ORIGINAL ARTICLE
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DOI: https://doi.org/10.2298/SGS2002091V
UDC: 616.314.14-089.48-06

Apical extrusion of root canal filling material during the removal of gutta-percha and resilon

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SUMMARY

Introduction Root canal filling material may be extruded during retreatment through the apical foramen and cause flare-up or chronic infection. The aim of this study was to compare the apical extrusion of gutta-percha and resilon filling materials during retreatment using hand and rotary instruments.

Methods Sixty extracted single-rooted teeth with single, straight canal were selected. Canals were prepared with ProTaper Universal rotary system to a size F2. Two groups (30 teeth in each) were filled with gutta-percha or resilon points, respectively. In both groups teeth were randomly divided into the three subgroups (10 teeth in each), based on the instruments used for retreatment: Hedstrom hand files and two rotary groups- ProTaper and Twisted File instruments. Apical extrusion was detected visually, using a 4-degree scoring system. Mean scores were calculated and analyzed statistically (*t*-test and ANOVA). The level of significance was set at $p < 0.05$.

Results Under tested experimental conditions, the type of canal filling material did not have significant effect on the results of apical extrusion during retreatment. Significantly more material was extruded in the resilon group when manual, Hedstrom file was used (1.80 ± 1.13) than rotary ProTaper (0.60 ± 0.70) and Twisted File (0.50 ± 0.71).

Conclusions The use of a rotary technique is recomended to minimize apical extrusion, especially when resilon obturation material is removed during retreatment.

Keywords: apical extrusion; gutta-percha; resilon; retreatment; root canal obturation; rotary instruments

INTRODUCTION

Non-surgical retreatment is often indicated as the first choice to eliminate or reduce persistent microbial infection of the root canal system. During this procedure, thorough removal of filling material is an important factor, since it enables adequate chemo-mechanical instrumentation and disinfection of the root canal system, in order to reestablish healthy periapical tissues [1]. One inherent problem related to all root canal treatment procedures is the extrusion of intracanal debris and irrigants through the apical foramen into the periapical tissue that could result in inflammation even infection, as both may be contaminated with microorganisms. This could lead to an interappointment flare-up, postoperative pain, delayed healing or even treatment failure as an undesirable occurrence, both for patient and practitioner [1, 2].

It is generally accepted that none of the currently available instruments and techniques can prepare root canals or remove root-filling material without producing apical extrusion. However, selecting the appropriate retreatment technique could minimize the risk of apical extrusion, even though it may not be prevented [3–6]. During mechanical instrumentation, the number and virulence of extruded microorganisms are decisive and critical factors that determine the extent of the periradicular reaction [6]. Although this qualitative factor is not under the control of the practitioner, selecting techniques such as crown-down instrumentation to provide a gradual approach to the apical end is important. This allows the control of the amount of irritants extruded periapically [2]. One of the major tasks of dental practitioner during root canal treatment procedures is to use instruments and techniques that minimize the amount of apically extruded debris in order to avoid or minimize irritation of the periapical tissues [6, 7]. The most often used hand files for retreatment are the Hedstrom files. Recently, several nickel-titanium (NiTi) rotary instruments have been specially designed to remove obturation material. The Protaper Universal Retreatment system (Dentsply, Maillefer, Ballaigues, Switzerland) contains three instruments with various tapers and tip diameters: D1 (size 30/.09 taper), D2 (size 25/.08 taper) and D3 (size 20/.07 taper). Also, a new type of instruments-Twisted File (SybronEndo, Orange, CA, USA) has become available, but it has not been specially designed for the removal of obturation materials. The Twisted File system has been developed through a specific manufacturing process [8]. These files have twisted design, not ground surface treatment, triangular cross-section, variable pitch and safe-ended tip that allow their use in retreatment cases. The manufacturer claims that Twisted Files can be used to remove obturation materials. To the

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author`s knowledge, no studies are present in the current literature on the apical extrusion of gutta-percha and resilon during their removal with Twisted Files and only one study evaluated the cleaning efficacy of Twisted File instruments in retreatment procedures [9].

Until now, several materials have been used to fill root canals, with gutta-percha being the most popular. However, gutta-percha has two major drawbacks: no adhesion to the canal walls and inability to strengthen the teeth [9]. Recently, a new obturation material has been developed that has some properties similar to gutta-percha. Resilon (Resilon Research LLC, Madison, CT, USA) is a thermoplastic synthetic polymer-based root filling material that bonds to dentinal walls when used in conjunction with an adhesive root canal sealer (Epiphany/Real Seal) and forms a "monoblock" within the canal [10]. The retreatment efficacy of this material has been examined, although not in such extent as gutta-percha, while the apical extrusion during resilon removal has been examined in two studies only [11, 12].

The aim of this study was to compare *in vitro* the influence of different filling materials (gutta-percha and resilon) and different instruments (Hedstrom files, ProTaper Retreatment and Twisted Files) on the degree of apically extruded debris during retreatment.

