ACTA
STOMATOLOGICA
CROATICA
www.ascro.hr

Acta stomatol Croat. 2022;56(1):2-11.
DOI: 10.15644/asc56/1/1

ORIGINAL SCIENTIFIC PAPER
IZVORNI ZNANSTVENI RAD

Adriana Katunarić[1], Petra Dijanić[2], Danijela Jurić Kaćunić[3], Jurica Matijević[1], Nada Galić[1]

Efficiency Evaluation of Various Solvents in Retreatment of Endodontic Filling in Extracted Teeth

Procjena učinkovitosti različitih otapala pri reviziji endodontskoga punjenja na ekstrahiranim zubima

[1] Department of Endodontics and Restorative Dentistry, School of Dental Medicine, University of Zagreb Gundulićeva 5, 10000 Zagreb, Croatia
Zavod za endodonciju i restaurativnu stomatologiju Stomatološkog fakulteta Sveučilišta u Zagrebu, Gundulićeva 5, Zagreb, Hrvatska
[2] Private Dental Clinic, Zagreb, Croatia
Privatna stomatološka ordinacija, Zagreb, Hrvatska
[3] Private Dental Clinic, Gaggenau, Germany
Privatna stomatološka ordinacija, Gaggenau, Njemačka

Abstract
Objectives: The aim of this study was to evaluate the retreatment duration and efficacy of eucalyptol and tea tree oil in engine driven and manual retreatment of epoxy resin based endodontic filling in extracted human teeth. **Material and methods:** Sixty human single rooted teeth were randomly divided into two groups. The first group was prepared using hand files, and the second one using Reciproc system. Root canals were filled with gutta-percha points and AH Plus sealer. Retreatment was performed using K-reamers and Hedström files for the first group, and Reciproc instruments for the second group. Each group was divided into two subgroups (n=15) according to the retreatment solvent used (eucalyptol or tea tree oil). Root canals were longitudinaly split and analized with stereomicroscope (15x magnification). The surface of the remaining filling material was measured using an image processing software. **Results:** There were no statistically significant differences in the area of residual filling material among used solvents, nor in applied technique. Retreatment with Reciproc instruments was significantly faster compared to retreatment using hand files. The manual retreatment technique was faster when tea tree essential oil was used as a solvent compared to eucalyptol. **Conclusions:** Australian tea tree oil and eucalyptus oil were equally effective in removing endodontic filling material, but none of canals were completely free of the residual filling material. Retreatment with Reciproc instruments was faster compared to retreatment using hand files. The manual retreatment technique is faster when tea tree essential oil is used as a solvent compared to eucalyptol.

Received: December 4, 2021
Accepted: February 20, 2022

Address for correspondence
Petra Dijanić
Školska 11, 10410 Velika Gorica, Croatia
Tel. 00385915688785
petradumlija@gmail.com

MeSH terms: Root Canal Obturation; Root Canal Irrigants; Eucalyptol; Tea Tree Oil
Author keywords: Endodontic Retreatment; Reciprocating Instrument

Introduction

Endodontic retreatment is indicated in cases of unsuccessful primary endodontic treatment (1, 2). The main goal of retreatment is to establish conditions that will enable healing of the periapical process. This includes the removal of inadequate filling, cleaning of root canals and making a new filling and the restoration that will disable marginal leakage into the endodontic space from the oral cavity, the periapical and periradicular area. An adequate threedimensional and void-free filling inactivates all irritants in root canal that were not removed during cleaning, which prevents their survival and harmful effects. Root canals are usually filled with a combination of gutta-percha points and a sealer (1-3) Gutta-percha is the main material that fills the most of the root canal space, whereas the sealer flows to areas that are not regular and are hard-to-reach for mechanical instrumentation. The importance of sealers is significant. Sealers are neccesary for formation of a leakproof barrier between the gutta-percha and the walls of root canal (4). Retreatment of this type

Uvod

Revizija endodontskoga punjenja indicirana je u slučaju neuspješnoga primarnog endodontskoga liječenja (1, 2). Glavna svrha revizije je uspostava uvjeta koji će omogućiti cijeljenje periapikalnoga procesa. To podrazumijeva uklanjanje neadekvatnoga punjenja, čišćenje korijenskih kanala i novo punjenje te restauraciju koja će zabrtviti putove rubnoga propuštanja u endodontski prostor iz usne šupljine, periapikalnoga i periradikularnoga područja. Pravilnim trodimenzionalnim i kompaktnim punjenjem brtve se i svi podražajni čimbenici koji nisu uklonjeni tijekom čišćenja unutar korijenskih kanala, što onemogućuje njihov opstanak i štetno djelovanje. Korijenski kanali najčešće se pune kombinacijom štapića gutaperke i cementa (1 – 3). Gutaperka je glavni materijal kojim se ispunjava većina prostora korijenskoga kanala, a punilo ulazi u nepravilna područja teško dostupna mehaničkoj instrumentaciji. Važnost cementa je velika. Cementi su nužni za stvaranje nepropusne barijere između gutaperke i zidova korijenskoga kanala (4). Revizija te vrste pu-

of filling can be performed with or without solvents; using hand stainless steel instruments; by engine-driven, reciprocating and rotating techniques using Ni-Ti instruments; using an ultrasound and laser or devices that release heat and soften the gutta-percha (1-3).

The introduction of nickel–titanium (Ni–Ti) engine-driven instruments in endodontics made mechanical preparation of root canals easy and predictable. Improved simplicity is a consequence of reduced number of instruments that shortened the root canal treatment duration. Moreover, Ni–Ti engine-driven instruments improved the shaping and cleaning ability of the root canal during clinical procedures (5, 6).

In 2011, the reciprocating instrumentation system, Reciproc (VDW, Munich, Germany) was introduced into clinical practice. It requires an engine-driven device (VDW Silver or Gold Reciproc, VDW Gmbh, Munich, Germany) and three different files: R25 (red, 25/0.08), R40 (black, 40/0.06), R50 (yellow, 50/0.05). Since rotary techniques are longer in use than reciprocating ones, numerous studies have evaluated their effectiveness and compared them with other techniques (7-10). Many studies have stated that rotary techniques are more efficient than hand techniques (7, 8), while others (9, 10), didn't find any signifficant differences between these two techniques.

When the reciprocating root canal instrumentation and retreatment techniques appeared, numerous studies have evaluated their effectiveness and compared it with other techniques (11-14). Most of them reported the superiority of the reciprocating technique over others (11, 13). There are studies that didn't find significant differences between reciprocating and other (usually engine-driven) techniques (12, 14).

A number of studies have shown that, regardless of the retreatment technique (whether hand or engine-driven), with or without the use of a solvent, it is not possible to completely remove the filling material from root canals (11, 14, 15). Therefore, according to some authors (16-20), the use of solvents is definitely recommended because they are necessary for dissolving filling material from hard-to-reach anatomical ramifications and dentinal tubules. During solvent-free retreatment, there is a risk of various mechanical damage to the original endodontic space due to excessive friction between the canal walls and the cutting edges of the instruments, which releases heat high sufficiently to soften the gutta-percha, which is then further pushed into the canal space (21).

