Ultrastructural analysis of uninstrumented root canal areas following various irrigation regimens

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SUMMARY

Introduction During endodontic treatment smaller or larger areas of root canal wall remain non-instrumented. This can affect prognosis of endodontic treatment as some bacteria may be left behind. The purpose of this study was to evaluate the morphology of non-instrumented areas of the root canal wall using scanning-electron-microscopy (SEM) after completed instrumentation and various irrigation regimens.

Materials and Methods Eighteen single-rooted extracted teeth were divided into the six groups. One tooth in each group represented a control sample. In all samples only one half of the canal was instrumented using ISO 40 hand files. Control samples were subjected to an irrigation protocols without instrumentation. Irrigants used were physiological saline, 3% sodium hypochlorite and 15% of ethylene-diamine-tetra-acetate. Irrigation protocol included using each of these irrigants alone, or a combination of NaOCl and EDTA, as well as their combination with final irrigation using NaOCl or chlorhexidine. Then after, roots were sectioned longitudinally and prepared for SEM.

Results Saline irrigation left pulpal debris on uninstrumented areas of the canal wall. Irrigation with 3% NaOCl left behind canal wall with different forms of calcospherites. However, after EDTA irrigation dentin appeared as an undulating surface with open tubules without a smear layer. The combination of NaOCl and EDTA showed remnants of calcospherites and open slightly widened dentinal tubules. Final irrigation with NaOCl on the uninstrumented areas showed enlarged dentinal tubules along with dentinal erosion, while after final irrigation with CHX clean dentin and open dentinal tubules without smear layer were noted.

Conclusion From the morphological point of view, the most favorable effect of irrigation on both uninstrumented and uninstrumented canal walls was achieved after irrigation with NaOCl and EDTA or NaOCl, EDTA and chlorhexidine as the final irrigant.

Keywords: root canal instrumentation; uninstrumented root canal areas; root canal irrigation; SEM

INTRODUCTION

One of the basic preconditions for successful endodontic treatment is adequate instrumentation of the root canal. However, satisfactory instrumentation and irrigation is difficult to achieve due to the very specific and complex root canal morphology, as well as limited effect of instruments [1]. Morphological variations of the root canal system and inability of endodontic instruments to reach all parts of root canal wall make cleaning of complete root canal practically impossible [1, 2]. Micro-computerized tomography has confirmed that some areas of root canal walls remain untouched after instrumentation [3-6]. These areas may contain bacteria and compromise endodontic treatment [7]. In addition, the presence of smear layer and debris as a result of instrumentation is significant clinical problem [2, 8]. This layer often contains bacteria and blocks dentinal tubules, which significantly decrease the effect of used irrigant affecting the quality of obturation and the outcome of endodontic treatment [8, 9].

Due to limited effectiveness of endodontic instruments in root canal cleaning, it is necessary to use appropriate chemical agents during and after instrumentation. Their role is to eliminate and reduce any remaining microorganisms as well as remove smear layer [8-10]. Even though there is no general consensus about removing smear layer immediately before obturation, most endodontists agree that if it is not removed, it could disintegrate and lead to microleakage due to the low quality of the bond strength between the sealer and root canal walls [9, 10]. The aim of this study was to use a SEM analysis to evaluate the morphology of uninstrumented areas of the root canal walls following mechanical instrumentation and application of various irrigation regimens.

MATERIALS AND METHODS

The material used in this research included 18 freshly extracted intact human maxillary single-rooted teeth without...
any visible damage (root caries, cracks, internal or external resorption, etc.). According to the irrigation regimens, all teeth were divided into six groups, with one tooth in each group representing a control specimen. The teeth samples were kept for eight hours in 0.5% NaOCl solution to facilitate removal of organic debris. After rinsing teeth under running water, they were immersed in saline solution and refrigerated until the beginning of the experiment.