METHODS

Teeth selection and preparation

Sixty extracted single-rooted teeth with single, straight canals without previous root canal treatment and with completely developed root apices were selected. To standardize specimen lengths, all teeth were shortened to 16 mm by removing the crown (with a fissure diamond bur in a high-speed handpiece under copious water cooling). After the root canal orifice was identified, canal patency was confirmed with a size 10 K-file (Senseus FlexoReamer, Dentsply, Maillefer, Ballaigues, Switzerland) until it was visible at the apical foramen. Working length was determined 1 mm short from the observed length. Primary root canal preparation was performed with a NiTi rotary system-ProTaper Universal (Dentsply, Maillefer, Switzerland). Canals were enlarged in a crown-down technique to a size 25 (F2) at working length, for all teeth. Canal irrigation was performed between each successive instrument with 2 ml of 5.25% sodium hypochlorite (NaOCl). Before obturation, a final rinse was performed with 10% citric acid for 1 minute, to remove smear layer, followed by a rinse with 10 ml of distilled water. The teeth were randomly divided into 2 groups of thirty teeth each (n = 30). After drying with paper points, all root canals were filled using cold lateral compaction technique. One group was filled with gutta-percha points (Protaper Universal F2, Dentsply, Maillefer, Switzerland) and an epoxy sealer (AHplus, Dentsply, Detrey GmbH, Germany); the other group was filled with resilon points (Resilon Research LLC, Madison, CT) and an adhesive, methacrylate sealer (RealSeal, Root Canal Sealant, SybronEndo, Kerr Corporation, USA). Additional warm vertical compaction of the obturation material was carried out with pluggers. The coronal surface of the resilon group was light cured for 40 seconds, according to the manufacturer's instruction. Total length of the root canal fillings did not exceed more than 15 mm, so the volume of filling material was approximately equal for all specimens. Obturation quality was confirmed radiographically, in buccolingual and mesiodistal directions. Access openings were sealed with a temporary filling material (Citodur, Dorident, Austria) and samples were stored at 37°C in 100% humidity for 14 days, to allow for complete setting of the sealer.

Retreatment methods

Before beginning the retreatment procedure, teeth from both groups (n = 30) were randomly divided into the three groups of ten teeth each, based on the instruments used for retreatment. Each set of instruments was used to retreat maximally 5 root canals and after that discarded. All instruments were used respecting the manufacturer's instructions. Rotary instruments were used with an endodontic electric motor (X-Smart, Dentsply, Maillefer, Ballaigues, Switzerland) in a crown-down sequence.

In the group 1, hand instrumentation was performed with Hedstrom files (Senseus Hedstroem Dentsply, Maillefer, Switzerland) from size 40–20, in a circumferential quarter-turn push-pull motion and by pushing against the root canal walls until working length was reached. Re-preparation of the canal apical part was carried out with Hedstrom files from size 20 to size 40. In group 2, ProTaper Retreatment instruments (Dentsply, Maillefer, Switzerland) were applied, using D1 file to remove filling material from the coronal portion of the root canal, whereas the material from the middle and the apical third was removed using D2 and D3 files, respectively, using a brushing action with lateral pressing movements. D3 was taken to the working length. After that, ProTaper Universal files size F3 (#30) and F4 (#40) were used, to enlarge the apical preparation. In group 3, Twisted File (TF) instruments (SybronEndo, CA, USA) were used in the following sequence: TF #25/.08 taper instrument was applied in the coronal third and followed by #30 and #35/.06 taper instruments, until reaching the working length. Then, TF #40/.04 was used to enlarge the apical portion of the canal and again TF #25/.08 to additionally clean the canal walls.

During retreatment, the flutes of all instruments were frequently cleaned and 2 ml of 5.25% NaOCl was used after each instrument and also for final irrigation of the canal. Material removal was considered complete when the working length was reached and no more material could be seen on the last instrument and during irrigation. After re-preparation, the canals were irrigated with 10% citric acid for one minute, to remove the smear layer. The canals were finally flushed with 10 ml of distilled water. The same operator performed primary root canal preparation, obturation and retreatment and the procedure was done in the same manner for all samples.

Apically extruded debris

The amount of apically extruded material during the retreatment procedure was detected visually. A different person who was blinded to the experimental group assignment performed scoring of apically extruded debris. The following score system was used [3, 11] :

0 – no extruded debris, no filling material escaping through the foramen

1 – minimal extruded debris, small amounts of filling material escaping through the foramen

2 – moderate extruded debris, greater amounts of filling material escaping through the foramen

3 – severe extruded debris, even greater amounts of filling material escaping through the foramen.

Statistical analysis

The obtained data are presented in tables and numerically processed by standard descriptive methods. Mean scores of apically extruded material were calculated. The data were analyzed statistically by t-test and one-way analysis of variance (ANOVA). Analysis was performed with SPSS (version 20) at a significance level $p < 0.05$.