For many years chloroform has been used as root canal retreatment solvent (16-18). However, since in 1976, the U.S. Food and Drug Administration banned chloroform because of potential carcinogenicity and cytotoxicity (22), eucalyptus essential oil became often used alternative solvent which, in addition to biocompatibility and relatively successful and rapid dissolution of root canal filling, also has antibacterial, antifungal and antiviral effect (17, 23, 24). Apart from eucalyptol, other essential oils, such as orange oil, pine needle oil, white pine and tea tree oils (Australian tea tree - melalleuca alternifolia) have also been researched (18). Tea tree oil is also a successful solvent for gutta-percha since it has antibacterial, antifungal, antiviral and anti-inflammatory effects (25, 26).

njenja može se provoditi s otapalom ili bez otapala, ručnim instrumentima od nehrđajućega čelika, strojno, recipročnim i rotirajućim tehnikama s pomoću nikal-titanijevih (Ni-Ti) instrumenata te ultrazvučno i laserom, uređajima koji oslobađanjem topline razmekšavaju gutaperku (1 – 3).

Uvođenje Ni-Ti strojnih instrumenata u endodonciju učinilo je mehaničku preparaciju korijenskih kanala laganom i predvidivom. Poboljšana je jednostavnost zbog smanjenoga broja instrumenata, što je skratilo trajanje revizije. Nadalje, Ni-Ti strojnim instrumentima poboljšala se mogućnost oblikovanja i čišćenja korijenskoga kanala u kliničkoj praksi (5, 6).

Godine 2011. u kliničku praksu uvedena je recipročna tehnika instrumentacije Reciproc (VDW, München, Njemačka). Pritom se upotrebljavaju tri instrumenta – R25 (crveni, 25/0,08), R40 (crni 40/0,06), R50 (žuti, 50/0,05) i pripadajući motor (VDW Silver ili Gold Reciproc, VDW Gmbh, München, Njemačka). Budući da su rotacijske tehnike dulje u uporabi od recipročnih, o njihovoj učinkovitosti i uspoređivanju s ostalim tehnikama rađena su mnogobrojna istraživanja (7 – 10). Autori mnogih ističu da su rotacijske tehnike učinkovitije u usporedbi s ručnima (7, 8), a u nekim istraživanjima (9, 10) nije pronađena značajna razlika između tih dviju tehnika.

Nakon uvođenja recipročne tehnike instrumentacije i revizije korijenskih kanala, u mnogobrojnim istraživanjima ispitivana je njezina učinkovitost te je uspoređena s učinkovitošću ostalih tehnika (11 – 14). U većini njih navodi se superiornost recipročne tehnike u odnosu prema ostalima (11, 13). Ima i istraživanja u kojima nisu pronađene značajne razlike između recipročne tehnike i ostalih, ponajprije onih strojnih (12, 14).

Autori mnogobrojnih istraživanja pokazali su da, bez obzira na tehniku revizije (ručna ili strojna), s uporabom otapala ili bez njih, nije moguće potpuno ukloniti materijal za punjenje iz korijenskih kanala (11, 14, 15). Zato se prema mišljenju nekih autora (16 – 20) svakako treba preporučiti uporaba otapala jer su prijeko potrebna za otapanje materijala za punjenje iz teško dostupnih anatomskih ramifikacija i dentinskih tubulusa. Pri reviziji bez primjene otapala, postoji i opasnost od raznih mehaničkih oštećenja izvornoga endodontskoga prostora zbog prevelikoga trenja između stijenki kanala i reznih bridova instrumenata kada se oslobađa toplina dostatna za omekšavanje gutaperke koja se tada dodatno potiskuje u kanalni sustav tretiranoga zuba (21).

Godinama se pri reviziji endodontskoga punjenja rabio kloroform (16 – 18). No kako je 1976. godine odredbom Agencije za hranu i lijekove Sjedinjenih Američkih Država (USFDA) zabranjena njegova uporaba zbog potencijalne kancerogenosti i citotoksičnosti (22), kao alternativno otapalo često se koristi eterično ulje eukaliptusa koje, uz biokompatibilnost i razmjerno uspješno i brzo otapanje punjenja iz korijenskih kanala, djeluje i antibakterijski, antifungalno i antivirusno (17, 23, 24). Uz eukaliptol, istražena su i druga eterična ulja – ulje naranče, igličastog bora, bijeloga bora i čajevca (australsko čajno drvo – *Melalleuca alternifolia*) (18). Ulje čajevca također je uspješno otapalo gutaperke, a pritom ima antibakterijski, antifungalni, antivirusni i protuupalni učinak (25, 26).

The purpose of this study was to compare the efficacy and time required for dissolving gutta-percha and AH Plus sealer from root canals between eucalyptus essential oil (Eucalyptus globulus) and Australian tea tree oil (Melaleuca alternifolia) in manual (K-reamers and Hedström files) and the machine (Reciproc) retreatment technique.

The first null hypothesis of the study was that there is no significant difference in efficacy of dissolving root filling using eucalyptus essential oil and Australian tea tree oil in manual and machine retreatment technique.

The second null hypothesis of the study was that there is no significant difference in time required for dissolving root filling using eucalyptus essential oil and Australian tea tree oil in manual and machine technique.

Material and methods

Sample selection

The Ethics Committee of the Faculty of Dentistry, University of Zagreb approved the research (05-PA-26-3/2018).

This study was carried out on permanent maxillary and mandibular human teeth with fully developed roots without signs of tooth decay, external resorption and previous endodontic treatment. The teeth were extracted because of periodontal, orthodontic and other health reasons at the Department of Oral Surgery, School of Dental Medicine, University of Zagreb. After extraction, the teeth were rinsed under running water, cleaned of soft tissue deposits and stored in 0.5% chloramine. Specimens were sterilized in an autoclave.

The access cavities were made on the occlusal side of the lateral, and the oral side of anterior teeth, using a fissure diamond drill No. 016 (Komet, Rock Hill, SC, USA) mounted on a turbine, under water cooling. The roof of the pulp chambers was removed with a round carbide drill #3. The pulp was removed with a pulp extirpation instrument, and the root canal lengths were measured by inserting a K-file #10 or #15 (Maillefer, Ballaigues, Switzerland) to the apical orifice after which the instrument was retracted for one millimeter. The average root canal length was 14 mm. According to the instrumentation technique, 60 root canals were divided into two groups (n = 30). Sample size was chosen according to comparable research in the available literature. Test samples were randomly assigned to test groups by using a chance procedure. Single operator was performing sample preparation and measurements.

Root canal preparation and filling

Group I

The first group was prepared using hand files; K-reamers, K-files and H-files (Maillefer, Ballaigues, Switzerland), apically up to ISO #40 (MAF) and coronally up to ISO #80, using the "step-back" technique. Between each instrument, the root canals were rinsed with 1 ml of 2.5% sodium hypochlorite (NaOCl) (T.T.T. d.o.o., Sveta Nedjelja, Croatia) with a disposable plastic syringe (volume 2 ml) and a 30G blunt tip needle. Final removal of the residual smear layer was performed by rinsing the root canal with 1 ml of 2.5% NaOCl for 30 sec., 15% ethylenediamintetraacetic acid (EDTA)

Svrha ovog istraživanja bila je usporediti učinkovitost i vrijeme potrebno za otapanje gutaperke i punila AH plus iz korijenskih kanala između eteričnoga ulja eukaliptusa (*Eucalyptus globulus)* i ulja australskoga čajnoga drva (*Melaleuca alternifolia*) pri ručnoj (Kerr proširivači i Hedström pilice) i strojnoj (Reciproc) tehnici revizije.

Prva nulta hipoteza istraživanja bila je da nema značajne razlike u učinkovitosti pri otapanju korijenskoga punjenja eteričnim uljem eukaliptusa i uljem australskoga čajevca tijekom ručne i strojne tehnike revizije.

