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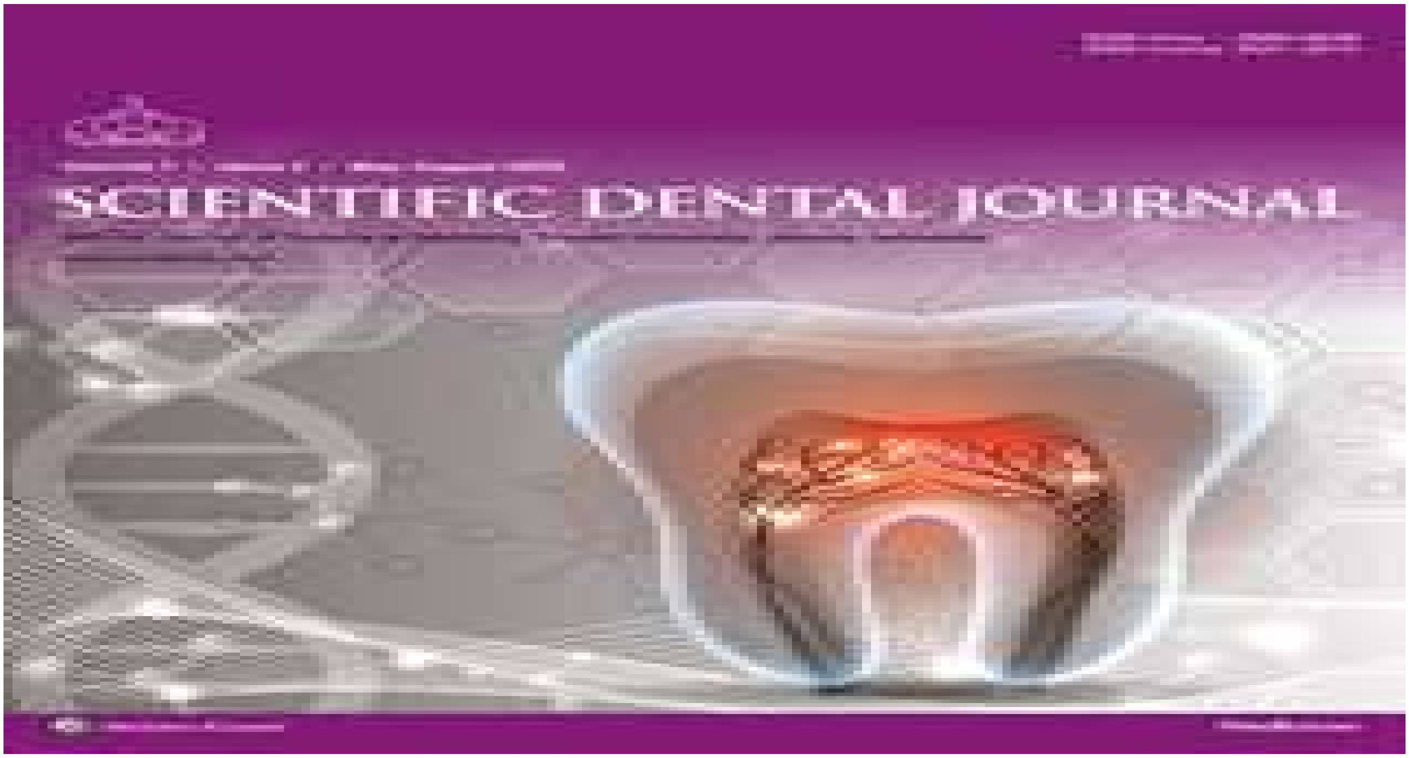

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Original Article

A Comparative Evaluation of Two Irrigating Solutions Combination Effectiveness on Apical Sealing of Different Root Canal Sealers

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ABSTRACT

Background: Root canal irrigants play an essential role in removing the smear layer, pulp tissue, and microorganisms in the root canal system. The irrigation solution can remove the smear layer, which can interfere with the bond between the sealers. As a result of sealer penetration into dentin tubules following smear layer removal, an apical seal was obtained. One of the most recent innovations in root canals consists of a combination of silver citrate (BioAKT, New Tech Solution, Brescia, Italy) and chlorhexidine-ethylenediaminetetraacetic acid (CHX-EDTA; SmearOFF, Vista Dental, Racine, USA). These irrigants were used as the final irrigant for root canal disinfection. Epoxy sealers (AH26, Dentsply Maillefer, Ballaigues, Switzerland) and bioceramic sealers (ceraseal, Meta Biomed Co., Cheongju, Korea) have excellent adhesive properties and sealing ability and are commonly used as obturation materials. **Objective:** The aim of this study was to compare the effectiveness of a root canal combination irrigant between silver citrate and CHX-EDTA on the apical sealing ability of epoxy sealer and bioceramic sealer. **Materials and Methods:** Forty extracted mandible single-root premolars were used in this study. The root canal preparation was done with a rotary instrument until no. 30.06. Irrigation was performed using 5.25% NaOCl between instrumentations. The final irrigant and sealers were Group I: BioAKT + ceraceal; Group II: BioAKT + AH26; Group III: SmearOFF + ceraceal; and Group IV: SmearOFF + AH26. Obturation was then performed using the warm vertical compaction technique. The sealing ability of endodontic sealers was evaluated using the dye penetration method under the magnification of the stereomicroscope. The data were statistically analyzed using a two-way analysis of variance (ANOVA) (SPSS, IBM, USA). **Results:** No significant difference ($P > 0.05$) was observed between the four experimental groups. **Conclusion:** Both combination irrigants and sealers showed comparable effectiveness in smear layer removal and a similar sealing ability.

