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Procjena centriranosti rotirajućih instrumenata tijekom obrade korijenskih kanala

Assessment of the Centralization of Root Canal Preparation with Rotary Systems

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Sažetak

Svrha rada: Transportacija apeksa važan je čimbenik u endodontskom liječenju jer može uzrokovati terapijski neuspjeh. Svrha ovog istraživanja bila je odrediti centriranost instrumentacije sustavima rotirajućih instrumenata *ProTaper Universal*™, *Twisted File*™ i *Revo-S*® s pomoću CBCT snimaka prije obrade korijenskih kanala i poslije toga postupka. **Materijali i metode:** Trideset meziobukalnih korjenova ljudskih prvih donjih kutnjaka podijeljeno je u tri skupine po deset, te su obrađeni rotirajućim instrumentima kako slijedi: skupina 1 – *ProTaper Universalom*™; skupina 2 – *Twisted Fileom*™; skupina 3 – *Revo-S-om*®. Svi zubi snimljeni su CBCT-om kako bi se procijenio položaj korijenskog kanala prije i poslije instrumentacije (4 mm, 3 mm i 2 mm od apeksa). Slike tretiranih i netretiranih kanala analizirane su softverskim programom ICAT VISION. **Rezultati:** Rezultati su statistički analizirani Kolmogorov-Smirnovljevim testom normalnosti za kvantitativne varijable. Uspoređivane su dvije skupine (Mann-Whitneyev test – nenormalna distribucija) i više od dviju skupina (Kruskal Wallisov test – nenormalna distribucija). Razina značajnosti bila je postavljena na $p < 0,05$. Statistički značajna razlika ustanovljena je na udaljenosti od 4 milimetra između sustava *ProTaper Universal* i *Twisted File*. Za sustav *Twisted File* pronađena je statistički značajna razlika 4 i 3 milimetra od apeksa. **Zaključak:** Ni jedan od ispitanih instrumenata nije bio potpuno učinkovit u biomehaničkoj obradi korijenskih kanala s obzirom na to da je kod svih zabilježeno određeno odstupanje od izvorne anatomije kanala.

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korijenski kanal, preparacija; konična računalna tomografija; stomatološka oprema

Uvod

Uspjeh endodontskog liječenja izravno ovisi o pravilnoj trepanaciji, o kvaliteti biomehaničke preparacije i o hermetičkom brtvljenu korijenskoga kanalnog sustava. Cilj je postići neometan pristup apikalnom foramenu kroz korijenski kanal i pritom sačuvati njegov izvorni, konusni oblik (1 – 4).

Biomehanička preparacija korijenskog kanalnog sustava osobito je važna. To uključuje čišćenje, oblikovanje i dezinfekciju (5, 6). U tom kontekstu nove nikal-titanijske (NiTi) žice potaknule su razvoj novih endodontskih instrumenata, a time i sve češću zamjenu manualne tehnike instrumentacije kanala strojnom. Razvoj rotirajućih instrumenata omogućio je veću fleksibilnost i bolju učinkovitost rezanja, a smanjen je i broj neuspjeha povezanih s instrumentacijom kanalnog sustava (5).

Među trenutačno dostupnim sustavima rotirajućih instrumenata, oni izrađeni od nikla i titanija, kao što je *ProTaper Universal*™ (Dentsply/Maillefer, Ballaigues, Švicarska), temelje se na tehnološkoj inovaciji *ProTaper*™ i često se koriste u kliničkoj praksi. Ovaj sustav uključuje instrumente za oblikovanje kanala (SX, S1 i S2), završnu obradu (F1, F2, F3, F4

Introduction

The success of endodontic treatment depends directly on a correct coronary opening, well-executed biomechanical preparations and on hermetic closure of the root canal system. This leads to the attainment of free access to the apical foramen through the root canal with a tapered conical shape, thus preserving its original form. (1-4)

The biomechanical preparation of the root canal system is particularly important. This involves cleaning, modelling and disinfection, (5, 6) as well as the introduction of Nickel-Titanium (NiTi) wires, associated with a new design of endodontic files, and the consequent "replacement" of manual preparation by automatic modelling techniques. The development of rotary instruments has provided a greater flexibility and an excellent cutting capacity, while also reducing the number of failures related to the instrumentation of the root canal system. (5)

Among the currently available rotary instrumentation systems designed with nickel and titanium, ProTaper Universal™ (Dentsply / Maillefer, Ballaigues, Switzerland) is based on a technological innovation of the ProTaper™ Rotary Sys-

i F5) i reviziju (D1, D2 i D3), te multikonične instrumente koji se postupno sužavaju od 2 do 19 posto u jednom instrumentu. Također se odlikuju većom fleksibilnošću pri vrhu i većom otpornošću na bazi svakog instrumenta, s reznim bridovima pod promjenjivim spiralnim kutom, što rezultira većom snagom rezanja i manjim uvijanjem (1, 6 – 9).

Sustav *Twisted File*™ (TF) (SybronEndo, CA, SAD) pionir je među rotirajućim instrumentima koji sadržavaju NiTi zbog novoga proizvodnog procesa koji uključuje torziju žice i diferenciranu termičku obradu (grijanje, hlađenje i torzija), čime se pogoduje stvaranju R-faze u strukturi. Posljedica su iznimna mehanička i fizička svojstva, kao što su veća fleksibilnost i otpornost na zamor, pa se smanjuju ograničenja koja nameću instrumenti proizvedeni urezivanjem (5, 6, 10).