RESULTS

The mean scores and standard deviations (SD) of apical extrusion for each group of material and for each group of tested instruments are presented in Table 1 and 2. The results indicated that in both groups of materials, all of the tested instruments caused apical debris extrusion at some degree. Comparison by t-test of the mean scores for apical extrusion during gutta-percha and resilon removal (Table 1) did not showed statistically significant differences between the two materials (p=0.101). The highest mean score for apical extrusion (Table 2) was present in the resilon group of material during retreatment with Hedstrom files (1.80±1.13), while the samples that showed the lowest mean score were observed in the gutta-percha group of material when Twisted File instruments were used (0.11 ± 0.33). The difference between these two results was statistically significant (ANOVA, Post Hoc; p = 0.027). Analysis of the results by ANOVA in both groups of materials revealed statistically significant differences between instruments only during resilon removal (p = 0.004; Table 2). Further statistical analysis with Post Hoc tests indicated that the difference was significant between manual Hedstrom files (1.80 ± 1.13) and the two rotary instruments used, ProTaper (0.60 ± 0.70) and Twisted File (0.50 ± 0.71).

Table 1. Mean scores of apically extruded material during retreatment of gutta-percha and resilon
Tabela 1. Srednje vrednosti rezultata apikalno ekstrudiranog materijala tokom retretmana gutaperke i resilona

Material Materijal	N	Mean Srednja vrednost	SD	SE
Gutta-percha Gutaperka	29*	0.55	0.87	0.16
Resilon Resilon	30	0.97	1.03	0.19

* One sample was discarded because of a ledge formation during retreatment with Twisted File instruments.
* Jedan uzorak je odbačen zbog formiranja stepenika tokom retretmana instrumentima Twisted File.

Table 2. Mean scores of apically extruded material during retreatment of gutta-percha and resilon with different instruments
Tabela 2. Srednje vrednosti rezultata apikalno ekstrudiranog materijala tokom retretmana gutaperke i resilona različitim instrumentima

Material Materijal	Instrument	N	Mean Mean Srednja vrednost	SD	SE	Min	Max
Gutta-percha Gutaperka	Hedstrom	10	0.80	1.23	0.39	0	3
	ProTaper	10	0.70	0.67	0.21	0	2
	Twisted File	9*	0.11[a]	0.33	0.11	0	1
Resilon Resilon	Hedstrom	10	1.80[A]	1.13	0.36	0	3
	ProTaper	10	0.60[a]	0.70	0.22	0	2
	Twisted File	10	0.50[a]	0.71	0.22	0	2

* One sample was discarded because of a ledge formation during retreatment using Twisted File.
The mean difference is significant at the 0.05 levels between A-a (Post Hoc).
* Jedan uzorak je odbačen zbog formiranja stepenika tokom retretmana instrumentima Twisted File.
Razlika je značajna na nivou 0,05 između vrednosti obeleženih sa A-a (Post Hoc).

DISCUSSION

Even during primary root canal instrumentation debris such as dentin chips, necrotic pulp tissue, microorganisms and irrigants may be extruded into the periradicular tissues [13]. Successfull non-surgical retreatment depends on complete removal of pre-existing filling material from the canal, where it would be crucial to clean the apical foramen [14]. However, this could promote apical transportation and force obturation material into the periradicular tissues [15]. In addition, extrusion during retretment may be accompanied by solvents, necrotic tissue, bacteria or irrigants, which might be introduced into the apical region [11].

In the present study, apical extrusion was evaluated during removal of gutta-percha and resilon. The results showed that the type of obturation material did not have a significant impact on the mean scores of apical extrusion, although the mean score was higher during resilon removal. Other studies also evaluated the extrusion of obturation material during retreatment [7, 15, 16, 17], but these studies observed only the removal of gutta-percha. Apical extrusion during removal of different materials (gutta-percha, resilon and resin-coated gutta-percha) was compared in one study with a visual technique and a 4-degree scoring system [11]. The authors concluded that the type of filling material did not play a statistically significant role on the amount of apically extruded material, which is consistent with the findings of the presented study. Another group of authors [12] evaluated apical extrusion during gutta-percha and resilon removal using a quantitative method, however the results regarding the difference between the two materials were also not statistically significant.

Using an instrumentation technique that minimizes apical extrusion would be advantageous. Therefore, this aspect should always be investigated for a newly developed root canal instrumentation system [13]. This study evaluated three different instruments (Hedstrom, ProTaper and Twisted File) during retreatment and their impact on apically extruded material. The present study showed that *in vitro,* all of the tested instruments produced apical extrusion of obturation material and these results are consistent with other apical extrusion studies [7, 11, 12, 14, 16, 18]. As already mentioned, no studies are present in the current literature on the apical extrusion during retreatment with Twisted File instruments. In the present study the highest mean score of extruded material during retreatment was observed in the manual Hedstrom group and the lowest when Twisted File rotary instruments were used. The results of the present study are in agreement with previous retreatment studies that also compared hand and engine-driven instruments and their impact on apical extrusion [7, 12, 14, 16, 17]. This could be explained with rotation and a crown-down preparation technique during instrumentation, which tends to pull dentinal debris into the flutes of the file and direct it toward the coronal part of the canal [3, 19]. Also, rotary movements produce a certain degree of frictional heat which might plasticize the obturation material and facilitate removal [3]. Based on the results of this study, it can be concluded that Twisted File instruments, although not primarily intended for use in retreatment, can be associated with the extrusion of smaller degree of apical debris during material removal. However, these instruments should also be tested in different conditions of experimental set up and in relation to other retreatment efficiency indicators such as canal wall cleanliness, time of retreatment and frequency of instrument fracture.