Keywords: *Apical sealing, BioAKT, bioceramic sealer, epoxy resin sealer, SmearOFF*

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Background

Endodontics is a branch of dentistry that deals with the prevention, diagnosis, and treatment of dental pulp and surrounding tissue pathosis. The necrotic pulp no longer has a defense mechanism, and the damaged

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tissue will lyse, resulting in periapical inflammation.[1,2] Endodontic treatment is used to eliminate intracanal infections caused by pulp necrosis.[2]

The irrigation solution removes bacteria and debris; it must be able to dissolve necrosis tissue and vital tissues, as well as eliminate bacteria, and it can remove smear layers on the entire root canal wall caused by mechanical preparation procedures. Smear layers can interfere with the bond between the sealer, as well as the penetration of intracanal medicament into the dentin tubules, and the need for removal to increase adhesion and achieve apical seal.[3] The irrigation solution can remove the smear layer, affecting the sealer's adhesion and apical density to dentin.[4,5] As a result of sealer penetration into dentin tubules following smear layer cleaning, an apical seal is obtained.[3,6] There is currently no single irrigation solution that meets all of the criteria above.[7-9]

Because it has antibacterial and proteolytic properties that can dissolve the necrotic tissue of the pulp in the root canal, as well as the organic component of dentin, sodium hypochlorite (NaOCl) solution is most widely used as an irrigation solution. Because NaOCl is less effective at removing the inorganic smear layer, it is combined as a chelating material with ethylenediaminetetraacetic acid (EDTA).[10,11] EDTA acts as a chelating solution and removes inorganic mineral components from smear layers. When in contact with the root canal wall, it effectively removes the smear layer in 1 min at a concentration of 17%; however, its antibacterial ability is limited.[7,11] Chlorhexidine (CHX) is a broad-spectrum antibacterial with a cationic property that can damage the bacterial cell wall's outer layer and interfere with its permeability. Despite this, CHX is incapable of dissolving organic or dental tissue, so NaOCl remains the preferred solution.[8,11]

When combined with EDTA, NaOCl causes peritubular and intertubular erosion as a result of proteolytic degradation and alters the collagen structure of dentin.[8] When NaOCl interacts with EDTA, the hypochlorite anion is reduced, making NaOCl less effective at dissolving necrosis tissue and decreasing antibacterial effectiveness. When NaOCl reacts with CHX, it causes discoloration and precipitation, which can affect root canal obturation.[10,11] Manufacturers are attempting to present irrigation solution innovations despite these limitations to find the most effective irrigation solution.[12]

The combination irrigation solution contains 1% CHX gluconate and 18% tetrasodium ethylenediaminetetraacetate dihydrate, which is one of the innovations by the manufacturer. In previous studies, it was discovered that the combined irrigation solution CHX and EDTA (SmearOFF) produced similar results to the 17% EDTA solution in cleaning smear layers. Despite the presence of CHX, its use with NaOCl results in no precipitation. The use of CHX and EDTA irrigation solutions is considered to be more advantageous for reducing step irrigation, that is, using only two types of solutions combining NaOCl and having antimicrobial effectiveness comparable to CHX.[9,13] This solution is used only for the final rinse.[14]

A silver-citric dihydrate, nano-based irrigation solution (silver 100 ppm, citric acid 1000 ppm) is currently being introduced in liquid form (BioAKT). Tonini *et al.*'s[10] research revealed that this solution and EDTA are extremely effective at removing smear layers, and that the resin-based sealer can then penetrate the dentin tubules. BioAKT performed significantly better than EDTA in removing smear layers and sealer penetration in the apical region, with significant antibacterial properties. There has been limited research on this combination solution.

Sealers can fill space in lateral root canals and accessories, as well as space between gutta-percha, during lateral condensation obturation.[15] The properties of a resin-based sealer are good adhesion, low toxicity, and antibacterial properties but a long setting time. With its high biocompatibility and bioactivity, calcium-silicate-based sealers have gained popularity in recent years. Bioceramic sealer is insoluble, radiopaque, does not shrink, and is not toxic; it can form hydroxyapatite. According to the studies, it reduces apical leakage.[3,15-18]

Subjects and Methods

For this study, 40 single-rooted human mandibular premolar teeth were extracted. The coronal portion of the teeth was removed near the cementoenamel junction with a fissure diamond disk and a high-speed handpiece perpendicular to the long axis in all samples to achieve a length of 14 mm. By inserting a #15 file (Dentsply) into each tooth until the tip of the file reached the apex, the length of each canal was visually determined. An endogauge was used to confirm the working length after subtracting 1 mm from the previous length.

The canals were prepared with a rotary file up to #30.06 (NIC, Shenzhen, China). After each endodontic file change, the apical patency was checked with a #15 k-file, and every canal was irrigated with 3 mL of 5.25% NaOCl (Chloraxid, Cerkamed) and flushed with 3 mL of aquadest.

The teeth were randomly divided into four groups of 10 samples each. Group I: Teeth were irrigated with a silver citrate solution as the final rinse, followed by obturation with bioceramic sealers. Group II: Teeth were irrigated with a silver citrate solution as the final rinse, followed by obturation with epoxy resin sealers. Group III: Teeth were irrigated with a CHX-EDTA solution as the final rinse, followed by obturation with bioceramic sealers. Group IV: Teeth were irrigated with a CHX-EDTA solution as the final rinse, followed by obturation with epoxy resin sealers. The canal was dried with a paper point before obturation. All irrigation solutions amounted to 10 mL in 2 min for silver citrate (BioAKT, New Tech Solution, Italy) and CHX-EDTA (SmearOFF, Vista Dental).

Obturation was done with AH-26 (Denstply) and Ceraseal (MetaBiomed, Korea) sealers inserted into the root canal with in–out movements using gutta-percha. The sealers were manipulated according to the manufacturer's instructions. The warm vertical compaction technique was used for obturation. Excess gutta-percha was removed and condensed to a depth of 2 mm below the orifice. The barrier was applied with glass ionomer cement, and radiographic photos were taken for confirmation.

All root surfaces except the apical 2 mm were covered with two layers of nail varnish (OPI, Los Angeles, California). The teeth were immersed in Indian ink (Royal Talens, Apeldoorn, Netherlands) and then stored in an incubator for 72 h. The roots were rinsed in running water and dried with paper towels, and the varnish was removed.

