

The Effect of Root Canal Irrigants on the Sealing Ability of Different Sealers

Kök Kanal İrigasyon Solüsyonlarının Farklı Patların Örtücülüğü Üzerine Etkisi

Figen SEVGİCAN¹ Murat TÜRKÜN² Burcu ARAN¹ Yeşim ERATLI¹

Ege Üniversitesi, Dişhekimliği Fakültesi, Diş Hastalıkları ve Tedavisi AD, ¹Endodonti BD, ²Konservatif Diş Tedavisi BD, İZMİR

Abstract

Objective: The aim of the present study was to evaluate the effect of commonly used endodontic irrigants on the sealing ability of two different resin based canal sealers, Diaket and AH Plus.

Methods: Ninety teeth with straight single root canals were instrumented to master apical point #45. Sodium hypochlorite, hydrogen peroxide, Tubulicid plus or Cetrexidine was used for irrigation during root canal preparation. Each irrigation group was again divided into two root canal sealer groups, Diaket and AH Plus. Following the obturation of the root canals, the specimens were immersed in India ink and cleared to allow visualization of the leakage. All measurements were obtained by means of a stereomicroscope at X6 magnification.

Results: Sodium hypochlorite and hydrogen peroxide groups demonstrated higher leakage scores than Cetrexidine and Tubulicid plus in both sealer groups.

Conclusion: The apical sealing property of resin based canal sealers as adversely influenced by sodium hypochlorite and hydrogen peroxide.

Keywords: Apical leakage, irrigation, sealers

Özet

Amaç: Bu çalışmada, sık kullanılan endodontik irigasyon solüsyonlarının, AH Plus ve Diaket gibi iki farklı rezin esaslı patın örtüleme yeteneği üzerine etkisi değerlendirildi.

Gereç ve Yöntem: Düz tek köklü doksan adet diş ana apikal eğe #45 olana kadar step back yöntemi kullanılarak genişletildi. Kök kanallarının preparasyonu sırasında sodyum hipoklorit, hidrojen peroksit, Tubulicid plus ve Cetrexidin irigasyon solüsyonu olarak kullanıldı. Her bir irigasyon grubu kendi içinde Diaket ve AH Plus'in olduğu iki gruba bölündü. Kök kanallarının doldurulmasını takiben örnekler çini mürekkebine batırıldı ve sızıntının gözlenmesi için şeffatlaştırıldı. Bütün ölçümler x6 büyütmeli stereo mikroskop altında yapıldı.

Bulgular: Her iki kanal patı grubunda sodyum hipoklorit ve hidrojen peroksit grupları, Cetrexidin ve Tubulicid plus'a göre daha yüksek sızıntı skorları gösterdi.

Sonuç: Rezin bazlı kanal patlarının apikal örtüleme yeteneği sodyum hipoklorit ve hidrojen peroksitin irigasyonundan olumsuz etkilenmektedir.

Anahtar sözcükler: Apikal sızıntı, irigasyon, kanal patları

Introduction

One of the most important objectives in endodontic therapy is disinfection of the entire root canal system, elimination of the bacteria, their products and the substrate, before obturation of the canals.¹ Unfortunately, the mechanical action of instruments is unable to reach the whole areas of the root-canal system due to complex morphologies and the irregularities. Therefore, cleaning of the root canals may not be performed completely. Sodium hypochlorite (NaOCl) in various concentrations (0.5-5.25 %) has been the irrigant of choice because of its antimicrobial activity and tissue-dissolving ability.² The antimicrobial ability of NaOCl results from the formation of hypochlorous acid (HOCl), when in contact with organic debris, HOCl exerts its effect by the oxidation of sulphhydryl groups within bacterial enzyme systems, thereby disrupting the metabolism of the microorganism.³ H_2O_2 also has been widely used for irrigation of the root canal system, although it has less bactericidal activity.⁴ The endodontic literature contains many reports on complications during root canal irrigation, including inadvertent injection of H_2O_2 into the periapical tissues, and allergic reactions to NaOCl.⁴ Furthermore, the major disadvantage of using NaOCl and H_2O_2 is that they are unable to completely remove the smear layer.

The smear layer which is consisted of pulpal tissue remnants, bacteria, and dentine debris, can be forced 1-5 μ m into the dentinal tubules, to create a smear plug that reduces dentine permeability up to 78%.⁵ This layer is acid labile, and can be dissolved by fluids with pH between 6.0 and 6.8.⁵ The removal of the smear layer provides more efficient disinfection and improves the seal of root fillings due to penetration of sealer into the open dentinal tubules thus decreasing microleakage.⁵

More recently, the ability of acids or chelating agents to remove the smear layer has gained a great deal of attention.⁶ When used as an endodontic irrigant, EDTA has an efficient chelating action, dissolving mineralized tissues and promoting smear-free surfaces to obtain maximum cleansing effect after instrumentation.⁵ Therefore, chelating agents such as EDTA or REDTA are recommended to use in

combination with NaOCl. Liolios *et al.*⁷ have shown that Tubulicid plus which has 3 % EDTA and 0.5 % benzalkonium chlorite, regardless of the method of instrumentation, removed the smear layer, opened the dentinal tubules and left only minimal debris.