The majority of investigations used a quantitative method to determine the amount of apically transported material and debris, by collecting and measuring their amount in grams [12, 13, 16, 20, 21]. In some studies the amount of apically extruded filling material during retreatment was detected visually and evaluated with a scoring system [3, 11, 14], as in the present study. Criticism of this kind of evaluation methodology can be made due to the existence of a certain degree of subjectivity as well as less precision in assessing the extruded material amount. However, the reaction of periapical tissues does not depend so much on the quantity of extruded material, as much of its infectious and antigenic potential and the host defense system. It must be emphasized that the results of *in vitro* studies should not be directly extrapolated to clinical situations. Transported material amount can be lesser *in vivo* because the presence of periapical tissues may act as a natural barrier against apical extrusion [6].

Further studies on material extrusion with different engine-driven instruments that can be used in retreatment will be needed for clarifying the importance of torque and rotational speed. Also, instruments with reciprocating movements should be evaluated [14, 22, 23]. Moreover, apical extrusion during removal of other obturation materials, such as resilon should be examined in a greater extent.

CONCLUSION

Under the conditions of this *in vitro* study, all retreatment techniques produced apical extrusion of filling material. The difference between results for apical extrusion for the two materials tested (gutta-percha and resilon) was not statistically significant. However, rotary Twisted File and ProTaper instruments resulted in significantly less debris extrusion compared to hand instruments (Hedstrom files) while removing resilon. There was no significant difference among the two rotary instruments. Therefore, the use of a rotary technique can be recomended to minimize apical extrusion, especially when resilon is removed during retreatment.

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Received: 17.02.2020 • Accepted: 15.05.2020

Apikalna ekstruzija materijala za kanalno punjenje tokom uklanjanja gutaperke i resilona

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KRATAK SADRŽAJ

Uvod Tokom uklanjanja kanalnog punjenja materijal se može istisnuti kroz apeks u periapikalna tkiva, što može dovesti do akutne egzacerbacije ili nastanka hronične infekcije. Cilj ovog istraživanja bio je da se ispita apikalna ekstruzija materijala tokom uklanjanja gutaperke i resilona, primenom različitih instrumenata.

Materijal i metode rada Istraživanje je sprovedeno na 60 jednokorenih, jednokanalnih ekstrahovanih humanih zuba. Primarna preparacija kanala korena vršena je rotirajućim instrumentima tipa ProTaper Universal, do veličine F2. Zubi su podeljeni u dve grupe od po 30 zuba (n = 30) i opturisani gutaperka, odnosno resilon poenima. Svaka grupa je dalje podeljena na tri podgrupe (n = 10) u odnosu na instrumente korišćene za retretman: ručni, Hedstrom i rotirajući, ProTaper odnosno Twisted File instrumenti. Stepen apikalno istisnutog materijala ocenjivan je vizuelno, pomoću četvorostepene skale. Izračunate prosečne vrednosti su statistički analizirane (t-test i ANOVA). Prag značajnosti definisan je kao $p < 0,05$.

Rezultati U datim uslovima ispitivanja vrsta materijala za punjenje kanala nije imala značajan uticaj na rezultate apikalne ekstruzije u toku retretmana. Stepen apikalno istisnutog materijala bio je najveći u resilon grupi posle upotrebe turpija Hedstrom (1,80 ± 1,13) i razlika je bila statistički značajna u odnosu na rezultate kada su korišćeni rotirajući instrumenti ProTaper (0,60 ± 0,70), odnosno Twisted File (0,50 ± 0,71).

Zaključak Upotreba rotirajućih instrumenata u toku retretmana može da se preporuči u svrhu smanjenja stepena apikalne ekstruzije, u odnosu na ručne turpije Hedstrom, naročito kada se u toku retretmana uklanja resilon, kao opturacioni materijal.

Ključne reči: apikalna ekstruzija; gutaperka; opturacija kanala korena; resilon; retretman; rotirajući instrumenti

UVOD

Nehirurški retretman često je indikovan kao terapija izbora kako bi se uklonila ili bar smanjila uporna mikrobna infekcija u kanalnom sistemu korena zuba. Tokom ovog postupka, temeljno uklanjanje materijala za kanalno punjenje je važan faktor koji omogućava adekvatnu hemomehaničku instrumentaciju i dezinfekciju kanalnog sistema, kako bi se omogućilo ozdravljenje periapikalnih tkiva [1]. Jedan veoma važan problem koji se javlja u toku preparacije kanala korena zuba je istiskivanje intrakanalnog debrisa i sredstava za ispiranje kroz apikalni foramen u periradikularna tkiva. Tokom retretmana kanala korena dentinski opiljci ili materijal za punjenje mogu se istisnuti kroz apikalni foramen, što može rezultovati inflamacijom periradikularnih tkiva ili čak infekcijom, jer oba ova supstrata mogu biti kontaminirani mikroorganizmima. Ovo bi moglo dovesti do akutizacije simptoma, nastanka postoperativnog bola, odloženog periapikalnog zaceljenja ili čak do neuspeha endodontske terapije, kao neželjene pojave, kako za pacijenta, tako i za terapeuta [1, 2].