Sample diaphanization

To achieve demineralization, the specimens were stored in a 5% nitric acid solution (Smart-Lab, Indonesia) at room temperature for 72 h. The solution was stirred three to four times per day and replaced once a day. For 4 h, samples were rinsed under running water. Dehydration is achieved through a series of ethyl alcohol (Smart-Lab, Indonesia) rinses, beginning with an 80% solution for 12 h, followed by a 90% solution for an hour, and finally a 100% ethyl alcohol rinse for an hour. The dehydrated teeth were then immersed in methyl salicylate for 2 h in an incubator (Jisico, Seongdong-gu, Korea).

Assessment of apical sealability in the apical third

The staining in the apical third of the root canal was examined using a stereomicroscope (Zeiss Stemi 508 Stereo Microscope). The sample was placed on a petri dish and immersed in methyl salicylic liquid before being transferred to millimeter block paper. The penetration of Indian ink staining was measured from the apical to the deepest staining in the coronal direction. The measurement results were photographed and recorded using a stereomicroscope at 10x magnification.

Data and statistical analysis

Statistics were used to analyze the results of the calculations performed on the sample. The Shapiro–Wilk test was used to determine normality, followed by a two-way analysis of variance (ANOVA). Statistical testing was performed with a significance level of $P < 0.05$ using SPSS (IBM).

Results

The purpose of this study was to compare the effectiveness of a combined irrigation solution of silver citrate and CHX-EDTA against the apical seals of epoxy resin and bioceramic-based sealers. The penetration of Indian ink staining from the apical to the most coronal side of a millimeter block under a 10× stereomicroscope revealed apical leakage [Figure 1].

The observations in Table 1 show that samples using silver-citrate irrigation with bioceramic sealer have the shortest dye penetration distance into the root canal when compared to the other groups, with an average of 0.695 mm. The group with CHX-EDTA irrigation and epoxy resin sealer had the greatest penetration distance of dye penetration in the root canal, with an average distance of 1.13 mm.

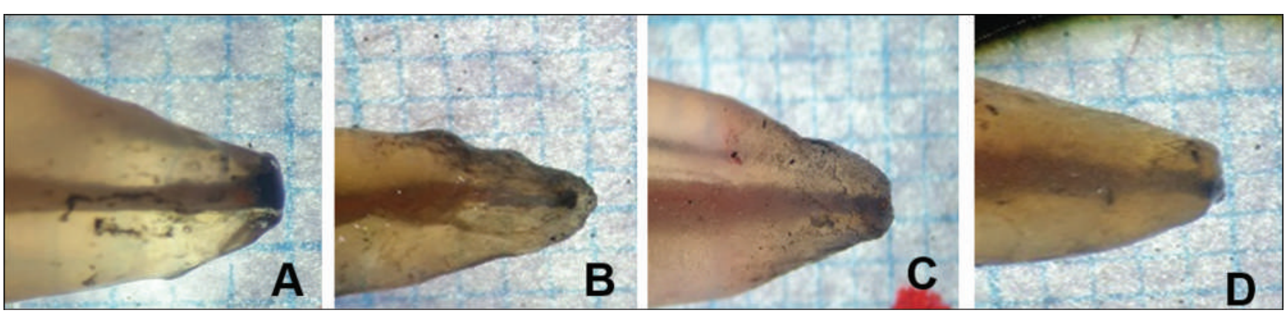

Figure 1: (A) Group 1 (silver-citrate irrigation with bioceramic-based sealer). (B) Group 2 (silver-citrate irrigation with epoxy resin-based sealer). (C) Group 3 (CHX-EDTA irrigation with bioceramic-based sealer). (D) Group 4 (CHX-EDTA irrigation with epoxy resin-based sealer)

Table 1: Mean value and standard deviation of apical leakage between sealer and irrigation solution in mm units

Irrigating solution	Sealer	*n*	Mean + SD
Silver-citrate	Bioceramic	10	0.695±0.29
Silver-citrate	Epoxy resin	10	1.090±0.27
CHX-EDTA	Bioceramic	10	0.998±0.13
CHX-EDTA	Epoxy Resin	10	1.13±0.21

Table 2: Results of the two-way ANOVA analysis of two apical leakages using different irrigation materials and sealers

Source	df	Mean	*f*	Sig.
Irrigation	1	5.45	15.28	0.056
Sealer	1	14.65	41.05	0.006*
Irrigation*sealer	1	1.12	3.15	0.472

*Sig. $P < 0.05$

The results of a two-way ANOVA with the deepest dye penetration distance into the root canal as a bound variable are shown in Table 2. Irrigation had a value of 0.056 ($P > 0.05$), indicating that irrigation had no significant effect on staining. The sealer has a value of 0.006 ($P < 0.05$), indicating that it has a significant influence on staining. The ANOVA test gave a value of 0.472, indicating that the effect of irrigation and sealer on staining was not significant ($P > 0.05$). As a result, the hypothesis that there was a difference in the effectiveness of irrigating solutions between the combination of silver citrate and CHX-EDTA on the apical sealing ability of resin epoxy and bioceramic-based sealers is rejected.

Discussion

The goal of root canal therapy is to provide a root canal free of debris and microbes for obturation. Furthermore, a coronal and apical seal must be obtained to prevent fluid percolation from periapical tissues and to ensure the treatment's long-term success.[3] Apical seal is determined by the penetration of sealer into dentin tubules following smear layer cleaning.[3,6] There was no difference in the effectiveness of the combined irrigation solution of silver-citrate and CHX-EDTA against the apical seal of epoxy resin and bioceramic-based sealer ($P > 0.05$) in this study.

The penetration of Indian ink into the root canal caused leakage in this study. The ink molecule has a diameter of 3 m, which is smaller than the bacterial molecule in the root canal, making it easier to penetrate by coloring the gap if there is a leak in the apical root canal.[19] Because of the smaller molecules, the staining may be easily penetrated, giving the impression that there are more leaks than occur.

