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Comparison of the Efficacy of NeoNiTi, ProTaper, and Reciproc Files in the Retreatment of Curved Root Canals: a CBCT Assessment

Usporedba učinkovitosti instrumenata Neoniti, ProTaper i Reciproc u reviziji zakrivljenih korijenskih kanala: CBCT procjena

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Abstract

Objective: Effective tools and methods are applied during root canal retreatment to eliminate root canal obturation materials and preserve the initial root canal anatomy. The present study compared the efficacy of Reciproc, Neoniti, ProTaper, and Hedstrom files in the retreatment of curved root canals. **Material and methods:** In the present *in vitro* study, 100 root canals with 25–45º curvatures were used. After the samples were initially prepared and examined by CBCT, the root canals were obturated with gutta-percha and randomly assigned to four groups (n=25). A retreatment was carried out in each group with NeoNiTi, ProTaper, Reciproc, and Hedstrom files. CBCT examinations were carried out again under the same conditions. The samples were evaluated at 3-, 6-, and 9-mm distances from the apex on the first and the second CBCT image for root canal transportation and remaining gutta-percha in the root canals. The time required for retreating each canal in each sample was recorded. One-way ANOVA and corresponding non-parametric tests were applied for data analysis. **Results:** The root canal transportation in the NeoNiTi group was lower than that in the other groups and significantly different from the ProTaper group ($P<0.05$). There was a remaining gutta-percha after retreatments in all the four groups, which was not statistically significant ($P>0.05$). **Conclusion:** Despite the fact that the NeoNiTi file produced less transportation than other file systems evaluated in the retreatment of curved root canals, all the files were very effective at the clinically acceptable levels.

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Introduction

Despite an 86-96% success rate of root canal treatment, postoperative conditions might necessitate retreatment (1). One of the most critical steps in root canal retreatment is to eliminate the root canal filling materials from the root canal, which is carried out with different tools (2-4). Rotary systems are effectively used during root canal retreatment. These sys-

Uvod

Unatoč stopi uspješnosti endodontskog liječenja od 86 do 96 %, postoperativna stanja mogu zahtijevati reviziju (1). Jedan od najkritičnijih postupaka u reviziji endodontskog liječenja jest uklanjanje materijala za punjenje iz korijenskog kanala, a to se obavlja različitim instrumentima (2 – 4). Rotacijski sustavi učinkovito se upotrebljavaju tijekom revizi-

tems have been developed using NiTi alloys. However, conventional NiTi alloys exhibit some drawbacks, including precurvature inability, structural shortcomings, and inadequate cutting ability (5). Of all the different rotary systems, ProTaper universal files (Dentsply, Ballaigues, Switzerland) used for retreatment are effective in straight and curved root canals (6-8).

The NeoNiTi (Neolix, Chatres-La-Forte, France) was introduced in 2012 as a single file rotary system. A study showed that this file could provide easy and safe access to the root canal without a binding effect, even in curved root canals (9). However, there is currently not sufficient number of studies on the efficacy of this system and its comparison with other tools used for curved root canals treatment.

Reciproc files (VDW, Munich, Germany), too, are single-file systems but they have a reciprocal mechanism. Numerous NiTi rotary systems have been developed to overcome this shortcoming (10), with their efficacy being evaluated in the retreatment procedures of curved root canals in some studies (11-13).

However, hand files, such as Hedstrom (Dentsply, Ballaigues, Switzerland), are still used in the retreatment of root canals as a conventional method. Some studies have shown that these files can be more effective in removing gutta-percha than the ProTaper universal files designed for retreatment (2, 4). However, some other studies have reported similar efficacy for these files compared to ProTaper and Reciproc files designed for the retreatment of straight and curved root canals (4, 7, 11). However, it has been reported that irrespective of the file type, it is not possible to completely eliminate root canal filling materials from the root canals with the available methods (4, 14).

On the other hand, the root canal retreatment of curved root canals is challenging due to variations in the normal anatomy of the root canal and root canal transportation (15). To overcome this problem, we can use rotary systems due to their NiTi alloy, which has unique properties that lead to greater flexibility and reduced transportation (16).

Different techniques are available to evaluate root canal transportation, including scanning electron microscopy (17), radiographic evaluation (18), photographic evaluation (19), etc. The CBCT is a non-invasive and non-destructive technique introduced to evaluate the root canal anatomy and compare it before and after its preparation. According to previous studies, this technique can provide accurate cross-sectional 3D images of samples that can be verified and is more accurate than other techniques. Besides, this technique preserves the samples and can provide several images from one sample (20, 21).

Considering the discrepancies in the results of studies evaluating the efficacy of different rotary and manual systems in the retreatment of root canals, the present study aimed to compare the efficacy of NeoNiTi, ProTaper, and Reciproc rotary files in comparison to Hedstrom hand files in the retreatment of curved root canals. The hypothesis of this study was: A) The efficiency of Reciproc, NeoNiTi, ProTaper, and Hedstrom files in removing gutta-percha from the canal and maintaining the curvature of the root canal is not different.

je endodontskog liječenja. Ti sustavi razvijeni su korištenjem nikal-titanijevih (Ni-Ti) legura. No konvencionalne NiTi legure pokazuju neke nedostatke kao što su nemogućnost prethodne zakrivljenosti, strukturni nedostatci i neadekvatno svojstvo rezanja (5). Od svih različitih rotacijskih sustava, univerzalni instrumenti ProTaper (Dentsply, Ballaigues, Švicarska) koji se upotrebljavaju za reviziju liječenja, učinkoviti su u ravnim i zakrivljenim korijenskim kanalima (6 – 8).

Neoniti (Neolix, Chatres-La-Forte, Francuska) predstavljen je 2012. kao jednoinstrumentni rotacijski sustav. Istraživanje je pokazalo da omogućuje jednostavan i siguran pristup korijenskom kanalu bez efekta vezivanja, čak i u slučaju zakrivljenih korijenskih kanala (9). Međutim, nema dovoljno istraživanja o učinkovitosti toga sustava i njegovoj usporedbi s drugim instrumentima za obradu zakrivljenih korijenskih kanala.

Reciproc (VDW, München, Njemačka) također je jednoinstrumentni sustav, ali ima recipročni mehanizam rada. Kako bi se prevladao taj nedostatak, razvijeni su mnogobrojni nikal-titanijevi rotacijski sustavi (10) i njihova je učinkovitost u nekim istraživanjima procijenjena u postupcima revizije liječenja zakrivljenih korijenskih kanala (11 – 13).

Međutim, ručni instrumenti, kao što je Hedstrom (Dentsply, Ballaigues, Švicarska), još uvijek se upotrebljavaju u reviziji liječenja korijenskih kanala kao konvencionalna metoda. U nekim je istraživanjima istaknuto da ti instrumenti mogu biti učinkovitiji u uklanjanju gutaperke od univerzalnih instrumenata ProTaper namijenjenih reviziji (2, 4). U nekim drugim istraživanjima autori su izvijestili o sličnoj učinkovitosti tih instrumenata u usporedbi s instrumentima ProTaper i Reciproc oblikovanih za reviziju ravnih i zakrivljenih korijenskih kanala (4, 7, 11). No objavljeno je da dostupnim metodama, neovisno o vrsti instrumenta, nije moguće potpuno eliminirati materijale za punjenje iz korijenskih kanala (4, 14).