Opšte je prihvaćeno da se nijednom od trenutno dostupnih tehnika i instrumenata ne može preparisati kanal korena ili ukloniti materijal za punjenje kanala korena bez pojave određenog stepena apikalne ekstruzije. Međutim, iako se ne može sprečiti, odabir odgovarajuće tehnike retretmana može umanjiti rizik od nastanka apikalne ekstruzije [3–6]. U toku mehaničke instrumentacije, broj i virulencija apikalno prebačenih mikroorganizama su presudni i kritični faktori koji određuju stepen periradikularne reakcije [6]. Iako ovaj kvalitativni faktor nije moguće kontrolisati, na kvantitativne faktore se može uticati odabirom odgovarajuće tehnike preparacije, kao što je koronarno-apeksna tehnika, kako bi se postigao postepen pristup apikalnom delu kanala. Na ovaj način se omogućava kontrola količine periapikalno prebačenih iritanasa [2]. Dakle, jedan od glavnih zadataka stomatologa tokom terapije kanala korena je pravilan odabir instrumenata i tehnika kojima se smanjuje količina apikalno ekstrudiranog debrisa da bi se izbegla ili minimizirala iritacija periapikalnih tkiva [6, 7]. Ručni instrumenti koji se najčešće koriste za retretman su turpije Hedstrom. U skorije vreme je dizajnirano nekoliko nikl-titanijumskih (NiTi) rotirajućih instrumenata posebno namenjenih za uklanjanje materijala iz kanala korena. Univerzalni sistem Protaper Retreatment (Dentsply, Maillefer, Ballaigues, Švajcarska) sadrži tri instrumenta različite koničnosti i prečnika vrhova: D1 (veličina 30 / koničnost 0,09), D2 (veličina 25 / koničnost 0,08) i D3 (veličina 20 / koničnost 0,07). Takođe, na tržištu se pojavila nova vrsta instrumenta pod nazivom Twisted File (SybronEndo, Orange, CA, SAD); međutim, ovaj instrument nije posebno dizajniran za uklanjanje opturacionog materijala iz kanala korena. Sistem Twisted File razvijen je kroz drugačiji proizvodni proces [8]. Ovi instrumenti se proizvode uvrtanjem, a ne obradom površine nikl-titanijuma, na preseku su oblika trougla, imaju promenljiv broj sečiva i zaobljen vrh koji, prema tvrdnji proizvođača, omogućava njihovu upotrebu i u svrhu retretmana. U aktuelnoj literaturi ne postoje podaci o apikalnoj ekstruziji opturacionog materijala tokom njihovog uklanjanja instrumentima Twisted File, a samo je jedna studija procenila efikasnost čišćenja zidova kanala korena posle retretmana sa ovim instrumentima [9].

Za punjenje kanala korena zuba do sada je korišćeno više materijala, pri čemu je gutaperka jedna od najzastupljenijih. Međutim, gutaperka ima dva glavna nedostatka: ne prianja za zidove kanala i nema mogućnost ojačavanja korena zuba [9].

Nedavno je razvijen novi materijal za opturaciju, koji je po načinu primene sličan gutaperki. Resilon (Resilon Research LLC, Madison, CT, SAD) jeste materijal za punjenje kanala korena na bazi termoplastičnog sintetičkog polimera koji se vezuje za dentinske zidove kanala korena kada se koristi zajedno sa odgovarajućom adhezivnom pastom (Epiphany / Real Seal) i tako formira „monoblok" unutar samog kanala [10]. Efikasnost uklanjanja ovog materijala iz kanala je ispitivana, mada ne u tolikoj meri kao gutaperka, dok je apikalna ekstruzija tokom uklanjanja resilona ispitana dosad samo u dve studije [11, 12].

Cilj ove studije bio je poređenje uticaja različitih materijala za punjenje (gutaperke i resilona) i različitih instrumenata (Hedstrom, ProTaper Retreatment i Twisted File) na stepen apikalno ekstrudiranog materijala tokom retretmana kanala u eksperimentalnim uslovima.