The leakage of the irrigation solutions did not differ significantly ($P > 0.05$) in this study, with the average value of leakage in the silver-citrate combination irrigation solution (BioAKT) being lower than that of the CHX-EDTA combination solution (SmearOFF). BioAKT is a silver-citrate solution in which silver ions can form weak bonds with citric acid.[20] Although the SmearOFF irrigation solution contains EDTA, CHX, and surfactants, it is also used as the final irrigation in endodontic treatment.[21]

Previous research found that 17% EDTA is as effective as SmearOFF, which also contains EDTA in its solution.[9,14,21] Furthermore, at high concentrations, 17% EDTA causes demineralization, resulting in intraradicular dentin erosion.[21] This may cause the study's findings to be altered. As a result, 17% EDTA was not used as a control in this study, and the efficacy of chelating and antibacterial combination irrigation solutions could be compared equally.

The combination of the silver citrate irrigation solution (BioAKT) and CHX-EDTA (SmearOFF) produced comparable results in this study. Surface tension, viscosity, penetration, and solubility in the root canal are all factors that influence the irrigation solution's properties. Because BioAKT has a lower viscosity and molecular weight than EDTA, it can penetrate deeper into dentin tubules, with or without detergent. As viscosity and surface tension decrease, tubular penetration will increase.[20] There has not been much research on BioAKT irrigation solutions.

These findings are in line with Tonini *et al.*'s[10] research, which found that BioAKT has a better ability to remove smear layers and open dentin tubules in the apical part of the root canal than EDTA, although it does not differ significantly in the coronal and middle parts of the root canal. Citric acid at a low concentration (less than 10%) has the effect of 17% EDTA and stabilizes the bond with silver nanoparticles. At an acidic pH, 5% citric acid is sufficient to remove smear layers equivalent to a high concentration.

Surfactants are present in the SmearOFF component. Previous research has shown that adding surfactants to EDTA does not affect viscosity but does reduce surface tension, making it similar to BioAKT.[20] This study also explains how BioAKT and SmearOFF can be equivalent despite their different compositions.

According to the findings of Mahdi and Bakr's research, SmearOFF can dissolve smear layers equivalent to 17% EDTA. The viscosity of SmearOFF with EDTA was comparable. However, variations in surface tension, viscosity, molecular weight, and pH can all have an impact on the chelating solution. Viscosity and surface tension both influence solution penetration into the root canal. The concentration of EDTA in SmearOFF is lower to avoid being too aggressive in dentin, and the addition of CHX as an antibacterial agent can reduce EDTA's effectiveness. SmearOFF effectively eliminates the smear layer on the apical third of the root canal with ultrasonic activation and can be the chelating solution, as well as the antibacterial of choice at a later date.[21]

The difference between sealer and leakage was significant in this study, with the average value of bioceramic-based sealer leakage being lower than that of the resin-based sealer. The study's findings were influenced by the different properties of the two types of sealers. A calcium silicate-based sealer with stable dimensions and alkaline properties can cause denaturation in collagen dentin for penetration. Meanwhile, the resin sealer polymerizes and shrinks, causing microtag bonds to fail. As a result, the resin sealer and dentin walls have poor adhesion.[22]

The findings of this study are similar to the results of Abdelrahman and Hassan's[22] research, which showed that calcium silicate-based sealer penetration provides better sealing than resin-based sealers, as seen with scanning electron microscope (SEM). Ceraseal and resin sealer were used in this study, whereas NaOCl 2.5% was used for irrigation. Ceraseal (Metabiomed) is a calcium silicate-based sealer that is, available in the form of a paste in a syringe and contains calcium silicate, zirconium oxide, and thickening agents. Calcium hydroxide crystallizes as a result of moist dentin tubules and the chemical reaction of calcium silicate. This material is dimensionally stable and can be obturated with a single cone. It is said to be able to provide a hermetic seal of the root canal with a pH of 12.73 and a setting time of 3.5 h.[23]

Asawaworarit *et al.*'s[24] research using the liquid infiltration method revealed the same thing, with calcium silicate-based bioceramic sealer significantly outperforming resin sealer. In contrast to the bioceramic sealer, which has hydrophilic properties, the resin's hydrophobic properties prevent adaptation to the moist walls of the channel. Moist dentin tubules cause a chemical reaction in bioceramic sealers, resulting in the formation of hydroxyapatite, which improves adaptation to root canal walls and prevents leakage. This study used NaOCl 2.5% and EDTA 17% irrigation to remove smear layers.

The findings of this study are similar to those of Kharouf *et al.*,[25] who discovered that mixed sealer is superior to liquid and powder sealer, which must be mixed manually. In contrast to the preparation of powders and liquids that must be manually mixed with the ratio according to the manufacturer's direction, a mixed calcium silicate-based sealer has an already homogeneous mixture. This can change the compressive strength, solubility, and bond between the sealer and dentin. According to a study using SEM, ceraseal sealer has better sealing with lower solubility than calcium silicate sealer with powder and liquid preparations due to its chemical composition and mixing method. NaOCl 6%, EDTA 17%, and aquadest were the irrigation protocols used in the study.

AH-26 is a resin-based sealer made up of small-molecule epoxy resins and amines that combine to form polymers. This sealer is available in liquid and powder forms and has a 34-h setting time.[17] Epoxy resin-based sealers shrink during setting, resulting in less adaptation to the root canal wall. The tubular dentin in the apical third was smaller than in the middle and coronal parts. As a result, sealer penetration in the dentine tubules and apical seal is reduced in the apical region.[24]

A 17% EDTA solution can be used to dissolve the smear layer and expose more dentin tubules. As a result, many irregular surfaces are formed, improving AH-26 ADhesion to dentin. When the smear layer is removed, the adhesion strength of AH-26 increases significantly, and it becomes resistant to microleakage, according to previous studies. To achieve optimal adeshion, each type of sealer necessitates a different dentin treatment.[26]

Antunovic *et al.*[27] discovered that of the four types of bioceramic-based sealers and epoxy resin-based sealers tested, one type of calcium silicate-based bioceramic sealer performed significantly better than the others. The irrigation solution used in this study was NaOCl 2.5%, followed by EDTA 15%, which was rinsed with saline as the final irrigation solution. Tricalcium silicate-based bioceramic sealers and mineral trioxide aggregate were also used in this study. However, in this study, gutta-percha was also coated with bioceramic nanoparticles, allowing monobloc bonds to form in the root canal. Later in this study, leakage was measured using bacterial penetration, as well as SEM rather than staining.