Druga nulta hipoteza istraživanja glasila je da nema značajne razlike u vremenu potrebnom za uklanjanje korijenskoga punjenja eteričnim uljem eukaliptusa i uljem australskoga čajevca pri uporabi ručne i strojne tehnike.

Materijali i metode

Odabir uzorka

Istraživanje je odobrilo Etičko povjerenstvo Stomatološkog fakulteta Sveučilišta u Zagrebu (05-PA-26-3/2018).

Za potrebe istraživanja korišteni su trajni maksilarni i mandibularni ljudski zubi potpuno razvijenih korijena i bez znakova karijesnog oštećenja, eksterne resorpcije i endodontskoga liječenja. Vađeni su iz parodontoloških, ortodontskih i drugih zdravstvenih razloga u Zavodu za oralnu kirurgiju Stomatološkog fakulteta Sveučilišta u Zagrebu. Nakon vađenja zubi su isprani pod mlazom vode, očišćeni od mekotkivnih naslaga te pohranjeni u 0,5-postotnu otopinu kloramina. Uzorci su sterilizirani u autoklavu.

Trepanacijski otvori rađeni su s okluzalne strane lateralnih zuba i oralne strane frontalnih zuba fisurnim dijamantnim svrdlom br. 016 (Komet, Rock Hill, SC, SAD) montiranim na turbinu, uz vodeno hlađenje. Krov pulpnih komorica uklonjen je okruglim karbidnim svrdlom #3. Pulpa je uklonjena pulpekstripatorom, a dužine korijenskih kanala izmjerene su uvođenjem strugača veličine #10 ili #15 (Kerr strugač, Maillefer, Ballaigues, Švicarska) do apikalnoga otvora nakon čega je instrument uvučen za milimetar. Prosječna dužina korijenskih kanala iznosila je 14 mm. S obzirom na tehniku instrumentacije, 60 korijenskih kanala podijeljeno je u dvije skupine (n = 30). Veličina uzorka odabrana je prema usporedivim istraživanjima u dostupnoj literaturi. Testni uzorci nasumično su, slučajnim odabirom, raspoređeni po ispitnim skupinama. Pripremu uzorka i mjerenja obavljao je jedan operater.

Priprema korijenskih kanala i punjenje

Skupina I.

Prva skupina mehanički je obrađena ručnim instrumentima – strugačima, proširivačima i pilicama Hedström (Maillefer, Ballaigues, Švicarska), apikalno do #40 (ISO #40 master file), a koronarno do #80, klasičnom "step-back" tehnikom. Korijenski su kanali između svakoga instrumenta isprani jednim mililitrom 2,5-postotne otopine natrijeva hipoklorita (NaOCl) (T. T. T. d.o.o., Sveta Nedjelja, Hrvatska), a za to se koristila jednokratna plastična štrcaljka (vol. 2 mL) i 30 G igla tupoga vrha. Završno uklanjanje zaostatnoga sloja provedeno je 30-sekundnim ispiranjem kanala jednim mililitrom

(Calsinase, Lege artis, Dettenhausen, Germany) for 60 sec. and saline (B. Braun Adria d.o.o., Zagreb, Croatia). The canals were then dried with sterile paper points.

The root canals were filled with standard gutta-percha points (DiaDent, Seoul, Korea) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany), mixed according to the manufacturer's instructions, using the cold lateral condensation technique. The master cone #40 was coated with sealer and applied to the canal to a previously measured length and pushed laterally and apically with a spreader #25, creating space for an additional gutta-percha point of appropriate size. Additional gutta-percha points coated with sealer were repeatedly inserted into the canal until the spreader could not penetrate into the filling deeper than 2 mm. The excess gutta-percha points were cut off with flat plugger heated on an open fire at the level of the root canal orifice. The filling was additionally condensed in the vertical direction.

Group II

The second group was prepared using engine-driven Reciproc instruments; R25 and R40 (VDW, Munich, Germany) powered by VDW Reciproc Gold engine device (VDW, Munich, Germany), up to size 40/0.6, according to the manufacturer's instructions. Chemical treatment during instrumentation and removal of the residual smear layer was performed in the same way as in the group I. After drying with paper points, the root canals were filled with VDW Reciproc gutta-percha #40 coated with AH Plus sealer. The excess gutta-percha points were cut off with flat plugger heated on an open fire at the level of the root canal orifice and vertically condensed.

After filling, all samples of both groups were stored in saline at thermostat temperature of 37°C.

Retreatment

After seven days, the samples were taken out of the thermostat and dried with gauze. Gates Glidden drill #3 (Maillefer, Ballagius, Switzerland) was used to make a small solvent tank in the coronal third of each canal. Engine driven and hand instrumented groups were divided into two subgroups (n=15), denoted by the letters *a* and *b*. Subgroups *a* were treated with eucalyptol, and subgroups *b* with tea tree oil.

Group I (Ia and Ib)

Hand instruments were used for retreatment of the first group. After application of 1 ml of solvent, a path for the solvent was made by rotating the K-reamer #15 120°clockwise with slight apical pressure, and the softened gutta-percha was removed with a same sized H-file. The size of the instruments was gradually increased to #40. The solvent was added as needed. The procedure was repeated until reaching the working length and was completed and there were no more visible traces of filling material on the instruments and paper points.

Group II (IIa and IIb)

The second group was retreated with engine-driven, Reciproc instruments according to the manufacturer's instructions. First, 1 to 2 drops of solvent were applied into a previously made container at the root canal orifice. Then, the R25 instru-

2,5-postotne otopine NaOCl-a, 15-postotnom otopinom etilendiaminotetraoctene kiseline (EDTA) (Calsinase, Lege artis, Dettenhausen, Njemačka) tijekom 60 sekunda i fiziološkom otopinom (B. Braun Adria d.o.o., Zagreb, Hrvatska). Poslije toga kanali su osušeni sterilnim papirnatim štapićima.

Korijenski kanali punjeni su standardnim štapićima gutaperke (DiaDent, Seul, Koreja) i pastom AH Plus (Dentsply DeTrey, Konstanz, Njemačka) zamiješanom prema uputi proizvođača, tehnikom hladne lateralne kondenzacije. Glavni štapić gutaperke #40 (engl. *Master cone*) nakon uranjanja u pastu, apliciran je u kanal do prije izmjerene duljine te je lateralno i apikalno potisnut ručnim raširivačem #25 (engl. *Spreader*), čime je stvoren prostor za dodatni štapić gutaperke odgovarajuće veličine. Dodatni štapići obloženi pastom, ponovno su unošeni u kanal sve dok se raširivačem nije moglo prodrijeti u punjenje dublje od dva milimetra. Ravnim nabijačem, zagrijanim na plameniku, odrezan je višak štapića gutaperke u razini ulaza u korijenski kanal te je punjenje dodatno kondenzirano u vertikalnom smjeru.

Skupina II.

Druga skupina obrađena je strojno instrumentima Reciproc R25 i R40 (VDW, München, Njemačka) koje je pokretao motor VDW Reciproc Gold (VDW, München, Njemačka), do veličine 40/0,6, prema protokolu proizvođača. Kemijska obrada između svake rekapitulacije i završno uklanjanje zaostatnoga sloja obavljeno je istim irigansima kao i u skupini *I*. Poslije sušenja papirnatim štapićima, korijenski su kanali punjeni VDW Reciproc gutaperkom #40 obloženom prije zamiješanom pastom AH Plus. Višak gutaperke uklonjen je zagrijanim ravnim nabijačem i završno vertikalno kondenziran.