Chlorhexidine gluconate seems to be effective in reducing the bacterial microflora in the infected root canal but has no effect on the pulpal tissue remnants.⁸ Its major advantage is prevention of microbial activity with residual effects in the root canal system for 48 to 72 hours.⁹ Chlorhexidine gluconate, by attaching to bacterial cytoplasmic membranes, causes the loss of osmotic balance, and results in the leakage of intracellular material.⁵ It also binds to hydroxyapatite and soft tissues, changing their electrical field to compete with bacterial binding.^{1,5} Cetrexidin, composed of 0.2 % chlorhexidine gluconate and 0.2 % cetrimide, is another alternative to NaOCl. Cetrimide (cetyl trimethyl ammonium bromide), is a quaternary ammonium compound and a strong cationic detergent that is effective against many Gram-positive and Gram-negative bacteria.⁵ Several studies have shown that chlorhexidine gluconate is able to remove smear layer, or to prevent the formation of smear layer.^{10,11} A possible clinical advantage of chlorhexidine gluconate over NaOCl is its low toxicity.¹ Another advantage is that it could be used in patients that are allergic to NaOCl.¹ On the other hand, its major disadvantage is the lack of ability to dissolve necrotic pulp tissue.

Good obturation and adhesion of AH26 (DeTrey Dentsply, Konstanz, Germany) on the root-canal walls have been demonstrated.⁵ AH Plus (DeTrey Dentsply) have improved its properties, including long-term dimensional stability.⁷ Because of the chemistry of the epoxy amines, the material no longer releases toxic substances like formaldehyde compared to AH26.⁷ The sealer AH Plus is based on epoxy amine resins, and is a recent material on the market. It is described as having a faster setting time, with more pronounced radiopacity than AH26. Diaket, a polyvinyl resin cement has been also reported to prove an adequate seal.¹²

Failure of root-canal treatment can be attributed to a number of causes, but leakage through the root

filling itself is thought to be a major factor.¹³ The use of some disinfectant solutions during root canal preparation may have an adverse effect on the adhesion of sealers to root canal dentin. Therefore, the aim of this study was to evaluate the effect of four different endodontic irrigants on the sealing ability of two different canal sealers.

Materials and Methods

A total of 90 intact single-rooted human mandibular premolars were carefully cleaned to eliminate tartar and tissue remnants, followed by immersion in distilled water containing thymol crystals until use. The preparation of the teeth was carried out by the same operator.

Canal preparation

The crowns were removed 2 mm over the cemento-enamel junction with a high-speed fissure bur and water spray. After manual exploration of the canals, a size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) with a rubber stop was introduced carefully into each canal until it was just visible in the apical foramen. This length was recorded and 1mm was subtracted to give the working length of the root. The instrument was used with a half turn reaming action until the file became loose within the canal. Step-back flaring of the canal was performed using larger files at 1mm intervals manipulated in a filling action. The file used to prepare the apical stop was used to recapitulate. Step-back preparation was completed after the use of three files larger than the file used to prepare the apical stop. A size 45 file was used to establish the apical stop and step-back technique was performed up to a size 80 file. The eighty teeth were randomly distributed to four irrigation groups each including 20 specimens. Then, each irrigation group was divided into two canal sealer groups of 10 specimens each (Table 1).

Canal irrigation and obturation

Irrigation with 2mL of irrigant was performed at each instrument change, using a 27-gauge needle attached to a 10mL syringe and 5mL of irrigant was

used for final irrigation. After final irrigation, all root canals were dried with paper points. The specimens obturated with standardized gutta-percha points (Hygenic) and root canal sealers, Diaket (3M/ESPE) and AH Plus (Dentsply) using the lateral compaction technique. A standard size gutta-percha cone was fitted to the working length with tug back. The sealers were mixed according to the manufacturer's instructions, and applied to the walls of the canal with a size 40 K-file. The master cone corresponding to the last master apical file was lightly coated with the sealer and placed in the canal. Finger spreaders and size 20 and 25 gutta-percha cones were used for lateral compaction. Gutta-percha cones were added until the spreader penetrated into the coronal one-third of the root canal space. After obturation, a hot plugger was used to remove excess gutta-percha 1mm from the cemento-enamel junction. Finally, the access cavities of all teeth were restored with glass ionomer (Ketac-Bond, Espe, Seefeld, Germany). The teeth were then incubated for 10 days at 37°C to allow the sealer to set. Then, the teeth were coated with first layer of nail polish (Lancome, Paris, France), covering the whole tooth, including the coronal restoration of the access cavity, but leaving a 2mm area around the apical foramen uncoated. One hour later, a second coat was applied with a polish of slightly different color than the first.