Sakr *et al.*[28] discovered that calcium silicate-based bioceramic sealers had significantly less leakage than AH-26 sealers using methylene blue staining. The AH-26 sealer's adaptation is determined by the structure of the dentin tubules, which is also determined by the use of irrigation solutions to remove the smear layer. The irrigation solution used in this study was EDTA 17%

and NaOCl 2.25%, with saline as the final rinse. This last flushing solution difference could have influenced the study's findings.

The findings of this study indicate that the research hypothesis is rejected. The combined irrigation solutions of silver citrate and CHX-EDTA showed no significant difference against the apical sealing of epoxy resin and bioceramic-based sealers in this study. Silver citrate and CHX-EDTA irrigation solutions produced insignificant results. Despite their different compositions, these two solutions are equally effective and produce the same results. This solution can be viewed as both an alternative and an innovation in terms of shortening irrigation protocols in endodontic treatment. The properties of calcium silicate sealer and epoxy resin sealer differ. Several studies have shown that calcium silicate sealers are superior, and this study found significant differences in the best density values with bioceramic sealer.[22,24,25,27,28]

There have been few studies on the effectiveness of silver citrate irrigation solutions. More research is required to investigate the effectiveness of the silver–citrate combination irrigation solution on the cleanliness of the smear layer and the penetration of bioceramic-based sealer into dentin tubules.

The manual agitation of irrigation solutions with gutta-percha so that further activation assistance can be used with sonic tools is one of the study's limitations. In comparison to using a stereomicroscope, you can use the same method using a SEM to observe the sealer penetration in greater clarity and detail.

Conclusion

The findings of this study indicate that the research hypothesis is rejected. According to the outcomes of this study, the combined irrigation solution of silver citrate with bioceramic sealer had the highest sealing ability compared to the other groups. The CHX-EDTA group had the lowest sealing ability. However, the differences were not significant, which showed that both irrigants had equal effects on the apical seals of epoxy resin and bioceramic-based sealers.

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Conflicts of interest

There are no conflicts of interest.

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Comparative evaluation

by Tien Suwartini FKG

Original Article

A Comparative Evaluation of Two Irrigating Solutions Combination Effectiveness on Apical Sealing of Different Root Canal Sealers

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ABSTRACT

Background: Root canal irrigants play an essential role in removing the smear layer, pulp tissue, and microorganisms in the root canal system. The irrigation solution can remove the smear layer, which can interfere with the bond between the sealers. As a result of sealer penetration into dentin tubules following smear layer removal, an apical seal was obtained. One of the most recent innovations in root canals consists of a combination of silver citrate (BioAKT, New Tech Solution, Brescia, Italy) and chlorhexidine-ethylenediaminetetraacetic acid (CHX-EDTA; SmearOFF, Vista Dental, Racine, USA). These irrigants were used as the final irrigant for root canal disinfection. Epoxy sealers (AH26, Dentsply Maillefer, Ballaigues, Switzerland) and bioceramic sealers (ceraseal, Meta Biomed Co., Cheongju, Korea) have excellent adhesive properties and sealing ability and are commonly used as obturation materials. **Objective:** The aim of this study was to compare the effectiveness of a root canal combination irrigant between silver citrate and CHX-EDTA on the apical sealing ability of epoxy sealer and bioceramic sealer. **Materials and Methods:** Forty extracted mandible single-root premolars were used in this study. The root canal preparation was done with a rotary instrument until no. 30.06. Irrigation was performed using 5.25% NaOCl between instrumentations. The final irrigant and sealers were Group I: BioAKT + ceraceal; Group II: BioAKT + AH26; Group III: SmearOFF + ceraceal; and Group IV: SmearOFF + AH26. Obturation was then performed using the warm vertical compaction technique. The sealing ability of endodontic sealers was evaluated using the dye penetration method under the magnification of the stereomicroscope. The data were statistically analyzed using a two-way analysis of variance (ANOVA) (SPSS, IBM, USA). **Results:** No significant difference ($P > 0.05$) was observed between the four experimental groups. **Conclusion:** Both combination irrigants and sealers showed comparable effectiveness in smear layer removal and a similar sealing ability.

Keywords: *Apical sealing, BioAKT, bioceramic sealer, epoxy resin sealer, SmearOFF*

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Background

Endodontics is a branch of dentistry that deals with the prevention, diagnosis, and treatment of dental pulp and surrounding tissue pathosis. The necrotic pulp no longer has a defense mechanism, and the damaged

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tissue will lyse, resulting in periapical inflammation.[1,2] Endodontic treatment is used to eliminate intracanal infections caused by pulp necrosis.[2]

The irrigation solution removes bacteria and debris; it must be able to dissolve necrosis tissue and vital tissues, as well as eliminate bacteria, and it can remove smear layers on the entire root canal wall caused by mechanical preparation procedures. Smear layers can interfere with the bond between the sealer, as well as the penetration of intracanal medicament into the dentin tubules, and the need for removal to increase adhesion and achieve apical seal.[3] The irrigation solution can remove the smear layer, affecting the sealer's adhesion and apical density to dentin.[4,5] As a result of sealer penetration into dentin tubules following smear layer cleaning, an apical seal is obtained.[3,6] There is currently no single irrigation solution that meets all of the criteria above.[7-9]

Because it has antibacterial and proteolytic properties that can dissolve the necrotic tissue of the pulp in the root canal, as well as the organic component of dentin, sodium hypochlorite (NaOCl) solution is most widely used as an irrigation solution. Because NaOCl is less effective at removing the inorganic smear layer, it is combined as a chelating material with ethylenediaminetetraacetic acid (EDTA).[10,11] EDTA acts as a chelating solution and removes inorganic mineral components from smear layers. When in contact with the root canal wall, it effectively removes the smear layer in 1 min at a concentration of 17%; however, its antibacterial ability is limited.[7,11] Chlorhexidine (CHX) is a broad-spectrum antibacterial with a cationic property that can damage the bacterial cell wall's outer layer and interfere with its permeability. Despite this, CHX is incapable of dissolving organic or dental tissue, so NaOCl remains the preferred solution.[8,11]

