrigation with 10% citric acid, single cone technique with Bioserra sealer (n=10).

- Group 4A: irrigation with 10% BA, cold lateral condensation with AH Plus sealer (n=10).

- Group 4B: irrigation with 10% BA, single cone technique with Bioserra sealer (n=10).

- Group 5A: irrigation with 10% propolis, cold lateral condensation with AH Plus sealer (n=10).

- Group 5B: irrigation with 10% propolis, single cone technique with Bioserra sealer (n=10).

After the root canal fillings completed, the orifices of the root canals were filled with temporary filling material. The specimens were kept at 37 °C temperature in the incubator for 1 week for the sealer to set completely. Then teeth were embedded in cold acrylic resin blocks vertically. Horizontal sections with thickness of 2 mm were taken from the middle level of the each tooth's root under water cooling with a low-speed-saw (IsoMet 1000, Buehler, Illinois, USA).

Specimens were placed on a metal plate with a hole in the middle. A universal testing machine (Shimadzu Corporation, Kyoto, Japan) was used in the push-out bond strength (POBS) test to provide a break in the connection (debonding) of the samples. In order to apply this test to root canals of different diameters, metal pins with diameters of 0.5, 0.7 and 1 mm were designed. The diameters were measured and checked with a digital caliper.

Vertical load was applied in apico-coronal direction with the universal testing machine until the bond failure occured. The maximum force measured at the moment of bond failure was recorded in Newtons (N) for each sample in the Trapezium X software (Shimadzu Corporation, Kyoto, Japan) on the computer connected to the universal testing machine. After it, the bond strength value in Megapascal of each sample was calculated.

The bond strength value was calculated according to the following formula:

$$\text{Push} - \text{out Bond Strength} = \frac{F}{2\pi(r_1 + r_2)h}$$

F: the maximum force measured at the moment of bond failure (N); π: The number of Pi = 3,14; r_1: the apical radius of the root canal section (mm); r_2: the coronal radius of the root canal section (mm); h: thickness of sample =2 mm.

After the POBS test, the root canals of the specimens were examined and photographed with a binocular microscope (Leica, Danaher Corporation, Germany) at 4x magnification and the types of failures in each sample were detected and recorded. The mode of failures were classified into three groups as adhesive failure (no material left on the canal wall), mixed failure (partial material left on the canal wall) and cohesive failure (material left along the entire canal wall) (Figure 1).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 23.0 software (IBM Corporation, Armonk, New York, USA) and the conformity of the data to normal distribution was checked by Kolmogorov-Smirnov test. At the irrigation solution groups without normal distribution, the Kruskal-Wallis test was used to compare the mean of the groups and in the root canal sealer groups without normal distribution, the Mann-Whitney U test was used to compare the mean. When the p-value was below 0.05, it was accepted that there was statistically significant difference.

Results

All specimens had measurable adhesion to the root dentin and no premature failure occurred. The mean ± standard deviation, median, minimum and maximum push-out bond strength values of all experimental groups are shown in Table 1. It was accepted that there was a statistically significant difference if the results were p<0.05. In the 17% EDTA and 10% citric acid irrigation solution groups; the samples using AH Plus as root canal sealer produced significantly higher POBS values than the samples using Bioserra (p<0.05). There was no significant difference in the push-out bond strength values of other root canal irrigation solution groups in terms of any sealer.

There was no statistically significant difference between the mean POBS values compared to the irrigation solution groups using AH Plus root canal sealer (p>0.05). Besides that; in the groups using Bioserra root canal sealer, when it was compared according to the irrigation solutions, the group irrigated with 5.25% NaOCl revealed significantly the highest dislodgement resistance (p<0.05) (Table 2).