Table 1. Test groups.

Groups	Irrigation solution	Canal Sealer
1	5.25 % NaOCl	Diaket
2	5.25 % NaOCl	AH Plus
3	3 % H ₂ O ₂	Diaket
4	3 % H ₂ O ₂	AH Plus
5	Tubulicid plus	Diaket
6	Tubulicid plus	AH Plus
7	Cetrexidin	Diaket
8	Cetrexidin	AH Plus

Control Groups

Ten teeth were used as controls. For positive controls, the canals of 5 teeth were enlarged as described above, but the root canals were not

filled. Five teeth serving as negative controls were completely covered with nail varnish following the obturation of the root canals.

Staining and clearing

After 1 hour of drying, all specimens were immersed in India ink (Pelikan, Hanover, Germany) for 24 h at 37 °C. At the end of this period, the teeth were rinsed with running water, and lightly scrubbed to remove ink residue from the external surface. The nail polish was removed with a razor blade and the teeth were soaked in acetone for 1h to remove residues of nail polish. The teeth were air-dried, and then were prepared for clearing. They were demineralized in 5ml of 5% nitric acid for approximately 5 days until the texture was rubbery; completion of demineralization was confirmed when a pin would pass through an unimportant part of the root. The acid was changed daily, and the teeth were agitated regularly.

The teeth were left under running tap water for 24 hours, and were then dehydrated in ascending grades (70–100%) of alcohol. Finally, the teeth were cleared and stored in methyl salicylate at room temperature for 3 weeks, until they became clear; thus, visualization and measurement of india ink penetration would be possible.

Evaluation

For elimination of bias, apical leakage was measured independently by two evaluators in a blind-folded fashion. Each observer judged the depth of the stain independently according to the standard ranking for leakage. If the observers achieved different scores, new readings were performed until a consensus was reached. All measurements were obtained by means of a stereomicroscope (Olympus Co, Tokyo, Japan) at X6 magnification on an arbitrary scale:

- 0 Dye not visible on the canal wall
- 1 Dye infiltration up to 1 mm
- 2 Dye infiltration up to 1.5 mm
- 3 Dye infiltration up to 2 mm
- 4 Dye infiltration more than 2 mm.

A non-parametric one-way ANOVA (Kruskal-Wallis) test was used to determine whether there were significant differences among the irrigation groups for each canal sealers. Pair-wise comparisons were performed using the Mann Whitney-U test with Bonferroni correction, and the level of significance was set as $p < 0.05$ in all tests. However, after Bonferroni correction, this level was reset as $p < 0.005$.

Results

The apical microleakage scores are shown in Table 2. No leakage was observed in negative controls during the experiment; however, positive controls showed leakage along the entire length of the root canal. Although AH Plus demonstrated less leakage than Diaket, the leakage differences among the canal sealers were found to be statistically significant in Cetrexidin and Tubulicid plus groups ($p < 0.05$), but were not significant in NaOCl and hydrogen peroxide (H_2O_2) groups ($p > 0.05$). Cetrexidin presented the lowest level of dye penetration followed by Tubulicid plus. Leakage scores frequently observed for Cetrexidin were 0 and 1 (Figs. 1-2), except two specimens in Diaket group. However, all four leakage scores except 0 were observed in the NaOCl and H_2O_2 groups (Figs. 3-4).

Table 2. Leakage scores in different experimental groups (n=10 for each group).

SCORES	GROUPS							
	1	2	3	4	5	6	7	8
0	-	-	-	1	-	-	7	8
1	-	2	6	7	4	6	3	2
2	5	-	1	-	-	1	-	-
3	-	3	1	-	3	-	-	-
4	5	5	2	2	3	3	-	-

When the sealing ability of two different root canal sealers was compared; we determined that there were statistically significant differences in Tubulicid Plus and Cetrexidin groups ($p < 0.005$). There were not statistically significant differences between Diaket and AH Plus when either 5.25 % NaOCl or H_2O_2 used as an irrigant solution ($p > 0.005$).

