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

Procjena učinkovitosti različitih otapala pri reviziji endodontskoga punjenja na ekstrahiranim zubima

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 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 necessary for formation of a leakproof barrier between the gutta-percha and the walls of root canal (4). Retreatment of this type

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 longitudinally split and analyzed 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.

Revizija endodontskoga punjenja indicirana je u slučaju neuspješnoga primarnog endodontskoga liječenja (1, 2). Glavna svrha revizije je uspostava uvjeta koji će omogućiti cijeljenje periapikalnog procesa. To podrazumijeva uklanjanje neadekvatnoga punjenja, čišćenje korijenskih kanala i novo punjenje te restauraciju koja će zabritviti putove rubnoga propuštanja u endodontski prostor iz usne šupljine, periapikalnoga i periradikularnoga područja. Pravilnim trodimenzionimalnim i kompaktnim punjenjem brtve se i svi podržajni čimbenici koji nisu uklonjeni tijekom čišćenja unutar korijenskih kanala, što onemogućuje njihov otpadan 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 significant 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 - melaleuca 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).
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.D. d.o.o., Sveta Nedelja, 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% ethylendiamintetraacetic 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 eukaliphtusa (Eucalyptus globulus) i ulja australskoga čajnoga drva (Melaleuca alternifolia) pri ručnoj (Kerr proširivači i Hedström pilice) i strojnoj (Reciproc) tehnič revizije. Prva nulta hipoteza istraživanja bila je da nema značajne razlike u učinkovitosti pri otapanju korijenskoga punjenja eteričnim uljem eukaliphtusa i uljem australskoga čajevca tijekom ručne i strojne tehnike revizije.

Drug nulta hipoteza istraživanja glasila je da nema značajne razlike u vremenu potrebnom za uklanjanje korijenskog punjenja eteričnim uljem eukaliphtusa 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. Eticke povjerenstvo više odobrava istraživanja u kojima je metoda revizije istrogom postupkom određenije troškova.

Za potrebe istraživanja korišteni su trajni maksičarni i mandibularni ljudski zubi potpuno razvijeni koji su bili ukljenjeni iz zubne zaleđenosti. Zubi su suđeni u zavodu za oralnu kirurgiju Stomatološkog fakulteta Sveučilišta u Zagrebu. Nakon uklanjanja zubne zaleđenosti, zubi su isprani 5 septum 15 ml vazeline. Zubi su prvo sterilizirani uz pomoc sterilizatora.

Uzorci su sterilizirani u autoclavi.

Trepanacijski otvori su izvršeni na lateralnim zubima uz uključenje mandibularnih zuba. Uzorci su prvo stabilizirani uz pomoc sterilizatora. Oprema za uključenje na lateralnim zubima uzorci su stabilizirani uz pomoc sterilizatora.

Zubi su suđeni u zavodu za oralnu kirurgiju Stomatološkog fakulteta Sveučilišta u Zagrebu.
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. The filling was additionally condensed in the vertical direction.

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 (la and lb)
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 (lla and llb)
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 papiritim 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, aplikiran je u kanal do prije izmjere duljine te je lateralno i apikalno potisnut ručnim raširivačem #25 (engl. Spreader), čime je stvoren prostor za dodatni štapić gutaperke odgovarajućeg veličine. Dodatni štapići obloženi pastom, ponovno su unošeni u kanal sve dok se raširivačem nije moglo prodrijet 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 iriganima kao i u skupini I. Poslije sušenja papiritim 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 uzori pohranjeni u fiziološkoj otopini u termostatu pri temperaturi od 37 °C.

Revizija
Nakon sedam dana uzori 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) oznacene slovima a i b. Podskupina a tretirana je eukaliptolom, a podskupina b čajevcem.

Skupina I. (l.a i l.b)
Za reviziju prve skupine korišteni su ručni instrumenti. Nakon primjene jednog millilitra otapala, okretanjem proširivača #15 u smjeru kalajlcke na satu za 120°, uz lagani apikalni pritisak, izrađen je put za otapalo, a plicama Hedströma jednake veličine uklonjena je omekšala gutaperka. Veličina instrumenta 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 papiritim štapićima.

Skupina II. (l.b i l.b)
Druga skupina revidirana je strojno instrumentima Reciproc, slijedeci protokol proizvođača. Nakon unošenja jedne do dvije kapi otapala u već izrađeni spremnik na ulazu korijenskog kanala instrumentom R25, uz lagani pritisak pre-
ment was used with light pressure towards the apical and “in-side - 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 “in-side - 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 analyzed 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.

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 Ia (dolje lijevo), Ib (gore lijevo), IIa (gore desno), IIb (dolje desno).

Legenda: Ia - ručna revizija/eukaliptol, Ib - ručna revizija/ulje čajevca, IIa - strojna revizija/eukaliptol, IIb - 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: Ia - ručna revizija/eukaliptol, Ib - ručna revizija/ulje čajevca, IIa - strojna revizija/eukaliptol, IIb - strojna revizija/ulje čajevca.