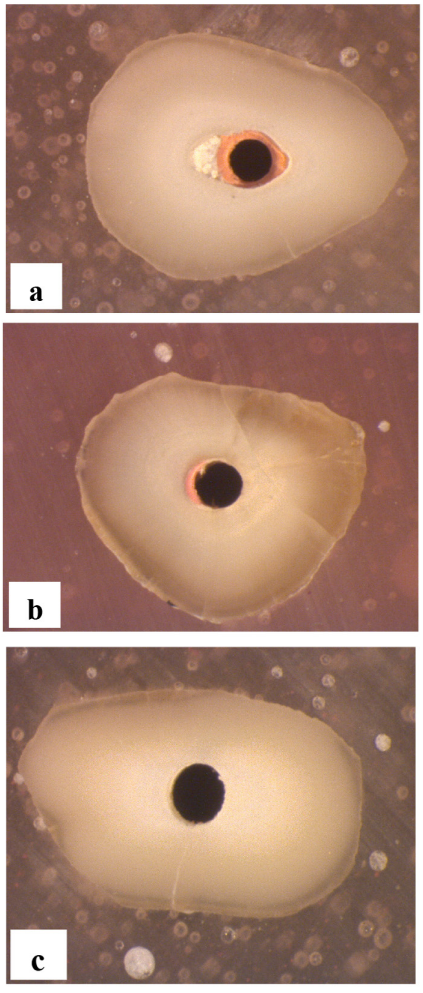

Figure 1. Images obtained by binocular microscope at 4x magnification for observation of the mode of failure types in samples; a: Cohesive failure, b: Mixed failure, c: Adhesive failur

When the groups were compared according to just the irrigation solutions regardless of the root canal sealer used, the mean push-out bond strength values were found to be statistically significantly higher in the groups where 5.25% NaOCl was used as irrigation solution compared to other solution groups (p<0.05) (Table 3). Also, when it was compared according to the root canal sealer regardless of the irrigation solution, AH Plus groups produced significantly higher POBS values than those of the groups using Bioserra sealer (p<0.05) (Table 4).

According to the samples examined by binocular microscope, the results of the rates of mode of failures in the experimental groups are shown in Figure 2. Cohesive failure type was most often observed in NaOCl-AH Plus group, adhesive failure was most often observed in BA-AH Plus group and in the Propolis-Bioserra group, it was most often observed mixed failure type (Figure 2).

Table 1. Mean ± standard deviation, median, minimum and maximum push-out bond strength values of all experimental groups in MPa

Groups	Mean ± SD (MPa)	Median (minimum-maximum)
5.25% NaOCl		
1A (AH Plus)	10.4±5.5	9.7 (5.0-21.9)
1B (Bioserra)	10.5±4.9	10.7 (4.7-20.6)
17% EDTA		
2A (AH Plus)	7.2±2.6*	6.6 (4.2-12.6)
2B (Bioserra)	3.9±2.6	3.5 (1.6-10.8)
10% citric acid		
3A (AH Plus)	7.9±3.6*	8.9 (1.9-12.2)
3B (Bioserra)	4.5±2.6	4.2 (1.6-10.8)
10% boric acid		
4A (AH Plus)	7.3±3.6	6.7 (3.0-12.9)
4B (Bioserra)	6.9±3.5	6.9 (2.1-2.8)
10% propolis		
5A (AH Plus)	6.8±1.9	6.9 (3.6-9.4)
5B (Bioserra)	5.3±3.3	3.9 (2.4-12.6)

SD: Standard deviation, MPa: Megapascal, *p<0.05

Table 2. The mean POBS values of the experimental groups filled with Bioserra according to the irrigation solutions

Irrigation solution-Bioserra	Mean ± SD (MPa)
NaOCl (n=10)	10.5±4.9*
EDTA (n=10)	3.9±2.6
Citric acid (n=10)	4.5±2.6
Boric acid (n=10)	6.9±3.5
Propolis (n=10)	5.3±3.3
Total (n=50)	6.2±4.1