S druge strane, revizija zakrivljenih korijenskih kanala izazovna je zbog varijacija normalne anatomije i transportacije korijenskog kanala (15). Kako bismo prevladali taj problem, možemo upotrijebiti rotacijske sustave od nikal-titanijeve legure jer ima jedinstvena svojstva koja dovode do veće fleksibilnosti i smanjene transportacije (16).

Dostupne su različite tehnike za procjenu transportacije korijenskog kanala, uključujući skenirajuću elektronsku mikroskopiju (17), radiološku procjenu (18), fotografsku procjenu (19) itd. CBCT je neinvazivna i nedestruktivna tehnika koja omogućuje procjenu anatomije korijenskog kanala te usporedbu prije instrumentacije i poslije nje. Prema dosadašnjim istraživanjima tom se tehnikom mogu dobiti točne 3D slike presjeka uzoraka koje se mogu provjeriti i točnija je od drugih tehnika. Uz to, ta tehnika čuva uzorke i može se dobiti nekoliko slika iz jednog uzorka (20, 21).

Uzimajući u obzir odstupanja u rezultatima istraživanja koja su procjenjivala učinkovitost različitih rotacijskih i ručnih sustava u reviziji endodontskog liječenja, cilj ovog istraživanja bio je usporediti učinkovitost rotacijskih instrumenata Neoniti, ProTaper i Reciproc s ručnim instrumentima Hedstrom u reviziji zakrivljenih korijenskih kanala. Hipoteze ovoga istraživanja bile su: A) nema razlike u učinkovito-

B) The time required to retreat curved canals with Hedstrom files is longer than the time required with NeoNiTi, ProTaper, and Reciproc files.

Material and methods

The steps of the study are presented in Figure 1.

Selection and initial preparation of the samples

Firstly, the software PASS 11 and the One-way ANOVA method was used to determine the sample size. For this purpose, with $\alpha = 0.05$ and $\beta = 0.2$ (power=80%), and considering the mean values and the required standard deviation from similar studies, the number of samples in each group was calculated at n=25 (a total of 100 samples).

The present study evaluated one hundred freshly extracted human teeth, including maxillary and mandibular molars. The teeth had been extracted due to periodontal problems or caries and could not be preserved. The teeth were stored in 0.5% chloramine T solution until they were used in the study. The inclusion criteria consisted of a root canal length of 11–13 mm (from the root canal orifice at CEJ to the radiographic apex), a curvature range of 25–45° according to the method proposed by Schneider (22), no visible obstruction of the root canal, calcification, resorption, fracture, and root defects under visual evaluation of the radiographs, no double curvature of the root, and no previous root canal treatment.

First, an access cavity was prepared with a 0.12 fissure carbide bur (Tizkavan, Tehran, Iran) in a high-speed handpiece (Bien Air, Switzerland) under air and water spray to prepare the samples. Then the tooth crowns were removed using a diamond disk (Tizkavan, Tehran, Iran) in a slow-speed handpiece (Bien Air, Bienne, Switzerland) to leave one single root (the mesiobuccal root of maxillary molars and the mesial root of mandibular molars), measuring 18 mm in length. Then the patency of the root canals was evaluated with a # 10 K-file (Dentsply, Ballaigues, Switzerland), and when the file was slightly entangled in the working length, these root canals were confirmed for the study. The samples were separately mounted in fast-setting acrylic resin (Acroopars 200, Tehran, Iran) and numbered from 1 to 100.

In the first step, the samples were prepared with the RaCe rotary system (FKG Dentaire, La Chaux-de-Fonds, Switzerland) up to file #25, with 4% taper using an endodontic motor (NSK, Japan) at 500 rpm and 1 Ncm; 5.25% NaOCl was used for root canal irrigation between instruments.

The sampling method was non-randomized (sequentially judgmental). The samples were numbered from 1 to 100 and randomly distributed among the groups by Research randomizer program software (www.randomizer.org) and mounted in a hand-made arch-form wax cast for CBCT examinations; 5-10 samples were mounted in each cast. Then, the prepared casts underwent CBCT (Planmeca ProMax 3D, Helsinki, Finland) examinations under the following exposure conditions: mA = 6, kVp = 76, time = 6 s, vocal size = 0.15 × 0.15 × 0.15 mm, FOV = 8 × 8 cm.

sti instrumenata Reciproc, Neoniti, ProTaper i Hedstrom u uklanjanju gutaperke iz unutrašnjosti kanala i održavanju zakrivljenosti korijenskog; B) vrijeme potrebno za reviziju zakrivljenih kanala Hedstrom instrumentima dulje je od vremena potrebnoga za taj postupak s instrumentima Neoniti, ProTaper i Reciproc.

Materijal i metode

Postupci istraživanja prikazani su na slici 1.

Odabir i inicijalna priprema uzoraka

Najprije su za određivanje veličine uzorka korišteni softver PASS 11 i jednosmjerna ANOVA. U tu svrhu, uz $\alpha = 0,05$ i $\beta = 0,2$ (snaga = 80 %), a uzimajući u obzir srednje vrijednosti i traženu standardnu devijaciju iz sličnih istraživanja, izračunat je broj uzoraka n = 25 u svakoj skupini (ukupno 100 uzoraka).

U ovom istraživanju procjenjivalo se 100 svježe izvađenih ljudskih zuba, i to gornje i donje kutnjake. Zubi su ekstrahirani zbog parodontoloških problema ili karijesa i nisu se mogli sačuvati. Odmah su bili pohranjeni u 0,5-postotnoj otopini kloramina T do upotrebe u istraživanju. Kriteriji za uključivanje bili su dužina korijenskog kanala od 11 do 13 mm (od ušća korijenskog kanala na CCS-u do radiološkog apeksa), raspon zakrivljenosti od 25 do 45° prema metodi koju je predložio Schneider (22), bez vidljive opstrukcije korijenskog kanala, kalcifikacija, resorpcija, fraktura i defekata korijena na temelju vizualne procjene rendgenskih snimaka, bez dvostruke zakrivljenosti korijena i bez prethodnoga endodontskog liječenja.

Najprije je prepariran pristupni kavitet u uzorcima fisurnim karbidnim svrdlom 0,12 (Tizkavan, Teheran, Iran) i crvenim kolječnikom (Bien Air, Švicarska) pod mlazom zraka i vode. Zatim su krune zuba uklonjene dijamantnim diskom (Tizkavan, Teheran, Iran) i plavim kolječnikom (Bien Air, Bienne, Švicarska) kako bi ostao jedan korijen (meziobukalni korijen gornjih kutnjaka i mezijalni korijen donjih kutnjaka) dužine 18 mm. Zatim je prohodnost korijenskih kanala procijenjena K-instrumentom #10 (Dentsply, Ballaigues, Švicarska), a kada je instrument malo zapeo u radnoj duljini, ti su korijenski kanali potvrđeni za istraživanje. Uzorci su zasebno postavljeni u brzovezujuću akrilnu smolu (Acroopars 200, Teheran, Iran) i označeni brojevima od 1 do 100.

