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IZVORNI ZNANSTVENI RAD
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Usporedba učinkovitosti 10 rotacijskih i recipročnih endodontskih sustava: *in vitro* istraživanje u AutoCAD-u

Comparison of Shaping Ability of 10 Rotary and Reciprocating Systems: an In Vitro Study with AutoCAD

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Sažetak

Cilj: Usporediti reznu površinu, očuvanje anatomije korijenskog kanala i neinstrumentiranu površinu nakon instrumentacije sustavima F360®, F6SkyTaper®, HyflexEDM®, iRace®, Neoniti®, O.Shape®, P.Next®, Reciproc®, Revo-S® i WaveOneGold® s veličinom instrumenta 25. **Materijali i metode:** Tristo zubi s jednim ravnim korijenom i okruglim ili eliptičnim presjekom korijenskog kanala podijeljeno je u 10 skupina (1-F360®, 2-F6SkyTaper®, 3-HyflexEDM®, 4-iRace®, 5-Neoniti®, 6-O Shape®, 7-P.Next®, 8-Reciproc®, 9-Revo-S® i 10-WaveOneGold®) i poprečno prerezano na trećine ultrafinim reznim diskovima. Uzorci su fotografirani pod stereomikroskopom i provedena je predinstrumentacijska analiza prije ponovnog spajanja zuba K-instrumentom #10 i epoksi smolom. Ručno je uspostavljena prohodnost K-instrumentima #10 i #15 te je svaka skupina instrumentirana jednim od rotacijskih ili recipročnih sustava. Rezna površina, očuvanje anatomije korijenskog kanala i neinstrumenirana površina analizirani su s pomoću AutoCAD-a 2015. Za statističku analizu korišteni su Leveneov test, Welchov test, Games-Howellsov test i Pearsonov hi-kvadrat test. **Rezultati:** Leveneov test nije pokazao jednakost varijacije ($P < 0,05$), pa su primijenjeni Welchov i Games-Howellov test u analizi rezne površine, pokazujući statistički značajne razlike za sve trećine i ukupno ($P < 0,05$). Nisu zabilježene razlike u očuvanju anatomije korijenskog kanala ($P > 0,05$). Što se tiče neinstrumentirane površine, pronađene su statistički značajne razlike ($P < 0,05$), pri čemu su u srednjoj trećini bili bolji Reciproc®, Neoniti® i WaveOneGold®, a u apikalnoj trećini P.Next®, Reciproc®, HyflexEDM®, Neoniti® i WaveOneGold®. **Zaključci:** Što se tiče rezne površine, P.Next® i Reciproc® bili su bolji u koronarnoj trećini, Neoniti® i HyflexEDM® u sredini i apikalno, a sveukupno Neoniti® i Reciproc®. Što se tiče očuvanja anatomije korijenskog kanala, svi su sustavi bili slični. S obzirom na neinstrumentiranu površinu, svi su sustavi postigli slične rezultate koronarno, ali Reciproc®, Neoniti® i WaveOneGold® bili su bolji u srednjoj trećini te P.Next®, Reciproc®, HyflexEDM®, Neoniti® i WaveOneGold® apikalno.

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Uvod

Mehanička obrada kanala jedan je od najvažnijih postupaka u endodontskom liječenju koji utječe na mogućnost ispiranja i punjenja korijenskog kanala (1). Važno je očuvati anatomiju kako bi se smanjilo oštećenje zubne strukture nakon uklanjanja kontaminiranog dentina i oblikovanja korijenskog kanala (2). U idealnom slučaju oblikovanjem korijenskog kanala trebalo bi postići njegov kontinuirano koničan oblik od krune do apeksa, zadržavajući izvornu putanju kanala i što manju veličinu apeksnog foramena (3). Međutim, instrumentacijom korijenskog kanala može doći do transportacije apeksnog foramena (4), promjene oblika korijenskog kanala (5), pa čak i perforacije (6).

Posljednjih godina kliničari su se koristili različitim rotacijskim i recipročnim sustavima koji se razlikuju po simetriji, poprečnom presjeku, broju instrumenata, leguri itd. Razvijena je i nova generacija endodontskih sustava od nikal-titanij-

Introduction

Biomechanical preparation is one of the most important procedures in endodontic treatment, influencing irrigation and root canal filling (1). It is important to preserve the anatomy in order to reduce damage to dental structures when contaminated dentin is removed and the root canals are formed (2). Ideally, root canal shaping should create a continuous tapered preparation from crown to apex while maintaining the original path of the canal and keeping the foramen size as small as is practical (3). However, root canal instrumentation can produce apical transportation (4), changes in the shape of the root canal (5) and even perforations (6).