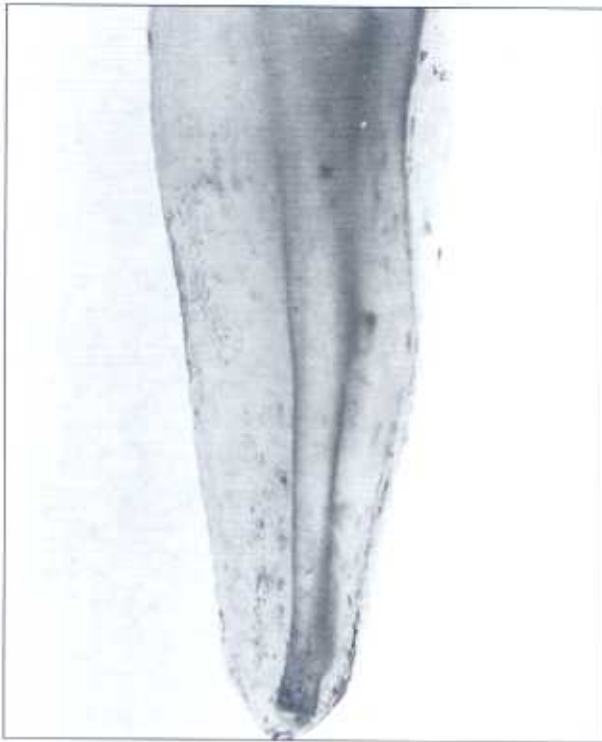


Fig. 1. Representative photograph showing grade 0 apical leakage from the group irrigated with Cetuxadlin and filled with AH Plus (Group 8).

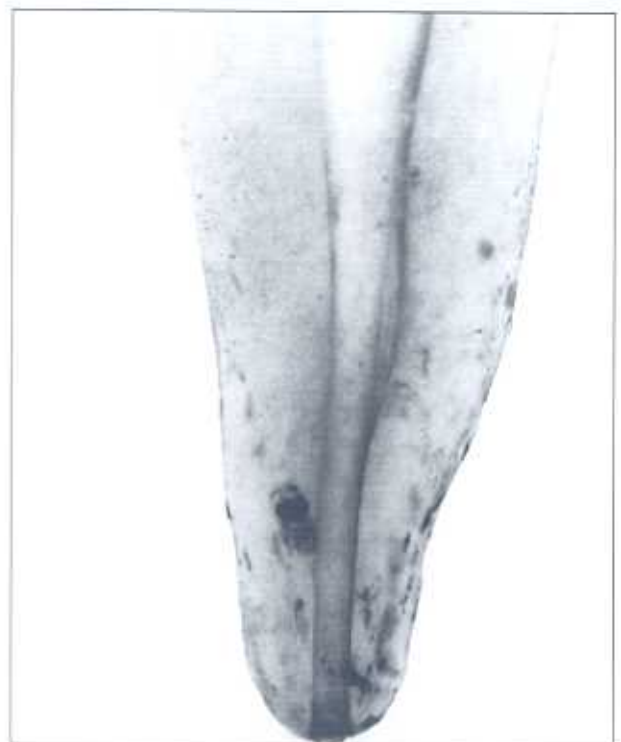


Fig. 2. Representative photograph showing grade 1 apical leakage from the group irrigated with Tiodolend plus and filled with Diaket (Group 5).



Fig. 3. Representative photograph showing grade 3 apical leakage from the group irrigated with NaOCl and filled with Diaket (Group 1).

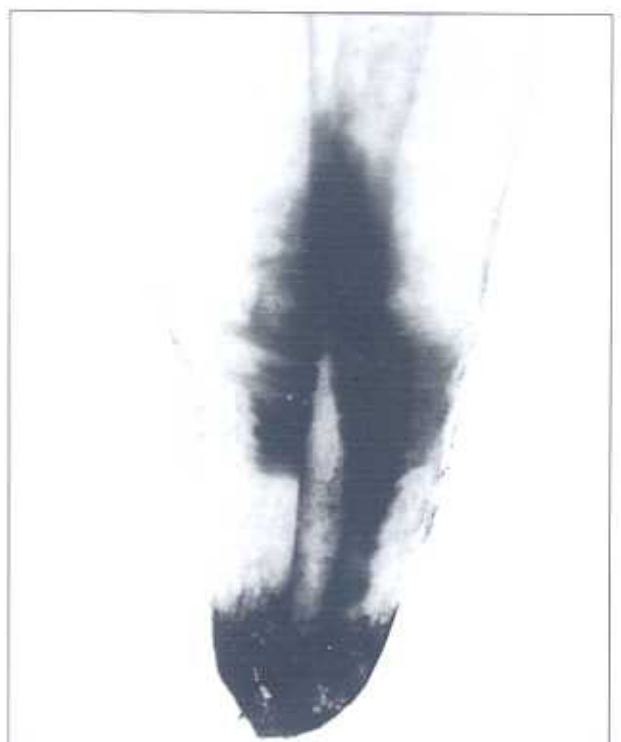


Fig. 2. Representative photograph showing grade 4 apical leakage from the group irrigated with H₂O₂ and filled with AH plus (Group 4). Dye leakage evident throughout the tubules and along the sealer dentine interface more than 2 mm.