Uzorci su najprije u obrađeni rotacijskim sustavom RaCe (FKG Dentaire, La Chaux-de-Fonds, Švicarska) do instrumenta #25, s 4-postotnim konusom s pomoću endomotora (NSK, Japan) pri 500 okretaja u minuti i 1 Ncm. Za ispiranje korijenskog kanala između instrumenata korišten je 5,25-postotni NaOCl.

Uzorci su označeni brojevima od 1 do 100 i nasumično raspodijeljeni među skupinama programskim softverom Research randomizer (www.randomizer.org) i montirani u ručno izrađeni voštani odljevak za CBCT preglede; 5 do10 uzoraka montirano je u svaki odljev. Zatim su pripremljeni odljevci podvrgnuti CBCT pregledima (Planmeca ProMax 3D, Helsinki, Finska) pod sljedećim uvjetima ekspozicije: mA = 6, kVp = 76, vrijeme = 6 s, veličina voksela = 0.15 × 0.15 × 0.15 mm, FOV = 8 × 8 cm.

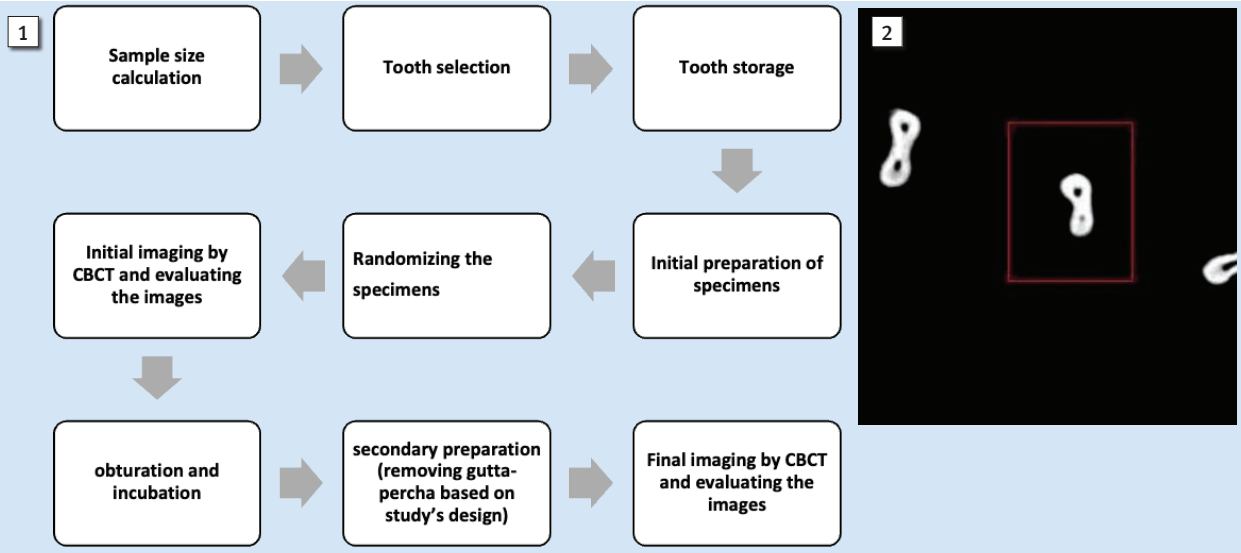

Figure 1 Flowchart of study's methodology sequences
Slika 1. Dijagram metodologije istraživanja
Figure 2 One sample of initial recorded image in CBCT
Slika 2. Primjer inicijalno snimljene slike CBCT-om
Figure 3 The measurements made to calculate root canal transportation on axial cross-sections.
Slika 3. Mjerenja obavljena za izračunavanje transportacije korijenskog kanala na aksijalnim poprečnim presjecima
Figure 4 One sample of the image of the residual root fillings recorded by CBCT
Slika 4. Primjer zaostatnoga korijenskog punjenja snimljenog CBCT-om

Axially images were recorded for each sample at 3-, 6- and 9-mm distances from the apex using the Planmeca Romixs Viwewes 5.4.0.R software (Planmeca, Helsinki, Finland) separately and saved as the initial record (Figure 2).

The lateral compaction technique was applied for root canal obturation with gutta-percha (Ariadent, Tehran, Iran) and AH26 sealer (Dentsply, Ballaigues, Switzerland) using a #B spreader (Dentsply, Ballaigues, Switzerland). After cutting and removing gutta-percha from the root canal orifice, the access cavity was sealed with Cavisol (Golchai, Karaj, Iran) temporary dressing. The samples were radiographically examined using a digital intraoral x-ray unit (Planmeca, Helsinki, Finland) to confirm the accuracy of all the steps at exposure conditions of mA=8, kVp=60, and 0.16 s with a PSP sensor and a phosphor plate Acteon scanner (Sopro, La Ciotat, France). Then, the obturation quality was confirmed by an endodontist. Finally, the samples were incubated for one week at 100% relative humidity at 37°C for the complete setting of the sealer.

Aksijalne slike snimljene su za svaki uzorak na udaljenosti od 3, 6 i 9 mm od apeksa s pomoću softvera Planmeca Romixs Viwewes 5.4.0.R (Planmeca, Helsinki, Finska) zasebno i spremljene kao početni zapis (slika 2.).

Tehnika lateralne kondenzacije primijenjena je za opturaciju korijenskog kanala gutaperkom (Ariadent, Teheran, Iran) i pastom AH26 (Dentsply, Ballaigues, Švicarska) s pomoću spredera #B (Dentsply, Ballaigues, Švicarska). Nakon rezanja i uklanjanja viška gutaperke s ulaza korijenskog kanala, pristupni kavitet zapečaćen je privremenim ispunom Cavisol (Golchai, Karaj, Iran). Uzorci su radiološki pregledani s pomoću digitalne intraoralne rendgenske jedinice (Planmeca, Helsinki, Finska) da bi se potvrdila točnost svih postupaka u uvjetima izloženosti od mA = 8, kVp = 60 i 0,16 s PSP senzorom i skenerom s fosfornom pločom Acteon (Sopro, La Ciotat, Francuska). Zatim je endodont potvrdio kvalitetu opturacije. Na kraju su uzorci, za potpuno stvrdnjavanje brtvila, inkubirani tjedan dana pri 100-postotnoj relativnoj vlažnosti i na temperaturi od 37 °C.

Root canal retreatment

The temporary dressing was removed, and the area was irrigated with normal solution. The gutta-percha was removed up to 1 mm from the canal orifices by a heat carrier, and 0.2 mL of chloroform solution (Sina Bartar, Tehran, Iran) was placed. A #15 C-Pilot file (VDW, Munich, Germany) was used to create a path along the root canal. Preparations were carried out in each group as follows:

ProTaper group (n=25): ProTaper universal files (Dentsply, Ballaigues, Switzerland) in an endodontic motor (NSK, Osaka, Japan) were used at 500 rpm and 1 Ncm^{-1} torque in the root canals, respectively, as follows: D1 file for the coronal third with 11-mm length, D2 file for the middle third with 14-mm length, and D3 file for the apical third with 17-mm length, followed by ProTaper F2 file up to the working length for the final apical preparation (23).