Nikal-titanijski sustav *Revo-S*® (Micro-Mega, Besançon, Francuska) razvijen je kako bi se pojednostavnilo endodontsko liječenje i optimizirao postupak čišćenja. Ovaj sustav poboljšava dubinsko čišćenje korijenskog kanala i apikalnu obradu koja zadovoljava anatomske i biološke kriterije. Ima dva instrumenta za početnu penetraciju (SC1 i SC2) i jedan za rekapitulaciju i čišćenje (SU). Također se proizvode instrumenti za apikalnu završnu obradu (AS30, AS35, AS40) (11 – 13).

U endodontskom liječenju iznimno su važne kvaliteta i količina podataka dobivenih rendgenskim pretragama jer utječu na dijagnozu, planiranje i ishod terapije. Zato su se za procjenu učinkovitosti NiTi instrumenata u osiguravanju centrirane instrumentacije kanala primjenjivale različite metode. Jedna od njih je kompjutorizirana tomografija (CT) kojom su se prvi put 1990. godine, kao dijagnostičkim *alatom* u endodonciji, koristili Tachibana i Matsumoto (14). Ova tehnika istraživačima omogućuje vizualizaciju struktura koje nisu vidljive na konvencionalnim rendgenskim snimkama.

CT se u endodonciji preporučuje kao neinvazivna metoda za analizu geometrije kanala i određivanje učinkovitosti tehnika instrumentacije, zatim za uspoređivanje anatomske strukture korijenskog kanala prije instrumentacije i nakon nje, te za procjenu načina preparacije korijenskog kanala. CT omogućuje detaljne 3D slike kanala i mjeri količinu dentina uklonjenog sa stijenki korijenskog kanala (15).

Posljednjih godina CBCT se razvio u obećavajući *alat* u endodontskim istraživanjima, s mogućnošću generiranja 3D slika visoke rezolucije bez mijenjanja izvorne slike (16, 17).

Zato je svrha ovog istraživanja bila CBCT-om procijeniti centriranost rotacijskih instrumenata *ProTaper Universal, Twisted File i Revo-S* tijekom biomehaničke obrade korijenskih kanala i nakon toga postupka.

tem and is widely used in clinical practice. This system includes modelling (SX, S1 and S2), finishing (F1, F2, F3, F4 and F5) and retreatment (D1, D2 **e** D3) instruments, as well as multi-tapers that range from 2 to 19% in a single instrument. It also exhibits greater flexibility at the tip and greater resistance at the base of each instrument, with cutting edges at a variable helical angle, which provides greater cutting power and leads to a lower screw effect. (1, 6-9)

The Twisted File™ (TF) (SybronEndo, CA, USA) system represents the first real starting point for other rotary instruments containing NiTi, with a new fabrication process that involves torsion of the wire and differentiated thermal treatment (heating, cooling and torsion), thus favoring the occurrence of the R-phase in its structure. This creates exceptional mechanical and physical properties, such as greater flexibility and resistance to fatigue, thereby reducing the limitations imposed by instruments that are fabricated through machining (5, 6, 10).

NiTi, the Revo-S® (Micro-Mega, Besançon, France) system was developed in order to simplify endodontic treatment and optimize its cleaning. This system promotes a deep cleaning of the root canal and apical finishing that satisfies the anatomical and biological criteria of the root canal. The system uses two instruments for the initial penetration (SC1 and SC2) and one instrument for recapitulation and cleaning (SU). It also offers a selection of instruments for apical finishing (AS30, AS35, AS40). (11-13)

In endodontic therapy, the quality and quantity of the data obtained from radiographic examinations are extremely important since they affect the diagnosis, planning and endodontic treatment to be executed. Thus, different methodologies have been used to assess the efficiency of NiTi instruments in terms of maintaining the centering of the preparation. One of these methods is computed tomography (CT), which was first used as a diagnostic tool in endodontics by Tachibana and Matsumoto in 1990. (14) This technique enabled researchers to visualize structures that had not been previously visible using conventional radiography.

CT has been recommended to endodontists as a non-invasive method of analyzing the geometry of the canal, determining the efficiency of modeling techniques, comparing the anatomical structure of the root canal before and after instrumentation and assessing the type of preparation of the root canal. CT provides detailed 3D images of the canal and measures the quantity of dentin removed from the wall of the root canal. (15)

More recently, cone beam computed tomography has evolved into a promising tool in endodontic research, with the capacity to provide high-resolution 3D images without altering the original image (16, 17).

Therefore, the aim of the present study was to assess the centering capacity of the ProTaper Universal, Twisted file and Revo S rotary systems during and after the biomechanical preparation of root canals using cone beam computed tomography.

Materijali i metode

1) Odabir uzoraka

Za ovo istraživanje, prije početka prikupljanja podataka, pribavljeno je odobrenje Etičkog povjerenstva za istraživanja na ljudima. Zubi su dobiveni od banke zuba Odjela za orofacijalnu kirurgiju i protetiku Saveznog sveučilišta Pernambuco. Čuvani su u destiliranoj vodi u hladnjaku, a prije toga dezinficirani su 30 minuta uranjanjem u 2-postotnu otopinu glutaraldehida i sterilizirani u autoklavu.