MATERIJAL I METODE

Odabir i priprema zuba

Odabrano je šezdeset ekstrahovanih jednokorenih zuba sa jednim, ravnim kanalom bez prethodnog tretmana kanala i sa potpuno razvijenim vrhom korena. Da bi se standardizovale dužine uzoraka, svi zubi su skraćeni na 16 mm uklanjanjem krunice (dijamantskim svrdlom za turbinu i vodenim hlađenjem). Posle identifikacije ulaza u kanal potvrđena je prohodnost kanala turpijom veličine 10 K (Senseus FlexoReamer, Dentsply, Maillefer, Ballaigues, Švajcarska) sve dok njen vrh nije postao vidljiv na apikalnom otvoru korena. Radna dužina je određena za 1 mm kraće od posmatrane dužine. Primarna preparacija kanala korena izvedena je pomoću mašinskog, NiTi rotirajućeg sistema – ProTaper Universal (Dentsply, Maillefer, Švajcarska). Kanali svih zuba su preparisani krunično-apeksnom (*crown-down)* tehnikom do veličine 25 (F2), do radne dužine. Ispiranje kanala sprovedeno je između svakog instrumenta sa po 2 ml 5,25% natrijum-hipohlorita (NaOCl). Pre opturacije kanali su isprani 10% limunskom kiselinom u trajanju od jednog minuta, radi uklanjanja razmaznog sloja, a zatim sa 10 ml destilovane vode. Zubi su nasumično podeljeni u dve grupe od po trideset zuba u svakoj (n = 30). Posle sušenja kanala papirnim poenima svi uzorci su opturisani tehnikom hladne lateralne kompakcije. Jedna grupa je napunjena gutaperka poenima (Protaper Universal F2, Dentsply, Maillefer, Švajcarska) i pastom na bazi epoksi smole (AHplus, Dentspli, Detrei GmbH, Nemačka); druga grupa je napunjena resilon poenima (Resilon Research LLC, Madison, CT) i adhezivnom, metakrilatnom pastom (RealSeal, Root Canal Sealant, SibronEndo, Kerr Corporation, USA). Dodatna vertikalna kompakcija kanalnog punjenja izvršena je pomoću vertikalnog kompaktera i nabijača. Koronarna površina kanalnog punjenja resilon grupe je svetlosno polimerizovana u trajanju od 40 sekundi, prema uputstvu proizvođača. Ukupna dužina ispuna kanala korena nije prelazila više od 15 mm, tako da je zapremina materijala za punjenje bila približno jednaka u svim uzorcima. Kvalitet opturacije kanala korena potvrđen je radiografski iz bukolingvalnog i meziodistalnog pravca. Koronarni deo korena zuba zapečaćen je materijalom za privremeno zatvaranje (Citodur, Dorident, Austrija) i uzorci su čuvani na 37°C u 100% vlažnoj sredini tokom 14 dana, kako bi se omogućilo potpuno vezivanje paste za opturaciju.

Metode retretmana

Pre započinjanja retretmana zubi u obe grupe materijala (n = 30) nasumično su podeljeni u tri grupe od po deset zuba, na osnovu instrumenata koji su korišćeni za uklanjanje materijala za opturaciju. Svaki set instrumenata korišćen je za retretman maksimalno pet korenskih kanala i posle toga odbačen. Svi instrumenti su korišćeni poštujući uputstva proizvođača. Rotirajući instrumenti su pokretani pomoću endodontskog elektromotora (X-Smart, Dentsply, Maillefer, Ballaigues, Švajcarska) u *crown-down* maniru.

U grupi 1 ručna instrumentacija izvedena je turpijama Hedstrom (Senseus Hedstroem Dentsply, Maillefer, Švajcarska) veličine 40–20, uz blago potiskivanje vrha instrumenta u materijal, rotaciju za četvtinu kruga i izvlačenje instrumenta potiskivanjem uz zidove kanala korena, sve do postizanja radne dužine. Ponovna preparacija apikalnog dela kanala obavljena je turpijama Hedstrom do veličine 40. U grupi 2 primenjeni su instrumenti ProTaper Retreatment (Dentsply, Maillefer, Švajcarska), korišćenjem instrumenta D1 za uklanjanje materijala za punjenje iz koronarnog dela kanala, dok je materijal iz srednje i apikalne trećine uklonjen pomoću instrumenata D2 i D3, korišćenjem blagog pritisaka apikalno uz bočni pritisak na zidove kanala (tzv. pokreti četkanja). Instrument D3 je dosegao radnu dužinu. Posle toga korišćeni su instrumenti ProTaper Universal veličine F3 (# 30) i F4 (# 40), radi uvećanja apikalnog dela preparacije. U grupi 3 instrumenti Twisted File (TF) (SybronEndo, CA, USA) korišćeni su prema sledećem redosledu: u koronarnoj trećini je primenjen instrument TF # 25 / koničnosti 0,08, a zatim instrumenti # 30 i # 35 / koničnosti 0,06, do dostizanja radne dužine. Zatim je korišćen TF # 40 / 0,04 za proširivanje apikalnog dela kanala i ponovo TF # 25 / koničnosti 0,08, za dodatno čišćenje bočnih zidova kanala.