Prior to canal instrumentation, using a diamond disc, longitudinal grooves were created on the facial and lingual surfaces of the root, without penetrating it, in order to facilitate the fracture. The crowns were amputated and discarded, while the remaining debris was removed using running water. Following pulp extirpation, one tooth from each group (two control samples) underwent different irrigation regimens only without previous instrumentation. All root canals were checked for patency and working length was determined by shortening the distance to the anatomical foramen by 1 mm. The apex was sealed with a pink wax piece.

The root canals of experimental teeth were instrumented using the step back technique to the instrument size 40 (NiTi files I-FLEX, IMD, USA). Only one half of each root canal, either the facial or the lingual half, was particularly marked and instrumented [11]. During the instrumentation, care was taken that endodontic instruments did not come in contact with the opposing side of the canal wall that represented the “uninstrumented” half. The control sample from each group was used for comparison of uninstrumented areas of the canal with the uninstrumented main root canal following identical irrigation regimens. The amount of the irrigant used for each irrigation regimen was identical and carefully controlled, and the total time of chemomechanical preparation was 10 min.

The following irrigation regimens were used: (I) saline; (II) 3% sodium hypochlorite (NaOCl-Parcan, Septodont®); (III) 15% Ethylene diaminetetraacetic acid (EDTA - Largal Ultra, Septodont®); (IV) combination of 3% NaOCl+15% EDTA; (V) combination of 3% NaOCl+15% EDTA and 3% NaOCl as the final irrigant; (VI) combination of 3% NaOCl+15% EDTA and 2% chlorhexidine (R4, Septodont) as the final irrigant (Table 1).

Applying mild pressure and using a spatula, the samples were fractured in half (so that a total of 36 samples were obtained) and placed in open Petri dishes to dry at the room temperature. After 24 hours, they were attached to cylindrical tooth carriers using a fixing agent (Dotite paint xc 12 Carbon JEOL, Tokyo, Japan), gold sputtered (using a JFC 1100E Ion Sputter JEOL) and analyzed using scanning electron microscopy (SEM, JEOL-JSM-5300).

### Table 1. Irrigants and irrigation regimens of the experimental and control samples

| Groups Grupe | Irrigants Irišigraci rastvor | Irrigation regimen of the experimental samples (uninstrumented areas in uninstrumented canals)* | Irrigation regimen of the control samples (uninstrumented canals)* |
|--------------|----------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| I            | Saline solution            | Irrigation using 3 ml saline solution after pulp extirpation and after each endodontic instrument | Irrigation using 3 ml saline solution following pulp extirpation   |
| II           | 3% NaOCl (Parcan, Septodont) | Irrigation using 3 ml NaOCl following pulp extirpation and after each endodontic instrument | Irrigation using 3 ml NaOCl following pulp extirpation            |
| III          | 15% EDTA (Largal Ultra, Septodont) | Irrigation using 3 ml saline solution following pulp extirpation and after each endodontic instrument | Irrigation using 3 ml saline solution following pulp extirpation; final irrigation using 3 ml EDTA for 60 seconds |
| IV           | 3% NaOCl (Parcan, Septodont) + 15% EDTA (Largal Ultra, Septodont) | Irrigation using 3 ml NaOCl following pulp extirpation and after each endodontic instrument; final irrigation using 3 ml EDTA for 60 seconds | Irrigation using 3 ml NaOCl following pulp extirpation; final irrigation using 3 ml EDTA for 60 seconds; završno ispiranje sa 3 ml EDTA u trajanju od 60 sekundi |
| V            | 3% NaOCl+15% EDTA and 3% NaOCl as the final irrigant / kao završni irigans | Irrigation using 3 ml NaOCl following pulp extirpation and after each endodontic instrument; final irrigation using 3 ml NaOCl for 3 min. | Irrigation using 3 ml NaOCl following pulp extirpation; final irrigation using 3 ml NaOCl for 3 min. |
| VI           | 3% NaOCl+15% EDTA and 2% chlorhexidine (R4, Septodont) as the final irrigant / kao završni irigans | Irrigation using 3 ml NaOCl following pulp extirpation and each endodontic instrument; flushing using 3 ml EDTA for a period of 60 seconds, final irrigation using 3 ml CHX for 3 min. | Irrigation using 3 ml NaOCl following pulp extirpation; flushing using 3 ml EDTA for 60 seconds, final irrigation using 3 ml CHX for 3 min. |

*At the end of all the irrigation regimens, as well as after irrigation with each tested irrigant, sterile water was used [11] in the amount of 3 ml, and canal was dried with sterile paper points prior to the use of the following instrument/irrigant.