When the sealing ability of Diaket was determined, statistically significant differences were found between 5.25% NaOCl and Cetrexidin and 5.25% NaOCl and Tubulicid Plus ($p < 0.005$). On the other hand, H_2O_2 was not significantly different from Cetrexidin, Tubulicid Plus and 5.25% NaOCl, when Diaket was used as a canal sealer ($p > 0.005$).

Considering the sealing ability of All Plus; both 5.25 % NaOCl and H_2O_2 showed the statistically significant differences from Cetrexidin and Tubulicid Plus ($p < 0.005$).

Discussion

Even though various methods have been used to assess the quality of the root canal seal by evaluation of microleakage, a universally accepted method still does not exist for the assessment of leakage. Leakage studies include coloured dye penetration, bacterial leakage, analysis of radiolabeled tracer penetration, dissolution of hard tissue, clearing of teeth, spectrometry of radioisotopes, electrochemical methods and gas chromatography.¹⁰ Among these methods, dyes are most commonly preferred since this is simple to use, cheap, safe, easy to handle and widely available.⁹ Therefore, this is a common method to explore apical leakage of root fillings after splitting the roots or after clearing them.^{10,14} The main advantage of the clearing technique is that in a transparent tooth, dye penetration can be observed in three dimensions, which enables the reading of the maximum extent of dye.¹⁴ The clearing technique seems to be more precise in detecting leakage than the cross-sectional approach, because the loss of part of the dentinal tissues and dye (corresponding to a thickness equivalent to that of the saw blade) is observed as a result of sectioning itself.¹⁰ In addition, clearing makes it possible to assess leakage magnitudes to tenths of a millimeter, whereas cross-sectioning only determines the presence of leakage. Clearing leaves the roots intact, thereby it not only reduces the working time, but also affords greater information. Since there appears to be no significant differences between the amount of leakage obtained by passive or by negative-pressure penetration methods,¹⁵ a passive

dye penetration technique was preferred in this study.

The leakage marker used in this study was India ink. Although it has been suggested that methylene blue had a comparable leakage to butyric acid, which is a metabolic product of microorganisms,¹⁵ and has a low molecular weight, enabling deeper penetration along root-canal filling than India ink,¹⁵ the latter was used due to several disadvantages of methylene blue. It is reported that methylene blue particles may dissolve during the demineralization and clearing process,¹⁵ and the end point of the dye penetration is sometimes difficult to determine.^{14,15} However, the carbon particles of India ink are stable during the decalcification stage at the clearing process,⁸ the particles in the India ink used in this study are less than or equal in size to $3\mu m$, and this ink can penetrate a $0.22\mu m$ -bacteria filter.¹⁵ Therefore, bacterial invasion of an apical seal seems to be unlikely if this dye did not succeed in penetrating into the root canal via a gap between the root-canal sealer and the canal wall. Chong *et al.*⁶ noted that bacterial ingress and India ink penetration provided a similar rank order for the sealing ability of the materials tested. India ink has been shown to consist of a range of particles in sizes between $0.5\mu m$ and $600\mu m$ in diameter. Approximately 8% of the particles were smaller than $1.60\mu m$.¹⁶ As dentinal tubules have an average diameter of $1.65\mu m$ ¹⁷ these particles are capable of entering the tubules. Also, approximately 57% of the particles were below $20.90\mu m$.¹⁶ Therefore, they would be able to penetrate cervical contraction gaps ($7-22\mu m$) observed *in vitro*.¹⁸ Youngson *et al.*¹⁶ reported that India ink staining tended to appear less intense than that of other tracers such as eosin, methylene blue, and silver nitrate. This might have been due to the small percentage of particles within India ink, which were small enough to enter dentinal tubules. Furthermore, they suggested that the decreased tendency of ink to enter dentine might be of benefit as it could decrease the problem of differentiating true leakage from dentinal permeability.¹⁶

One of the desirable properties of irrigants is smear layer removal. Many authors have demonstrated