In recent years, clinicians have used different rotary and reciprocating systems that differ in symmetry, cross-section, number of uses, alloy, etc. Currently, a new generation of endodontic systems made from nickel-titanium alloys has ar-

skih legura promijenjenog dizajna kako bi se poboljšala fleksibilnost, otpornost na ciklički zamor i učinkovitost rezanja, s predvidivim rezultatima i manje jatrogenih oštećenja, ali te modifikacije ne poboljšavaju sva svojstva endodontskih instrumenata (7, 8).

Uvođenje recipročnih sustava s jednim instrumentom otvorilo je nove mogućnosti u preparaciji korijenskih kanala (9, 10). Krivulja učenja tih sustava i ušteda u usporedbi s rotacijskim sustavima s više instrumenata privlače zanimanje zbog pojednostavnjenja tehnike, jer se za obradu korijenskih kanala rabi samo jedan instrument (11). Dodatno, recipročna kretnja oslobađa instrument iz dentina prije nego što se može zaglaviti u kanalu i smanjuje rizik od deformacije korijenskog kanala i loma instrumenta (12, 13).

Danas je niz različitih legura poboljšaoo svojstva konvencionalnog NiTi-ja. M-Wire, legura stvorena toplinskom obradom konvencionalnog NiTi-ja, korištena je u sustavima Reciproc® (VDW, München, Njemačka) i Wave One® (Dentsply Maillefer, Ballaigues, Švicarska) (14, 15). Gold-Wire je još jedna legura koja se nedavno pojavila poboljšavajući svojstva sustava ProTaper Universal® (Dentsply Maillefer, Ballaigues, Švicarska) i Wave One® (Dentsply Maillefer, Ballaigues, Švicarska) te stvarajući nove sustave ProTaper Gold® (Dentsply Maillefer, Ballaigues, Švicarska) i Wave One Gold® (Dentsply Maillefer, Ballaigues, Švicarska) (16, 17), s novom termičkom obradom površine (18). CM-Wire legura upotrebljava se u sustavima Hyflex CM® (Coltene, Altstätten, Švicarska), Hyflex EDM® (Coltene, Altstätten, Švicarska) i Neoniti® (Neolix, Chatres-La-Foret, Francuska) koji su korisni za liječenje jako zakrivljenih korijenskih kanala (19, 20, 21), a proizvode se postupkom električnog pražnjenja (22). Aktualni sustavi razlikuju se u smislu koničnosti, kretnje, dizajna, legure, brzine i okretnog momenta te broja instrumenata.

Trenutačno se, s obzirom na kliničke implikacije koje se tiču uzrokovanja dentinskih defekata, ne može donijeti konačan zaključak. Štoviše, nije poznato sprječava li NiTi legura stvaranje defekata. Svrha ovog istraživanja bila je analizirati reznu površinu, očuvanje anatomije korijenskog kanala i neinstrumentiranu površinu nakon instrumentacije sustavima F360® (Komet Dental, Lemgo, Njemačka), F6 SkyTaper® (Komet Dental, Lemgo, Njemačka), Hyflex EDM®, iRace® (FKG Dentaire, La Chaux-de-Fonds, Švicarska), Neoniti®, One Shape® (Micro-Mega, Besançon, Francuska) ProTaper Next® (Dentsply Maillefer, Ballaigues, Švicarska), Reciproc®, Revo-S® (Micro-Mega, Besançon, Francuska) i Wave One Gold® veličinom instrumenta 25.

Materijali i metode

Primijenjene su slične metode kao u radu istog autora objavljenom 2015. (23).

Tristo izvađenih trajnih zubi sličnih značajki podijeljeno je slučajnim odabirom u 10 skupina (n = 30). Kriteriji odabira bili su: zubi s jednim ravnim korijenom i kružnim ili eliptičnim presjekom korijenskog kanala. Zub je trepaniran okruglim dijamantnim svrdlom (Komet Dental, Lemgo,

rived, with changes in design to improve flexibility, cyclic fatigue resistance and cutting efficiency, with more predictable results and less iatrogenic damage, but these modifications do not improve all the properties of endodontic files (7, 8).