SD: Standard deviation, POBS: Push-out bond strength, *p<0.05

Table 3. The mean POBS values according to the root canal irrigation solution, regardless of the sealer

Irrigation solution	Mean ± SD (MPa)
NaOCl (n=20)	10.4±5.1*
EDTA (n=20)	5.6±3.1
Citric acid (n=20)	6.2±3.6
Boric acid (n=20)	7.1±3.4
Propolis (n=20)	6.1±2.7
Total (n=100)	7.1±4.0

SD: Standard deviation, POBS: Push-out bond strength, NaOCl: Sodium hypochlorite, EDTA: Ethylenediamine tetraacetic acid, *p<0.05

Table 4. The mean POBS values according to the root canal sealer, regardless of the irrigation solution

Root canal sealer	Mean ± SD (MPa)
AH Plus (n=50)	7.9±3.7*
Bioserra (n=50)	6.2±4.1
Total (n=100)	7.1±4.0

SD: Standard deviation, POBS: Push-out bond strength, MPa: Megapascal *p<0.05

Discussion

In an ideal endodontic treatment, it is very important to fill the root canals three-dimensionally and hermetically to prevent reinfection after they are completely cleared and cleaned of pathogens, vital or necrotic tissues (15). In a review, root canals prepared with both current nickel-titanium rotary tool systems and traditional stainless steel hand files were examined as two separate groups and it was found that about half of the root canal walls in both groups were left unprepared (16). Due to this condition, microorganisms in the canal system may not be completely cleaned and a growth medium for bacterias may form on them. In order to completely clean the root canals, irrigation protocol is very important and various irrigation solutions are used to support the mechanical preparation and to open the dentin tubules on root surface. However, it has also been shown that the use of antimicrobial irrigation solutions significantly reduces bacteria, but cannot completely eliminate them and achieve a sterile root canal system (17).

A study has been conducted showing that interfacial stress distributions and POBS value measurements are mostly unaffected when the ratio of the tip diameter to the diameter of the sample is less than 0.85 and the ratio of the section thickness of the sample to the diameter of the sample is greater than 0.6 (18). We have prepared sample groups and experimental materials by paying attention to these criteria in our own study.

We have done research on which root canal obturation technique we should choose for root canal filling of sample groups and decided that we should use cold obturation techniques and stay away from warm gutta percha obturation techniques when using bioceramic-based sealer Bioserra. Because studies have shown

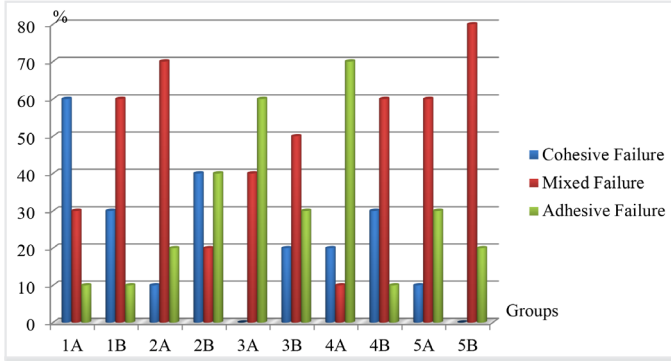

Figure 2. Distribution of mode of failure types in all experimental groups (in %)

that heat can alter the physical properties of bioceramic-based sealers, especially their viscosity and hardening time (19,20). This may affect the quality of the root canal filling.

Donnermeyer et al. (21) found that AH Plus revealed significantly higher POBS values than other root canal sealers used, and also found that EDTA irrigation solution positively affected POBS values of AH Plus root canal sealer. These results are parallel to the results we have indicated in our study. In addition, it was found that EDTA had a negative effect on the POBS values of the bioceramic-based root canal sealer used in the study (21). Similar to this; in our study, when we used EDTA solution and bioceramic-based sealer Bioserra together, we found the lowest POBS values.