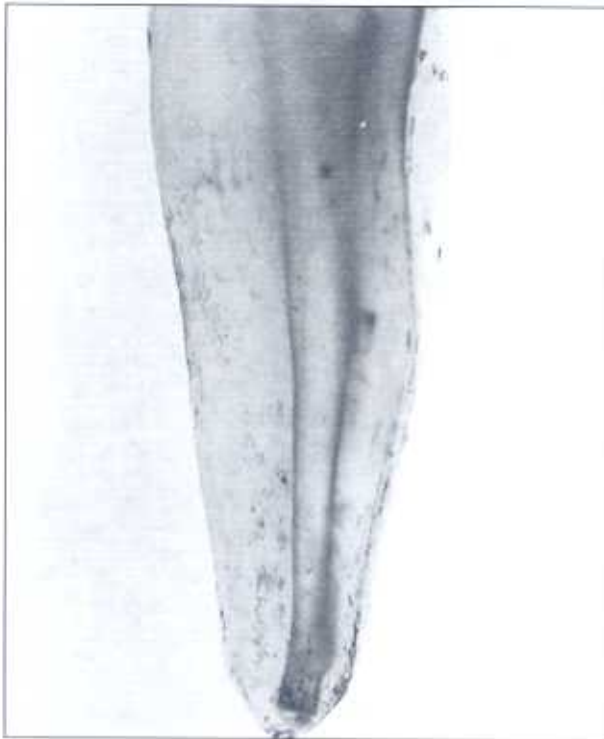


Fig. 1. Representative photograph showing grade 0 apical leakage from the group irrigated with Centrxalm and filled with AH Plus (Group 8).



Fig. 2. Representative photograph showing grade 1 apical leakage from the group irrigated with Tuthalcul plus and filled with Diaket (Group 3).



Fig. 3. Representative photograph showing grade 3 apical leakage from the group irrigated with NaOCl and filled with Diaket (Group 1).

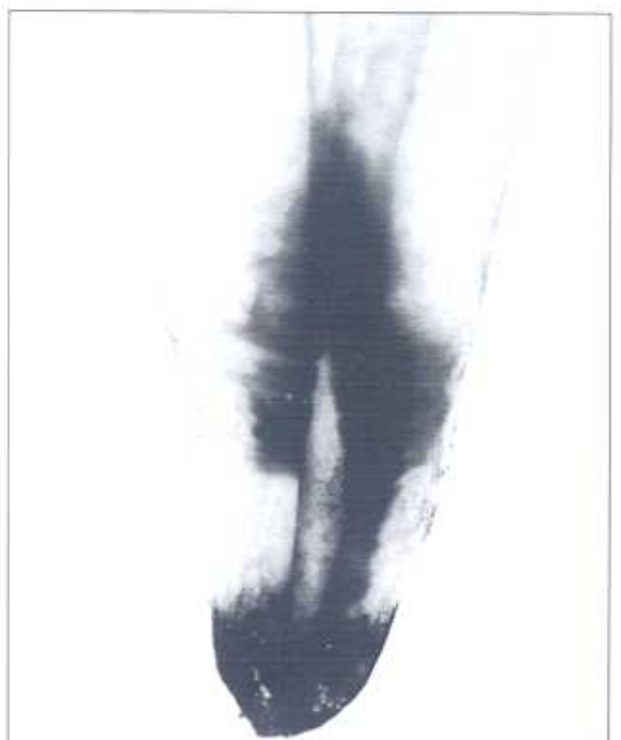


Fig. 4. Representative photograph showing grade 4 apical leakage from the group irrigated with H₂O₂ and filled with AH plus (Group 4). Dye leakage evident throughout the tubules and along the sealer dentine interface more than 2 mm.

that canal surfaces without a smear layer permit penetration of filling materials into patent dentinal tubules, increasing the contact surface, improving mechanical retention and reducing the possibility of microleakage through the filled canal.⁷ New sealers are mostly polymers. Because of their good handling characteristics they have been extensively used as a sealer. They have a good flow, seals well to dentin walls, and allows for a sufficient working time.¹⁹ The results of the present study indicated that irrigation of the root canals with NaOCl affected the sealing ability of All plus and Diaket. H_2O_2 also had an adverse effect on the sealing ability of All plus. Likewise, Nikaido *et al.*²⁰ reported that irrigation of the root canals with NaOCl and H_2O_2 adversely affected the bond strength of several dentin bonding systems to coronal superficial dentin. Morris *et al.*²¹ also found that irrigation of the root canals with NaOCl produced significantly large reduction in the bond strength of dentin bonding resins to root canal dentin. In a recent study, Turkun and Turkun²² showed that intracoronary bleaching with 10% carbamide peroxide of which end product is 3% H_2O_2 interfered with the sealing ability of resin composite coronal restorations.

Generally, NaOCl is believed to damage the organic components of dentine, mainly collagen. This may influence the penetration of monomers into the demineralized dentin structure. Additionally, apart from being an effective deproteinizing agent, NaOCl also a potent biological oxidant, since it breaks down to sodium chloride and oxygen.²³ H_2O_2 also breaks down to water and oxygen. Oxygen from such chemicals causes strong inhibition of the interfacial polymerization of dentin bonding resin. The generation of oxygen bubbles at the resin-dentin interface may also interfere with resin infiltration of the tubules and intertubular dentin.²¹