The introduction of single use reciprocating systems has raised new perspectives for the preparation of root canals (9, 10). The learning curve of these systems and the cost savings compared to rotary systems with multiple instruments are arousing interest due to their simplification of the technique, since a single instrument is used to prepare the root canals (11). This movement also disengages the instrument from dentin before it can lock into the canal and reduces the risk of root canal deformation and instrument separation (12, 13).

Nowadays, a number of different alloys have improved the properties of conventional NiTi. M-Wire, an alloy created by applying a heat treatment to conventional NiTi, is presented in Reciproc® (VDW, Munich, Germany) and Wave One® (Dentsply Maillefer, Ballaigues, Switzerland) (14, 15). Gold-Wire is another alloy that has recently appeared, enhancing the properties of ProTaper Universal® (Dentsply Maillefer, Ballaigues, Switzerland) and Wave One® (Dentsply Maillefer, Ballaigues, Switzerland), to create ProTaper Gold® (Dentsply Maillefer, Ballaigues, Switzerland) and Wave One Gold® (Dentsply Maillefer, Ballaigues, Switzerland) (16, 17), with a new thermal surface treatment (18). CM-Wire is an alloy that gives Hyflex CM® (Coltene, Altstätten, Switzerland), Hyflex EDM® (Coltene, Altstätten, Switzerland) and Neoniti® (Neolix, Chatres-La-Foret, France) instruments controlled memory, which is very useful when treating root canals with severe curvatures (19, 20, 21), manufactured with wire cut electrical discharge machining (EDM) process (22). The current systems have many different taper, movement, design, alloy, speed and torque characteristics and different numbers of files.

Currently, in terms of clinical implications of dentinal defects in long-term situations, no definitive conclusions can be made. Moreover, it is not known whether the improvements of nickel titanium alloys avoid the formation of defects. The purpose of this investigation was to examine the cutting area, root canal anatomy preservation and non-instrumented areas using F360® (Komet Dental, Lemgo, Germany), F6 SkyTaper® (Komet Dental, Lemgo, Germany), Hyflex EDM®, iRace® (FKG Dentaire, La Chaux-de-Fonds, Switzerland), Neoniti®, One Shape® (Micro-Mega, Besançon, France) ProTaper Next® (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc®, Revo-S® (Micro-Mega, Besançon, France) and Wave One Gold® size 25 files.

Materials and methods

Methods similar to those mentioned in another scientific paper, which was published in 2015 by the same authors, were used (23).

300 extracted permanent teeth with similar characteristics were divided randomly into 10 groups (n = 30). The selection criteria were: teeth with a single straight root and a circular or elliptical root canal. The endodontic opening was

Njemačka) uz hlađenje vodom, a zatim svrdlom Endo-Z (Komet Dental, Lemgo, Njemačka). Digitalni RTG korišten je za procjenu radne duljine s pomoću ručnih instrumenata.

Vodootporni markeri korišteni su za ucrtavanje crvene oznake na lingvalnoj/palatinoj i crne na vestibularnoj plohi. Dužine korjenova i točke rezanja procijenjene su prema dužini, koristeći se pomičnom mjerkom 532 Vernier (Mitutoyo, Takatsuku, Japan).

Kao u radu Grandea i sur. (24), nasadni instrument (KMD Europa, Bilbao, Španjolska) s ultratankim reznim diskom (0,17 mm) (Horico, Berlin, Njemačka) korišten je za poprečno presijecanje korijena na trećine. Za snimanje svih trećina korišten je stereomikroskop (Nikon, Tokyo, Japan) s Nikonovom kamerom (Nikon, Tokio, Japan) (povećanje 15x).

Sve su skupine analizirane prije instrumentacije po trećinama i ukupno. Pomična mjerka korištena je za izračunavanje meziodistalne širine koronalne trećine zuba br. 3, prenoseći dimenziju u AutoCAD 2015 (Autodesk, San Rafael, SAD) (5 mm) kako bi se kalibrirala i izmjerila područja kanala prije instrumentacije. Kalibracija je provedena učitavanjem slike zuba br. 3 u AutoCAD 2015, nakon ucrtavanja meziodistalne linije od 5 mm i kvadriranja mezijalnog i distalnog ruba koronarne trećine, dobivena je referentna vrijednost za usporedbu drugih slika. Program SPSS 18 ($P < 0,05$) korišten je za preoperativnu analizu Leveneovim i Welchovim testom kako bi se procijenila varijanca i predinstrumentacijski parametri. Kako bi se uravnotežile skupine, neki zubi bili bi uključeni, a drugi odbačeni ako bi se utvrdile značajne razlike.

