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The Effect of pH of the Sodium Hypochlorite on Smear Layer Removal

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SUMMARY

Introduction Canal irrigation is an important segment of endodontic treatment. The aim of this study was to assess the efficacy of 0.5% NaOCl solutions of different pH values on smear layer removal.

Material and Methods Thirty-two freshly extracted single rooted teeth with gangrenous pulp were used in the study. The samples were divided into four groups of eight teeth in each. Four solutions of 0.5% NaOCl having pH values 5, 7, 9 and 12 respectively, were used during chemomechanical instrumentation with hand instruments and using step back technique. SEM analysis was done to assess the quality of smear layer removal in apical, middle and coronal part of root canal. Presence and quantity of smear layer and detritus was quantified using the scale from 1 to 5.

Results SEM analysis results showed similar results for 0.5% NaOCl solutions of different pH values in root canal cleaning with no statistically significant differences.

Conclusion The most effective cleaning root canal was achieved with 0.5% NaOCl solution of pH 5.

Keywords: sodium hypochlorite; smear layer

INTRODUCTION

Adequate root canal cleaning and shaping followed by copious irrigation are main factors for successful endodontic treatment [1]. Irrigation plays an important role during biomechanical preparation of the root canal. It facilitates instrumentation (lubricant effect), changes chemically and dissolves debris and smear layer from the canal walls. Also, it eliminates organic and inorganic content from the root canal [2, 3, 4] and acts against microorganisms [5, 6].

NaOCl is the most commonly used for root canal irrigation [7] and its pH is between 11 and 12. It is in use in concentrations from 0.5-5.25% and is considered to be irrigant of choice in contemporary endodontic therapy [1, 8]. NaOCl dissolves pulp tissue and organic components of smear layer [9]. However, NaOCl can not completely remove smear layer (other than superficial layer), and therefore it is used in combination with chelate solutions (EDTA and citric acid) [10].

NaOCl has strong antibacterial effect for a short contact time. Several in vitro studies and one clinical study confirmed antifungal effect of NaOCl on *Candida albicans* [11-14]. Many Gram-negative anaerobic bacteria showed high sensitivity to NaOCl in concentrations of 0.5% to 5% [13], while *Enterococcus faecalis* is resistant to action of these solutions. In comparative studies on the effect of different irrigants against biofilms, solutions of 1% NaOCl and 6% killed 99.7% of bacteria after contact time of 1 or 5 minutes, while 2% of chlorhexidine and MTAD killed only 60.5% [15].

Antibacterial effect and tissue dissolving ability of NaOCl depend on its concentration, however, with higher concentrations cytotoxicity is increased, too [16, 17]. Significant difference between the 0.5%, 1%, 2.5% and 5% NaOCl against *E. faecalis* and anaerobic flora was not found in *in vivo* studies [18]. This justifies use of NaOCl in concentrations of 0.5% and 1% as optimal in clinical praxis [19]. These concentrations represent good balance between the tissue dissolving ability, antimicrobial activity and biocompatibility.

Instead of using high concentration of NaOCl, the effectiveness of this solution can be improved by increasing temperature [19]. It was confirmed that 1% NaOCl solution at a temperature of 45°C dissolves the same amount of tissue as the concentration of 5.25% NaOCl at 20°C, and 1% NaOCl at 60°C is more efficient than 5.25% NaOCl solution [20]. Heated solution shows much better antimicrobial effect, however, if solution was heated and not used, it would lose its efficiency and could not be used anymore [21].

In addition to concentration and temperature, the duration of irrigation is also important. Studies have shown that NaOCl in concentrations of 1-5% is able to eliminate all microorganisms for 60 minutes, while 30 minutes is short period. This means that the contact time must be between 30 and 60 minutes [22].

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Quantity of irrigant is also important. Increasing the amount correlates with reduction of microorganisms and cleanliness of canals [23]. Yamada et al [11] proposed 10-20ml of irrigant for each canal with mandatory final flushing.

If NaOCl enters periapical tissue, it can cause severe pain that lasts a few minutes. It can also cause swelling, emphysema, paresthesia, periapical tissue necrosis and abundant hemorrhage through the root canal [16].