Nakon punjenja svi su uzorci pohranjeni u fiziološkoj otopini u termostatu pri temperaturi od 37 °C.

Revizija

Nakon sedam dana uzorci su izvađeni iz termostata i posušeni gazom. Gates Glidden svrdlom #3 (Maillefer, Ballagius, Švicarska) u koronarnoj trećini svakoga kanala učinjen je mali spremnik za otapalo. Strojno i ručno instrumentirane skupine podijeljene su u dvije podskupine (n = 15) označene slovima *a* i *b*. Podskupina *a* tretirana je eukaliptolom, a podskupina *b* čajevcem.

Skupina I. (I. a i I. b)

Za reviziju prve skupine korišteni su ručni instrumenti. Nakon primjene jednog mililitra otapala, okretanjem proširivača #15 u smjeru kazaljke na satu za 120°, uz lagani apikalni pritisak, izrađen je put za otapalo, a pilicama Hedström jednake veličine uklonjena je omekšala gutaperka. Veličina instrumenata postupno je povećavana do #40. Otapalo je dodavano prema potrebi. Postupak se ponavljao dok se nije postigla radna duljina te je završen u trenutku kada više nije bilo vidljivih tragova punila na instrumentima i papirnatim štapićima.

Skupina II. (II. a i II. b)

Druga skupina revidirana je strojno instrumentima Reciproc, slijedeći protokol proizvođača. Nakon unošenja jedne do dvije kapi otapala u već izrađeni spremnik na ulazu korijenskoga kanala instrumentom R25, uz lagani pritisak pre-

ment was used with light pressure towards the apical and "inside - out" movements through 3 consecutive amplitudes of 3 mm, followed by cleaning the instrument with sterile gauze, until reaching the working length. After that, the R40 instrument was introduced into the root canal and the remaining filling material was removed from the canal walls by the "inside - out" and "side" movements, according to the mentioned protocol. The retreatment was completed when there were no more visible traces of filling material on the instruments.

Finally, all canals were rinsed with 0.5% NaOCl, 15% EDTA and saline and dried with paper points. The complete retreatment time was measured in minutes.

Results

Statistical analysis

After retreatment, the samples were longitudinally split, and recorded by a camera mounted on a stereomicroscope (Olympus SZX12) under a 15x magnification and the surface of the residual filling material in the root canals was quantified. The obtained images were transferred to a computer and the areas of residual gutta-percha and sealer were measured using an image processing program, ImageJ (Figure 1). Data were statistically analized by Student - T test. The computer program SPSS 17.1 for Windows was used for data processing. The normality of the data distribution was checked by a descriptive statistical method (P-P plot). P values less than 0.05 were considered significant.

Retreatment duration

The time required for retreatment of all samples by groups is shown in Table 1 and in Figure 2.

ma apikalno, pokretima „unutra – van" u tri konsekutivne amplitude od tri milimetra, između kojih je slijedilo čišćenje instrumenta sterilnom gazom, postupno je postignuta radna duljina. Zatim je u korijenski kanal uveden instrument R40 te je pokretima „unutra – van" i „u stranu", navedenim protokolom, uklonjeno preostalo punjenje sa stijenki kanala. Revizija se i u ovoj skupini smatrala završenom kada više nije bilo vidljivih tragova punila na instrumentima.

Završno su svi kanali isprani 0,5-postotnom otopinom NaOCl-a, 15-postotnom otopinom EDTA-e i fiziološkom otopinom te su posušeni papirnatim štapićima. Ukupno vrijeme revizije mjereno je u minutama.

Rezultati

Statistička obrada podataka

Nakon revizije uzorci su uzdužno razrezani i snimljeni kamerom montiranom na stereomikroskop (Olympus SZX12) pod povećanjem od 15 puta u svrhu kvantifikacije površine punjenja zaostaloga u korijenskim kanalima. Dobivene slike prenesene su na računalo te su površine zaostale gutaperke i paste izmjerene računalnim programom ImageJ (slika 1.). Dobiveni podatci statistički su obrađeni Studentovim t-testom. U obradi podataka korišten je Windowsov računalni program SPSS 17.1. Normalnost distribucije podataka provjerena je deskriptivnom statističkom metodom (P – P plot). P vrijednosti manje od 0,05 smatrane su značajnima.

Trajanje revizije

Vrijeme potrebno za ponovnu obradu svih uzoraka po skupinama prikazano je u tablici 1. i na slici 2.

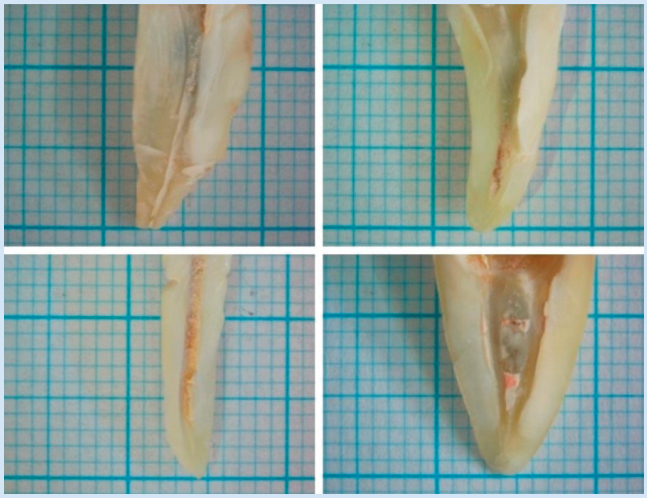

Figure 1 Residual gutta-percha and sealer after retreatment; groups Ia (bottom left), Ib (top left), IIa (top right), IIb (bottom right)
Figure legend: Ia-hand retreatment/eucalyptol, Ib-hand retreatment/tea tree oil, IIa-engine driven retreatment/eucalyptol, IIb-engine driven retreatment/tea tree oil

Slika 1. Zaostatna gutaperka i punilo nakon revizije; skupine I. a (dolje lijevo), I. b (gore lijevo), II. a (gore desno), II. b (dolje desno)
Legenda: I. a - ručna revizija/eukaliptol, I. b - ručna revizija/ulje čajevca, II. a - strojna revizija/eukaliptol, II. b - strojna revizija/ulje čajevca

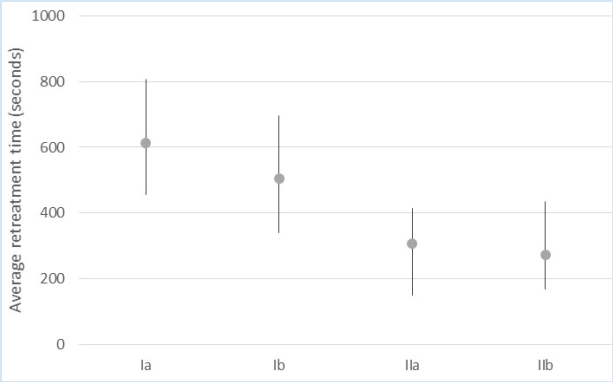

Figure 2 Graphical representation of the average time (seconds) required for retreatment by groups
Figure legend: Ia-hand retreatment/eucalyptol, Ib-hand retreatment/tea tree oil, IIa-engine driven retreatment/eucalyptol, IIb-engine driven retreatment/tea tree oil

Slika 2. Grafički prikaz prosječnoga vremena (sekunde) potrebnog za reviziju po skupinama
Legenda: I. a -ručna revizija/eukaliptol, I. b - ručna revizija/ulje čajevca, II. a - strojna revizija/eukaliptol, II. b - strojna revizija/ulje čajevca