K-instrument #10 (Dentsply Maillefer, Ballaigues, Švicarska) i epoksi smola korišteni su za ponovno spajanje svih zuba, prilagođavajući sekcije zahvaljujući prethodno ucrtanim crnim i crvenim oznakama. Otopina NaClO koncentracije 5,25 % korištena je za ispiranje korijenskih kanala tijekom instrumentacije. K-instrumenti #10 i #15 korišteni su za osiguravanje prohodnosti kanala. Korijenski kanali instrumentirani su kružnim pokretom. Protokoli su bili sljedeći:

- Skupina 1 (F360®): F360 25/0,04 do 300 rpm i 1,8 N · cm
- Skupina 2 (F6 SkyTaper®): F6 SkyTaper 25/0,06 do 300 rpm i 2,2 N · cm
- Skupina 3 (Hyflex EDM®): Hyflex EDM 25/0,05 do 500 rpm i 2,5 N · cm
- Skupina 4 (iRace®): Rl (15/0,06) i R2 (25/0,04) do 600 rpm i 1,5 N · cm
- Skupina 5 (Neoniti®): A1 (25/0,08) do 400 rpm i 1,5 N · cm
- Skupina 6 (One Shape®): One Shape 25/0,06 do 400 rpm i 4 N · cm
- Skupina 7 (ProTaper Next®): X1 (17/0,04) i X2 (25/0,06) do 300 rpm i 2 N · cm
- Skupina 8 (Recipro®): R25 (25/0,08) do 300 rpm i 2 N · cm
- Skupina 9 (Revo-S®): SC1 (25/0,06), SC2 (25/0,04) i SU (25/0,06) do 350 rpm i 0,8 N · cm
- Skupina 10 (Wave One Gold®): Primary (25/0,07) do 350 rpm i 2 N · cm.

performed with a round diamond bur (Komet Dental, Lemgo, Germany) using water cooling, followed by an Endo-Z bur (Komet Dental, Lemgo, Germany). X-rays were used to estimate the working length with hand files.

Permanent markers were used to draw a red marking on lingual/palatine and a black marking on vestibular part. Root lengths and section points were estimated in agreement with the length, using a 532 Vernier caliper (Mitutoyo, Takatsuku, Japan).

A hand piece (KMD Europa, Bilbao, Spain) equipped with ultrafine cutting disc (0.17mm) (Horico, Berlin, Germany) was used to section transversely the roots in thirds in the same manner as in Grande et al. (24). A stereo microscope (Nikon, Tokyo, Japan) with Nikon camera (Nikon, Tokyo, Japan) was used to take pictures of all thirds (x15 magnification).

In thirds and overall, all groups were balanced by performing preinstrumentation analysis. A caliper was used to calculate mesiodistal width of coronal third of tooth No. 3, transferring to AutoCAD 2015 (Autodesk, San Rafael, USA) this calculation (5mm) to scale up and measure preinstrumentation areas. Scaling up was performed by loading the image of tooth No. 3 into AutoCAD 2015, after painting a 5mm mesial to distal line and squaring the mesial and distal edges of the coronal third, subsequently validating the sizes of other images against the abovementioned image. The SPSS 18 program ($P<0.05$) was used to make a preoperative analysis, using Levene´s and Welch´s tests, to evaluate variances and preinstrumentation areas. To balance the groups, some teeth would have been included and others discarded if significant differences had been achieved.