The aim of this study was to assess the efficacy of 0.5% NaOCl solutions of different pH values on smear layer removal.

MATERIAL AND METHODS

Thirty-two freshly extracted single rooted teeth with gangrenous pulp were used in the study.

The crowns of the tooth were removed and chemomechanical instrumentation using manual instruments and step back technique and 0.5% NaOCl solutions of different pH values was performed. After each instrument, canal was rinsed with 2 mL of NaOCl. After completed instrumentation each canal was rinsed with 10 ml of NaOCl. Teeth were allocated into four groups (8 teeth in each group) and rinsed with the following solutions: Group I: 0.5% NaOCl solution, pH 5; Group II: 0.5% NaOCl solution, pH 7; Group III: 0.5% NaOCl solution, pH 9; Group IV: non buffered 0.5% NaOCl solution, pH 12.

Electrolysis of diluted NaOCl solution was achieved in aqueous solutions where concentration of NaOCl was 3% (30 g/l). All solutions used in this study were prepared by dissolving chemicals in distilled water (18 MΩ) three times distilled using the device from water company Milipore, USA. Electrolysis was performed in reaction container having capacity of 5 liters and electric current of 20 A (100 mA/cm^2) in the time period of 4 hours. After the electrolysis solution was transferred to five containers with volume of 1000 ml each. Adjusting the pH value in these containers was achieved using hydrochloric acid for acid solutions and sodium hydroxide for the base solutions. The pH values of the solutions at 298 K were 4.8, 5, 8, 10, and 12. Solutions were buffered and pH value was measured by digital pH meter from Iskra company.

At the end of the experiment, the canal was dried and two grooves on buccal and lingual surfaces were created. Tooth was frozen in liquid nitrogen, cut into two halves using chisel. The inner wall of the canal was preserved. The samples were coated with palladium-gold in high vacuum using the device JEOL-SS-RT, Japan. The prepared samples were observed under the microscope JEOL-JSM-S800, Japan at three levels of root canal: coronal, middle and apical at different magnifications. The presence and quantity of smear layer and debris on the canal walls was rated by the scale proposed by Hülsmann et al [24].

Table 1. The effect of NaOCl on the coronal part of the root canal
Tabela 1. Efekat rastvora NaOCl na koronarnom delu kanala korena zuba

Coronal part Koronarni deo	NaOCl			
	pH=5	pH=7	pH=9	pH=12
Average (SD) Prosek (SD)	1.75 (0.96)	2.75 (0.96)	3.25 (0.96)	2.25 (1.89)
Median (range) Medijana (opseg)	1.50 (1-3)	2.50 (2-4)	3.50 (2-4)	1.50 (1-5)

RESULTS

SEM analysis of the coronal third of the canal confirmed the most efficient smear layer removal using 0.5% NaOCl solution of pH 5, then using the solution pH 7 and pH 12. The least effective was 0.5% solution of pH 9. The difference was not statistically significant (Table 1, Figures 1 and 2).

SEM analysis of the middle third of the canal also showed that the most efficient smear layer removal was achieved with NaOCl solution pH 5, then with the solution of pH 7 and pH 9. The least effective was 0.5% solution with pH 12. The difference was not statistically significant (Table 2, Figures 3 and 4).

SEM analysis of the apical third of the canal showed the most effective smear layer removal with NaOCl solu-

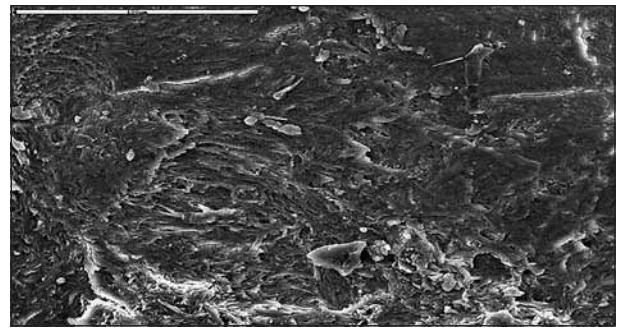

Figure 1. Coronal part of the root canal flushed with NaOCl (pH 7). The canal walls are completely covered by homogenous smear layer and no dentin openings could be seen. More than 50% of the walls is covered with the debris. Grade 4 (magnification 500×).
Slika 1. Koronarni deo kanala korena zuba ispiran rastvorom NaOCl (pH 7). Zidovi kanala potpuno prekriveni homogenim razmaznim slojem i nema otvorenih dentinskih kanala. Više od 50% zidova kanala prekriveno debrisom. Ocena 4 (uveličanje 500×).