NeoNiTi group (n=25): After preparation of the coronal third with #3 and #2 Gates-Glidden drills up to 11 mm with the crown-down technique, the middle and apical thirds were prepared with an A1 file (Neelix, Chatres-La-Forte, France) up to the working length in an endodontic motor at 500 rpm and 1.5 Ncm^{-1} torque.

Reciproc group (n=25): After preparing the coronal third, similar to the NeoNiTi group, the R25 file (VDW, Munich, Germany) was used in a Silver Reciproc motor (VDW, Munich, Germany) for the middle and apical thirds up to the WL following the manufacturer's instructions.

Hedstrom group (n=25): After preparing the coronal third, similar to the NeoNiTi group, the procedure continued with #20 to #35 Hedstrom files (Dentsply, Ballaigues, Switzerland) with the crown-down technique, and the final apical preparation was carried out up to #30 file.

Each file was replaced by a new one after four uses. After the final irrigation, the root canals were dried with paper points. One operator carried out all the preparation procedures (a senior postgraduate student in endodontics). In addition, the time required to complete the retreatment procedure was calculated in each group.

At the end of these procedures, the samples were put back to their places in the wax casts to undergo the CBCT examinations under the same conditions.

Determining root canal transportation and residual gutta-percha

To increase the accuracy of the CBCT measurements before evaluating axial cross-sections, first, the distance between the CEJ and the apex of the samples was determined on the coronal plane on the two preoperative and postoperative images superimposed to eliminate possible errors. Then axial sections were prepared at 3-, 6-, and 9-mm distances from the apex in each sample, similar to the initial CBCT, and saved.

To create a similar condition for correct measurement on initial and secondary CBCT images, first, the longest buccolingual diameter in each axial cross-section was drawn as a guide using the Paint 10.0 software (Coronal Corporation Inc., USA) (BL) (Figure 3A). Then, from a point on the BL line at the root canal center, a line was drawn perpendicular

Revizija liječenja

Privremeni ispun je uklonjen, a područje je irigirano normalnom otopinom. Gutaperka je uklonjena do 1 mm od otvora kanala s pomoću nosača topline i stavljeno je 0,2 mL otopine kloroforma (Sina Bartar, Teheran, Iran). Za osiguravanje putanje duž korijenskog kanala korišten je C-Pilot instrument #15 (VDW, München, Njemačka). Instrumentacije su se obavljale u svakoj skupini na sljedeći način:

ProTaper skupina (n = 25): univerzalni instrumenti ProTaper (Dentsply, Ballaigues, Švicarska) u endomotoru (NSK, Osaka, Japan) korišteni su pri 500 o/min. i 1 Ncm^{-1} okretnog momenta u korijenskim kanalima redom kako slijedi: D1 instrument za koronarnu trećinu dužine 11 mm, D2 instrument za srednju trećinu dužine 14 mm i D3 instrument za apikalnu trećinu dužine 17 mm, a zatim ProTaper F2 instrument do radne dužine za završnu apikalnu preparaciju (23).

Neoniti skupina (n=25): nakon preparacije koronarne trećine Gates-Gliddenovim svrdlima #3 i #2 do 11 mm „crown-down" tehnikom, srednja i apikalna trećina preparirane su instrumentom A1 (Neelix, Chatres-La-Forte, Francuska) do radne dužine u endomotoru pri 500 o/min. i momentu od 1,5 Ncm^{-1}.

Reciproc skupina (n=25): nakon instrumentacije koronalne trećine, slično kao kod skupine Neoniti, instrument R25 (VDW, München, Njemačka) korišten je u Silver Reciproc motoru (VDW, München, Njemačka) za srednju i apikalnu trećinu do radne dužine prema uputama proizvođača.

Hedstrom skupina (n=25): nakon instrumentacije koronalne trećine, slično kao u Neoniti skupini, postupak je nastavljen Hedstrom instrumentima #20 do #35 (Dentsply, Ballaigues, Švicarska) „crown-down" tehnikom, a za završnu apikalnu instrumentaciju korišten je instrument #30.

Svaki je instrument zamijenjen novim poslije četiriju upotreba. Nakon završnog ispiranja korijenski su kanali osušeni papirnatim štapićima. Sve postupke instrumentacije obavljao je jedan operater (student poslijediplomskog studija). Uz to, u svakoj je skupini izračunato vrijeme potrebno za završetak postupka revizije.

Na kraju tih postupaka uzorci su vraćeni na svoja mjesta u voštanim odljevima kako bi bili podvrgnuti CBCT ispitivanju u istim uvjetima.

Određivanje transportacije korijenskog kanala i zaostatne gutaperke

Kako bi se povećala točnost CBCT mjerenja prije evaluacije aksijalnih presjeka, najprije je udaljenost između CCS-a i ksa uzoraka određena na koronalnoj ravnini na dvjema superponiranim preoperativnim i postoperativnim slikama da bi se eliminirale moguće pogreške. Zatim su pripremljeni aksijalni presjeci na udaljenosti od 3, 6 i 9 mm od apeksa na svakom uzorku, slično početnom CBCT-u, i spremljeni.

Da bi se stvorili slični uvjeti za ispravno mjerenje na inicijalnim i sekundarnim CBCT slikama, najprije je najduži bukolingvalni promjer u svakom aksijalnom presjeku nacrtan kao vodič s pomoću softvera Paint 10.0 (Coronal Corporation Inc., SAD) (BL) (Slika 3A). Zatim je iz točke na liniji BL u središtu korijenskog kanala povučena linija okomita na B (MD) (slika 3. B). U toj fazi slike su spremljene

to B (MD) (Figure 3B). At this stage, the images were saved and transferred to the Image Tool 3.0 software (University of Texas Health Science Center, USA) to calculate root canal transportation extent. In the software, the BL line was measured first, based on which the initial and final CBCT cross-sections were matched. The a and b values, as the distances between the external border of the root cross-section and the border of the prepared root canal on the MD line on the mesial and distal aspects, respectively, were then calculated on the initial and final CBCT images (Figure 3C). Finally, root canal transportation was calculated using the formula below and recorded for statistical analysis for each axial cross-section (in which a1 and b1 represent the values before retreatment; in addition, a2 and b2 represent the values after retreatment.):

Transportation = [(a1 – a2) – (b1 – b2)]To determine the amount of residual gutta-percha after retreatment, the surface area determining tool was first used to calculate the root canal surface area in mm^2 on each cross-section of the final CBCT. Then, the surface area occupied by gutta-percha was measured, and the percentage of the residual gutta-percha was calculated on each cross-section (Figure 4) (5). All the measurements in the present study were made by one operator (a radiologist). Three measurements were taken, and their mean value was used as the data.

Statistical analysis

Statistical analyses were performed using SPSS 20 (IBM Corp., Armonk, NY, USA). First, the distribution of data was analyzed using the Kolmogorov-Smirnov test. Normally distributed data were analyzed with one-way ANOVA to compare the groups. Tukey tests were used for two-by-two comparisons of the groups. Besides, repeated-measures ANOVA was used to compare the different sections; the Bonferroni test was used for two-by-two comparisons of the sections. In cases when the data were not distributed normally, non-parametric Kruskal-Wallis and Mann-Whitney tests were used to compare the groups. Friedman and Wilcoxon signed-rank tests were used to compare the sections. Statistical significance was set at $P<0.05$.