The #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and epoxy glue were used to rebuild all of the teeth. The sections were adapted thanks to black and red markings that had previously been drawn. The 5.25% NaClO solution was used to flush root canals during instrumentation. The #10 K-file was used for patency filing, and #10 and #15 K-files were used to make a glide path. The root canals were instrumented using a circumferential movement. The protocols were as follows:

- Group 1 (F360®): F360 25/0.04 to 300rpm and 1.8 N·cm.
- Group 2 (F6 SkyTaper®): F6 SkyTaper 25/0.06 to 300rpm and 2.2 N·cm.
- Group 3 (Hyflex EDM®): Hyflex EDM 25/0.05 to 500rpm and 2.5 N·cm.
- Group 4 (iRace®): R1 (15/0.06) and R2 (25/0.04) to 600rpm and 1.5 N·cm.
- Group 5 (Neoniti®): A1 (25/0.08) to 400rpm and 1.5 N·cm.
- Group 6 (One Shape®): One Shape 25/0.06 to 400rpm and 4 N·cm.
- Group 7 (ProTaper Next®): X1 (17/0.04) and X2 (25/0.06) to 300rpm and 2 N·cm.
- Group 8 (Reciproc®): R25 (25/0.08) to 300rpm and 2 N·cm.
- Group 9 (Revo-S®): SC1 (25/0.06), SC2 (25/0.04) and SU (25/0.06) to 350rpm and 0.8 N·cm.

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U svim skupinama na kraju obrade korijenskoga kanala za ispiranje je korišteno 2 ml 5,25 %-nog NaClO, 2 ml 5 %-tne otopine etilendiamantetetske kiseline (EDTA) (Dentaflux, Algete, Španjolska) i 2 ml 5,25 %-tnog NaClO.

Mikroskop je korišten za snimanje zubi koji su ponovno podijeljeni na trećine (uvećanje 15 x). Na temelju preoperativne ljestvice izračunate su postoperativne dimenzije svih trećina. Razlika između preinstrumentacijskog i postinstrumentacijskog nalaza procijenjena je kako bi se odredila rezna površina (Slika 1.). Neinstrumentirana površina i očuvanje anatomije korijenskog kanala proučavani su preklapanjem preoperativnih i postoperativnih slika u sustavu AutoCAD 2015 (Slika 1.). Ti su parametri izračunati kao postotci za svaku trećinu.

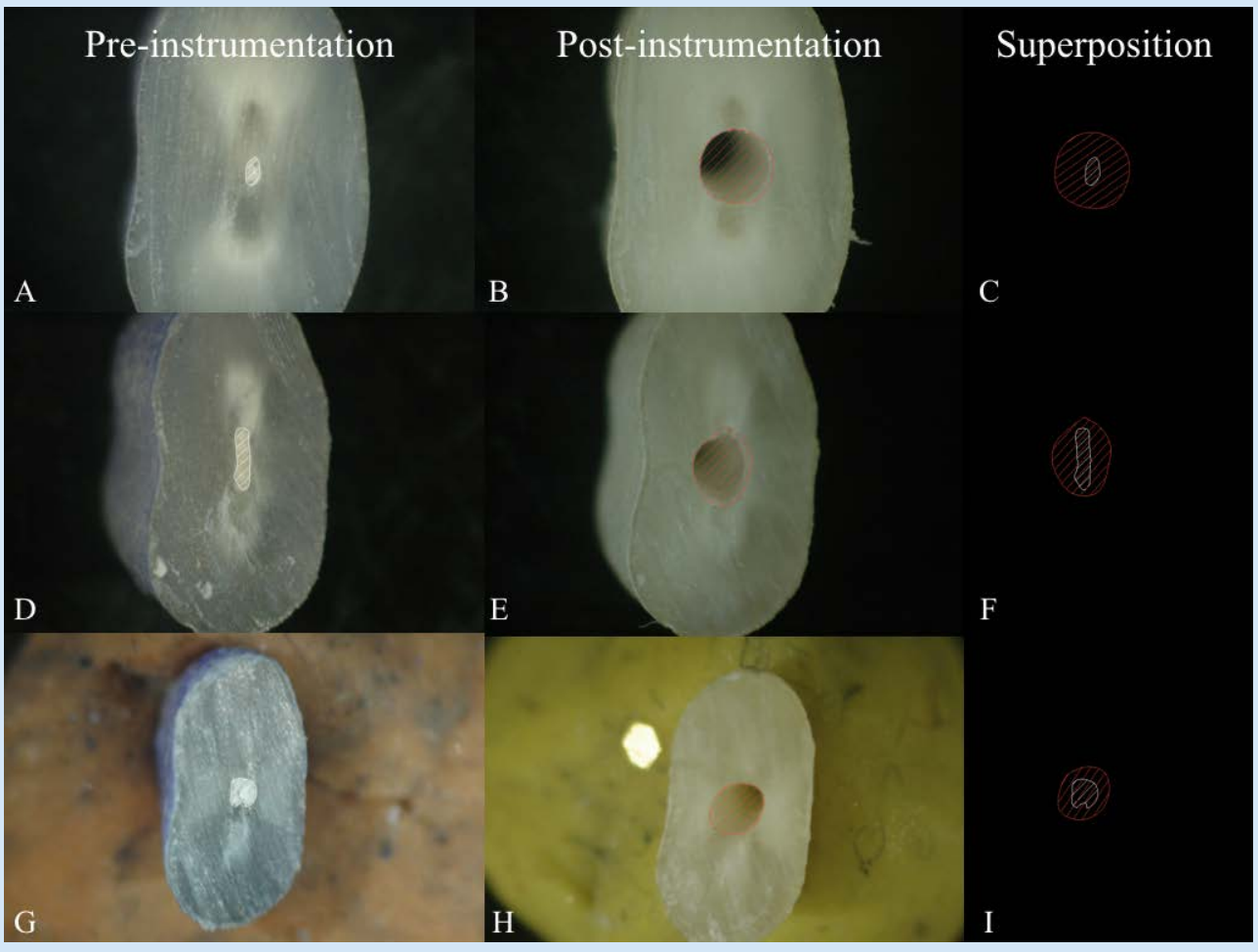
Za statističku analizu korišten je program SPSS 18. Primijenjeni su Leveneov i Welchov test radi procjene varijance i reznih površina. Pearsonov hi-kvadrat primijenjen je za analizu razlika postotaka neinstrumentiranih površina i očuvanja anatomije korijenskog kanala.