Korišteno je 30 ljudskih trajnih donjih kutnjaka. Odabrani su potpuno razvijeni meziobukalni kanali svih zuba zbog složene anatomije i stupnja zakrivljenosti koji se kretao od 50° do 60°, u skladu s kutom pristupa kanalu.

Kutnjaci su pregledani vizualno kako bi se odredilo je li korijen potpuno razvijen. Nakon toga svaki je zub rendgenski snimljen kako bi se potvrdilo da nema kalcifikata u meziobukalnom korijenu.

Da bi se odredila radna duljina, ušće korijenskog kanala dobro je isprano natrijevim hipokloritom (1%) (Roval, Recife, Brazil), a zatim je instrument Senseus-Flexofile #10 (Dentsply/Maillefer, Ballaigues, Švicarska) pažljivo uveden u njegovu unutrašnjost sve dok mu vrh nije dotaknuo apikalni foramen. Od ukupne duljine oduzet je 1 milimetar, čime je dobivena radna duljina.

Zubi su označeni brojevima od jedan do 30 i podijeljeni u tri skupine po 10 prije fiksiranja u voštane blokove.

2) Snimanje CBCT-om

Načinjene su CBCT snimke uzoraka uređajem *I-Cat Next Generation* sa sljedećim postavkama: visokofrekventne X-zrake 120 kV; 7mA; žarišna točka 0,5 mm; ekspozicija 26,9 s; voksel 0,2 mm (Imaging Science International Hartfield, PA, SAD). Na taj način dobivene su trodimenzionalne predoperativne snimke svakog zuba. Od vrha korijena slike su rezane 2, 3 i 4 milimetra koronarno od vrha korijena.

3) Biomehanička obrada korijenskih kanala

Uzorci su po skupinama instrumentirani sljedećim sustavima:

Methodology

1) Sample selection

The present study received approval from the Human Research Ethics Committee prior to the beginning of data collection. The teeth were obtained from the Tooth Bank of the Department of Orofacial Surgery and Prosthetics of the *Universidade Federal de Pernambuco.* The teeth were stored in distilled water, under refrigeration with prior disinfection by immersion in 2% glutaraldehyde for 30 minutes and autoclave sterilization.

Thirty human permanent lower molars were used. The mesiobuccal canals of all teeth with complete rhizogenesis were selected, due to their complex anatomy and the degree of curvature, which ranged from 50° to 60° in accordance with the canal access angle.

The molars were examined visually to determine the complete formation of the root. Subsequently, the teeth were individually radiographed to confirm the absence of calcifications in the mesiobuccal root.

In order to determine the actual working length (AWL), the mouth of the root canal was abundantly irrigated with sodium hypochlorite (1%) (Roval, Recife, Brazil) and a 10 # Senseus-Flexofile (Dentsply / Maillefer, Ballaigues, Switzerland) was carefully introduced into the interior of the root canal until its tip coincided with the apical foramen. Subsequently, 1 mm of the length obtained was removed, thereby establishing the AWL.

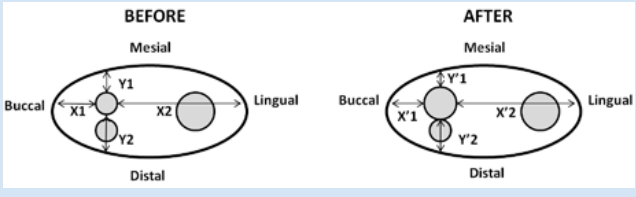
The teeth were numbered from one to 30 and randomly divided into three groups of 10, before being placed on a block of utility wax.

2) Image acquisition

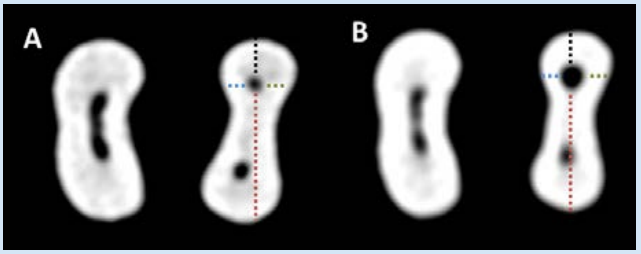
The specimens were submitted to cone beam computed tomography using the i-Cat Next Generation CT scanner, with the following settings: high-frequency X-rays 120 kV; 7mA; 0.5 mm focal point; 26.9 s of exposure; 0.2mm voxel acquisition (Imaging Sciences International Hartfield, PA, USA). Thus, three-dimensional pre-operatory images of each tooth were obtained. From the root apex, the images were cut 2mm, 3mm and 4mm coronally to the root apex.

3) Biomechanical preparation of root canals

The groups were instrumented with the following systems:



Slika 1. Shematski prikaz kako se procjenjuje centriranost instrumentacije, kao što su to opisali Gambill i sur. (1996.)
Figure 1 Schematic representation of the image used in the assessment of centering, as described by Gambill et al. (1996)



Slika 2a,b. Slike dobivene CBCT-om prije strojne instrumentacije i nakon toga postupka
Figure 2a,b Images obtained using cone beam computed tomography before and after rotatory instrumentation.