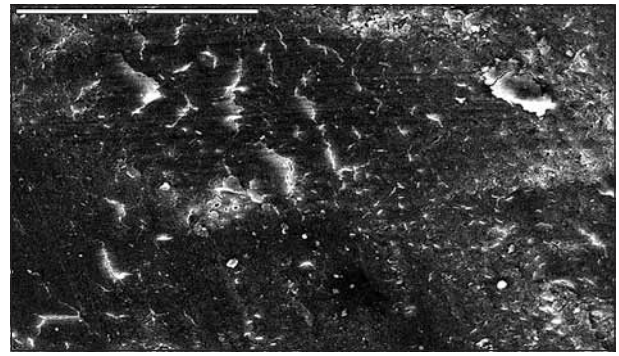

Figure 2. Coronal part of the root canal flushed with NaOCl (pH 9). The canal walls are completely covered by homogenous smear layer and no dentin openings could be seen. More than 50% of the walls is covered with the debris. Grade 4 (magnification 500×).
Slika 2. Koronarni deo kanala korena zuba ispiran rastvorom NaOCl (pH 9). Zidovi kanala potpuno prekriveni homogenim razmaznim slojem i nema otvorenih dentinskih kanala. Više od 50% zidova kanala prekriveno debrisom. Ocena 4 (uveličanje 500×).

Table 2. The effect of NaOCl on the middle part of the root canal
Tabela 2. Efekat rastvora NaOCl na srednjem delu kanala korena zuba

Middle part Srednji deo	NaOCl			
	pH=5	pH=7	pH=9	pH=12
Average (SD) Prosek (SD)	1.25 (0.50)	2.25 (0.50)	2.00 (0.00)	3.00 (1.41)
Median (range) Medijana (opseg)	1.00 (1-2)	2.00 (2-3)	2.00 (2-2)	2.50 (2-5)

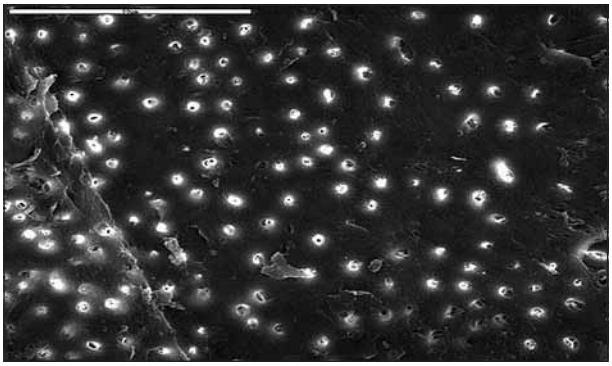

Figure 3. Middle part of the root canal flushed with NaOCl (pH 5). Smear layer is removed and dentin tubules are open. Canal walls are clean without the debris. Grade 1 (magnification 1000×).
Slika 3. Srednji deo kanala korena zuba ispiran rastvorom NaOCl (pH 5). Nema razmaznog sloja i svi dentinski kalanići su otvoreni. Zidovi su čisti skoro bez naslaga debrisa. Ocena 1 (uveličanje 1000×).