* Kod svih irrigacionih protokola je na kraj, kao i posle irrigacije sa svakim testiranim iriganom, korišćena sterilna voda [11] u količini od 3 ml, a kanal je sušen papirnatim poenima pre korišćenja sledećeg instrumenta/irigansa.
Table 2. SEM analysis of uninstrumented and instrumented areas in the root canal after different irrigation protocols

| Groups/Grupe | Irrigants/ I was to analyze the morphology of uninstrumented areas of the root canal walls after canal instrumentation using SEM. Several studies used micro-computerized tomography to determine the presence of uninstrumented surfaces in the main root canal by calculating the area that remains intact after instrumentation (canal volume before and after instrumentation, distance between canal surface before and after instrumentation in μm, the size of a specific area, the width of the canal, taper, etc.) [3-6]. On the other hand, SEM analysis allows visualization of root canal walls, their cleanliness, dentinal tubules covered with smear layer, as well as complete dentin morphology at ultrastructural level [13-15].

In the current study the control samples included uninstrumented canals after performed irrigation regimens. That way it was possible to compare the morphology of uninstrumented canals with uninstrumented surfaces of instrumented canals. According to Peters et al. after biomechanical instrumentation, both hand or rotary, approximately 35% of the canal wall remains untouched by the instruments [16]. In addition, other studies have also confirmed the presence of uninstrumented surfaces, especially in the apical third of the root canal, where any irregularities on canal walls (grooves and depressions) prevent contact between the wall and instrument [17, 18]. Endodontic instruments are mostly designed to fit into the conical root configuration, which leaves untreated regions in oval and flat canals [16]. Beside complex canal morphology [19], limitation of instrumentation techniques

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[20], instrument taper [21] or file alloy properties [22] add to impossibility to instrument all canal walls.

In the current study we assumed that uninstrumented surfaces in the main root canal actually exist, which is why biomechanical instrumentation was performed with the intention of leaving half of the root canal uninstrumented. On the other hand, instrumented areas of the root canal showed surfaces with expected morphology and more-less

Figure 1. Saline solution. a) uninstrumented area – remnants of pulpal components, parts of odontoblasts, noticeable elongated dentinal tubules; b) instrumented area with a tree-bark model of smear layer which appears in both hand and rotary root canal instrumentation [9].

Slika 1. Fiziološki rastvor. a) neinstrumentisana površina – zaostale komponente pulp, delovi odontoblasta, uočljivi uzdužno presečeni dentinski kanalici; b) instrumentisana površina sa tree-bark modelom razmaznog sloja koji se pojavljuje i kod ručne i kod mašinske obrade kanala korena [12].

Figure 2. NaOCl. a) uninstrumented area – dome-shaped calcospherites with a grainy, uneven surface; b) instrumented area – smear layer covers dentin, with barely visible tubular orifices

Slika 2. NaOCl. a) neinstrumentisana površina – kupolasti kalcisferiti sa sitno zrnastom, neravnom površinom; b) instrumentisana površina – razmazni sloj pokriva dentinskou površinu, jedva uočljivi otvori dentinskih kanalića.