- Skupina 1*:* sustavom rotirajućih instrumenata *ProTaper Universal*™ (Dentsply/Maillefer, Ballaigues, Švicarska)
- Skupina 2: sustavom rotirajućih instrumenata *Twisted File*™ (SybronEndo, Kalifornija, SAD)
- Skupina 3: sustavom rotirajućih instrumenata *Revo-S*® (Micro-Mega, Besançon, Francuska)

Sve instrumentacije obavio je isti istraživač iskusan u radu s korištenim sustavima, kao što je opisano u nastavku.

Električni motor korišten je pri brzini od 300 okretaja u minuti, u skladu s uputama proizvođača (X-Smart, Dentsply/Maillefer, Ballaigues, Švicarska), uz sljedeći redoslijed uporabe instrumenata:

- Skupina 1: sustav rotirajućih instrumenata *ProTaper Universal*™
  (a) SX cervikalna trećina;
  (b) instrument S1 4 milimetra kraći od radne dužine;
  (c) S1 i S2 do pune radne dužine;
  (d) F1 i F2 do pune radne dužine.
- Skupina 2: sustav rotirajućih instrumenata *Twisted File* ™
  (a) instrument #25,08 u cervikalnoj trećini;
  (b) # 25,06 – 4 milimetra kraće od radne dužine;
  (c) #25,04 i #25,06 do pune radne dužine.
- Skupina 3: sustav rotirajućih instrumenata *Revo-S*®
  (a) instrument #25,06 (SC1) u cervikalnoj trećini;
  (b) #25,04 (SC2) i #25,06 (SU) do pune radne duljine.

Za ispiranje kanala korištena je Miltonova otopina natrijeva hipoklorita (1 %) koja je odabrana zbog svojstava, poput antimikrobnog djelovanja, otapanja organskih tvari i površinske aktivnosti s natrijevim kloridom (16 %) (Roval, Recife, Brazil). Korištena je naizmjenično sa 17-postotnom etilendiamintetra kiselinom (EDTA) (Biodinâmica, Ibiapora, Brazil) kao kelirajućim sredstvom. Korištena je svježe pripremljena 1-postotna otopina NaOCl-a (Farmacia Escola Carlos Dumont de Andrade, Recife, Brazil). Za aplikaciju je korištena 3-ml štrcaljka sustava FCF (FCF, Sao Paulo, Brazil) s iglom 30G (Injecta, Diadema, Brazil). Nakon svake promjene instrumenta korijenski kanali isprani su s 3 mililitra otopine. Tijekom postupka ispiranja vrh igle položen je 1 milimetar kraće od radne dužine te je otopina aplicirana kretnjom naprijed-natrag. Ispiranje je obavljeno na početku instrumentacije, između promjena instrumenata i na kraju biomehaničke obrade.

Nakon završetka biomehaničke obrade uzorci su ponovno snimljeni CBCT-om, slijedeći isti protokol kao i za prvu tomografsku snimku.

4) Procjena centriranosti instrumenta

Korištenjem softvera ICAT VISION mogle su se usporediti snimke korijenskih kanala prije instumentacije i poslije nje. Jednadžba Gambilla i suradnika iz 1996. (18) korištena je za određivanje centriranosti instrumentacije (slika 1.):

$$D1: (X1 - X'1)/(X2 - X'2)$$
$$D2: (Y1 - Y'1)/(Y2 - Y'2)$$

gdje je D1 = vestibulooralna udaljenost, a D2 = meziodistalna udaljenost.

- Group 1: ProTaper Universal™ rotary system (Dentsply / Maillefer, Ballaigues, Switzerland)
- Group 2: Twisted File™ rotary system (SybronEndo, California, USA)
- Group 3: Revo-S® rotary system (Micro-Mega, Besançon, France)

All of the instrumentation was performed by a single operator with experience of the systems to be used, as described below:

An electric motor was used at a speed of 300 rpm, according to manufacturers' instructions (X-Smart, Dentsply / Maillefer, Ballaigues, Switzerland), in continuous instrumentation as follows:

- Group 1: ProTaper Universal™ rotary system
  (a) SX cervical third;
  (b) instrument S1 used 4 mm below the AWL;
  (c) S1 and S2 for the entire AWL;
  (d) F1 and F2 for the entire AWL.
- Group 2: Twisted File™ rotary system
  (a) Instrument 25.08# used on the cervical third;
  (b) 25.06# used 4mm below the AWL;
  (c) 25.04# and 25.06# used for the entire AWL.
- Group 3: Revo-S® Rotary system
  (a) Instrument 25.06# (SC1) used in the cervical third;
  (b) 25.04# (SC2) and 25.06# (SU) used for the entire AWL.