Table 1 Retreatment duration (minutes)
Tablica 1. Trajanje revizije (minute)

Group • Skupina	N	Mean • Sredina	SD	Minimum	Maximum • Maksimum	Percentiles • Percentile		
						25th	50th	75th
Ia • I. a	15	10:13	0:29	7:37	13:26	8:29	10:03	12:18
Ib • I. b	15	8:25	0:31	5:39	11:37	6:10	8:02	10:07
IIa • II. a	15	5:08	0:20	2:30	6:55	4:15	5:10	6:05
IIb • II. b	15	4:32	0:23	2:48	7:16	3:21	4:11	5:40

Table legend: Ia-hand retreatment/eucalyptol, Ib-hand retreatment/tea tree oil, IIa-engine driven retreatment/eucalyptol, IIb-engine driven retreatment/tea tree oil •
Legenda: I. a - ručna revizija/eukaliptol, I. b - ručna revizija/ulje čajevca, II. a - strojna revizija/eukaliptol, II. b - strojna revizija/ulje čajevca

Table 2 Percentage of residual filling material surface by groups
Tablica 2. Postotak površine zaostatnoga punjenja po skupinama

Group • Skupina	N	Mean • Sredina	SD	Minimum	Maximum • Maksimum	Percentiles • Percentile		
						25th	50th	75th
Ia • I. a	15	6.59%	0.60%	2.44%	11.97%	5.29%	6.18%	7.88%
Ib • I. b	15	6.66%	0.56%	3.88%	11.28%	4.35%	6.75%	8.16%
IIa • II. a	15	7.23%	0.52%	3.22%	10.76%	6.30%	7.68%	8.35%
IIb • II. b	15	6.13%	0.51%	2.60%	9.31%	5.29%	6.10%	7.60%

Table legend: Ia-hand retreatment/eucalyptol, Ib-hand retreatment/tea tree oil, IIa-engine driven retreatment/eucalyptol, IIb-engine driven retreatment/tea tree oil •
Legenda: I. a - ručna revizija/eukaliptol, I. b - ručna revizija/ulje čajevca, II. a - strojna revizija/eukaliptol, II. b - strojna revizija/ulje čajevca

Student T test for independent samples showed that there was a statistically significant difference in the retreatment duration between *IIa* and *Ia* (p<0.001), *IIa* and *Ib* (p<0.001), *IIb* and *Ib* (p<0.001), *Ia* and *Ib* (p=0.017) and *IIb* and *Ia* (p<0.001) groups.

Machine retreatment using Reciproc engine-driven instruments was statistically significantly faster compared to the manual retreatment using hand files. Among manually retreated root canals, tea tree oil-treated group was retreated significantly faster.

Residual filling material surface

The percentage of the residual filling material surface by groups is shown in Table 2.

Student T test for independent samples showed that there was no statistically significant differences in the percentage of

Studentov t-test za nezavisne uzorke pokazao je da postoji statistički značajna razlika u vremenu potrebnom za reviziju između skupina *II. a* i *I. a* (p < 0,001), *II. a* i *I. b* (p < 0,001), *II. b* i *I. b* (p < 0,001), *I. a* i *I. b* (p = 0,017) i *II. b* i *I. a* (p < 0,001).

Revizija instrumentima Reciproc statistički je bila znatno brža u usporedbi s ručnom revizijom. Među ručno revidiranim korijenskim kanalima, skupina tretirana čajevcem bila znatno brže revidirana.

Površina zaostatnoga punjenja

Postotak površine zaostaloga materijala za punjenje po skupinama prikazan je u tablici 2.

Studentov t-test za nezavisne uzorke pokazao je da nema statistički značajne razlike u postotku zaostatnoga punjenja

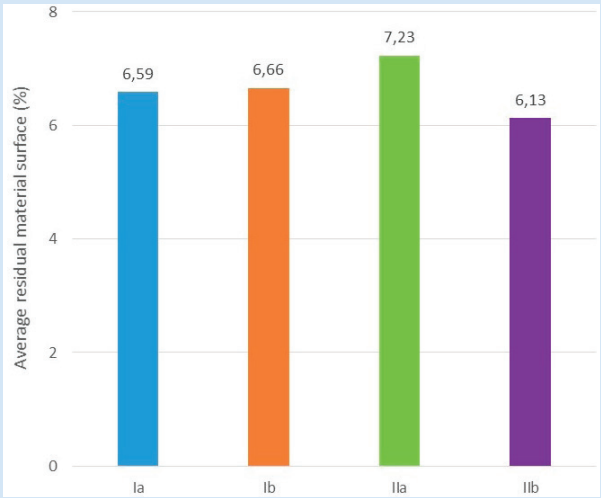

Figure 3 Graphical representation of the average residual filling material surface (%) by groups
Figure legend: Ia-hand retreatment/eucalyptol, Ib-hand retreatment/tea tree oil, IIa-engine driven retreatment/eucalyptol, IIb-engine driven retreatment/tea tree oil
Slika 3. Grafički prikaz prosječne površine zaostatnoga punjenja (%) po skupinama
Legenda: I. a - ručna revizija/eukaliptol, Ib - ručna revizija/ulje čajevca, II. a - strojna revizija/eukaliptol, II. b - strojna revizija/ulje čajevca

residual filling material between *IIa* and *Ia* (p>0.05), *Ia* and *Ib* (p>0.05), *Ia* and *IIb* (p>0.05), *IIa* and *IIb* (p>0.05) and *IIb* and *Ib* (p>0.05) groups.

In all examined specimens, approximately the same filling material surface was left (Figure 3).

Discussion

The aim of this study was to evaluate the retreatment duration and efficacy of eucalyptol and tea tree oil in machine and manual retreatment of epoxy resin based endodontic filling. As there were no statistically significant differences the in area of the remaining filling material among used solvents, nor in applied technique, the first null hypothesis was confirmed. As retreatment with Reciproc instruments was significantly faster compared to retreatment using hand files, and the manual retreatment technique was faster when tea tree essential oil was used as a solvent compared to eucalyptol, the second null hypothesis was rejacted.

When the use of chloroform was forbidden, many studies have been conducted to determine the most effective organic solvent. Because chloroform and xylene have been described as toxic, and halothane (which has been used as an inhalation anesthetic since 1956 for induction of general anesthesia) has low toxicity, is relatively biocompatible and shows unpleasant side effects, the choice of solvent narrows to essential oils (2, 17, 27).

Eucalyptus oil (cineole) is one of the chemical agents that has been advocated for the removal of gutta-percha (2), hence it was used in the present study.

In 1990, Kaplowitz compared the solubility of gutta-percha in five different solvents (purified white turpentine, melaleuca oil, eucalyptus oil, white pine oil, and needle pine oil) with solubility in chloroform and reported that all solvents dissolved at least 50% of the gutta-percha at 37°C during 15 minutes, while chloroform and rectified white turpentine dissolved gutta-percha completely (18). Gorduysus et al. compared the solubility of gutta-percha in halothane, chloroform, xylene, acetone, isopropyl alcohol, turpentine, melaleuca oil, and eucalyptus oil. Halothane, chloroform, and xylene were far more potent solvents for gutta-percha than the remaining agents; eucalyptus oil, melaleuca oil and turpentine were less effective in dissolving gutta-percha; acetone and isopropyl alcohol did not dissolve gutta-percha at all (25).