Figure 3. EDTA. a) uninstrumented area – groovy surface of dentin with no calcospherites; b) instrumented area – removed smear layer, but with presence of debris

Slika 3. EDTA. a) neinstrumentisana površina – talasasta površina dentina bez kalcisferita; b) instrumentisana površina – uklonjen razmazni sloj, ali prisutan debris

Figure 4. NaOCl + EDTA. a) uninstrumented area – a reduction in calcospherites, no organic debris; b) instrumented area – root canal wall with removed debris and smear layer

Slika 4. NaOCl + EDTA. a) neinstrumentisana površina – izrazita redukcija kalcisferita sa levkasto proširenim dentinskim kanalićima, odsutan organski debris; b) instrumentisana površina – zid kanala korena sa uklonjenim debrišom i razmaznim slojem, ali i sa istorjenim intratubularnim dentinom. Dentinska erozija na nekim mestima spaja dva ili više otvora dentinskih kanalića.

Figure 5. NaOCl + EDTA + NaOCl. a) uninstrumented area – pronounced reduction in calcospherites with a funnel-like widening on dentinal tubules, no organic debris; b) instrumented area – root canal wall with removed debris and smear layer, but with intratubular dentin which has worn away. Dentin erosion in some areas connects two or more orifices of the dentin tubules

Slika 5. NaOCl + EDTA + NaOCl. a) neinstrumentisana površina – izrazita redukcija kalcisferita sa levkasto proširenim dentinskim kanalićima, odsutan organski debris; b) instrumentisana površina – zid kanala korena sa uklonjenim debrišom i razmaznim slojem, ali i sa istorjenim intratubularnim dentinom. Dentinska erozija na nekim mestima spaja dva ili više otvora dentinskih kanalića.

Figure 6. NaOCl + EDTA + CHX. a) uninstrumented area–moderately reduced calcospherites, some of which have retained their dome-shaped form; b) instrumented area – root canal wall with removed debris and smear layer, no erosion of intratubular and peritubular dentin

Slika 6. NaOCl + EDTA + CHX. a) neinstrumentisana površina – umereno redukovni kalcisferiti, pojedini su zadržali kupolasti oblik; b) instrumentisana površina – zid kanala korena sa uklonjenim debrišom i razmaznim slojem, nema erozije intratubularnog i peritubularnog dentina.

Figure 7. a) the darker areas on the micrography represent instrumented surfaces; b) An ultrastructural appearance of the uninstrumented root canal following irrigation using NaOCl solution, magnified at 350×. On dentin walls dome-shaped and ridge-shaped calcospherites are noted. Slika 7. a) tamna polja na mikrografiji predstavljaju instrumentisane površine; b) ultrastrukturni izgled neinstrumentisanim kanala korena posle irrigacije sa NaOCl na uvećanju 350×. Na dentinskim zidovima se uočavaju kupolasti i grebenasti kalcisferiti.
clean wall surfaces following certain irrigation regimens as reported in other studies [13-15]. In our study we analyzed only the coronal and middle third of the canal, while the apical third was excluded due to its complexity and possible presence of a smear layer even after irrigation that could influence the interpretation of obtained results.

Uninstrumented areas of the canal were difficult to notice prior to irrigation with NaOCl that removed organic debris and exposed conical and wedge-shaped calcospherites. Structures that were found on uninstrumented areas included pulpal tissue remnants, odontoblastic extensions, but no smear layer was found. In the current study 3% NaOCl solution was used and completely removed organic debris. In studies where canals were irrigated with 0.5% NaOCl solution, dentin of uninstrumented areas was not completely cleaned of organic debris [23].

According to the findings of many studies, NaOCl irrigation is exceptionally important because it dissolves organic tissue very efficiently. Even though it has an inadequate surface tension and cannot reach narrow canals, NaOCl can effectively clean uninstrumented areas of the main canal that consist of predentin, necrotic pulp tissue and a bacterial biofilm [7, 24].

Following irrigation regimens IV, V, and VI (NaOCl+EDTA; NaOCl+EDTA+NaOCl; NaOCl+EDTA+CHX) uninstrumented surfaces showed more organic debris and exposed conical and wedge-shaped calcospherites after the same irrigation regimen [11,18].