Tokom retretmana navoji svih instrumenata često su čišćeni i kanali ispirani sa 2 ml 5,25% NaOCl posle svakog instrumenta, kao i posle završenog retretmana. Retretman je smatran završenim kada je postignuta radna dužina i na poslednjem instrumentu, kao i u toku irigacije, nije više bio vidljiv materijal. Posle toga kanali su jedan minut ispirani rastvorom 10% limunske kiseline, kako bi se uklonio razmazni sloj, a nakon toga destilovanom vodom u količini od 10 ml. Primarnu preparaciju, opturaciju i retretman kanala sprovela je jedna osoba, kako bi postupak bio obavljen na isti način za sve uzorke.

Procena apikalne ekstruzije materijala

Količina apikalno istisnutog materijala tokom postupka retretmana posmatrana je vizuelno. Ocenjivanje količine apikalno ekstrudovanog materijala i debrisa izvršilo je drugo lice, kome nije bila poznata pripadnost uzoraka eksperimentalnim grupama. Korišćen je sledeći sistem za ocenjivanje [3, 11]:

0 – bez vidljive ekstruzije debrisa i materijala za punjenje kroz foramen; 1 – minimalna, jedva primetna količina istisnutog materijala za punjenje kroz foramen; 2 – umerena, lako primetna količina materijala za punjenje istisnuta kroz foramen; 3 – ekstruzija znatne količine materijala za punjenje kroz foramen.

Statistička analiza

Dobijeni podaci su predstavljeni u tabelama i numerički obrađeni standardnim deskriptivnim metodama. Izračunate su srednje

vrednosti rezultata apikalno ekstrudiranog materijala. Podaci su statistički analizirani pomoću t-testa i jednosmerne analize varijanse (ANOVA). Analiza je izvršena pomoću programa SPSS (verzija 20) na nivou značajnosti $p < 0,05$.

REZULTATI

Srednje vrednosti i standardna devijacija za apikalnu ekstruziju za svaku grupu materijala i za svaku grupu testiranih instrumenata predstavljeni su u tabelama 1 i 2. Rezultati su pokazali da su u obe grupe materijala svi ispitivani instrumenti doveli do apikalne ekstruzije debrisa u nekom stepenu. Poređenje srednjih vrednosti pomoću t-testa, dobijenih za apikalnu ekstruziju tokom uklanjanja gutaperke i resilona (Tabela 1), nije ukazalo na statistički značajne razlike između dva materijala ($p = 0,101$). Najveća količina apikalno istisnutog materijala (Tabela 2) bila je prisutna u grupi kada je resilon uklanjan turpijama Hedstrom (1,80 ± 1,13), dok su uzorci sa najmanjom količinom istisnutog materijala primećeni u gutaperka grupi kada su korišćeni instrumenti Twisted File (0,11 ± 0,33). Razlika između ova dva rezultata je bila statistički značajna (ANOVA, Post-hoc; $p = 0,027$). Analiza rezultata pomoću ANOVA u obe grupe materijala otkrila je statistički značajne razlike između instrumenata samo tokom uklanjanja resilona ($p = 0,004$; Tabela 2). Dalja statistička analiza sa post-hoc testovima pokazala je da je razlika bila značajna između ručnih, Hedstrom turpija (1,80 ± 1,13) i dva rotirajuća instrumenta, ProTaper (0,60 ± 0,70) i Twisted File (0,50 ± 0,71).

DISKUSIJA

Čak i tokom primarne instrumentacije kanala korena, dentinski opiljci, nekrotično pulpno tkivo, mikroorganizmi i sredstva za irigaciju se mogu istisnuti u periradikularna tkiva [13]. Uspešno sprovođenje nehirurškog retretmana zavisi od potpunog uklanjanja postojećeg materijala za punjenje iz kanala, pri čemu je najvažnije očistiti apikalni foramen [14]. Međutim, time bi se dodatno promovisali apikalna ekstruzija i istiskivanje materijala za opturaciju u periradikularna tkiva [15]. Pored toga, ekstruzija tokom retretmana može biti praćena prisustvom rastvarača, nekrotičnog tkiva, bakterija ili iriganasa, koji mogu biti prebačeni u periapikalnu regiju [11].

U prezentovanoj studiji procenjen je stepen apikalne ekstruzije tokom uklanjanja gutaperke i resilona. Rezultati su pokazali da vrsta materijala za punjenje kanala nije imala značajan uticaj na vrednosti apikalne ekstruzije, iako je dobijena srednja vrednost bila nešto veća tokom uklanjanja resilona. Druge studije su takođe ocenile ekstruziju opturacionog materijala tokom retretmana [7, 15, 16, 17], ali su ove studije ispitivale samo uklanjanje gutaperke. Apikalna ekstruzija tokom uklanjanja različitih materijala (gutaperka, resilon i gutaperka obložena smolom) upoređena je u jednoj studiji, takođe primenom vizuelne tehnike i ocenjivanjem pomoću četvorostepene skale [11]. Autori su zaključili da vrsta materijala za punjenje nije imala statistički značajnu ulogu u količini apikalno istisnutog materijala, što je u skladu i sa nalazima ove studije. Druga grupa autora [12] ispitivala je apikalnu ekstruziju tokom uklanjanja gutaperke i resilona kvantitativnom metodom; međutim, ni u ovoj studiji razlika u rezultatima između dva ispitivana materijala nije bila statistički značajna.