According to the results of this study, leakage produced by NaOCl and H_2O_2 seemed to vary from the other irrigation solutions. This may be attributed to breaking down of NaOCl to sodium chloride and oxygen. This oxidizing action of NaOCl leads to the oxidation of some component in the dentin matrix that is critical for the interfacial initiation of polymerization of the resin systems, leading to

lower bond strengths.²⁴ The generation of oxygen bubbles at the resin-dentin interface may also interfere with resin infiltration into the tubules and intertubular dentine. H_2O_2 may also oxidize collagen or other matrix components, thereby interfere with the interfacial polymerization of the resin.²⁴

Under the condition of this study, Cetrexidin and Tubulicid Plus allowed better sealing following root filling than 5.25% NaOCl and H_2O_2 . Microleakage scores of the groups irrigated with Tubulicid Plus were higher than those of Cetrexidin irrigated groups, but were lower than those of NaOCl and H_2O_2 irrigated groups for both of the canal sealers. Since there is a lack of research regarding the effect of Tubulicid Plus on the microleakage of canal sealers, we were not able to compare our finding. Many authors have demonstrated that canal surfaces without a smear layer permit penetration of canal sealers into patent dentinal tubules, improving mechanical retention and reducing the possibility of microleakage through the filled canal. Liolios *et al.*⁷ showed that, regardless of the method of instrumentation, Tubulicid Plus removed the smear layer, opened the dentinal tubules and left only minimal debris. It has been claimed by the manufacturer that the additives in Tubulicid Plus decrease the viscosity and the surface tension. Therefore, its high wetting ability and improved infiltration may provide the removal of the smear layer.⁷

The potential for chlorhexidine gluconate use in endodontics has been clearly demonstrated by numerous investigators.¹ However there is no literature available about its interactions with canal sealers.

Turkun *et al.*²⁵ found that when Cetrexidine was used as both working and final irrigating solutions, it produced more effective root canal cleanliness than both Cetrexidine used only as a final irrigating solution, and 5.25% NaOCl used as working and final irrigating solutions. Thus, in the present study, same irrigating solution was used for both working and final irrigation in each groups. Somma *et al.*¹¹ compared 1% NaOCl and Cetrexidin and reported that Cetrexidin was more effective than 1% NaOCl. Vivacqua-Gomes *et al.*⁶ assessed *in vitro* coronal

microleakage after root-canal treatment, using different endodontic irrigants, and showed that the chlorhexidine gel (viscous form) did not interfere with the sealing ability of the sealer. According to their results, Chlorhexidine gel allowed better sealing than 1% NaOCl, whereas the combination of 1% NaOCl with 2% chlorhexidine gel showed the worst results. In that reaction, NaOCl dissociates in to H^+ , O^{2-} and Cl^- ions, the chloride group then reacts with the chlorhexidine molecule in the guanine group (NH), resulting in chlorhexidine chloride ($NHCl$). The viscous dark-brown precipitate material stained the dentine and adhered to the root-canal walls. It could not be completely removed from the root canals, probably acting as residual film, damaging the seal of the root-canal filling, and favoring coronal microleakage.

The present study also demonstrated that chlorhexidine gluconate and cetrimide containing irrigation solution, Cetrexidin, did not have an adverse effect on the sealing ability of the canal sealers.

Conclusions

The results of the present study indicated that NaOCl and H_2O_2 adversely affected the sealing ability of AH plus, and NaOCl adversely affected the sealing ability of Diaket, Tublicid Plus and Cetrexidin did not have an adverse effect on the sealing ability of AH plus and Diaket. According to the findings and within the limitations of this study, it can be concluded that the use of Cetrexidin or Tubulicid plus, plays an important role in minimizing apical microleakage of resin based canal sealers. Both can be considered as alternative endodontic irrigants with no adverse effects on the apical seal. Properties of an ideal irrigant include to be tissue or debris solvent, to have low toxicity, low surface tension in order to flow into inaccessible areas, to make lubrication, sterilization, and remove the smear layer. Other factors include availability, cost, ease of use, convenience, adequate shelf life, and ease of storage. Without irrigation, instruments become quickly ineffective due to debris accumulation. NaOCl can dissolve pulp tissues and is of prime importance in canal instrumentation. Until whether is demonstrated, chlorhexidine and Tubulicid Plus

are effective in pulp tissue debridement as well; they cannot be considered superior to NaOCl. From this perspective, future studies are still needed to find out the method that will neutralize the adverse effect of the most popular irrigation solutions on the sealing ability of resin-based canal sealers.