In the current study, following irrigation regimen V (NaOCl+EDTA+NaOCl), erosion of intertubular and peritubular dentin occurred on both uninstrumented and instrumented surfaces. Most likely NaOCl was not able to prevent demineralizing effect of EDTA on peritubular and intertubular dentin due to its slow degradation [25]. In addition, there was an interaction between EDTA and NaOCl that manifested in sudden decrease in the amount of free chlorine causing loss of NaOCl activity and inability to dissolve soft tissue within the canal [26]. In our study no organic debris was noted after this irrigation regimen, but many authors do not recommend the use of NaOCl as the final irrigant (after EDTA) due to possible dentinal erosion [25, 27].

The literature reports interaction between irrigants that can be manifested as mutual inactivation, coloring and intertubular dentin due to its slow degradation [25]. Therefore, flushing canals with sterile water between each irrigation regimen, but many authors do not recommend the use of NaOCl after EDTA or CHX as the final irrigant [24].

CONCLUSION

Taking into consideration limitations of all in vitro studies, the following can be concluded:

The morphology of uninstrumented areas of main root canal is similar to the morphology of those parts of the canal endodontic instruments cannot reach (narrowings, lateral canals, anastomosis, invagination of the root canal, etc.).

The presence of uninstrumented areas in the root canal during endodontic instrumentation is inevitable due to the complex morphology of the canals and indicates the importance of irrigants use during instrumentation.

Even though this was not the primary aim of this study, the most favorable effect of irrigation (including instrumented and uninstrumented areas of the canal) was noted following the irrigation regimen: NaOCl+EDTA, or even better using NaOCl+EDTA+CHX as the final irrigant.

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Ultrazrskutorna analiza neinstrumentisanih površina u kanalu korenja posle različitih irigacionih protokola

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UVOD
Jedan od osnovnih preduslova za uspeh endodontskog lečenja je adekvatna preparacija kanala korenja zuba. Međutim, instrumentaciju i irigaciju je uglavnom teško realizovati zbog vrlo specifične i kompleksne kanalne morfologije, ali i ograničenog efekta instrumenta u nepristupačnom i ograničenom prostoru [1].

Morfološke varijacije kanalnog sistema i nemogućnost endodontskog instrumenta da dopre do svih delova zidova kanala korenja potpuno čišćenje kanala čine praktično nemoguće [1, 2]. Nekoliko studija je primenom mikrokompjuterizovane tomografije potvrdilo da tokom preparacije kanala deo zidova ostaje potpuno neobrađen [3-6]. Na ovim nepristupaćnim površinama zidova kanala mogu se zadržavati bakterije i time ugroziti i kompromitovati endodontsko lečenje [7].

Osim toga, i prisustvo razmaznog sloja i debresa kao posledica instrumentacije i sečenja dentina predstavlja značajan klinički problem [2, 8]. Ovaj sloj često sadrži bakterije i blokira dentinske tubule, čime značajno umanjuje kvalitet opturacije. Potencijalna eliminačka uloga je u eliminaciji i redukciji ostataka organskog tkiva. Njihova blokada opturacije, pa i povećanje erozija dentina, može doći do nekih oštećenja (karijes korenja, pukotine, unutrašnje ili spoljašnje resorpcije itd.). U odnosu na irigacioni protokol, svi zubi su podeljeni u šest grupa, pri čemu je potrebno poduzeti odgovarajuće korak premještanja za eliminaciju ostataka organskog tkiva.

Materijal i metode rada

Kao materijal u ovom istraživanju korišćeno je 18 svežih jednokorenih intaktnih i necenjenih zuba bez vizualne oštećenja (karijes korenja, pukotine, unutrašnje ili spoljašnje resorpcije itd.). U odnosu na irigacioni protokol, svi zubi su podeljeni u šest grupa, pri čemu je potrebno poduzeti odgovarajuće korak premještanja za eliminaciju ostataka organskog tkiva.

Korena predmetna analiza uključuje: 1) pomjeranje zuba u toku endodontskog lečenja; 2) primjenu rastvora za opturaciju; 3) morfološku analizu i izvođenje SEM analize. Cilj ovog rada je upravo donijeti teoretske zaključke o učinkovitosti endodontskog instrumenta u neinstrumentisanim delovima zidova kanala posle primjene različitih protokola za irigaciju i opturaciju.