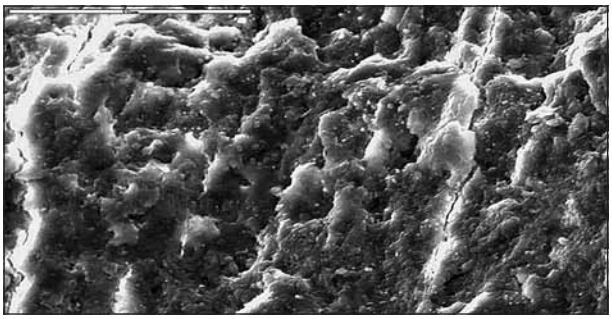

Figure 4. Middle part of the root canal flushed with unbuffered NaOCl (pH 12). Non-homogenous smear layer is present covering the walls of the root canal. Grade 5 (magnification 1000×).
Slika 4. Srednji deo kanala korena zuba ispiran nepuferovanom rastvorom NaOCl (pH 12). Veoma izražen nehomogen razmazni sloj koji potpuno pokriva zidove kanala korena zuba. Ocena 5 (uveličanje 1000×).

tion pH 9, pH 5 and pH 7. The least effective was the 0.5% solution with pH 12. The difference was not statistically significant (Table 3, Figure 5).

DISCUSSION

After endodontic treatment of the root canal, the debris and smear layer remain on the surface of the canal. Smear layer is composed of inorganic and organic substances, contains remnants of pulp, microorganisms and their products as well as a part of mineral origin and dentin [25]. Because of possible contamination and adverse effect on the outcome of endodontic treatment smear layer should be removed from the canal walls. Previous methods for

Table 3. The effect of NaOCl on the apical part of the root canal
Tabela 3. Efekat rastvora NaOCl na apeksnom delu kanala korena zuba

Apical part Apeksni deo	NaOCl			
	pH=5	pH=7	pH=9	pH=12
Average (SD) Prosek (SD)	3.00 (0.00)	3.00 (0.82)	2.75 (0.96)	3.25 (1.26)
Median (range) Medijana (opseg)	3.00 (3-3)	3.00 (2-4)	2.50 (2-4)	3.00 (2-5)

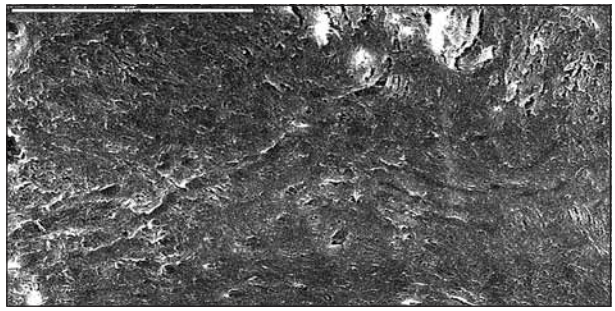

Figure 5. Apical part of the root canal flushed with NaOCl (pH 5). Smear layer covers the walls of the canal and some dentin tubules are open. Less than 50% of the walls is covered with the debris. Grade 3 (magnification 1000×).
Slika 5. Apeksni deo kanala korena zuba ispiran rastvorom NaOCl (pH 5). Razmazni sloj pokriva zidove kanala, a poneki dentinski kanalić je otvoren. Veće količine debrisa pokrivaju manje od 50% zidova. Ocena 3 (uveličanje 1000×).

smear layer removal (chemical, ultrasonic, laser) were not satisfactory [26].

This research was conducted to investigate the effect of 0.5% NaOCl solutions of different pH values on smear layer removal. First use of buffered NaOCl solutions was by Dakine who buffered 0.5% NaOCl with sodium bicarbonate and created NaOCl solution with pH 9. This solution was more efficient on necrotic then living tissue; it had significantly reduced cytotoxicity and showed good antimicrobial effect [27].

The current study showed that the NaOCl solution (pH 5) was the most effective in removing smear layer in the coronal and middle part of the root canal. In acidic solutions of NaOCl, pH 5, the electrolysis of NaCl creates the greatest amount of hypochlorous acid (HClO) on anode in relation to hypochlorous anion (ClO^-). Hypochlorous acid has three times stronger effect on the organic matter than hypochlorous anion. Hypochlorous acid hydrolysis on hydrochloric acid and oxygen, which in reaction with HCl releases chlorine (Cl_2). Chlorine penetration into living cells causes dysfunction of cell enzymes and amino acids causing bacterial death in root canal [27, 28]. All NaOCl solutions release active chlorine (HClO and ClO^-), in acid solutions amount of active chlorine increases while at higher pH increases the amount of hypochlorous anion. Results from the current study showed no significant difference in dissolving ability of different NaOCl solutions and therefore conclusion could be that quantitative relation of HClO and ClO^- is not of primary importance, the amount of released active chlorine is also important [27]. This fact is in favor of need for copious irrigation during root canal treatment with fresh hypochlorite solution.