A Milton solution of sodium hypochlorite (1%) - is a solution used worldwide for its properties such as antimicrobial activity, ability to dissolve organic matter and because it is surface-active with sodium chloride (16%) (Roval, Recife, Brazil) was used together with 17% ethylene diamine tetra acid (EDTA) (Biodinâmica, Ibiapora, Brazil) as a chelating agent to irrigate the canals. Freshly prepared 1% NaOCl solution (Farmácia Escola Carlos Dumont de Andrade, Recife, Brazil) was used for root canal irrigation. For irrigation of the root canal, a 3-mL FCF syringe system (FCF, Sao Paulo, Brazil) with a 30-G needle (Injecta, Diadema, Brazil) was used. After each instrument change, the root canals were rinsed with 3 mL of the irrigating solution. During the irrigation procedures, the irrigator tips were placed 1 mm from the WL and then moved backwards and forwards. A 3ml syringe with a 30G caliber needle (Injecta, Diadema, Brazil) was also used. Irrigation was performed at the beginning of instrumentation, between the instrumentation changes and at the end of the biomechanical preparation.

After the completion of the biomechanical preparation, the specimens were examined using a new computed tomography, following the same protocol described in the initial tomographic examination.

4) Assessment of the centering capacity

Using ICAT VISION software, it was possible to compare the pre- and post-operatory images of root canals. A formula described by Gambill et al. 1996 (18) was used to determine the centering of the preparations (Figure 1):

$$D1: (X1 - X'1)/(X2 - X'2)$$
$$D2: (Y1 - Y'1)/(Y2 - Y'2)$$

where D1= the vestibulo-lingual distance and D2= the mesiodistal distance.

Transportacija korijenskog kanala nakon instrumentacije odgovarala je odstupanju njegove središnje osi od početne. Količina i smjer transportacije određeni su mjerenjem udaljenosti između granica neinstrumentiranog kanala i granica korijena u mezijalnom i distalnom smjeru, te usporedbom vrijednosti istih mjerenja u obrađenom kanalu (slika 2a,b).

Usporedba mjerenja prije instrumentacije i nakon toga postupka upućivala je na područje s najviše odnesenoga zubnog tkiva, potvrđujući odstupanje ili neodstupanje od izvorne putanje kanala.

Prije bodovanja, sva tri istraživača ocijenila su prvih 20 kanala zajedno radi kalibracije. Na temelju rezultata dobivenih iz gore navedene jednadžbe, negativna vrijednost upućivala je na transportaciju u distalnom smjeru, a pozitivna na transportaciju u mezijalnom smjeru. Rezultat nula upućivao je na to da nije bilo transportacije.

5) Statistička analiza

Podatci su uneseni u tablice i analizirani softverom STATA/SE 12,0 i programom Microsoft Excel 2007. Svi statistički testovi provedeni su s intervalom pouzdanosti od 95 posto. Brojčane varijable prikazane su kao srednje vrijednosti i standardne devijacije. Podatci su analizirani Kolmogorov-Smirnovljevim testom normalnosti za kvantitativne varijable s normalnom distribucijom. Pri nenormalnoj distribuciji za usporedbu dviju skupina korišten je Mann-Whitneyev test, a za više od dvije skupine Kruskal Wallisov.

Rezultati

U tablici 1. su rezultati usporedbe prosječnih vrijednosti i standardnih devijacija transportacije kanala za sva tri ispitana sustava. Temelje se na mjerenjima meziobukalnog korijena u bukolingvalnom (D1) i meziodistalnom (D2) smjeru na udaljenosti od 4, 3 i 2 milimetra od vrha korijena.

Usporedba između skupina obavljena je neparametrijskim Kruskal-Wallisovim testom, s obzirom na to da su podatci pokazali nenormalnu distribuciju. Test je potvrdio da je postojala statistički značajna razlika između sustava *ProTaper Universal* i *Twisted* 4 milimetra od vrha korijena. U istoj skupini (*Twisted File*) nađene su statistički značajne razlike između udaljenosti od 4 i 3 milimetra od vrha korijena.

Root canal transportation corresponded to deviation of the central axis of the root canal after its instrumentation. The extension and the direction of the transportation were determined by measuring the distance between the limits of the non-instrumented canal and the root limits, in both the mesial and distal directions, subsequently by comparing the same measurements with the instrumented canal (Figure 2a,b).

The comparison of the pre-and post-operatory measurements indicated the area with most wear, confirming the presence or absence of deviation in the trajectory of the canal.

Before scoring, the 3 examiners assessed the first 20 specimens together for calibration. Based on the results of the above formula purposes, a negative value indicated that transportation occurred in distal direction, whereas a positive value indicated that it occurred in mesial direction. A result of zero indicated the absence of transport.

5) Statistical data analysis

The data were tabulated and analyzed using STATA/SE 12.0 software and Microsoft Excel 2007. All tests were applied with a confidence interval of 95%. The numerical variables were represented by the central tendency and dispersion measurements. The data were assessed using the Kolmogorov-Smirnov normality test for quantitative variables with normal distribution. Comparisons of two groups (Mann-Whitney - abnormal) and more than two groups (Kruskal Wallis - abnormal) were made.

Results

Table 1 shows the results of comparisons of mean values and standard deviation values for transportation of the three systems studied. These results are based on the mesiobuccal root in the buccolingual (D1) and mesial-distal (D2) measurements obtained by instruments at distances of 4mm, 3mm and 2mm from the root apex.

A comparison between the groups was made using the non-parametric Kruskal-Wallis test, given that the data exhibited an abnormal distribution. The test confirmed a statistically significant difference between the ProTaper Universal and Twisted File systems at a distance of 4mm below the root apex. Within the same group (Twisted File), statistically significant differences were found between the distances of 4mm and 3mm below the root apex.