Rezultati

Osamnaest jednokorenih ekstrahovanih zuba je podeljeno u šest grupa. Jedan zub iz svake grupe je predmetna analiza. Grupiranje zuba prikazano je u tabeli 1. U svakoj grupi je predmetna analiza neinstrumentisanih delova zidova kanala; neinstrumentisanih delova zidova kanala; neinstrumentisanih delova zidova kanala; irigacija kanala; SEM

Korenovi su uzdužno presečeni i pripremljeni za SEM. Pre instrumentacije kanala pažljivo su dijamantskim diskom rezirani do tipa ISO40. Kod svakog zuba su određene kontrolne uzorke u kojima su izvršeni operativni koraci pre opturacije. Apeks svakog uzorka zuba je potom zapečaćen kuglicom roze voska. Apeks svakog uzorka zuba je potom zapečaćen kuglicom roze voska. Apeks svakog uzorka zuba je potom zapečaćen kuglicom roze voska. Apeks svakog uzorka zuba je potom zapečaćen kuglicom roze voska. Apeks svakog uzorka zuba je potom zapečaćen kuglicom roze voska.
paraciji se vodilo računa da endodontski instrumenti ne dođu u kontakt sa drugim delom kanala koji je predstavljao „neinstrumentisanu“ polovinu kanala korena. Kontroloni uzorak iz svake grupe je služio za poredenje neinstrumentisanih delova kanala sa neinstrumentisanim kanalom korena posle identičnih irrigacionih protokola.

Količina irrigansa koja je korišćena sa svaki irrigacioni protokol bila je identična i pažljivo kontrolisana, kao i ukupno vreme hemomehaničke obrade svakog kanala (10 min).

U eksperimentu je korišćeno šest protokola ispiranja: (I) samo fiziološki rastvor; (II) samo 3% natrijev hipoklorit (NaOCl-Parcan, Septodont); (III) samo 15% etilen-diamin-tetraacetat (EDTA – Largal Ultra, Septodont); (IV) kombinacija 3% NaOCl+15% EDTA; (V) kombinacija 3% NaOCl+15% EDTA i 3% NaOCl kao završni irrigans; (VI) kombinacija 3% NaOCl+15% EDTA i 2% hlorheksidin (R4, Septodont) kao završni irrigans.

Uz blagi pritisak, uzorci su pomoću špatule podeljeni na polovine (tako je dobijeno 36 uzoraka) i stavljeni u otvorene kanale sa neinstrumentisanim kanalom korena posle identičnih svakog prometa. Ovo se može objasniti time što se izglede u konusnu konfiguraciju korena, što ovale ili sploštene kanale ostavlja sa nepreparisanim poljima [16]. Drugi autori postojanje neinstrumentisanih regija opravdavaju prema tome da se polovina zida korenskog kanala ostavi bez mehaničke obrade. S druge strane, instrumentisani delovi u kanalu korena su pokazali površinu sa očekivanom zrnušćenom manje ili više čistih zidova posle određenih irrigacionih protokola, kako je objavljeno i u drugim studijama [13-15]. U ovom istraživanju su analizirane samo cervikalna i srednja trećina kanala, dok je istraživanje u drugim studijama [16] ili osobinama legure od koje su izrađeni instrumenti [22].

U ovom istraživanju se poslo iz pretpostavke da neinstrumentisane površine u glavnom korenskom kanalu zaista postoje, zbog čega je hemomehanička instrumenacija ugrađena na osnovu da se polovina zida korenskog kanala ostavi bez mehaničke obrade. S druge strane, instrumentisani delovi du kanalu korena su pokazali površinu sa očekivanom zrnušćenom manje ili više čistih zidova posle određenih irrigacionih protokola, kako je objavljeno i u drugim studijama [13-15]. U ovom istraživanju su analizirane samo cervikalna i srednja trećina kanala, dok je izostavljena apleksna trećina, koja bi zbog svoje kompleksnosti i mogućeg prisustva razmaznog sloja i posle irrigacionih protokola mogla uticati na tumačenje dobijenih rezultata.