- Group 10 (Wave One Gold®): Primary (25/0.07) to 350rpm and 2 N·cm.

In all groups, 2 mL of 5.25% NaClO2 mL of 0.9% saline solution, 2mL of 17% ethylenediamenetetracetic acid (EDTA) solution (Dentaflux, Algete, Spain) and 2 mL of 5.25% NaClO were flushed to finish the root canal treatments.

In the end, a microscope was used to keep the re-sectioned thirds, making pictures (x15 magnification). Postoperative areas of all thirds were calculated using a preoperative scale. The difference between preinstrumentation and postinstrumentation was estimated to determine the cutting areas (Figure 1). Non-instrumented areas and root canal anatomy preservation were studied by superimposing the preoperative and postoperative areas in the AutoCAD 2015 system (Figure 1). These parameters were calculated as the percentage of teeth in each third.

The SPSS 18 Statistics software package with normal distribution was used for statistical analysis and Levene´s and Welch´s tests to evaluate variances and cutting surfaces. Pearson´s chi-squared test was used to contrast the percentages of teeth of non-instrumented and root canal anatomy preservation.



Slika 1. Analiza u AutoCAD-u koronarne (A do C), srednje (D do F) i srednje (G do I) trećine
Figure 1. AutoCAD analysis of coronal (A to C), middle (D to F) and apical (G to I) thirds.

Rezultati

Nijedan instrument nije slomljen tijekom istraživanja. Nije bilo značajnih razlika u predinstrumentacijskim područjima (Tablice 1. i 2.). Rezne površine izračunate su oduzimanjem postoperativnog područja od odgovarajućeg preoperativnog područja (Tablica 1). U koronalnoj trećini ProTaper Next® (1,586 ± 0,301 mm2) i Reciproc® (1,510 ± 0,275 mm²) imali su najveću reznu površinu, koji su za oba sustava bili statistički značajno veći nego za F360®, iRace® ili One Shape® (Tablica 2.). Međutim, u srednjim i apikalnim trećinama sustavi Neoniti® (0,789 ± 0,112 mm² - 0,475 ± 0,059 mm²) i Hyflex EDM® (0,707 ± 0,109 mm² - 0,538 ± 0,071 mm²) eliminirali su veću količinu dentina. U srednjoj trećini (Tablica 2.), i ProTaper Next® i Reciproc® bili su bolji od sustava F360®, iRace® i ProTaper Next®, ali Neoniti® je bio bolji od sustava Reciproc®, F6 SkyTaper® i One Shape®. U apikalnoj trećini (Tablica 2.), rezna površina bila je veće nego kod sustava

Results

No file was fractured during the study. There were no significant differences in preinstrumentation areas (Table 1 and Table 2). The cutting areas were calculated by subtracting the postoperative area from the corresponding preoperative area (Table 1).