Tablica 1. Prosječne vrijednosti i standardne devijacije za mjerenje centriranosti u svim ispitanim skupinama
Table 1 Mean and standard deviation values for the centering measurement in each experimental group

Duljina • Length	Instrument			p-value *
	Universal Protaper	Twisted File	Revo S	
	Mean ± DP	Mean ± DP	Mean ± DP	
4 mm	0.04 ± 0.08	0.26 ± 0.30	0.08 ± 0.14	0.026
3 mm	0.04 ± 0.13	0.04 ± 0.08	0.04 ± 0.08	0.682
2 mm	0.04 ± 0.13	0.07 ± 0.13	0.04 ± 0.08	0.616
p-value *	0.837	0.036	0.773	

(*) Kruskal-Wallisov test • Kruskal-Wallis Test

Rasprava

Pravilna biomehanička obrada korijenskog kanalnog sustava ostaje izazov za endodonta. Zanemarivanje protokola liječenja može potaknuti jatrogene posljedice, uključujući neželjeno odstupanje od izvorne anatomije korijenskog kanala. To može rezultirati nedovoljno očišćenim kanalom, uz moguću perzistenciju već postojećih apikalnih oštećenja ili oslabljenje korijena (19). Slijedom toga, neprestano se razvijaju nove tehnike proizvodnje i na tržištu se pojavljuju novi instrumenti.

Pojavom nikal-titanijskih (NiTi) rotirajućih instrumenata znatno se poboljšala kvaliteta instrumentacije korijenskih kanala, s obzirom na to da se odlikuju velikom elastičnošću i fleksibilnošću pa omogućuju učinkovitiju preparaciju. Sustavi *ProTaper Universal*™ i *Revo-S*® proizvode se tradicionalno, glodanjem NiTi žice. Sustav *Twisted File*™ proizvodi se uvijanjem, što smanjuje nastanak mikropukotinama i čini instrumente izdržljivijima. Osim toga mogu pratiti zakrivljenost kanala, čime se izbjegavaju devijacije tijekom obrade (20, 21, 22).

U ovom istraživanju kao uzorci su korišteni izvađeni ljudski zubi kako bi se pokušalo što više približiti stvarnim kliničkim uvjetima rada, kao što je opisano u nekoliko istraživanja (5, 7, 23 – 26). Ljudski zubi odabrani su zato što osiguravaju točniju simulaciju kliničkih uvjeta od akrilatnih blokova (2, 7).

U ovom istraživanju korišteni su meziobukalni kanali donjih kutnjaka jer su oni naglašeno zakrivljeni (3, 15, 24). Stoga je jednostavnije odrediti je li tijekom biomehaničke preparacije bilo odstupanja ili ne.

Za procjenu centriranosti preparacije korijenskog sustava u ovom istraživanju korišten je CBCT. Ta tehnika omogućila nam je snimanje nekoliko trodimenzionalnih slika čime su dobiveni detaljni prikazi korijenskih kanala prije instrumentacije i nakon toga postupka (3, 5, 14 – 17, 19, 21, 22, 27 – 29).

Svrha ovog istraživanja bila je usporediti centriranost instrumentacije rotirajućih instrumenata sustava *ProTaper Universal*™, *Twisted File*™ i *Revo-S*® u slučaju zakrivljenih kanala korištenjem CBCT snimaka prije i nakon instrumentacije mjereno 4, 3 i 2 milimetra od apikalne granice. Rezultati su potvrdili statistički značajne razlike između sustava *ProTaper Universal*™ i *Twisted File* ™ za dužinu od 4 milimetra i statistički značajnu razliku između dužine od 4 i 3 milimetra za sustav *Twisted File*™.

Ovi rezultati u skladu su s onima koje su objavili Aguiar i suradnici 2012. (21) i dva puta 2009. (2, 7), te Hashem i njegovi kolege (29), a koji pokazuju da rotacijski sustavi *Twisted File*™ i *Revo-S*® dovode do transportacije kanala.

Gergi i suradnici 2010. (3) su kompjutoriziranom tomografijom uspoređivali sposobnost centriranja sustava *Twisted File*™, *Pathfile-ProTaper*™ i ručnih K-instrumenata od nehrđajućeg čelika te su ustanovili manju transportaciju i bolju centriranost preparacije kada su se koristili instrumentima *Twisted File*™. Diemer i njegovi kolege (30) istaknuli su da rotacijski sustav *Revo-S*® omogućuje brzo oblikovanje, dobro čišćenje i zadržavanje izvornog smjera kanala, što nije u skladu s rezultatima ovog istraživanja.

Discussion

The correct biomechanical preparation of root canal systems remains a challenge for endodontists. Neglecting the treatment protocol can lead to iatrogenic sequelae, including unwanted deviations from the original anatomy of the root canal. This deviation may result in an inadequately clean canal, with possible persistence of pre-existing apical injuries or increasing weakness in the remaining root. (19) Consequently, a large number of preparation techniques and new instruments have been proposed and launched on the market.