Rezultati

Statistička obrada podataka

Nakon revizije uzorci su uzdužno razrezani i snimljeni kamerom montiranim 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 obradjeni 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.
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), IIIa and IIIb (p<0.001), IIa and Ib (p<0.001), Ia and Ib (p=0.017) and IIb and Ib (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

Table 1

| Group • Skupina | N | Mean • Sredina | SD | Minimum | Maximum • Maksimum | Percentiles • Percentile |
|-----------------|---|----------------|----|---------|---------------------|-------------------------|
| 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         |
| IIIa • II. a    | 15| 5.08           | 0.20| 2:30    | 6:55                | 4:15 5:10 6:05          |
| IIIb • 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, IIIa - engine driven retreatment/eucalyptol, IIIb-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

| Group • Skupina | N | Mean • Sredina | SD | Minimum | Maximum • Maksimum | Percentiles • Percentile |
|-----------------|---|----------------|----|---------|---------------------|-------------------------|
| 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%        |
| IIIa • II. a    | 15| 7.23%          | 0.52%| 3.22%   | 10.76%              | 6.30% 7.68% 8.35%        |
| IIIb • 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, IIIa-engine driven retreatment/eucalyptol, IIIb-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

Studentov t-test za nezavisne uzorke pokazao je da postoje statistički značajna razlike u vremenu potrebnom za reviziju između skupina II. a i I. a (p < 0,001), II. a i I. b (p < 0,001), III. a i I. b (p < 0,001), I. a i I. b (p = 0,017) i III. 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 je znatno brže revidirana.

Postotak površine zaostatnoga punjenja

Postotak površine zaostatnog 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 zaostatnog punjenja
residual filling material between IIa and Ia (p > 0.05), Ia and Ib (p > 0.05), Ia and IIb (p > 0.05), Ila and IIb (p > 0.05) and IIIa and IIIb (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 rejected.

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). Karlovich 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 antisepctic effects are distinct advantages of essential oils (26, 28, 29).

Rasprava

Cilj ovog istraživanja bio je procijeniti trajanje revizije i učinkovitost eukaliptola i ulja čajevca pri strojnoj i ručnoj reviziji endodontskoga punjenja na bazi epoksidske smole. Kako nije bilo statistički značajnih razlika ni u površini zastatnoga 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, dru- ga nulta hipoteza je odbačena.

Nakon zbране uporabе kloroформа, учинена су многоброjна истраживања у сврху утврђивања што уточиштевиога ота- пала. Будући да су kloroформ и ksilеn opisani као tоксиčни, a halotan (koristi se као inhalacijski anestetik od 1956. za uvo- đenje u опу anesteziju) ima niku tоксиčност, relativno je bi- okompatible и ima неugodне нуспојаве, избор отапал ов- зава se на етерична ulja (2, 17, 27).

Ulje eukaliptusa (cineol) jedno je од кемијских средстава које se предлађe за уklanjaњe gutaperke (2) te je zato korište- no u ovom istraživanju.

Kaplowitz je 1990. godine usporedio topljivost gutaperke у pet različitih otapala (pročišćeni bijeli terpentin, ulje melaleuke, ulje eukaliptusa, ulje bijelog bora i ulje igličastog bora) с topljivosti u kloroформу, te je izvijestio da su, при тем- peraturи од 37° Cležijevih и u trajanju од 15 minuta само kloroформ и pročišćeni bijeli terpentin potpuno otopili gutaperku, a ostala otapala otopila су најмање 50 % gutaperke (18). Gorduysus и suradnici uspoređivali су topljivost gutaperke у haloтану, kloroформу, ksilenu, acetonu, izopropil- nom alkoholu, terpentinu, ulje melaleuke и ulje eukaliptusa. Halotan, kloroform и ksilеn били су најмања оtopила gutaperke у usporedbi с осталим сredstvома – ulja eukaliptusa и melalе- uke ter pentin bили су slabije уткоинковити у otapanju gutaperke, a aceton и izopropilni alkohol uopće je nisu otopili (25).

Zaccaro-Scelza и suradnici izvijestili су da nema značajних razlika u učinkovitosti при otapanju између kloroформа, ulja narančе и eukaliptola (19). Karlovich i suradnici također su istaknuli da nema značajnih razlika u učinkovitости u uklanja- nju gutaperke између eukaliptola и kloroформа (17). Yadav и suradnici procjenjivali su učinkovitost при otapanju endo- dostnih punjenja uljem eukaliptusa, uljem narančе, ksilеn- nom и destiliranom vodom. U њиховим резултатима ksilеn se pokazao najуčinkовитијим otapalom, zatim су slijedila etери- na ulja (eukaliptus и ulje нaranчe), a najmanje учinkovita bila je destilirana voda (20).

Prema ovim istraživanjima, уткоинковитост etеричних ulja bi- la je jednaka (17, 19) или нешто manja (18, 20, 25), ali bio- kompatibilnost, nekancerogenost и антисеptички учинак izrazi- te су предности etеричних ulja (26, 28, 29).
Otapala za reviziju korijenskih kanala

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. 10:13 minutes/tea tree oil avg. 8:25 minutes). 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 mjerenje vrijeme potrebno za uklanjanje endodontskoga punjenja iz korijenskih kanala svih skupina.

Pronašli smo značajnu razliku između vremena potrebno-ga za uklanjanje punjenja stojeonom 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 Reciprocima 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, ulje 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 stoje-ndošksto 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 di-ljem svijeta (zbog cijene ili dostupnosti), naš nalaz može ima-ti kliničke implikacije u smislu brzine i učinkovitosti ručne revizije.

U svrhu izračuna površine punjenja zaостalog na kori-jenskim kanalima, nakon revizije uzorci su uzdužno razrezani i snimljeni kamerom montiranim na stereomikroskop (Olym-pus SZX12) pod povećanjem od 15 puta. Dobivene slike pre-nesene su na računalo te su površine zaostale gutaperke i pa- ste 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 zaosta-loga endodontskog punjenja ni između ručnih i stoje-njih tehnika, ni između primjene različitih otapala. No budući da je po-stotak zaostatnoga punjenja bio najmanji kod strojne revizi-je uz primjenu čajevca (6,13 %), i najviši kod strojne revizi-je uz primjenu eukaliptola (7,23 %), može se zaključiti da je postotak uklonjenoga endodontskoga punjenja u svim ekspe-rimentalnim 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.

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Data Availability Statement

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

Conflict of interest

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

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.

Zaključak

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

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

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

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