The ProTaper Next® system (1.586 ± 0.301 mm²) and Reciproc® system (1.510 ± 0.275 mm²) produced the largest cutting areas in the coronal third, which were significantly greater than with F360®, iRace® or One Shape® (Table 2) with both systems.

The Neoniti file system (0.789 ± 0.112 mm² - 0.475 ± 0.059 mm²)) and the Hyflex EDM® ® file system (0.707 ± 0.109 mm² - 0.538 ± 0.071 mm²) eliminated higher amounts of dentin in the middle and apical thirds.

In the middle third (Table 2), both ProTaper Next® and Reciproc® systems were superior to F360®, iRace® and ProTa-

Tablica 1. Srednje vrijednosti predinstrumentacijske i rezne površine (mm²) i statistička analiza predinstrumentacijskih obilježja
Table 1. Means of preinstrumentation and cutting area (mm²), and statistical analysis of preinstrumentation area.

		Predinstrumentacijska površina • Preinstrumentation			Rezna površina • Cutting area	
Trećina • Third	Sistema	Sredina±SD • Mean±SD	Min-Max	Test	Sredina±SD • Mean±SD	Min-Max
Koronarna • Coronal	F360	1,066±0,106	0,960-1,172	Levene 0.002	0,576±0,102	0,474-0,678
	F6	0,961±0,122	0,839-1,083		1,208±0,171	1,037-1,379
	Hyflex	1,003±0,098	0,905-1,101		1,083±0,177	0,906-1,260
	iRace	0,997±0,101	0,896-1,098		0,824±0,099	0,725-0,923
	Neoniti	0,976±0,152	0,824-1,128		1,153±0,126	1,027-1,279
	O.Shape	0,995±0,116	0,879-1,111	Welch 0.089	0,938±0,095	0,843-1,033
	P.Next	1,073±0,103	0,970-1,176		1,586±0,301	1,285-1,887
	Reciproc	1,059±0,183	0,876-1,242		1,510±0,275	1,235-1,785
	Revo-S	1,038±0,142	0,896-1,180		1,137±0,193	0,944-1,330
	WOG	1,000±0,121	0,879-1,121		1,047±0,193	0,854-1,240
Srednja • Middle	F360	0,520±0,108	0,412-0,628	Levene 0.005	0,278±0,058	0,220-0,336
	F6	0,551±0,090	0,461-0,641		0,522±0,084	0,438-0,606
	Hyflex	0,532±0,134	0,398-0,666		0,707±0,109	0,598-0,816
	iRace	0,532±0,107	0,425-0,639		0,325±0,048	0,277-0,373
	Neoniti	0,517±0,086	0,431-0,603		0,789±0,112	0,677-0,901
	O.Shape	0,505±0,093	0,412-0,598	Welch 0.095	0,521±0,081	0,440-0,602
	P.Next	0,503±0,156	0,347-0,659		0,477±0,053	0,424-0,530
	Reciproc	0,547±0,099	0,448-0,646		0,538±0,065	0,473-0,603
	Revo-S	0,542±0,151	0,391-0,693		0,676±0,085	0,591-0,761
	WOG	0,517±0,094	0,423-0,611		0,610±0,126	0,484-0,736
Apikalna • Apical	F360	0,217±0,045	0,172-0,262	Levene 0.003	0,176±0,030	0,146-206
	F6	0,222±0,038	0,184-0,260		0,352±0,053	0,299-0,405
	Hyflex	0,269±0,082	0,187-0,351		0,538±0,071	0,467-0,609
	iRace	0,188±0,057	0,131-0,245		0,176±0,028	0,148-0,204
	Neoniti	0,273±0,032	0,241-0,305		0,475±0,059	0,416-0,534
	O.Shape	0,294±0,075	0,219-0,369	Welch 0.099	0,354±0,035	0,319-0,389
	P.Next	0,224±0,024	0,200-0,248		0,240±0,030	0,210-0,270
	Reciproc	0,234±0,051	0,183-0,285		0,355±0,043	0,312-0,398
	Revo-S	0,252±0,043	0,209-0,295		0,456±0,051	0,405-0,507
	WOG	0,289±0,061	0,228-0,350		0,431±0,047	0,384-0,478
Ukupno • Overall	F360	0,601±0,064	0,537-0,665	Levene 0.019	0,343±0,052	0,291-0,395
	F6	0,578±0,081	0,497-0,659		0,694±0,100	0,594-0,794
	Hyflex	0,601±0,092	0,509-0,693		0,776±0,085	0,691-0,861
	iRace	0,572±0,072	0,500-0,644		0,441±0,068	0,373-0,509
	Neoniti	0,588±0,064	0,524-0,652		0,805±0,081	0,724-0,886
	O.Shape	0,598±0,082	0,516-0,680	Welch 0.063	0,604±0,066	0,538-0,670
	P.Next	0,600±0,102	0,498-0,702		0,768±0,157	0,611-0,925
	Reciproc	0,613±0,122	0,491-0,735		0,801±0,140	0,661-0,941
	Revo-S	0,610±0,099	0,511-0,709		0,756±0,091	0,665-0,847
	WOG	0,602±0,082	0,520-0,684		0,696±0,095	0,601-0,791