Zaccaro-Scelza et al. reported no significant differences in dissolving efficacy of chloroform, orange oil and eucalyptol (19). Karlović et al. also reported no significant differences in gutta-percha removal efficacy of eucalyptol and chloroform (17). Yadav et al. evaluated the dissolution effectiveness of eucalyptus oil, orange oil, xylene, and distilled water on endodontic sealers. Their results showed that xylene was the most effective solvent followed by the essential oils (eucalyptus and orange oil) and distilled water the least (20).

According to these studies, the effectiveness of essential oils was the same (17, 19) or slightly lower (18, 20, 25) but biocompatibility, non-carcinogenicity and antiseptic effects are distinct advantages of essential oils (26, 28, 29).

između skupina *II. a* i *I. a* (p > 0,05), I. a i I. b (p > 0,05), *I. a* i *II. b* (p > 0,05), *II. a* i *II. b* (p > 0,05) i *II. b* i *I. b* (p > 0,05).

U svim ispitivanim uzorcima zaostala je približno jednaka površina materijala za punjenje (slika 3.).

Rasprava

Cilj ovog istraživanja bio je procijeniti trajanje revizije i učinkovitost eukaliptola i ulja čajevca pri strojnoj i ručnoj reviziji endodontskoga punjenja na bazi epoksidne smole. Kako nije bilo statistički značajnih razlika ni u površini zaostatnoga punjenja među korištenim otapalima, ni u primijenjenoj tehnici instrumentacije, potvrđena je prva nulta hipoteza. Kako je revizija instrumentima Reciproc bila značajno brža u usporedbi s revizijom ručnim instrumentima, a tehnika ručne instrumentacije bila je brža kada je eterično ulje čajevca korišteno kao otapalo u usporedbi s eukaliptolom, druga nulta hipoteza je odbačena.

Nakon zabrane uporabe kloroforma, učinjena su mnogobrojna istraživanja u svrhu utvrđivanja što učinkovitijega otapala. Budući da su kloroform i ksilen opisani kao toksični, a halotan (koristi se kao inhalacijski anestetik od 1956. za uvođenje u opću anesteziju) ima nisku toksičnost, relativno je biokompatibilan i ima neugodne nuspojave, izbor otapala sužava se na eterična ulja (2, 17, 27).

Ulje eukaliptusa (cineol) jedno je od kemijskih sredstava koje se predlaže za uklanjanje gutaperke (2) te je zato korišteno u ovom istraživanju.

Kaplowitz je 1990. godine usporedio topljivost gutaperke u pet različitih otapala (pročišćeni bijeli terpentin, ulje melaleuke, ulje eukaliptusa, ulje bijeloga bora i ulje igličastoga bora) s topljivosti u kloroformu, te je izvijestio da su, pri temperaturi od 37° Celzijevih i u trajanju od 15 minuta samo kloroform i pročišćeni bijeli terpentin potpuno otopili guraperku, a ostala otapala otopila su najmanje 50 % gutaperke (18). Gorduysus i suradnici uspoređivali su topljivost gutaperke u halotanu, kloroformu, ksilenu, acetonu, izopropilnom alkoholu, terpentinu, ulju melaleuke i ulju eukaliptusa. Halotan, kloroform i ksilen bili su snažnija otapala gutaperke u usporedbi s ostalim sredstvima – ulja eukaliptusaa i melaleuke te terpentin bili su slabije učinkoviti u otapanju gutaperke, a aceton i izopropilni alkohol uopće je nisu otopili (25).

Zaccaro-Scelza i suradnici izvijestili su da nema značajnih razlika u učinkovitosti pri otapanju između kloroforma, ulja naranče i eukaliptola (19). Karlović i suradnici također su istaknuli da nema značajnih razlika u učinkovitosti u uklanjanju gutaperke između eukaliptola i kloroforma (17). Yadav i suradnici procjenjivali su učinkovitost pri otapanju endodontskih punjenja uljem eukaliptusa, uljem naranče, ksilenom i destiliranom vodom. U njihovim rezultatima ksilen se pokazao najučinkovitijim otapalom, zatim su slijedila eterična ulja (eukaliptus i ulje naranče), a najmanje učinkovita bila je destilirana voda (20).

Prema ovim istraživanjima, učinkovitost eteričnih ulja bila je jednaka (17, 19) ili nešto manja (18, 20, 25), ali biokompatibilnost, nekancerogenost i antiseptički učinak izrazite su prednosti eteričnih ulja (26, 28, 29).

In the present study, the time required to remove the endodontic filling material from the root canals of all groups was also measured.

We found a significant difference between the manual and machine retreatment duration regardless to the type of solvent applied (machine-eucalyptol avg. 5:08 minutes/tea tree oil avg. 4:32 minutes, hand-eucalyptol avg. 10:13/tea tree oil avg. 8:25). The results of our study showed that Reciproc machine retreatment was faster than manual, hand retreatment, which is consistent with the results of the study of Zuolo et al. (11).

A significant difference was also found between manual retreatment techniques (manual-eucalyptol avg. 10:13 minutes/tea tree oil avg. 8:25 minutes). Manual retreatment duration was measured by other authors also (17, 24, 30-33). Karlović et al. measured that a manual retreatment with eucalyptol took, on average, 8.14 minutes, while the retreatment with chloroform took 7.18 minutes (17). Zaccaro-Szelza et al. stated that it took them on average about 5 minutes to retreat root canal with hand files using chloroform, orange oil, and eucalyptol (19), while other authors reported a time range of 1.5 to 10.8 minutes (30-33).

Considering our results regarding a higher tea tree oil efficacy in manual retreatment group when compared to eucalyptol, tea tree oil may be considered a better solution in manual retreatment. As stated before, modern engine driven endodontic treatment and retreatment are more effective than manual (5, 6). However, due to the fact that manual instrumentation and retreatment are still methods of choice in many clinical environments worldwide (due to cost or availability), our finding may have clinical implications in the sense of speed and efficacy of manual retreatment.

For the purpose of measuring the residual filling material surface, after retreatment, the samples were split longitudinally and recorded with a camera mounted on a stereomicroscope (Olympus SZX12) under a 15x magnification. The obtained images were transferred to a computer and the areas of residual gutta-percha and sealer were measured by the image processing program (ImageJ). Such a procedure is used in a study of Scelza et al. (19).

Student T test for independent samples showed that there was no statistically significant difference in the percentage of the residual endodontic filling area between manual and machine techniques, nor between the application of tested solvents. However, since the percentage of the residual filling material was the lowest in machine retreatment with tea tree oil (6.13%) and the highest in machine retreatment with eucalyptol (7.23%), it can be concluded that the percentage of removed endodontic filling material in all experimental groups in this study was between 92.77% and 93.87%, which is in line with previous research (17), and represents a very high efficiency of these techniques and solvents. However, the results of this study also confirm the findings of all previous studies that no revision techniques which have been currently applied, can completely remove endodontic filling material from root canals (14, 34, 35).

U ovom istraživanju također je mjereno vrijeme potrebno za uklanjanje endodontskoga punjenja iz korijenskih kanala svih skupina.

Pronašli smo značajnu razliku između vremena potrebnoga za uklanjanje punjenja strojnom tehnikom u usporedbi s ručnom tehnikom, bez obzira na vrstu primijenjenog otapala (strojno – eukaliptol prosječno 5,08 minuta / čajevac prosječno 4,32 minute; ručno – eukaliptol prosječno 10,13, čajevac prosječno 8,25 minuta). Rezultati našeg istraživanja pokazali su da je strojna revizija Reciprocom bila brža od ručne revizije. To je u skladu s istraživanjem Zuola i suradnika (11).