Ethical Statement

This study was approved by the Ethics Committee of Qazvin University of Medical Sciences with an ethics code of IR.QUMS.REC.1394.391. There was no conflict with ethical considerations.

Results

The results of one-way ANOVA confirmed the homogeneity of the samples between the four study groups.

Root canal transportation

The one-sample Kolmogorov-Smirnov test confirmed the normal distribution of data of this variable ($P>0.05$). Repeated-measures ANOVA revealed significant reciprocal effects between the groups and cross-sections ($P<0.05$).

i prenesene u softver Image Tool 3.0 (Zdravstveni znanstveni centar Sveučilišta u Teksasu, SAD) da bi se izračunao opseg transportacije korijenskog kanala. U softveru je najprije izmjerena BL linija na temelju koje su upareni početni i završni CBCT presjeci. Vrijednosti a i b, kao udaljenosti između vanjske granice poprečnog presjeka korijena i granice prepariranog korijenskog kanala na liniji MD na mezijalnom, odnosno distalnom dijelu, tada su izračunate na početnoj i završnoj CBCT snimci (slika 3 C). Na kraju, transportacija korijenskog kanala izračunata je s pomoću donje formule i zabilježena za statističku analizu za svaki aksijalni presjek (u kojemu su a1 i b1 vrijednosti prije revizije; osim toga, a2 i b2 vrijednosti su nakon revizije).

Transportacija = [(a1 – a2) – (b1 – b2)] Da bi se odredila količina zaostale gutaperke nakon revizije najprije je korišten alat za određivanje površine za izračunavanje površine korijenskog kanala u mm^2 na svakom poprečnom presjeku konačnoga CBCT-a. Zatim je izmjerena površina koju zauzima gutaperka te je izračunat postotak zaostatne gutaperke na svakom presjeku (slika 4.) (5). Sva mjerenja u ovom istraživanju proveo je jedan operater (radiolog). Obavljena su tri mjerenja, a njihova srednja vrijednost korištena je kao podatak.

Statistička analiza

Statističke analize provedene su korištenjem SPSS-a 20 (IBM Corp., Armonk, NY, SAD). Najprije je analizirana distribucija podataka Kolmogorov-Smirnovljevim testom. Podatci s normalnom distribucijom analizirani su jednosmjernom ANOVA-om radi usporedbe skupina. Tukeyjevi testovi korišteni su za usporedbu skupina dva po dva. Uz to, ANOVA ponovljenih mjerenja korištena je za usporedbu različitih odjeljaka. Bonferronijev test korišten je za usporedbu dva po dva presjeka. U slučajevima kada podatci nisu bili normalno distribuirani, za usporedbu skupina korišteni su neparametrijski Kruskal-Wallisovi i Mann-Whitneyjevi testovi. Za usporedbu odjeljaka korišteni su Friedmanov i Wilcoxonov test s predznakom. Statistička značajnost postavljena je na $P < 0,05$.

Etičnost istraživanja

Istraživanje je odobrio Etički odbor Sveučilišta medicinskih znanosti Qazvin s etičkim kodeksom IR.QUMS.REC.1394.391. Nije bilo sukoba s etičkog stajališta.

Rezultati

Rezultati jednosmjerne ANOVA-e potvrdili su homogenost uzoraka između četiriju ispitivanih skupina.

Transportacija korijenskog kanala

Kolmogorov-Smirnovljev test s jednim uzorkom potvrdio je normalnu distribuciju podataka ove varijable ($P > 0,05$). ANOVA ponovljenih mjerenja otkrila je značajne učinke između skupina i presjeka ($P < 0,05$).

One-way ANOVA showed significant differences in the extent of root canal transportation at 6- and 9-mm distances from the apex between the study groups (P=0.027 and P=0.002, respectively), with no significant difference at 3-mm distance from the apex between the groups (P=0.8) (Table 1).

Based on the results of post hoc Tukey tests concerning the two-by-two comparisons of the groups, there was a significant difference in root canal transportation at the 9-mm distance from the root apex only between the NeoNiTi and ProTaper groups (P=0.008); at the 6-mm distance, there were significant differences only between the NeoNiTi and ProTaper and Reciproc groups (P=0.002 and P=0.016, respectively).

Repeated-measures ANOVA showed that the root canal transportation extent at different sections was not significantly different in the ProTaper and Reciproc groups (P=0.067 and P=0.097, respectively). However, the differences were significant in the NeoNiTi and Hedstrom groups (P=0.001 and P=0.044).

Two-by-two comparisons of different sections with the Bonferroni test showed significant differences in the extent of root canal transportation at 3- and 6-mm sections in the NeoNiTi and Hedstrom groups (P=0.002 and P=0.044, respectively).

Jednosmjerna ANOVA pokazala je značajne razlike u opsegu prijenosa korijenskog kanala na udaljenosti od 6 i 9 mm od vrha između ispitivanih skupina (P = 0,027, odnosno P = 0,002), bez značajne razlike na udaljenosti od 3 mm od vrha između skupina (P = 0,8) (tablica 1.).

Na temelju rezultata post hoc Tukeyjevih testova koji se odnose na usporedbe skupina dva po dva, postojala je značajna razlika u prijenosu korijenskog kanala na udaljenosti od 9 mm od vrha korijena samo između skupina Neoniti i ProTaper (P = 0,008); na udaljenosti od 6 mm postojale su značajne razlike samo između skupina Neoniti i ProTaper i Reciproc (P=0,002, odnosno P = 0,016).

ANOVA ponovljenih mjerenja pokazala je da se opseg transportacije korijenskog kanala u različitim dijelovima nije značajno razlikovao u skupinama ProTaper i Reciproc (P = 0,067, odnosno P = 0,097). No razlike su bile značajne u skupinama Neoniti i Hedstrom (P = 0,001 i P = 0,044).

Usporedbe dva po dva različita presjeka Bonferronijevim testom pokazale su značajne razlike u opsegu transportacije korijenskog kanala na presjecima od 3 i 6 mm u skupinama Neoniti i Hedstrom (P = 0,002, odnosno P = 0,044).

Residual gutta-percha

Since the data on this variable were not distributed normally, non-parametric tests were used to compare residual data in different study groups. The Kruskal-Wallis test showed no significant difference in the percentages of residual gutta-percha at 3-, 6-, and 9-mm sections from the apex between the study groups (P=0.311, P=0.266, and P=0.080, respectively). A comparison of different sections in each group with the non-parametric Friedman test showed significant differences in the amount of residual gutta-percha between different sections in all the groups (P<0.01) except for the NeoNi-

Zaostatna gutaperka

Budući da podatci o ovoj varijabli nisu bili normalno distribuirani, korišteni su neparametrijski testovi za usporedbu podataka u različitim ispitivanim skupinama. Kruskal-Wallisov test nije pokazao značajnu razliku u postotcima zaostatne gutaperke na presjecima od 3, 6 i 9 mm od apeksa između ispitivanih skupina (P = 0,311, P = 0,266, odnosno P = 0,080). Usporedba različitih presjeka u svakoj skupini s neparametrijskim Friedmanovim testom pokazala je značajne razlike u količini zaostatne gutaperke između različitih presjeka u svim skupinama (P < 0,01), osim u skupini Neoniti (P