With the advent of nickel and titanium (NiTi) rotary instruments, there has been a considerable improvement in the quality of preparations of root canals, since these instruments exhibit excellent elasticity and flexibility, thus favoring a more effective preparation. ProTaper Universal™ and Revo-S® are produced by a traditional NiTi grinding process. The Twisted File™ is produced by twisting that reduces formation of microfractures, making the file even more durable. They are also capable of maintaining the curvature of severely curved canals, thereby avoiding deviations during the instrumentation. (20, 21, 22).

Extracted human teeth were selected for the sample in the present study in an attempt to approximate the experiment with clinical working conditions, as described in several studies in the literature. (5, 7, 23-26). Human teeth were selected due to the fact that they provide a more accurate simulation of clinical conditions than acrylic blocks. (2, 7)

In the present study, mesiobuccal canals from lower molars were used as they often exhibit accentuated curves. (3, 15, 24) Therefore, it would be possible to determine whether there was a deviation or not during the biomechanical preparation.

Cone beam computed tomography was used in the present study to assess the centering of the root canal system preparation. This technique enabled us to capture several three-dimensional images, thereby providing detailed root canal data before and after the instrumentation took place. (3, 5, 14-17, 19, 21, 22, 27-29).

The aim of the present study was to compare the centering capacity of the ProTaper Universal™, Twisted File™ and Revo-S® rotary systems in the preparation of curved canals using cone beam computed tomography before and after instrumentation 4mm, 3mm and 2mm from the apical limit. The results confirmed statistically significant differences between the ProTaper Universal ™ and Twisted File™ systems for the length of 4 mm and a statistically significant difference between the lengths 4mm and 3mm for the Twisted File™ system.

These results are in agreement with those reported by Aguiar et al., 2012, (21) Aguiar et al., 2009 (2), Aguiar et al., 2009 (7) and Hashem *et al* (29), which stated that Twisted File™ and Revo-S® rotary systems produced canal deviation.

However, Gergi et al. 2010 (3) compared the centering ability of the Twisted File™, Pathfile-ProTaper™, and stainless steel hand k-files by using computed tomography and reported less transportation and a better centering of the preparation when using the Twisted File™ system. Diemer *et al.* (30)

U nekoliko dosadašnjih istraživanja postignuti su rezultati slični onima u ovom istraživanju i autori su upozorili na odstupanje od izvorne anatomije kanala, bez obzira na vrstu rotirajućih instrumenata (15 – 19). U drugim istraživanjima (19, 27 – 29) navodi se da sustav *ProTaper Universal*™ više potiče apikalnu transportaciju u odnosu na druge sustave koji se upotrebljavaju zbog površinske napetosti tijekom instrumentacije kanala. Transportacija kanala prema vanjskoj granici, izazvana sustavom *ProTaper,* bila je povezana s progresivnim sužavanjem rezne površine instrumenata u kombinaciji s oštrim reznim bridovima na poprečnom presjeku.

U sličnom istraživanju su Hashem i suradnici (2012.) (29) procjenjivali centriranost instrumentacije kanala 1,3, 2,6, 5,2 i 7,8 milimetara od apeksa. Sustavom *ProTaper Universal*™ uklonjena je bila znatno veća količina dentina u odnosu na druge sustave. Istraživači su zaključili da se sustavom *Twisted File*™ *Rotary* najbolje oblikuju zakrivljeni korijenski kanali te da su Revo-S® i GTX bili bolji od sustava *ProTaper* kad je riječ o transportaciji korijenskog kanala i centriranosti instrumentacije.

Ovi zaključci bili su slični onima koje su objavili Liu i Wu 2016. (17) kada su određivali naprezanje uzrokovano na površini korijena i stupanj transportacije sredine kanala tijekom instrumentacije sustavima *Twisted File*™, *ProTaper Next* i *WaveOne*. Zaključili su da su, u zakrivljenim kanalima obrađenima sustavom *Twisted File*™, naprezanje na površini korijena te transportacija u apikalnom dijelu bili manje izraženi.

U sličnom istraživanju (1) *Twisted File*™ pokazao je bolju centriranost u svim područjima korijena u usporedbi sa sustavima *Mtwo i Revo-S*®. Taj rezultat bio je u korelaciji s novim postupkom proizvodnje instrumenata. Sustav *Revo-S*® uzrokovao je najveći stupanj apikalne transportacije.

Na temelju svih tih rezultata može se zaključiti da nepravilno uklanjanje dentina s unutarnje površine korijenskih kanala zabrinjava i utječe na rezultate endodontskog liječenja. Ti su podatci potpuno relevantni kad se usporede s rezultatima ovog istraživanja u kojemu su sva tri ispitana sustava rotirajućih instrumenata rezultirala određenim stupnjem apikalne transportacije.

No važno je uzeti u obzir neke čimbenike, kao što su kut zakrivljenosti korijenskih kanala, koji se koriste u raznim istraživanjima i usporediti različite sustave instrumenata za njihovo oblikovanje. Osim toga, učinak treba procijeniti uzimajući u obzir oblik, način proizvodnje i mehanizam rada endodontskih instrumenata.

S obzirom na rezultate dobivene u ovom istraživanju, potrebna su daljnja istraživanja (uz iste postavke) kako bi se preciznije razjasnila korelacija između pojave apikalne transportacije i novih rotirajućih instrumenata koji su danas dostupni na tržištu.

reported that the Revo-S® rotary system enables a fast shaping quality, a real cleaning and maintains the original canal path, which is not in accordance with the results of the present research.