Također je ustanovljena značajna razlika između ručnih tehnika revizije (ručno – eukaliptol prosječno 10,13 minuta; ulje čajevca prosječno 8,25 minuta). Trajanje ručne revizije mjerili su i drugi autori (17, 24, 30 – 33). Karlović i suradnici izmjerili su da je za ručnu reviziju s eukaliptolom prosječno trebalo 8,14 minuta, a za reviziju s kloroformom trebalo je 7,18 minuta (17). Zaccaro-Szelza i suradnici ističu da im je u prosjeku trebalo 5 minuta za reviziju ručnim instrumentima s pomoću kloroforma, ulja naranče i eukaliptola (19), a drugi autori navode raspon od 1,5 do 10,8 minuta (30 – 33).

Uzimajući u obzir da su naši rezultati pokazali veću učinkovitost ulja čajevca u skupini ručne revizije u usporedbi s eukaliptolom, može ga se predložiti kao bolji izbor za ručnu reviziju. Kao što je već navedeno, moderno strojno endodontsko liječenje i revizija učinkovitiji su od ručnoga (5, 6). No zbog činjenice da je ručna instrumentacija i revizija još uvijek metoda izbora u mnogim kliničkim praksama diljem svijeta (zbog cijene ili dostupnosti), naš nalaz može imati kliničke implikacije u smislu brzine i učinkovitosti ručne revizije.

U svrhu izračuna površine punjenja zaostaloga u korijenskim kanalima, nakon revizije uzorci su uzdužno razrezani i snimljeni kamerom montiranom na stereomikroskop (Olympus SZX12) pod povećanjem od 15 puta. Dobivene slike prenesene su na računalo te su površine zaostale gutaperke i paste izmjerene računalnim programom ImageJ, što je u skladu s istraživanjem Scelze i suradnika (19).

Studentov t-test za nezavisne uzorke pokazao je da nema statistički značajne razlike u postotku površine zaostaloga endodontskoga punjenja ni između ručnih i strojnih tehnika, ni između primjene različitih otapala. No budući da je postotak zaostatnoga punjenja bio najmanji kod strojne revizije uz primjenu čajevca (6,13 %), a najviši kod strojne revizije uz primjenu eukaliptola (7,23 %), može se zaključiti da je postotak uklonjenoga endodontskoga punjenja u svim eksperimentalnim skupinama u ovom istraživanju iznosio između 92,77 % i 93,87 %, što je u skladu s ranijim istraživanjima (17) i pokazuje vrlo visoku učinkovitost navedenih tehnika i otapala. Međutim, rezultati ovog istraživanja također potvrđuju nalaze svih dosadašnjih istraživanja da se ni jednom tehnikom revizije, koje se trenutačno primjenjuju, ne može potpuno ukloniti endodontsko punjenje iz korijenskih kanala (14, 34, 35).

Conclusions

Since there is no significant difference in percentage of the residual filling material regardless of the retreatment technique and different solvents used, we have concluded that essential oils, Australian tea tree oil and eucalyptus oil are equally effective in removing endodontic filling material.

Retreatment with Reciproc instruments is significantly faster compared to retreatment using hand files. On the other hand, the manual retreatment technique is faster when tea tree essential oil is used as a solvent compared to eucalyptol.

Zaključak

Budući da nema značajne razlike u postotku zaostatnoga punjenja neovisno o primijenjenoj tehnici revizije i različitim otapalima, zaključujemo da su eterična ulja – ulje australskoga čajevca i ulje eukaliptusa jednako učinkovita u uklanjanju endodontskoga materijala za punjenje.

Revizija instrumentima Reciproc znatno je brža u usporedbi s ručnima. S druge strane, recipročna tehnika revizije brža je kada se kao otapalo koristi eterično ulje čajevca u usporedbi s eukaliptolom.

Funding Information

This study is funded by Croatian Science Foundation, „Investigation and development of new micro and nanostructure bioactive materials in dental medicine„; BIODENTMED No. IP-2018-01-1719.

Zahvala

Ovo istraživanje financirala je Hrvatska zaklada za znanost – „Istraživanje i razvoj novih mikro i nanostrukturnih bioaktivnih materijala u dentalnoj medicini“; BIODENTMED broj IP-2018-01-1719.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Izjava o dostupnosti podataka

Podatci koji podupiru nalaze iz ovog istraživanja mogu se od autora dobiti na zahtjev.

Conflict of interest

The authors declare no conflict of interest related to this study.

Sukob interesa

Autori nisu bili u sukobu interesa.

Author Contributions: **A.K., N.G.** - have contributed substantially to the concept and design of the study and to the acquisition of data; **J.M.** has analyzed and interpreted the data; **A.K., P.D., J.M., D.J.K.** and **N.G.** have performed the literature search, and wrote the manuscript. They have also revised the manuscript critically for important intellectual content, and all authors have read and agreed with published version of the manuscript.

Doprinos autora: **A. K.** i **N. G.** – znatno su pridonijele konceptu i dizajnu studije te prikupljanju podataka; **J. M.** – analizirao je i interpretirao podatke; **A. K., P. D., J. M., D. J. K.** i **N. G.** – pretraživali literaturu i pisali tekst, kritički su revidirali rukopis. Svi su autori pročitali tekst i pristali na objavljenu verziju.

Sažetak

Uvod: Svrha ovog istraživanja bila je procijeniti trajanje revizije i učinkovitost eukaliptola i ulja čajevca pri strojnoj i ručnoj reviziji endodontskoga punjenja baziranoga na epoksidnoj smoli na izvađenim ljudskim zubima. **Materijali i metode:** U dvije skupine nasumično je podijeljeno 60 ljudskih jednokorijenskih zuba. Prva je pripremljena ručnim instrumentima, a druga s pomoću sustava Reciproc. Korijenski kanali punjeni su štapićima od gutaperke i pastom AH Plus. U prvoj skupini revizija je rađena proširivačima i instrumentima Hedström, a u drugoj skupini instrumentima Reciproc. Svaka skupina podijeljena je u dvije podskupine (n = 15) s obzirom na korišteno otapalo za reviziju (eukaliptol ili ulje čajevca). Korijenski kanali uzdužno su razrezani i analizirani stereomikroskopom (povećanje 15 x). Površina zaostatnoga materijala za punjenje izmjerena je u računalnom programu za obradu slike. **Rezultati:** Nije bilo statistički značajnih razlika u površini zaostatnoga punjenja ni među korištenim otapalima, ni u primijenjenoj tehnici. Revizija učinjena instrumentima Reciproc bila je znatno brža u usporedbi s revizijom ručnim instrumentima. Revizija ručnim instrumentima, u usporedbi s eukaliptolom, bila je brža kada se kao otapalo koristilo eterično ulje čajevca. **Zaključak:** Australsko ulje čajevca i ulje eukaliptusa bili su podjednako učinkoviti u uklanjanju endodontskoga punjenja, ali ni jedan kanal nije bio potpuno očišćen od zaostaloga materijala za punjenje. Revizija instrumentima Reciproc bila je brža u usporedbi s revizijom ručnim instrumentima. Revizija ručnim instrumentima bila je brža kada se eterično ulje čajevca koristilo kao otapalo u usporedbi s eukaliptolom.

Zaprimljen: 4. prosinca 2021.
Prihvaćen: 20. veljače 2022.