In the apical part lesser amount of debris and smear layer was found compared to the other parts of teeth, rinsed by NaOCl solutions of higher pH values. The results of this study suggested that the canal walls debris was removed mostly by dissolving ability of NaOCl. Several studies confirmed no significant difference in tissue dissolving ability of NaOCl of different pH [27].

Dissolving ability primarily depends on the amount of released chlorine gas, which denatures proteins and thus dissolves tissue from the canal wall [28, 29]. Limited or incomplete effect on smear layer removal is due to the presence of mineral components derived from dentin in smear layer. Mineral components provide strength and homogeneity to smear layer and can be removed only by combination with chelate agents (EDTA, 10% citric acid) [10, 29]. However, despite the fact that buffered 0.5% NaOCl solution of pH 5 showed the best cleaning effect of the canal wall, it was not statistically significant to NaOCl solutions of different pH values. This conclusion and other states justify use of commercial NaOCl solution (home bleach) diluted by water (pH 12) for root canal irrigation [27].

CONCLUSION

Based on presented and analyzed results on the efficacy of 0.5% NaOCl solutions of different pH values, it can be concluded that there was no significant difference between the solutions in smear layer removal. 0.5% NaOCl solution (pH 5) showed slightly better cleaning and open dentin tubules could be seen in some parts of the root canal.

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Uticaj pH vrednosti rastvora natrijum-hipohlorita na uklanjanje razmaznog sloja

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KRATAK SADRŽAJ

Uvod Irigacija kanala je značajan segment svakog endodontskog lečenja zuba. Cilj ovog rada je bio da se proveri efekat čišćenja zida kanala korena zuba nakon ispiranja rastvorom od 0,5% natrijum-hipohlorita (NaOCl) različitih pH vrednosti.

Materijal i metode rada Kao materijal korišćena su 32 sveže izvađena jednokorena zuba sa gangrenoznom pulpom. Uzorci su svrstani u četiri grupe od po osam zuba. Za ispiranje tokom mehaničko-medikamentne obrade tzv. *step-back* tehnikom i ručnim endodontskim instrumentima primenjena su četiri rastvora koncentracije od 0,5% NaOCl sa puferovanim rastvorima čija je pH vrednost bila 5, 7 i 9, odnosno nepuferovanim rastvorom pH vrednosti 12. SEM analizom je proveren kvalitet čišćenja zida kanala od razmaznog sloja u apeksnom, srednjem i koronarnom delu kanala korena. Procena zastupljenosti i količine razmaznog sloja i detritusa vršena je ocenjivanjem na skali od 1 do 5.

Rezultati Rezultati SEM analiza su pokazali slično dejstvo različitih pH vrednosti rastvora NaOCl u čišćenju kanala korena zuba bez statističke značajne razlike.

Zaključak Najefikasnije čišćenje kanala korena ostvareno je 0.5% rastvorom NaOCl čiji je pH 5.

Ključne reči: natrijumhipohlorit; razmazni sloj

UVOD

Adekvatno čišćenje i oblikovanje kanala korena zuba i obilna irigacija tokom instrumentacije glavni su faktori uspeha endodontskog lečenja [1]. Irigacija je sastavni deo biomehaničke preparacije kanala i ima zadatak da olakša pokretanje instrumenata u kanalu (lubrikantno svojstvo), hemijski izmeni i rastvori debris i razmazni sloj sa zidova kanala, olakša eliminaciju organskog i neorganskog sadržaja sa zidova kanala [2, 3, 4] i deluje antiseptično na zaostale mikroorganizme u parakanalnom sloju [5, 6].