Neinstrumentisane oblasti zidova kanala je bilo teško uočiti pre irrigacije sa NaOCl, koji je uklonio organske ostatke i prikazao kupolaste ili grebenaste kalciferite. Na neinstrumentisanim površinama su nađeni komplexne strukture koje su zbog svoje kompleksnosti može biti kompleksna konfiguracija korena, što se moglo objasniti činjenicu da u ovom kanalu korena ostaje neinstrumentisano [16]. Takođe, i druge studije potvrđuju prisustvo neinstrumentisanih polja u kanalu korena, čime se objašnjava da je irrigacija sa NaOCl efikasna sa čitavom površinom delova kanala [23].

Prema nalazima veće studije, korišćenje NaOCl tokom irrigacije je izuzetno važno jer ovaj irrigans dobro rastvara organske ostatke i kompletno ispira glavni korenski kanal. U ovom studiju je uklonio organske ostatke i moguće prisustvo razmaznog sloja.

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NaOCl nije mogao da spreči demineralizujuće dejstvo EDTA na peritubularni i intertubularni dentin jer dovodi do veoma spore degradacije ovog helatora [25]. Pored toga, postoji interakcija između EDTA i NaOCl, koja se ogleda u naglom smanjenju količine slobodnog hlora odmah pri kontaktu ovih irigansa, što može da ima za posledicu gubitak aktivnosti NaOCl i nemogućnost rastvaranja mekog tkiva unutar kanala [26]. U ovom istraživanju nije primećen ni organski debris posle primene ovog protokola, ali mnogi autori ne preporučuju NaOCl kao finalni irigans (posle EDTA) zbog moguće erozije dentina [25, 27].

Literaturni podaci ukazuju i na postojanje interakcije između irigansa, koje se mogu ispoljiti međusobnom inaktivacijom, prebojavanjem dentina ili stvaranjem štetnih precipitata [28-30], zbog čega se preporučuje ispiranje kanala sa destilovanom (sterilnom) vodom između svakog irigansa i sušenje kanala pre uvođenja novog rastvora za irrigaciju [26, 29, 30]. U protokolu ovog istraživanja su uvažene ove preporuke, kako bi se sprečile neželjene interakcije između irigansa i pritom dobio adekvatan rezultat [11].

Posle irigacionog protokola VI (NaOCl + EDTA i CHX kao završni irigans) nije uočena erozija dentina. Prema podacima iz literature, pri kontaktu EDTA i CHX dolazi do neutralizacije anjonskog EDTA pomoću katjonskog CHX, zbog čega nema dalje redukcije dentina [30]. Pored toga, antimikrobni efekat CHX (enteroccus faecalis i Candida albicans), kao i osobina supstantivnosti ovog irigansa (proturhirani efekat), opravdavaju njegovu upotrebu kao završnog irigansa u endodontskom tretmanu [24].

**ZAKLJUČAK**

Uprkos ograničenjima karakteristišnim za sva in vitro istraživanja, na osnovu dobijenih rezultata može se zaključiti sledeće:

- Morfologija neinstrumentisanih delova glavnog korenskog kanala je slična morfologiji onih delova kanala do kojih endodontski instrumenti ne mogu dopreći (suženja, bočni kanali, anastomoze, invaginacije zidova korena itd.).
- Prisustvo neinstrumentisanih površina kanala korena tokom endodontske instrumentacije je neizbežno zbog kompleksne morfologije kanala i ukazuje na važnost adekvatne primene hemijskih sredstava i dezinfekcije svih oblasti kanalnog sistema.
- Iako to nije bio primarni cilj istraživanja, najpovoljniji efekat irrigacije (i kod instrumentisanih i kod neinstrumentisanih delova kanala) uočen je posle primene irigacionih protokola sa: NaOCl i EDTA, odnosno NaOCl, EDTA i CHX kao završnim irigansom.