Table 1 Comparison of the results of root canal transportation and residual gutta-percha variables at different sections between the four study groups

Tablica 1. Usporedba rezultata transportacije korijenskog kanala i zaostatne gutaperke na različitim dijelovima kanala između četiriju ispitivanih skupina

Cross-section • Presjek	Group • Skupina	Root canal transportation • Transportacija korijenskog kanala (mm)			Residual gutta-percha • Zaostatna gutaperka (%)	
		Mean	SD	p-value	Percent • Postotak	P-value
9-mm distance	ProTaper	0.17	0.02	0.002	42.48	0.08
	Neoniti	0.11	0.01		60.32	
	Reciproc	0.01	0.01		47.68	
	Hedstrom	0.13	0.01		46.10	
6-mm distance	ProTaper	0.17	0.02	0.027	44.27	0.266
	Neoniti	0.08	0.01		52.70	
	Reciproc	0.15	0.01		56.04	
	Hedstrom	0.13	0.01		43.10	
3-mm distance	ProTaper	0.13	0.02	0.8	42.48	0.311
	Neoniti	0.15	0.01		57.26	
	Reciproc	0.20	0.02		50.10	
	Hedstrom	0.18	0.02		46.56	

Ti group (P=0.184). Concerning two-by-two comparisons of different sections, there were significant differences between the 6- and 9-mm sections and between the 3- and 9-mm sections from the apex in the ProTaper group according to Wilcoxon signed-rank test (P=0.033 and P=0.014, respectively), with no significant difference between the 3- and 6-mm sections from the apex (P=0.404). In the Reciproc groups, too, similar results were obtained (P=0.344, P=0.008, and P=0.002, respectively). In the Hedstrom group, 3- and 6-mm sections and 3- and 9-mm sections from the apex exhibited significant differences (P=0.023 and P=0.002, respectively); however, 6- and 9-mm sections from the apex were significantly different (P=0.106) (Table 1).

The time spent completing retreatment

One-way ANOVA showed significant differences in the time required to complete retreatment between the four study groups (P=0.001). Based on the results of two-by-two comparisons with post hoc Tukey tests, presented in Table 2, the differences in this variable were not significant between the ProTaper, NeoNiTi, and Reciproc groups (P=0.944). However, the differences between the Hedstrom group and the three other groups were significant (P<0.001) (Table 2).

= 0,184). Kada je riječ o usporedbi različitih presjeka dva po dva, zabilježene su značajne razlike između isječaka od 6 i 9 mm i između isječaka od 3 i 9 mm od apeksa u skupini ProTaper prema Wilcoxonovu testu s predznakom (P = 0,033, odnosno P = 0,014), bez značajne razlike između isječaka od 3 i 6 mm od apeksa (P = 0,404). U Reciproc skupinama također su dobiveni slični rezultati (P = 0,344, P = 0,008, odnosno P = 0,002). U Hedstrom skupini su isječci od 3 i 6 mm i od 3 i 9 mm od apeksa pokazali značajne razlike (P = 0,023, odnosno P = 0,002); međutim, presjeci od 6 i 9 mm od vrha značajno su se razlikovali (P = 0,106) (tablica 1.).

Vrijeme potrebno za reviziju

Jednosmjerna ANOVA pokazala je značajne razlike u vremenu potrebnom za završetak revizije između četiriju ispitivanih skupina (P = 0,001). Na temelju rezultata usporedbi dva po dva s post hoc Tukeyjevim testom, prikazanih u tablici 2., razlike u ovoj varijabli nisu bile značajne između skupina ProTaper, Neoniti i Reciproc (P = 0,944). No razlike između Hedstrom skupine i ostalih triju skupina bile su značajne (P < 0,001) (tablica 2.).

Table 2 Comparison of the times required to complete retreatment between the different groups
Tablica 2. Usporedba vremena potrebnog za završetak revizije između različitih skupina

Group • Skupina	Time • Vrijeme (s)		P-value
	Mean • Srednja vrijednost	SD	
ProTaper	270.50	11.68	0.001
Neoniti	262.35	8.90	
Reciproc	266.40	8.84	
Hedstrom	594.16	11.48	

Discussion

Root canal retreatment is investible due to the possible failure of the initial treatment (1). One of the chief aims of root canal treatment is to preserve the original shape of the root canal during mechanical debridement and shaping of the root canal (2-4, 24). Therefore, it is necessary to gain access to tools and techniques that are effective in retreatment procedures.

We used the three rotary systems of NeoNiTi, ProTaper, and Reciproc files to compare the efficacy of different currently used systems in the retreatment of curved root canals. Reciproc (VDW, Munich, Germany), a single file system with an s-shaped cross-section, removes root canal dentin using the reciprocal back (150 degrees counterclockwise) and forward (30 degrees clockwise) movements. The ProTaper files are triangular in cross-section or exhibit a modified triangular cross-section with lower cutting efficiency and smaller space for debris accumulation compared to the Reciproc file system. NeoNiTi A1 (NEOLIX, Châtres-la-Forêt, France) constitutes a single-file system with full rotary and continuous rotating movements. It has been manufactured using a special alloy to achieve superior file flexibility. According to the manufacturer data, the wire-cut electric discharge machining

Rasprava

Revizija endodontskog liječenja katkad je nužna zbog neuspjeha primarnog liječenja (1). Jedan od glavnih ciljeva endodontskog liječenja jest očuvati izvorni oblik korijenskog kanala tijekom mehaničkog čišćenja i oblikovanja korijenskog kanala (2 – 4, 24). Zato su potrebni instrumenti i tehnike koji su učinkoviti u postupcima revizije.

Upotrijebili smo tri rotacijska sustava – Neoniti, ProTaper i Reciproc – kako bismo usporedili učinkovitost različitih instrumenata koji se upotrebljavaju za reviziju zakrivljenih korijenskih kanala. Reciproc (VDW, München, Njemačka) jedinstveni je sustav instrumenata s poprečnim presjekom u obliku slova S, uklanja dentin korijenskog kanala recipročnim pokretima unatrag (150 stupnjeva suprotno od kazaljke na satu) i prema naprijed (30 stupnjeva u smjeru kazaljke na satu). ProTaper instrumenti trokutastoga su presjeka ili imaju modificirani trokutasti presjek s manjom učinkovitošću rezanja i manjim prostorom za nakupljanje dentinske piljevine u usporedbi s Reciprocom. Neoniti A1 (NEOLIX, Châtres-la-Forêt, Francuska) sustav je s jednim instrumentom s punim i kontinuiranim rotacijskim pokretima. Proizveden je od posebne legure za postizanje vrhunske fleksibilnosti. Prema podatcima proizvođača rezni mehanizam za obradu električnim pražnje-

mechanism has provided a sharper edge and superb flexibility. This file system is associated with a single-length preparation procedure for canal preparation at WL with a single disposable file. Such simplified single-file systems might prove effective due to their ease of application (25-27).

One of the iatrogenic problems during root canal instrumentation is root canal transportation. If root canal transportation exceeds 0.3 mm, the apical sealing ability of root canal obturation materials is severely compromised, worsening the treatment prognosis (28). None of the evaluated files exceeded this limit in the present study, thus pointing to the efficacy of these files.