When combined with EDTA, NaOCl causes peritubular and intertubular erosion as a result of proteolytic degradation and alters the collagen structure of dentin.[8] When NaOCl interacts with EDTA, the hypochlorite anion is reduced, making NaOCl less effective at dissolving necrosis tissue and decreasing antibacterial effectiveness. When NaOCl reacts with CHX, it causes discoloration and precipitation, which can affect root canal obturation.[10,11] Manufacturers are attempting to present irrigation solution innovations despite these limitations to find the most effective irrigation solution.[12]

The combination irrigation solution contains 1% CHX gluconate and 18% tetrasodium ethylenediaminetetraacetate dihydrate, which is one of the innovations by the manufacturer. In previous studies, it was discovered that the combined irrigation solution CHX and EDTA (SmearOFF) produced similar results to the 17% EDTA solution in cleaning smear layers. Despite the presence of CHX, its use with NaOCl results in no precipitation. The use of CHX and EDTA irrigation solutions is considered to be more advantageous for reducing step irrigation, that is, using only two types of solutions combining NaOCl and having antimicrobial effectiveness comparable to CHX.[9,13] This solution is used only for the final rinse.[14]

A silver-citric dihydrate, nano-based irrigation solution (silver 100 ppm, citric acid 1000 ppm) is currently being introduced in liquid form (BioAKT). Tonini *et al.*'s[10] research revealed that this solution and EDTA are extremely effective at removing smear layers, and that the resin-based sealer can then penetrate the dentin tubules. BioAKT performed significantly better than EDTA in removing smear layers and sealer penetration in the apical region, with significant antibacterial properties. There has been limited research on this combination solution.

Sealers can fill space in lateral root canals and accessories, as well as space between gutta-percha, during lateral condensation obturation.[15] The properties of a resin-based sealer are good adhesion, low toxicity, and antibacterial properties but a long setting time. With its high biocompatibility and bioactivity, calcium-silicate-based sealers have gained popularity in recent years. Bioceramic sealer is insoluble, radiopaque, does not shrink, and is not toxic; it can form hydroxyapatite. According to the studies, it reduces apical leakage.[3,15-18]

Subjects and Methods

For this study, 40 single-rooted human mandibular premolar teeth were extracted. The coronal portion of the teeth was removed near the cementoenamel junction with a fissure diamond disk and a high-speed handpiece perpendicular to the long axis in all samples to achieve a length of 14 mm. By inserting a #15 file (Dentsply) into each tooth until the tip of the file reached the apex, the length of each canal was visually determined. An endogauge was used to confirm the working length after subtracting 1 mm from the previous length.

The canals were prepared with a rotary file up to #30.06 (NIC, Shenzhen, China). After each endodontic file change, the apical patency was checked with a #15 k-file, and every canal was irrigated with 3 mL of 5.25% NaOCl (Chloraxid, Cerkamed) and flushed with 3 mL of aquadest.

The teeth were randomly divided into four groups of 10 samples each. Group I: Teeth were irrigated with a silver citrate solution as the final rinse, followed by obturation with bioceramic sealers. Group II: Teeth were irrigated with a silver citrate solution as the final rinse, followed by obturation with epoxy resin sealers. Group III: Teeth were irrigated with a CHX-EDTA solution as the final rinse, followed by obturation with bioceramic sealers. Group IV: Teeth were irrigated with a CHX-EDTA solution as the final rinse, followed by obturation with epoxy resin sealers. The canal was dried with a paper point before obturation. All irrigation solutions amounted to 10 mL in 2 min for silver citrate (BioAKT, New Tech Solution, Italy) and CHX-EDTA (SmearOFF, Vista Dental).

Obturation was done with AH-26 (Denstply) and Ceraseal (MetaBiomed, Korea) sealers inserted into the root canal with in–out movements using gutta-percha. The sealers were manipulated according to the manufacturer's instructions. The warm vertical compaction technique was used for obturation. Excess gutta-percha was removed and condensed to a depth of 2 mm below the orifice. The barrier was applied with glass ionomer cement, and radiographic photos were taken for confirmation.

All root surfaces except the apical 2 mm were covered with two layers of nail varnish (OPI, Los Angeles, California). The teeth were immersed in Indian ink (Royal Talens, Apeldoorn, Netherlands) and then stored in an incubator for 72 h. The roots were rinsed in running water and dried with paper towels, and the varnish was removed.

Sample diaphanization

To achieve demineralization, the specimens were stored in a 5% nitric acid solution (Smart-Lab, Indonesia) at room temperature for 72 h. The solution was stirred three to four times per day and replaced once a day. For 4 h, samples were rinsed under running water. Dehydration is achieved through a series of ethyl alcohol (Smart-Lab, Indonesia) rinses, beginning with an 80% solution for 12 h, followed by a 90% solution for an hour, and finally a 100% ethyl alcohol rinse for an hour. The dehydrated teeth were then immersed in methyl salicylate for 2 h in an incubator (Jisico, Seongdong-gu, Korea).

Assessment of apical sealability in the apical third

The staining in the apical third of the root canal was examined using a stereomicroscope (Zeiss Stemi 508 Stereo Microscope). The sample was placed on a petri dish and immersed in methyl salicylic liquid before being transferred to millimeter block paper. The penetration of Indian ink staining was measured from the apical to the deepest staining in the coronal direction. The measurement results were photographed and recorded using a stereomicroscope at 10x magnification.

Data and statistical analysis

Statistics were used to analyze the results of the calculations performed on the sample. The Shapiro–Wilk test was used to determine normality, followed by a two-way analysis of variance (ANOVA). Statistical testing was performed with a significance level of $P < 0.05$ using SPSS (IBM).

Results

The purpose of this study was to compare the effectiveness of a combined irrigation solution of silver citrate and CHX-EDTA against the apical seals of epoxy resin and bioceramic-based sealers. The penetration of Indian ink staining from the apical to the most coronal side of a millimeter block under a 10× stereomicroscope revealed apical leakage [Figure 1].