They conducted another similar study in which they compared the bond strength resistance of 3 different calcium-silicate-based sealer with that of epoxy resin-based AH Plus, and as a result, AH Plus sealer had higher POBS values than all other calcium-silicate-based root canal sealer groups (22). Our study also found that the mean POBS values of the groups using AH Plus root canal sealer were significantly higher than the groups using calcium-silicate-based Bioserra sealer, regardless of the irrigation solution used. These findings correlate with their results. This result also confirms the findings of Donnermeyer et al. (23) in another study conducted in 2018 that the retreatment of the root canal fillings using calcium-silicate-based sealer led to more effective and efficient clinical results than the fillings using epoxy-resin-based sealer. On the contrary, in a study, the effect of warm gutta-percha obturation techniques on the bond strength of bioceramic-based sealer was investigated and, contrary to our results, they found significantly higher POBS values in calcium-silicate-based bioceramic root canal sealer than epoxy-resin-based AH Plus (24). In this research, Dewi et al. (24) defined a control group in which AH Plus, which had a lot of research on it and almost all of its' properties were known today, was applied by warm gutta-percha obturation techniques, and compared the bond strength values of the relevant sealers. The reason for this result, which contradicts our study, may be that heat application accelerates the chemical reaction of epoxy-resin-based sealer AH Plus and therefore the sealer cannot flow into complex anatomies such as the dentin tubules of the root canal system and cannot fill the gaps adequately, ultimately leading to lower bonding strength (25).

In a study conducted with a calcium-silicate-containing sealer known as "BioRoot RCS", the POBS values of this sealer were compared with those of AH Plus. As a result, the bonding strength of BioRoot RCS was found to be higher than AH Plus (26). Also in a study conducted by Ballal et al. (27); among the samples obturated with AH Plus and gutta-percha, the 5.25% NaOCl irrigation group had the lowest POBS values. The results of these two aforementioned studies contradicted the results of our study, in which we observed higher POBS values in the AH Plus sealer compared to the bioceramic-based one. The reasons for these differences may be factors such as different volumes of NaOCl solution used, the taper angle created as a result of the mechanical preparation of the root canal, and whether or not core material is used together with the root canal sealer during the endodontic obturation procedure.

When determining root canal irrigation solution groups, we also included citric acid, which is one of the demineralization agents, in our study. When we conducted a literature research about what percentage of citric acid we would use; we saw study results showing that 10% citric acid was a sufficient and effective material for removing the smear layer on the dentin tubules and surface (28), and a 10% concentration of citric acid could provide demineralization more effectively than a 1% concentration (29). For these reasons, we determined the concentration of citric acid to be used as irrigation solution in our study as 10%.

In our study, when evaluated regardless of the root canal sealer, the mean POBS values of the group which was irrigated with NaOCl solution were found to be significantly higher compared to other solution groups. At one study, the POBS values of bioceramic-based root canal sealers after irrigation with 2.5-3% NaOCl and 17% EDTA were compared in an experiment (30). As a result of this study, it was concluded that the NaOCl group, which is an alkaline solution, showed higher POBS values compared to the acidic EDTA solution group. One reason for this may be the composition of bioceramic-based root canal sealers containing calcium silicate, which are sensitive to low pH and the mechanism of hardening in an acidic environment can be adversely affected (30).

After chemomechanical preparation in the root canal system, the residual EDTA remaining in the root canal continues to chelate calcium ions released during hydration of bioceramic-based root canal sealers and affects the precipitation process, so reduces the adhesion of the root canal sealer to the root dentin walls (31). According to the findings we obtained from our study, in the study groups using 17% EDTA irrigation solution, average of POBS values was found to be significantly higher when AH Plus was used as root canal sealer compared to using bioceramic-based Bioserra sealer. This result can be explained by the result found by Lee et al. (31) in their study.