References

1. Economides N, Liolios E, Kolokuris I, Belles P. Long-Term evaluation of the influence of smear layer removal on the sealing ability of different sealers. *J Endod* 1999; 25: 123-125.
2. Caliskan MB, Turkun M, Turkun LS. Effect of calcium hydroxide as an intracanal dressing on apical leakage. *Int Endod J* 1998; 31: 173-177.
3. Weber CD, McClanahan SB, Miller GA, Diener-West M, Johnson JD. The effect of passive ultrasonic activation of 2% or 5.25% sodium hypochlorite irrigant on residual antimicrobial activity in root canals. *J Endod* 2003; 29: 562-564.
4. Hülsmann M, Hahn W. Complications during root canal irrigation - literature review and case reports. *Int Endod J* 2000; 33: 186-193.
5. Lucena-Martín C, Ferrer-Luque CM, Gonzalez-Rodriguez MP, Robles-Gijón V, Navajas-Rodriguez de Mondelo JM. A comparative study of apical leakage of Endomethasone, Top Seal, and Roeko Seal sealer cements. *J Endod* 2002; 28: 425-426.
6. Vivacqua-Gomes N, Ferraz CCR, Gomes BPFA, Zaia AA, Teixeira FB, Souza-Filho FJ. Influence of irrigants on the coronal microleakage of laterally condensed gutta-percha root fillings. *Int Endod J* 2002; 35: 791-795.
7. Liolios E, Economides N, Parisis-Messimeris S, Boutsoukis A. The effectiveness of three irrigating solutions on root canal cleaning after hand and mechanical preparation. *Int Endod J* 1997; 30: 51-57.
8. Chong BS, Pitt Ford TR, Watson TF, WilsoRF. Sealing ability of potential retrograde root filling materials. *Endod Dent Traumatol* 1995; 11: 264-269.
9. Schäfer E, Olthoff G. Effect of three different sealers on the sealing ability of both Thermafil obturators and cold later-ly compacted gutta-percha. *J Endod* 2002; 28: 638-642.
10. Poggio C, Genova U, Piacentini C. Valutazione morfologica al mes dedentina canalare dopo trattamento con differenti soluzioni irriganti. *Odontostomatologia* 1995; 5: 671-674.

11. Somma F, Cameli G, Capaldi R and Raffaelli L. Analisi al SEM di irriganti canalari. *Il Dentista Moderno* 1995; 5: 1-4.
12. Ser BH, Fiskin B, Baran N. The effect of tubular penetration of root canal sealers on dye microleakage. *Int Endod J* 1996; 29: 23-28.
13. Gagliani M, Brambilla E, Belluono G, Felloni A. Deteriorazione dello spazio endodontico per mezzo di ultrasuoni associati a due soluzioni irriganti: Osservazioni al SEM. *RIS* 1996; 9:15.
14. Ahlberg KMF, Assavanop P, Tay WM. A comparison of the apical dye penetration patterns shown by methylene blue and india ink in root-filled teeth. *Int Endod J* 1995; 28: 30-34.
15. Nikaido T, Takano Y, Sasaluchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. *Am J Dent* 1999; 12: 177-180.
16. Youngson CC, Glyn Jones JC, Manogue M, Smith IS. In vitro dentinal penetration by tracers used in microleakage studies. *Int Endod J* 1998; 31: 90-99.
17. Pashley DH. Dentine: a dynamic substrate a review. *Scanning Microsc* 1989; 3: 161-176.
18. Torstenson B, Brännström M. Composite resin contraction gaps measured with a fluorescent resin technique. *Dent Mater* 1988; 4: 238-242.
19. Spangberg L. Instruments, Materials, and Devices. In: Cohen S, Burns RC (eds). *Pathways of the pulp*. 8th ed., Mosby, St.Louis, Missouri, 2002.
20. Nikaido T, Takano Y, Sasaluchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. *Am J Dent* 1999; 12: 177-180.
21. Morris MD, Lee K-W, Aqee KA, Bouillaguet S, Pashley DH. Effects of sodium hypochlorite and RC-Prep on bond strengths of resin cement to endodontic surfaces. *J Endod* 2001; 27: 753-757.
22. Turkun M, Turkun US. Effect of nonvital bleaching with 10% carbamide peroxide on sealing ability of resin composite restorations. *Int Endod J* 2004; 37: 52-60.
23. Osorio R, Ceballos L, Tay F, Cabrerizo-Vilchez MA, Toledano M. Effect of sodium hypochlorite on dentin bonding with a polyalkenoic acid-containing adhesive system. *J Biomed Mater Res* 2002; 60: 316-324.
24. Boltrayd SV, Wynn RL, Reipa-Clark B. *Clinical pharmacology in dental practice*. 4th ed., CV Mosby, St. Louis, 1988, 332.
25. Turkun M, Eltem R, Ates M. Indagine comparative degli effetti antibatterici di differenti soluzioni per l'irrigazione canalare. *G R Endo* 1999; 3: 141-145.

Yazışma Adresi:

Prof. Dr. Figen SEVGİCAN

Ege Üniversitesi,

Dişhekimliği Fakültesi,

Diş Hastalıkları ve Tedavisi AD, Endodonti BD

35100 – Bornova -İZMİR

Tel : (232) 388 03 28

Faks : (232) 388 03 25

E-posta : fsevgican@yahoo.com