Different techniques, including radiography and CBCT, have been used in various studies to evaluate the efficacy of the instruments used in root canal retreatment. Due to the difficulty of the exact superimposition of images and the two-dimensional nature of radiographic images (29), the CBCT technique has attracted attention because it provides three-dimensional images (30). In the present study, the CBCT technique was used to evaluate the extent of root canal transportation and the residual gutta-percha in the retreatment of curved root canals.

The results showed differences in root canal transportation between the study groups at 6- and 9-mm distances from the apex, with no significant differences at 3-mm distance from the apex. At the 9-mm distance from the apex, the highest transportation was related to the ProTaper group, with the lowest in the NeoNiTi group. This difference might be attributed to not using Gates-Glidden drills in the ProTaper group because they are used at high speeds. Therefore, they soften gutta-percha by the heat they produce, decreasing the need to apply lateral forces to the root canal walls. On the other hand, the special files of the ProTaper system for retreatment procedures have a cutting tip, and the D1 file has higher rigidity than D2 and D3 files, which are considered factors in increasing root canal transportation in this area. At the 6-mm distance from the apex, the greatest root canal transportation was detected in the ProTaper and Reciproc groups, with the lowest in the NeoNiTi group. Such a difference might be attributed to differences in file design. In addition, a lack of significant difference in the extent of root canal transportation at the 3-mm distance from the apex might be attributed to the similarity in diameter and instrument convergence in these sections.

An evaluation of root canal transportation by each instrument in different sections showed no significant differences between the different sections in the ProTaper and Reciproc groups. However, in the NeoNiTi and Hedstrom groups, such difference was significant, with a higher mean of transportation in the 3-mm section than the 6-mm section. Such differences might be attributed to greater root curvature in the apical area and the higher tendency of these files to straighten the root curvature.

However, Arruda *et al.* reported a similar root canal transportation rate by ProTaper and Reciproc instruments during root canal retreatment, which was clinically acceptable (31). Nabawizadeh *et al.* and Gergi *et al.* showed a greater extent of root canal transportation by Reciproc files during root ca-

njem omogućio je oštriji rub i vrhunsku fleksibilnost. Taj sustav instrumenata omogućuje postupak preparacije kanala do radne dužine jednim jednokratnim instrumentom. Takvi pojednostavljeni sustavi s jednim instrumentom mogli bi se pokazati učinkovitima zbog jednostavne primjene (25 – 27).

Jedan od ijatrogenih problema tijekom instrumentacije korijenskog kanala jest transportacija kanala. Ako transportacija korijenskog kanala premašuje 0,3 mm, svojstvo apikalnog pečaćenja materijala za opturaciju ozbiljno je ugroženo, pogoršavajući prognozu liječenja (28). U ovom istraživanju ni jedan od ispitivanih instrumenata nije premašio tu granicu, što upućuje na njihovu učinkovitost.

Različite tehnike, uključujući radiološki prikaz i CBCT, korištene su u raznim istraživanjima za procjenu učinkovitosti instrumenata koji se upotrebljavaju za reviziju endodontskog liječenja. Zbog otežane točne superpozicije i dvodimenzionalne prirode rendgenskih slika (29), CBCT tehnika privukla je pozornost jer daje trodimenzionalni prikaz (30). U ovom istraživanju je ta tehnika korištena za procjenu opsega transportacije korijenskog kanala i zaostatne gutaperke pri reviziji zakrivljenih korijenskih kanala.

Rezultati su pokazali razlike u transportaciji korijenskog kanala između ispitivanih skupina na udaljenosti od 6 i 9 mm od apeksa, bez značajnih razlika na udaljenosti od 3 mm od apeksa. Na udaljenosti od 9 mm od apeksa najveća transportacija zabilježena je u skupini ProTaper, a najmanja u skupini Neoniti. Ta se razlika može pripisati nekorištenju Gates-Gliddenova svrdla u skupini ProTaper jer se ona koriste pri velikim brzinama i stoga omekšavaju gutaperku toplinom koju proizvode, smanjujući potrebu za primjenom bočnih sila na stijenke korijenskog kanala. S druge strane, posebni instrumenti ProTaper sustava za postupak revizije imaju rezni vrh, a instrument D1 krući je od instrumenata D2 i D3 koji se smatraju čimbenicima povećanja transportacije korijenskog kanala u ovom području. Na udaljenosti od 6 mm od apeksa, najveća transportacija korijenskog kanala zabilježena je u skupinama ProTaper i Reciproc, a najmanja u skupini Neoniti. Takva se razlika također može pripisati razlikama u obliku instrumenata. Osim toga, nedostatak značajnih razlika u opsegu transportacije korijenskog kanala na udaljenosti od 3 mm od apeksa može se pripisati sličnosti u promjeru i konvergenciji instrumenata u tim dijelovima.

Procjena transportacije korijenskog kanala svakim instrumentom u različitim dijelovima kanala nije pokazala značajne razlike u skupinama ProTaper i Reciproc. Međutim, u skupinama Neoniti i Hedstrom takva je razlika bila značajna, s većom transportacijom u dijelu od 3 mm nego u dijelu od 6 mm. Takve razlike mogu se pripisati većoj zakrivljenosti korijena u apeksnom području i većoj tendenciji tih instrumenata da isprave zakrivljenost kanala.

Međutim, Arruda i suradnici izvijestili su o sličnoj stopi transportacije korijenskog kanala s pomoću ProTaper i Reciproc instrumenata tijekom revizije liječenja, što je bilo klinički prihvatljivo (31). Nabawizadeh i suradnici te Gergi i suradnici pokazali su veći opseg transportacije korijenskog kanala s pomoću Reciproc instrumenata tijekom obrade korijenskog kanala (29, 32). S druge strane, Mokhtari i suradnici izvijestili su da ručni instrumenti od nehrđajućeg čelika rezultira-

nal preparation (29, 32). On the other hand, Mokhtari *et al.* reported that stainless steel hand files resulted in more root canal transportation than rotary files (33), which is different from the results of the present study. Such a difference might be attributed to two reasons. First, there are differences in the root canal anatomy during the initial root canal treatment. In addition, there is a difference between the root canal preparation during the initial treatment and retreatment. In the abovementioned study, the rotary files that were used differed from those used in the present study (33).

The amount of remaining gutta-percha at 3-, 6-, and 9-mm distances from the apex was not significantly different in different study groups, indicating similar efficacy of the files to eliminate gutta-percha from curved root canals.

Rodig *et al.* reported that Reciproc, ProTaper, and Hedstrom files were equally effective in eliminating gutta-percha from the curved root canal (11). Rios *et al.* compared the efficacy of Reciproc, ProTaper, and Wave-one files in root canal retreatment. They concluded that the reciprocal systems were as effective as rotary files in eliminating gutta-percha from the root canals (34), which was confirmed in a study by Caper *et al.* (12) and is consistent with the present study.

On the other hand, Unal *et al.* and Aguiar *et al.* showed that the efficacy of the ProTaper universal retreatment file was lower than Hedstrom files in eliminating gutta-percha in the retreatment of root canals (2, 35). However, in this respect, Grewal et al. and Ozyurek et al. reported higher efficacy for ProTaper files than Hedstrom files (36, 37). Such a discrepancy in the results might be attributed to differences in the root canal preparation techniques.