During the use of NaOCl in root canal treatment, many mishaps and accidents may occur, such as overflow from the apical foramen due to large apical foramen structure, root resorption and incorrect placement of the needle and as a result, periapical irritation and inflammation; injection instead of anesthesia by accident; occurence of allergic reaction in the patient to the solution; splashing into the patient's or dentist's eye, bleaching of the clothes when dripping on the patient and physician (32-34). For these reasons, the search for a different solution that can replace NaOCl with the same properties and with less risk of complications should be one of the main research topics of today's scientists. But it is an easy fact to predict that NaOCl has been a cornerstone among root canal irrigation solutions throughout the history of endodontics and will be for quite a while longer. If we compare the numerous advantages of NaOCl proven in studies conducted from the past to the present with its' disadvantages, it is preferable to continue using NaOCl in root canal treatment by taking the necessary precautions (for example; the use of endodontic irrigation needle tips in irrigation procedure, the use of protective glasses in the patient and the physician, the use of protective clothes by the physician) (35). Already in our study, NaOCl supports this preference by proving its' superiority once again with the superior POBS values in terms of bonding strength with root canal sealers in different groups. The application of the gel form of NaOCl instead of the solution form is an alternative that can reduce the risk of overflow from the apical of the root and thus reduce the occurrence of postoperative pain (36-38). But at this point, it is also a matter of debate whether the gel form of NaOCl, which has a more solid consistency than the solution, can penetrate into the dentin tubules at a sufficient depth during root canal irrigation (39).

Herbal ingredients have advantages such as having minimal side effects compared to routine irrigation materials in endodontics in general, being better tolerated by patients and being able to be renewed naturally (40). Propolis, which is rich in flavonoids and its' ethanolic extract has different biological properties such as antibacterial, antiviral, antifungal, anti-inflammatory, antioxidant, local anesthetic, is applied as an intracanal medicament and can be considered as a preferred material in the irrigation solution group, as Castaldo and Capasso (11) also suggested in their study on propolis. When we examined the 10% propolis solution as a root canal irrigation solution option, in the average POBS values that we found in our study, there was no significant difference that would provide an advantage between the other groups, and there was also no aspect that negatively affected the bonding of root dentin with the sealer. Accordingly, 10% propolis can also be considered as a material that can be used in root canal irrigation procedures in endodontics, just like other more commonly used irrigation solutions in our study.

Study Limitations

This study was prepared with *in vitro* design. *In vivo* conditions such as sudden intraoral temperature changes could not be provided, and the effects of these conditions on the properties of root canal sealers were not included. However, this study is first in which the effect of propolis on POBS was compared with this combination of irrigation solutions and sealer groups.

Conclusion

The bonding strength of AH Plus root canal sealer is superior to bioceramic-based Bioserra sealer. The POBS values of the NaOCl irrigation solution groups, regardless of the root canal sealer used; and the AH Plus root canal sealer groups, regardless of the irrigation solution, are high compared to other groups. If 17% EDTA or 10% citric acid is to be used as the irrigation solution during the root canal treatment procedures, then choosing AH Plus sealer for root canal filling will be a factor that increases the bonding strength values compared to choosing Bioserra sealer. When we examined the 10% propolis solution as an option for root canal irrigation procedure, there was no significant difference in the mean POBS values that would provide an advantage between the other groups, nor was there a difference that negatively affected the binding to the root canal dentin. Nevertheless, more researches need to be done on propolis as an irrigation solution option in endodontics, especially in *in vivo* conditions.

Ethics

Ethics Committee Approval: The ethics committee approval of this study was obtained from the Clinical Research Ethics Committee of the Faculty of Dentistry of Marmara University under decision number 2022/91, dated September 29, 2022.

Informed Consent: Informed consent is not required.

Authorship Contributions

Concept: D.İ., E.İ., Design: D.İ., E.İ., Data Collection or Processing: D.İ., Analysis or Interpretation: D.İ., Literature Search: D.İ., Writing: D.İ., E.İ.

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