The observations in Table 1 show that samples using silver-citrate irrigation with bioceramic sealer have the shortest dye penetration distance into the root canal when compared to the other groups, with an average of 0.695 mm. The group with CHX-EDTA irrigation and epoxy resin sealer had the greatest penetration distance of dye penetration in the root canal, with an average distance of 1.13 mm.

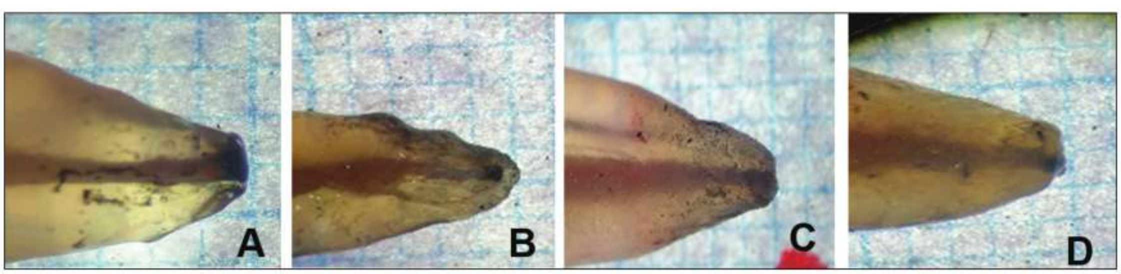

Figure 1: (A) Group 1 (silver-citrate irrigation with bioceramic-based sealer). (B) Group 2 (silver-citrate irrigation with epoxy resin-based sealer). (C) Group 3 (CHX-EDTA irrigation with bioceramic-based sealer). (D) Group 4 (CHX-EDTA irrigation with epoxy resin-based sealer)

Table 1: Mean value and standard deviation of apical leakage between sealer and irrigation solution in mm units

Irrigating solution	Sealer	*n*	Mean + SD
Silver-citrate	Bioceramic	10	0.695±0.29
Silver-citrate	Epoxy resin	10	1.090±0.27
CHX-EDTA	Bioceramic	10	0.998±0.13
CHX-EDTA	Epoxy Resin	10	1.13±0.21

Table 2: Results of the two-way ANOVA analysis of two apical leakages using different irrigation materials and sealers

Source	df	Mean	*f*	Sig.
Irrigation	1	5.45	15.28	0.056
Sealer	1	14.65	41.05	0.006*
Irrigation*sealer	1	1.12	3.15	0.472

*Sig. $P < 0.05$

The results of a two-way ANOVA with the deepest dye penetration distance into the root canal as a bound variable are shown in Table 2. Irrigation had a value of 0.056 ($P > 0.05$), indicating that irrigation had no significant effect on staining. The sealer has a value of 0.006 ($P < 0.05$), indicating that it has a significant influence on staining. The ANOVA test gave a value of 0.472, indicating that the effect of irrigation and sealer on staining was not significant ($P > 0.05$). As a result, the hypothesis that there was a difference in the effectiveness of irrigating solutions between the combination of silver citrate and CHX-EDTA on the apical sealing ability of resin epoxy and bioceramic-based sealers is rejected.

Discussion

The goal of root canal therapy is to provide a root canal free of debris and microbes for obturation. Furthermore, a coronal and apical seal must be obtained to prevent fluid percolation from periapical tissues and to ensure the treatment's long-term success.[3] Apical seal is determined by the penetration of sealer into dentin tubules following smear layer cleaning.[3,6] There was no difference in the effectiveness of the combined irrigation solution of silver-citrate and CHX-EDTA against the apical seal of epoxy resin and bioceramic-based sealer ($P > 0.05$) in this study.

The penetration of Indian ink into the root canal caused leakage in this study. The ink molecule has a diameter of 3 m, which is smaller than the bacterial molecule in the root canal, making it easier to penetrate by coloring the gap if there is a leak in the apical root canal.[19] Because of the smaller molecules, the staining may be easily penetrated, giving the impression that there are more leaks than occur.

The leakage of the irrigation solutions did not differ significantly ($P > 0.05$) in this study, with the average value of leakage in the silver-citrate combination irrigation solution (BioAKT) being lower than that of the CHX-EDTA combination solution (SmearOFF). BioAKT is a silver-citrate solution in which silver ions can form weak bonds with citric acid.[20] Although the SmearOFF irrigation solution contains EDTA, CHX, and surfactants, it is also used as the final irrigation in endodontic treatment.[21]

Previous research found that 17% EDTA is as effective as SmearOFF, which also contains EDTA in its solution.[9,14,21] Furthermore, at high concentrations, 17% EDTA causes demineralization, resulting in intraradicular dentin erosion.[21] This may cause the study's findings to be altered. As a result, 17% EDTA was not used as a control in this study, and the efficacy of chelating and antibacterial combination irrigation solutions could be compared equally.

The combination of the silver citrate irrigation solution (BioAKT) and CHX-EDTA (SmearOFF) produced comparable results in this study. Surface tension, viscosity, penetration, and solubility in the root canal are all factors that influence the irrigation solution's properties. Because BioAKT has a lower viscosity and molecular weight than EDTA, it can penetrate deeper into dentin tubules, with or without detergent. As viscosity and surface tension decrease, tubular penetration will increase.[20] There has not been much research on BioAKT irrigation solutions.

These findings are in line with Tonini *et al.*'s[10] research, which found that BioAKT has a better ability to remove smear layers and open dentin tubules in the apical part of the root canal than EDTA, although it does not differ significantly in the coronal and middle parts of the root canal. Citric acid at a low concentration (less than 10%) has the effect of 17% EDTA and stabilizes the bond with silver nanoparticles. At an acidic pH, 5% citric acid is sufficient to remove smear layers equivalent to a high concentration.

Surfactants are present in the SmearOFF component. Previous research has shown that adding surfactants to EDTA does not affect viscosity but does reduce surface tension, making it similar to BioAKT.[20] This study also explains how BioAKT and SmearOFF can be equivalent despite their different compositions.