A comparison of residual gutta-percha between different sections in each group revealed significant differences in all the groups except for the NeoNiTi group. In all these three groups, the maximum residual gutta-percha was found in the 3-mm sections from the apex. Such a difference might be attributed to differences in the designs of different files, lower efficacy of these instruments in the apical area, the use of Gates-Glidden drills and other instruments with a higher diameter and convergence in the coronal area, and differences in the root canal anatomy in the apical area, including greater root canal curve, the root canal coalescence area, the presence of isthmuses, and accessory root canals.

In the present study, more time was required to complete the retreatment procedure with hand files than that with engine-driven instruments, with no significant difference between the three engine-driven groups, which is consistent with studies by Zuolo *et al.*, Rodig *et al.*, Betti *et al.* (4, 11, 38).

Conclusion

All four file types effectively eliminated gutta-percha from curved root canals. Although the NeoNiTi file system resulted in less root canal transportation in the retreatment of curved root canals than the other file systems, all these files were clinically acceptable. More time is required to complete the retreatment of curved root canals with hand files compared with the time required to complete the retreatment of curved root canals with engine-driven files.

ju većom transportacijom korijenskog kanala nego rotirajući instrumenti (33), što se razlikuje od rezultata ovog istraživanja. Takva se razlika može pripisati dvama razlozima: prvo, razlikama u anatomiji korijenskog kanala tijekom početnoga liječenja korijenskog kanala, i drugo, razlici u instrumentaciji korijenskog kanala tijekom primarnoga liječenja i revizije. Osim toga, u gornjem istraživanju korišteni rotirajući instrumenti razlikovali su se od onih u ovom istraživanju (33).

Količina zaostatne gutaperke na udaljenostima od 3, 6 i 9 mm od apeksa nije se statistički značajno razlikovala u različitim ispitivanim skupinama, što upućuje na sličnu učinkovitost instrumenata u uklanjanju gutaperke iz zakrivljenih korijenskih kanala.

Rodig i suradnici izvijestili su da su instrumenti Reciproc, ProTaper i Hedstrom bili jednako učinkoviti u eliminaciji gutaperke iz zakrivljenoga korijenskog kanala (11). Rios i suradnici usporedili su učinkovitost instrumenata Reciproc, ProTaper i Wave-one u u reviziji liječenja. Zaključili su da su recipročni sustavi jednako učinkoviti kao i rotirajući u eliminaciji gutaperke iz korijenskih kanala (34), što je potvrđeno u istraživanju Capera i suradnika (12) i što je u skladu s rezultatima ovog istraživanja.

S druge strane, Unal i suradnici te Aguiar i suradnici pokazali su da je učinkovitost ProTaper univerzalnih instrumenata za reviziju manja od one Hedstrom instrumenata u eliminaciji gutaperke pri reviziji (2, 35). Međutim, u tom smislu, Grewal i suradnici te Ozyurek i suradnici izvijestili su o većoj učinkovitosti ProTaper instrumenata nego Hedstromovih (36, 37). Takvo odstupanje u rezultatima moglo bi se pripisati razlikama u tehnikama obrade korijenskih kanala.

Usporedba količine zaostatne gutaperke između različitih presjeka u svakoj skupini otkrila je značajne razlike u svim skupinama, osim u skupini Neoniti. U svim trima skupinama najviše zaostatne gutaperke pronađeno je u presjecima od 3 mm od apeksa. Takva se razlika može pripisati razlikama u dizajnu različitih instrumenata, manjoj učinkovitosti tih instrumenata u apikalnom području, upotrebi Gates-Gliddenova svrdla i drugih instrumenata s većim promjerom i konvergencijom u koronalnom području te razlikama u anatomiji korijenskog kanala u području apeksa, uključujući veću zakrivljenost korijenskog kanala, koalescencije korijenskog kanala, prisutnost istmusa i pomoćnih korijenskih kanala.

U ovom istraživanju vrijeme potrebno za dovršetak postupka revizije ručnim instrumentima bilo je dulje od onoga sa strojnim instrumentima, bez značajne razlike između triju strojnih sustava, u skladu s rezultatima Zuoloa i suradnika, Rodiga i suradnika te Bettija i suradnika (4, 11, 38).

Zaključak

Sve četiri vrste instrumenata učinkovito su eliminirale gutaperku iz zakrivljenih korijenskih kanala. Iako je sustav Neoniti rezultirao manjom transportacijom korijenskog kanala pri reviziji zakrivljenih korijenskih kanala od ostalih sustava, svi su instrumenti bili klinički prihvatljivi. Vrijeme potrebno za završetak revizije zakrivljenih korijenskih kanala ručnim instrumentima bilo je dulje nego sa strojnima.

Limitations

The rotary systems used in this study were different in removing gutta-percha from the coronal part of the canal. Finally, although Micro-CT is the gold standard to evaluate the aims of the study, it is not normally available.

Ograničenja

Rotacijski sustavi korišteni u ovom istraživanju bili su različiti u uklanjanju gutaperke iz koronalnog dijela kanala. Konačno, iako je Micro-CT zlatni standard za procjenu ciljeva istraživanja, obično nije dostupan.

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Sažetak

Svrha rada: Učinkoviti alati i metode primjenjuju se tijekom revizije endodontskog liječenja pri uklanjanju materijala za punjenje korijenskog kanala i kako bi se očuvala njegova početna anatomija. Ovo istraživanje uspoređivalo je učinkovitost instrumenata Reciproc, Neoniti, ProTaper i Hedstrom u reviziji zakrivljenih korijenskih kanala. **Materijal i metode:** U ovo istraživanje *in vitro* bilo je uključeno 100 korijenskih kanala sa zakrivljenošću od 25 do 45º. Nakon što su uzorci inicijalno instrumentirani i pregledani CBCT-om, korijenski kanali opturirani su gutaperkom i nasumično raspoređeni u četiri skupine (n = 25). Revizija je provedena u svakoj skupini instrumentima Neoniti, ProTaper, Reciproc i Hedstrom. Ponovno su obavljene CBCT pretrage pod istim uvjetima. Uzorci su procijenjeni na udaljenosti od 3, 6 i 9 mm od apeksa na prvoj i drugoj CBCT snimci s obzirom na transportaciju korijenskog kanala i zaostalu gutaperku u korijenskim kanalima. Zabilježeno je vrijeme potrebno za reviziju svakog kanala u svakom uzorku. Za analizu podataka primijenjeni su jednosmjerna ANOVA i odgovarajući neparametrijski testovi. **Rezultati:** Transportacija korijenskih kanala u Neoniti skupini bila je manja nego u drugima i statistički se značajno razlikovala od ProTaper skupine ($P < 0,05$). Nakon revizije zaostala je gutaperka u svim četirima skupinama, što nije bilo statistički značajno ($P > 0,05$). **Zaključak:** Unatoč manjoj transportaciji s instrumentima Neoniti u usporedbi s ostalim sustavima procijenjenima u reviziji zakrivljenih korijenskih kanala, svi su instrumenti bili vrlo učinkoviti na klinički prihvatljivim razinama.

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