Natrijum-hipohlorit (NaOCl) je najčešće korišćeno sredstvo za ispiranje kanala korena zuba, a njegova pH vrednost je između 11 i 12 [7]. Koristi se u koncentracijama od 0,5% do 5,25% i smatra se irigansom izbora u savremenoj endodontskoj terapiji [1, 8]. NaOCl razlaže pulpno tkivo i organske komponente dentina i razmaznog sloja [9]. Ipak, NaOCl ne može potpuno da ukloni razmazni sloj (osim površinskog sloja), pa se zato koristi u kombinaciji sa helatima (EDTA i limunskom kiselinom) [10].

NaOCl ima jako antibakterijsko dejstvo s kratkim kontaktnim vremenom. Nekoliko istraživanja *in vitro* i jedna klinička studija potvrdili su dejstvo NaOCl na *Candida albicans* [11-14]. Mnoge Gram-negativne anaerobne bakterije pokazale su visoku osetljivost na NaOCl u koncentracijama 0,5-5% [13], dok je *Enterococcus faecalis* otporan na delovanje ovog rastvora. U komparativnim studijama o efektu različitih irigansa na biofilm, rastvori NaOCl od 1% i 6% su uništili 99,7% bakterija posle kontaktnog vremena od jednog ili pet minuta, dok je dvoprocentni rastvor hlorheksidina i MTAD uništio samo 60,5% bakterija [15].

Dejstvo NaOCl na bakterije i razlaganje tkiva zavisi i od koncentracije, iako se s većim koncentracijama povećava i citotoksičnost [16, 17]. U istraživanjima *in vivo* nisu uočene značajne razlike između koncentracija od 0,5%, 1%, 2,5% i 5% NaOCl na *E. faecalis* i anaerobnu floru [18]. Time je potvrđeno da su koncentracije od 0,5% i 1% najbolje za kliničku praksu, jer čine najbolju ravnotežu između sposobnosti rastvaranja tkiva, antimikrobne aktivnosti i biokompatibilnosti [19].

Umesto primene visokih koncentracija NaOCl, efikasnost ovoga rastvora se može poboljšati i povećanjem temperature [19]. Potvrđeno je da jednoprocentni rastvor NaOCl na temperaturi od 45°C razlaže tkivo kao i NaOCl koncentracije 5,25% na 20°C, a 1% NaOCl na 60°C je mnogo efikasniji nego „punosnažni" rastvor NaOCl od 5,25% [20]. Zagrejani rastvor pokazuje i mnogo bolje antimikrobno dejstvo, međutim, treba znati da rastvor koji se zagreje a ne iskoristi gubi efikasnost i ne može se ponovo upotrebiti [21].

Pored koncentracije i temperature, važno je i vreme trajanja irigacije. Istraživanja su pokazala da rastvoru NaOCl koncentracije 1-5% treba 60 minuta da uništi sve mikroorganizme, dok je 30 minuta kratak period. To znači da kontaktno vreme mora biti između 30 i 60 minuta [22].

Količina irigansa je takođe bitna. Povećanje količine je u korelaciji sa redukcijom mikroorganizama i čistoćom kanala [23]. Jamada (*Yamada*) i saradnici [11] predlažu primenu 10-20 ml irigansa za svaki kanal i obavezan finalni snažni mlaz na kraju.

Ukoliko se utisne u periradikularno tkivo, NaOCl može da izazove jake bolove koji traju nekoliko minuta. Može da izazove otok, emfizem, parestezije, nekrozu periapeksnog tkiva i obilna krvarenja kroz kanal korena zuba [16].

Cilj ovog rada je bio da se SEM analizom proveri efekat uklanjanja razmaznog sloja sa zidova kanala korena primenom rastvora od 0,5% NaOCl različitih pH vrednosti.

MATERIJAL I METODE RADA

Kao materijal u istraživanju korišćena su 32 sveže izvađena jednokorena zuba sa gangrenozno raspadnutom pulpom.