According to the findings of Mahdi and Bakr's research, SmearOFF can dissolve smear layers equivalent to 17% EDTA. The viscosity of SmearOFF with EDTA was comparable. However, variations in surface tension, viscosity, molecular weight, and pH can all have an impact on the chelating solution. Viscosity and surface tension both influence solution penetration into the root canal. The concentration of EDTA in SmearOFF is lower to avoid being too aggressive in dentin, and the addition of CHX as an antibacterial agent can reduce EDTA's effectiveness. SmearOFF effectively eliminates the smear layer on the apical third of the root canal with ultrasonic activation and can be the chelating solution, as well as the antibacterial of choice at a later date.[21]

The difference between sealer and leakage was significant in this study, with the average value of bioceramic-based sealer leakage being lower than that of the resin-based sealer. The study's findings were influenced by the different properties of the two types of sealers. A calcium silicate-based sealer with stable dimensions and alkaline properties can cause denaturation in collagen dentin for penetration. Meanwhile, the resin sealer polymerizes and shrinks, causing microtag bonds to fail. As a result, the resin sealer and dentin walls have poor adhesion.[22]

The findings of this study are similar to the results of Abdelrahman and Hassan's[22] research, which showed that calcium silicate-based sealer penetration provides better sealing than resin-based sealers, as seen with scanning electron microscope (SEM). Ceraseal and resin sealer were used in this study, whereas NaOCl 2.5% was used for irrigation. Ceraseal (Metabiomed) is a calcium silicate-based sealer that is, available in the form of a paste in a syringe and contains calcium silicate, zirconium oxide, and thickening agents. Calcium hydroxide crystallizes as a result of moist dentin tubules and the chemical reaction of calcium silicate. This material is dimensionally stable and can be obturated with a single cone. It is said to be able to provide a hermetic seal of the root canal with a pH of 12.73 and a setting time of 3.5 h.[23]

Asawaworarit *et al.*'s[24] research using the liquid infiltration method revealed the same thing, with calcium silicate-based bioceramic sealer significantly outperforming resin sealer. In contrast to the bioceramic sealer, which has hydrophilic properties, the resin's hydrophobic properties prevent adaptation to the moist walls of the channel. Moist dentin tubules cause a chemical reaction in bioceramic sealers, resulting in the formation of hydroxyapatite, which improves adaptation to root canal walls and prevents leakage. This study used NaOCl 2.5% and EDTA 17% irrigation to remove smear layers.

The findings of this study are similar to those of Kharouf *et al.*,[25] who discovered that mixed sealer is superior to liquid and powder sealer, which must be mixed manually. In contrast to the preparation of powders and liquids that must be manually mixed with the ratio according to the manufacturer's direction, a mixed calcium silicate-based sealer has an already homogeneous mixture. This can change the compressive strength, solubility, and bond between the sealer and dentin. According to a study using SEM, ceraseal sealer has better sealing with lower solubility than calcium silicate sealer with powder and liquid preparations due to its chemical composition and mixing method. NaOCl 6%, EDTA 17%, and aquadest were the irrigation protocols used in the study.

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A 17% EDTA solution can be used to dissolve the smear layer and expose more dentin tubules. As a result, many irregular surfaces are formed, improving AH-26 ADhesion to dentin. When the smear layer is removed, the adhesion strength of AH-26 increases significantly, and it becomes resistant to microleakage, according to previous studies. To achieve optimal adeshion, each type of sealer necessitates a different dentin treatment.[26]

Antunovic *et al.*[27] discovered that of the four types of bioceramic-based sealers and epoxy resin-based sealers tested, one type of calcium silicate-based bioceramic sealer performed significantly better than the others. The irrigation solution used in this study was NaOCl 2.5%, followed by EDTA 15%, which was rinsed with saline as the final irrigation solution. Tricalcium silicate-based bioceramic sealers and mineral trioxide aggregate were also used in this study. However, in this study, gutta-percha was also coated with bioceramic nanoparticles, allowing monobloc bonds to form in the root canal. Later in this study, leakage was measured using bacterial penetration, as well as SEM rather than staining.

Sakr *et al.*[28] discovered that calcium silicate-based bioceramic sealers had significantly less leakage than AH-26 sealers using methylene blue staining. The AH-26 sealer's adaptation is determined by the structure of the dentin tubules, which is also determined by the use of irrigation solutions to remove the smear layer. The irrigation solution used in this study was EDTA 17%

and NaOCl 2.25%, with saline as the final rinse. This last flushing solution difference could have influenced the study's findings.

The findings of this study indicate that the research hypothesis is rejected. The combined irrigation solutions of silver citrate and CHX-EDTA showed no significant difference against the apical sealing of epoxy resin and bioceramic-based sealers in this study. Silver citrate and CHX-EDTA irrigation solutions produced insignificant results. Despite their different compositions, these two solutions are equally effective and produce the same results. This solution can be viewed as both an alternative and an innovation in terms of shortening irrigation protocols in endodontic treatment. The properties of calcium silicate sealer and epoxy resin sealer differ. Several studies have shown that calcium silicate sealers are superior, and this study found significant differences in the best density values with bioceramic sealer.[22,24,25,27,28]

There have been few studies on the effectiveness of silver citrate irrigation solutions. More research is required to investigate the effectiveness of the silver–citrate combination irrigation solution on the cleanliness of the smear layer and the penetration of bioceramic-based sealer into dentin tubules.

The manual agitation of irrigation solutions with gutta-percha so that further activation assistance can be used with sonic tools is one of the study's limitations. In comparison to using a stereomicroscope, you can use the same method using a SEM to observe the sealer penetration in greater clarity and detail.

Conclusion

The findings of this study indicate that the research hypothesis is rejected. According to the outcomes of this study, the combined irrigation solution of silver citrate with bioceramic sealer had the highest sealing ability compared to the other groups. The CHX-EDTA group had the lowest sealing ability. However, the differences were not significant, which showed that both irrigants had equal effects on the apical seals of epoxy resin and bioceramic-based sealers.

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Conflicts of interest

There are no conflicts of interest.

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