Several previous studies have reported similar results to those found in the present study, suggesting a deviation in the original anatomy of the canal, regardless of the type of rotary system used. (15-19) Other studies (19,27-29) have reported that the ProTaper Universal ™ Rotary system exhibited a greater tendency of apical transportation than other systems used due to tension on the surface during the preparation of canals. Canal transportation toward the outer aspect of the canal with ProTaper was related to their progressive tapers along the cutting surface of the instruments in combination with the sharp cutting edges of their cross-sectional design.

In a similar study, Hashem et al. (2012) (29) assessed the centering capacity of the canal 1.3, 2.6, 5.2 and 7.8 millimeters from the apex. The ProTaper Universal ™ rotary system removed a significantly greater quantity of dentin than other systems. The researchers concluded that the Twisted File™ Rotary system demonstrated the greatest modeling capacity in curved root canals, and that the Revo-S® and GTX systems were better than the ProTaper system with regard to root canal transportation and centering capacity.

These conclusions were similar to those reported by Liu and Wu, 2016, (17) who determined the root surface strain generated and the extent of canal center transportation during canal shaping using Twisted File™, ProTaper Next Files and WaveOne rotatory systems. They stated that the curved canals prepared using Twisted File™ exhibited lower root surface strain and less canal center transportation at the apical section.

In a comparable study, (1) the Twisted File™ rotary system was found to exhibit a better centering capacity in all regions of the root when compared with the Mtwo and Revo-S® rotary systems. This result was correlated with the new process of instrument fabrication. The Revo-S® system exhibited the greatest apical transportation.

Based on all these reports, it can be inferred that improper removal of dentin from the surface of root canals is a concern and affects the results of endodontic therapy. These data are entirely relevant when compared with those reported in the present study, in which the three rotary systems assessed achieved some degree of apical deviation.

However, it is important to consider some factors such as the curvature angle of root canals used in various studies and to compare different canal shaping instrumentation systems. Furthermore, their influence needs to be assessed by taking into account design, manufacturing and working mechanisms of endodontic files.

According to the results obtained in the present study, further research (following the same line of research) is needed in order to more accurately elucidate the correlation between the occurrence of apical transportation and new rotary instruments available on today's market. OuvirLer foneticamente

Zaključak

Sve navedene tehnike uzrokovale su određen stupanj apikalne transportacije. Jedina statistički značajna razlika pronađena je između sustava *ProTaper Universal*™ i *Twisted File*™ na udaljenosti od 4 milimetra od korijenskog apeksa. *ProTaper Universal*™ i *Revo-S*® pokazali su se sigurnima tijekom centrirane instrumentacije zakrivljenih korijenskih kanala, s niskim stopama odstupanja od njihova izvornog smjera. Rezultati ovog istraživanja moraju se približiti kliničkoj stvarnosti te su potrebna daljnja istraživanja rotacijskih instrumenata kako bi se pridonijelo uspješnijem endodontskom liječenju.

Sukob interesa

Autori ne navode sukob interesa u vezi s ovim istraživanjem.

Conclusion

In conclusion, all of the above mentioned techniques caused some degree of apical deviation. The only statistically significant difference was found between the ProTaper Universal™ and Twisted File™ systems when using a length of 4 mm below the root apex. The ProTaper Universal™ and Revo-S® systems were shown to be safe methods of performing the centralized preparation of curved root canals, with low rates of deviations from the original path of the root canal. The results of this research must be approximated to practical reality and further studies of rotatory instruments need to contribute to a more successful endodontic treatment.

Conflict of interest

The authors deny any conflicts of interest related to this study.

Abstract

Objective: Apical deviations are important factors in endodontic therapy, since they can cause the treatment failure. The aim of the present study was to determine the centering capacity of ProTaper Universal™, Twisted File™ and Revo-S® rotary systems using cone beam computed tomography analysis before and after the instrumentation of root canals. **Materials and Methods:** Thirty mesiobuccal roots from human lower first molars were divided into three groups of ten: Group 1 - ProTaper Universal™ Rotary System; Group 2 - Twisted File™ Rotary System; and Group 3 - Revo-S® Rotary System. All teeth were scanned using computed tomography to determine the condition of the root canal before and after instrumentation (4mm, 3mm and 2mm from the root apex). Images were made using ICAT VISION software for both instrumented and non-instrumented canals. **Results:** The results were analyzed statistically using the Kolmogorov-Smirnov normality test for quantitative variables. Comparisons were made with two groups (Mann-Whitney - abnormal) and with more than two groups (Kruskal Wallis - abnormal). The level of significance was set at $p<0.05$. A statistically significant difference was found for the measurement of 4 mm between the "ProTaper Universal" and "Twisted File" systems. For the Twisted File system, a statistically significant difference was recorded between the measurements of 4mm and 3 mm. **Conclusion:** None of the assessed instruments was completely effective in terms of the biomechanical preparation of root canals since all created deviation from the original anatomy of the canal.

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Key words
Tooth Apex; Root Canal Preparation; Cone-Beam Computed Tomography; Dental Equipment

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