Pre početka instrumentacije, dijamantskim diskom je odsečena klinička kruna zuba, a kanali su endodontski obrađeni rastvorom NaOCl različitih pH vrednosti. Kanali su obrađeni tzv. *step-back* tehnikom ručnim instrumentima. Posle svake promene instrumenta kanal je ispiran sa 2 ml NaOCl. Nakon mehaničke obrade svaki kanal je ispiran sa 10 ml rastvora. Uzorci zuba su svrstani u četiri grupe od po osam zuba. Prva grupa uzoraka je ispirana rastvorom NaOCl čija je pH vrednost bila 5, druga grupa rastvorom pH vrednosti 7, treća sa pH 9, a četvrta nepuferovanim rastvorom NaOCl pH vrednosti 12.

Elektroliza razblaženih rastvora NaOCl je ostvarena u vodenim rastvorima gde je koncentracija NaOCl bila 3% (30 g/l). Rastvori korišćeni u ovom istraživanju pravljeni su od p.a. hemikalija. Hemikalije su rastvarane u destilovanoj vodi (18 MΩ) koja je tri puta obrađena u uređaju za prečišćavanje vode (Millipore, USA). Elektroliza je izvođena u temperovanoj reakcionoj posudi zapremine 5 l s jačinom struje od 20 A (100 mA/cm^2) u trajanju od četiri časa. Nakon elektrolize rastvor iz reakcione posude je prebačen u pet mesgolben posuda zapremine od po 1000 ml. Podešavanje pH vrednosti u tim posudama ostvareno je hlorovodoničnom kiselinom za kisele rastvore i natrijum-hidroksidom za bazne rastvore. Vrednost pH rastvora na 298 K bila je 4,8, 5, 8, 10 i 12. Rastvori su bili puferovani, a vrednost pH je merena digitalnim pH-metrom (Iskra).

Nakon preparacije, kanal je osušen, a zatim je koren zasecan dijamantskim diskom vestibularno i oralno. Potom je zub zamrzavan u tečnom azotu i dletom cepan na dve polovine, čime se očuvao unutrašnji zid kanala. Nakon toga uzorci su naparavani paladijum-zlatom u visokom vakuumu (aparat JEOL-SS-RT, Japan). Pripremljeni uzorci su posmatrani na mikroskopu (JEOL-JSM-S800, Japan) na tri nivoa kanala korena (koronarnom, srednjem i apeksnom) i pri različitim uveličanjima. Ocena zastupljenosti i količine razmaznog sloja i detritusa vršena je na skali koju su predložili Hilsman (*Hülsmann*) i saradnici [24].

REZULTATI

SEM analizom koronarne trećine kanala potvrđeno je da je najefikasnije čišćenje kanala ostvareno rastvorom NaOCl čija je pH vrednost bila 5, potom rastvorom pH vrednosti 7 i 12. Najmanje efikasan je bio rastvor od 0,5% čija je pH vrednost bila 9. Međutim, razlika nije bila statistički značajna (Tabela 1; Slike 1 i 2).

SEM analiza srednje trećine kanala je takođe pokazala da je najefikasnije čišćenje kanala ostvareno rastvorom NaOCl čija je pH vrednost bila 5, zatim rastvorom pH vrednosti 7 i 9. Najmanje efikasan je bio rastvor od 0,5% čija je pH vrednost bila 12. Razlika nije bila statistički značajna (Tabela 2 i slike 3 i 4).

SEM analizom apeksne trećine kanala pokazalo se da je u ovom delu kanala najefikasnije čišćenje kanala ostvareno rastvorom NaOCl čija je pH vrednost bila 9, zatim rastvorom pH vrednosti 5 i 7. Najmanje efikasan je bio rastvor od 0,5% čija je pH vrednost bila 12. Razlika ni ovde nije bila statistički značajna (Tabela 3; Slika 5).

DISKUSIJA

Nakon endodontske obrade kanala korena zuba debris i razmazni sloj u različitoj meri ostaju na površinama kanala. Takav razmazni sloj sačinjen je od neorganskih i organskih materija i sadrži ostatke pulpe, mikroorganizme i njihove proizvode, kao i mineralni deo koji potiče od dentina [25]. Zbog moguće kontaminacije i lošeg efekta na ishod endodontskog lečenja, razmazni sloj se mora ukloniti iz kanalnog sistema zuba. Dosadašnje metode uklanjanja razmaznog sloja (hemijske, ultrazvučne, laserske) nisu pokazale potpunu efikasnost u uklanjanju ovoga sloja [26].