Adresa za dopisivanje
Petra Dijanić
Školska 11, 10410 Velika Gorica, Hrvatska
tel: 0915688785
petradumlija@gmail.com

MeSH pojmovi: punjenje korijenskog kanala; sredstva za ispiranje korijenskog kanala; eukaliptol; ulje čajevca
Autorske ključne riječi: revizija u endodonciji, recipročni instrument, ručna instrumentacija

References

1. Torabinejad M, Walton RE, editors. Endodoncija: Načela i praksa. 4 th ed. Zagreb: Naklada Slap; 2009.
2. Ingle JI, Bakland LK, editors. Endodontics. 5th ed. Hamilton: BC Decker Inc; 2002.
3. Cohen S, Hargeaves KM, editors. Pathways of the pulp. 9th ed. St Louis: Mosby; 2006.
4. Bhandi S, Mashyakhy M, Abumelha AS. Complete Obturation-Cold Lateral Condensation vs. Thermoplastic Techniques: A Systematic Review of Micro-CT Studies. Materials (Basel). 2021 Jul 18;14(14):4013.
5. Bhandi S, Seracchiani M, Donfrancesco O, Reda R, Mazzoni A, Nottola S, et al. Nickel-Titanium Rotary Instruments: An In Vitro Comparison (Torsional Resistance of Two Heat-treated Reciprocating Files). J Contemp Dent Pract. 2021;22(4):361-364.
6. Seracchiani M, Donfrancesco O, Relucenti M, Reda R, Zanza A, Gambarini G, et al. In Vitro Evaluation of a Recently Developed Rotary File: AF Rotary. Braz Dent Sci. 2021;24(4).
7. Hulsmann M, Bluhm V. Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment. Int Endod J. 2004 Jul;37(7):468-76.

8. Masiero AV, Barletta FB. Effectiveness of different techniques for removing gutta-percha during retreatment. Int Endod J. 2005 Jan;38(1):2-7.
9. Preetam CS, Chandrashekhar M, Gunaranjan T, Kumar SK, Miskeen Sahib SA, Kumar MS. A comparative evaluation of two rotary Ni-Ti instruments in the removal of gutta-percha during retreatment. J Int Soc Prev Community Dent. 2016 Aug;6(Suppl 2):S131-6.
10. Gergi R, Sabbagh C. Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an ex vivo study. Int Endod J. 2007 Jul;40(7):532-7.
11. Zuolo AS, Mello JE, Jr., Cunha RS, Zuolo ML, Bueno CE. Efficacy of reciprocating and rotary techniques for removing filling material during root canal retreatment. Int Endod J. 2013 Oct;46(10):947-53.
12. Rios Mde A, Villela AM, Cunha RS, Velasco RC, De Martin AS, Kato AS, Bueno CE. Efficacy of 2 reciprocating systems compared with a rotary retreatment system for guttapercha removal. J Endod. 2014 Apr;40(4):543-6.
13. Silva EJ, Orlowsky NB, Herrera DR, Machado R, Krebs RL, Coutinho-Filho Tde S. Effectiveness of rotatory and reciprocating movements in root canal filling material removal. Braz Oral Res. 2015;29:1-6.
14. Crozeta BM, Silva-Sousa YT, Leoni GB, Mazzi-Chaves JF, Fantinato T, Baratto-Filho F, et al. Micro-Computed Tomography Study of Filling Material Removal from Oval-shaped Canals by Using Rotary, Reciprocating, and Adaptive Motion Systems. J Endod. 2016 May;42(5):793-7.
15. Carvalho NK, Alvares GR, Sassona LM, Krebs LR, de Souza Coutinho-Filho T, da Silva EJNL. A comparative evaluation of efficacy of a reciprocating system for gutta-percha removal with or without solvent. Rev Bras Odontol. 2017;74(3):210-4.
16. Mounce R. Current concepts in gutta-percha removal in endodontic retreatment. N Y State Dent J. Aug-Sep 2004;70(7):32-5.
17. Karlović Z, Anić I, Azinović Z, Maršan T, Miletić I, Ciglar I. Endodontic retreatment with eucalyptol and chloroform solvent. Acta Stomatol Croat. 1998;32(3):405-407.
18. Kaplowitz GJ. Evaluation of Gutta-percha solvents. J Endod. 1990 Nov;16(11):539-40.
19. Scelza MF, Coil JM, Maciel AC, Oliveira LR, Scelza P. Comparative SEM evaluation of three solvents used in endodontic retreatment: an ex vivo study. J Appl Oral Sci. Jan-Feb 2008;16(1):24-9.
20. Yadav HK, Yadav RK, Chandra A, Thakkar RR. The effectiveness of eucalyptus oil, orange oil, and xilene in dissolving different endodontic sealers. J Conserv Dent. Jul-Aug 2016;19(4):332-7.
21. Rached-Junior FA, Sousa-Neto MD, Bruniera JF, Duarte MA, Silva-Sousa YT. Confocal microscopy assessment of filling material remaining on root canal walls after retreatment. Int Endod J. 2014;47(3):264-70.
22. International Agency Research of Cancer. IARC monographs on the evaluation of carcinogenic risk to humans. Int Agency Res Cancer. 1987;7:152-4.
23. Karlović Z, Anić I, Miletić I, Prpić-Mehičić G, Pezelj-Ribarić S, Maršan T. Antibacterial Activity of Halothane, Eucalyptol and Orange Oil. Acta Stomatol Croat. 2000;34(3):307-309.
24. Schnitzler P, Schön K, Reichling J. Antiviral activity of Australian tea tree oil and eucalyptus oil against herpes simplex virus in cell culture. Pharmazie. 2001 Apr;56(4):343-7.
25. Gorduysus MO, Tasman F, Tuncer S, Etikan I. Solubilizing efficiency of different gutta-percha solvents: a comparative study. J Nihon Univ Sch Dent. 1997 Sep;39(3):133-5.
26. Carson CF, Hammer KA, Riley TV. Melaleuca alternifolia (tea tree) oil: a review of antimicrobial and other medicinal properties. Clin Microbiol Rev. 2006 Jan;19(1):50-62.
27. Wilcox LR. Endodontic retreatment with halothane versus chloroform solvent. J Endod. 1995 Jun;21(6):305-7.
28. Bowls J. Eterična ulja. Zagreb: Veble commerce; 2012.
29. Johann JE, Marots J, Silveria LFM, Del Pino FAB. Use of organic solvents in endodontics: a review. Clin Pesq Odontol Curitiba. 2006;5(6):393-9.
30. Ezzie E, Fleury A, Solomon E, Spears R, He J. Efficacy of retreatment techniques for a resin-based root canal obturation material. J Endod. 2006;32(4):341-4.
31. Moshonov J, Trope M, Friedman S. Retreatment efficacy 3 months after obturation using glass ionomer cement, zinc oxide-eugenol, and epoxy resin sealers. J Endod. 1994 Feb;20(2):90-2.
32. Oliveira DP, Barbizam JVB, Trope M, Texeira B. Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment. J Endod. 2006 Apr;32(4):362-4.
33. Whitworth JM, Boursin EM. Dissolution of root canal sealer cements in volatile solvents. Int Endod J. 2000;33(1):19-24.
34. Simsek N, Keles A, Ahmetoglu F, Ocak MS, Yologlu S. Comparison of different retreatment techniques and root canal sealers: a scanning electron microscopic study. Braz Oral Res. 2014;28:S1806-83242014000100221.
35. Kim H, Kim E, Lee SJ, Shin SJ. Comparison of the retreatment efficacy of calcium silicate and epoxy resin-based sealers and residual sealer in dentinal tubules. J Endod. 2015 Dec;41(12):2025-30.