Od velikog značaja bilo bi korišćenje tehnike instrumentacije u toku retretmana koja smanjuje stepen apikalne ekstruzije. Zbog toga ovaj aspekt uvek treba istražiti za novorazvijeni sistem za instrumentaciju kanala korena [13]. U toku ove studije ispitivana su tri različita instrumenta (Hedstrom, ProTaper i Twisted File) tokom retretmana i njihov uticaj na stepen apikalno istisnutog materijala. Pokazalo se da su svi *in vitro* testirani instrumenti doveli do apikalne ekstruzije materijala za opturaciju i ovi rezultati su u skladu sa drugim studijama apikalne ekstruzije [7, 11, 12, 14, 16, 18]. Kao što je već napomenuto, u trenutnoj literaturi ne postoje studije na temu apikalne ekstruzije tokom retretmana instrumentima Twisted File. U ovoj studiji najveća srednja vrednost za količinu ekstrudiranog materijala tokom retretmana primećena je u ručnoj Hedstrom grupi, a najniža kada su korišćeni rotirajući instrumenti Twisted File. Rezultati ove studije slažu se sa prethodnim studijama retretmana u kojima su takođe upoređeni ručni i različiti mašinski pokretani instrumenti i njihov uticaj na apikalnu ekstruziju [7, 12, 14, 16, 17]. Ova pojava bi se mogla objasniti rotacijom i krunično-apeksnom tehnikom instrumentacije, kojom se teži da se dentinski debris i ostaci materijala povuku u navoje instrumenta i usmere prema koronarnom delu kanala [3, 19]. Takođe, pri pokretima rotacije stvara se određeni stepen trenja, što može dodatno omekšati materijal za punjenje i olakšati njegovo uklanjanje [3]. Na osnovu rezultata ove studije može se zaključiti da su instrumenti Twisted File, iako nisu prvenstveno namenjeni u svrhu retretmana, doveli do istiskivanja manjeg stepena apikalnog debrisa tokom uklanjanja materijala. Međutim, ove instrumente bi takođe trebalo testirati u različitim uslovima postavke eksperimenta i u odnosu na druge pokazatelje efikasnosti retretmana, poput čistoće zidova kanala, vremena potrebnog za retretman, kao i učestalosti loma instrumenta.

Većina istraživanja koristila je kvantitativnu metodu za utvrđivanje količine apikalno transportovanog materijala, prikupljanjem istisnutog materijala i debrisa i merenjem njihove količine u gramima [12, 13, 16, 20, 21]. U nekim istraživanjima je količina apikalno ekstrudiranog materijala za punjenje tokom retretmana vizuelno posmatrana i procenjena sistemom bodovanja [3, 11, 14], kao u ovoj studiji. Kritika ove vrste evaluacione metodologije može se dati zbog postojanja određenog stepena subjektivnosti, kao i manje preciznosti u proceni količine istisnutog materijala. Međutim, reakcija periapikalnih tkiva ne zavisi toliko od precizne količine ekstrudiranog materijala koliko od njegovog infektivnog i antigenog potencijala i odbrambenog sistema domaćina. Mora se naglasiti da rezultati *in vitro* studija ne bi smeli biti neposredno primenjeni na kliničke situacije. Količina transportovanog materijala može biti manja *in vivo* jer prisustvo periapikalnih tkiva može delovati kao prirodna barijera i dovesti do manjeg stepena apikalne ekstruzije [6].

Neophodna su dalja ispitivanja ekstruzije materijala različitim mašinski pokretanim sistemima koji se mogu koristiti u svrhu retretmana, kako bi se ispitao i uticaj obrtnog momenta i brzine rotacije, kao i studije sa instrumentima sa recipročnim pokretima [14, 22, 23]. Takođe, apikalno istiskivanje tokom uklanjanja drugih materijala za punjenje kanala, poput resilona, trebalo bi da se ispita u većoj meri.

ZAKLJUČAK

U uslovima ove *in vitro* studije, sve ispitivane metode retretmana proizvele su apikalnu ekstruziju materijala za punjenje. Razlika između rezultata dobijenih za apikalnu ekstruziju tokom uklanjanja dva testirana materijala (gutaperka i resilon) nije bila statistički značajna. Međutim, rotirajući instrumenti Twisted File i ProTaper doveli su do značajno manje ekstruzije materijala u poređenju s ručnim instrumentima (turpije Hedstrom) u toku uklanjanja resilona. Razlika u rezultatima između dva rotirajuća instrumenta nije bila statistički značajna. Zbog toga se upotreba rotirajućih instrumenata generalno može preporučiti za smanjenje apikalne ekstruzije materijala, naročito kada se tokom retretmana uklanja resilon.