Ovo istraživanje je urađeno da bi se ispitao efekat rastvora od 0,5% NaOCl različitih pH vrednosti na razmazni sloj na zidu kanala korena zuba nakon ispiranja. Prvi koji je koristio puferovane rastvore NaOCl bio je Dakin, koji je 0,5% NaOCl puferovao sa sodom bikarbonom i dobijao rastvor NaOCl pH vrednosti 9. Takav rastvor je pokazao agresivniji efekat na nekrotično, nego na živo tkivo, značajno je smanjio citotoksičnost i ispoljio dobro antimikrobno dejstvo [27].

Naše istraživanje je pokazalo da je rastvor NaOCl pH vrednosti 5 bio najefikasniji u uklanjanju razmaznog sloja u koronarnom i srednjem delu. Kod kiselih rastvora NaOCl pH vrednosti 5 elektrolizom NaCl na anodi nastaje najveća količina hipohloraste kiseline (HClO) u odnosu na hipohloritni anjon (ClO^-), koja ima trostruko jači efekat na organske materije od ClO^-. HClO se hidrolizuje na hlorovodoničnu kiselinu i kiseonik, a u daljoj rekciji sa HCl se oslobađa i hlor (Cl_2). Prodiranjem hlora u žive ćelije dolazi do izbacivanja iz funkcije ćelijskih enzima i aminokiselina, a time do smrti bakterija u kanalu korena [27, 28]. Naime, kod svih rastvora NaOCl se oslobađa tzv. aktivni hlor (HClO i ClO^-), ali je kod kiselijih rastvora to nešto više, pa kod većih pH vrednosti raste i količina ClO^-. Imajući u vidu ove rezultate, gde nije nađena značajna razlika u organolitičkoj efikasnosti, može se reći da količinski odnos HClO i ClO^- nije od primarnog značaja, već da je to količina oslobođenog aktivnog hlora [27]. Ovaj podatak govori u prilog potrebi za obilnim ispiranjem kanala korena tokom endodontske obrade svežim rastvorom hipohlorita.

U apeksnom delu je uočena manja količina debrisa i razmaznog sloja u poređenju sa delovima zuba koji su ispirani rastvorima NaOCl većih pH vrednosti. Rezultati ovog istraživanja potvrđuju da je debris sa zidova kanala uglavnom uklonjen primenom ovih rastvora zahvaljujući njegovim organolitičkim sposobnostima. Malobrojna ispitivanja dejstva rastvora različitih pH vrednosti pokazuju da nema razlike u organolitičkom efektu ovih rastvora kanala korena [27].

Rastvarački efekat prevashodno zavisi od količine oslobođenog gasa hlora, koji denaturiše proteine i tako razlaže naslage na zidu kanala [28, 29]. Ograničen efekat, odnosno nepotpun efekat uklanjanja razmaznog sloja, posledica je zastupljenosti mineralne komponente razmaznog sloja koja potiče od dentina i daje čvrstoću i homogenost razmaznom sloju, pa se jedino može ukloniti u kombinaciji s helatnim sredstvima (EDTA, desetoprocentna limunska kiselina) [10, 29]. Međutim, i pored toga što je puferovani rastvor od 0,5% NaOCl pH vrednosti 5 pokazao najbolji efekat čišćenja zida kanala, to nije bilo statistički značajno u poređenju s rastvorima NaOCl drugih pH vrednosti. Ovaj navod, kao i drugi navodi, opravdavaju primenu komercijalnih rastvora NaOCl (kućno belilo) razblaženih vodom (pH 12) za čišćenje kanala korena zuba [27].

ZAKLJUČAK

Na osnovu rezultata istraživanja efekata čišćenja zidova kanala korena zuba rastvorom NaOCl različitih pH vrednosti, može se zaključiti da ne postoji značajna razlika u kvalitetu čišćenja zidova kanala korena između njih. Nešto bolji efekat čišćenja pokazao je rastvor pH vrednosti 5, gde su se na zidu kanala mogli uočiti mestimično otvoreni i čisti dentinski kanalići.