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Tablica 2. Statistička analiza rezne površine
Table 2. Statistical analysis of cutting area.

Rezna površina • Cutting area				
	Trećina • Third			
Test	**Koronalna • Coronal**	**Srednja • Middle**	**Apikalna • Apical**	**Ukupno • Overall**
Levene	0.000	0.019	0.006	0.000
Welch	0.000	0.000	0.000	0.000
Games-Howell	P.Next-F360 0.000 Reciproc-F360 0.000 F6-F360 0.000 Hyflex-F360 0.000 Neoniti-F360 0.000 O.Shape-F360 0.000 Revo-S-F360 0.000 WOG-F360 0.004 iRace-F360 0.024 P.Next-iRace 0.001 Reciproc-iRace 0.001 F6-iRace 0.009 Neoniti-iRace 0.004 P.Next-O.Shape 0.006 Reciproc-O.Shape 0.010	P.Next-F360 0.000 Reciproc-F360 0.000 F6-F360 0.000 Hyflex-F360 0.000 Neoniti-F360 0.000 O.Shape-F360 0.000 Revo-S-F360 0.000 WOG-F360 0.001 P.Next-iRace 0.002 Reciproc-iRace 0.000 F6-iRace 0.005 Hyflex-iRace 0.000 Neoniti-iRace 0.000 O.Shape-iRace 0.004 Revo-S-iRace 0.000 WOG-iRace 0.005 Hyflex-P.Next 0.013 Revo-S-P.Next 0.007 Neoniti-P.Next 0.000 Neoniti-Reciproc 0.009 Neoniti-F6 0.010 Neoniti-O.Shape 0.008	Reciproc-F360 0.000 F6-F360 0.000 Hyflex-F360 0.000 Neoniti-F360 0.000 O.Shape-F360 0.000 Revo-S-F360 0.000 WOG-F360 0.000 Reciproc-iRace 0.000 F6-iRace 0.000 Hyflex-iRace 0.000 Neoniti-iRace 0.000 O.Shape-iRace 0.000 Revo-S-iRace 0.000 WOG-iRace 0.000 Reciproc-P.Next 0.002 F6-P.Next 0.019 Hyflex-P.Next 0.000 Neoniti-P.Next 0.000 O.Shape-P.Next 0.000 Revo-S-P.Next 0.000 WOG-P.Next 0.000 Reciproc-Hyflex 0.002 F6-Hyflex 0.003 Hyflex-O.Shape 0.001 O.Shape-Neoniti 0.027 O.Shape-Revo-S 0.045	P.Next-F360 0.000 Reciproc-F360 0.000 F6-F360 0.000 Hyflex-F360 0.000 Neoniti-F360 0.000 O.Shape-F360 0.000 Revo-S-F360 0.000 WOG-F360 0.000 P.Next-iRace 0.009 Reciproc-iRace 0.000 F6-iRace 0.002 Hyflex-iRace 0.000 Neoniti-iRace 0.000 O.Shape-iRace 0.029 Revo-S-iRace 0.000 WOG-iRace 0.001 Neoniti-O.Shape 0.008

Neoniti® i Hyflex EDM® nego kod sustava F360®, iRace®, ProTaper Next® ili One Shape®. Rezna površina sustava Hyflex EDM® također je bila veća nego kod sustava Reciproc® i F6 SkyTaper®. Sveukupno, Neoniti® (0,805 ± 0,081 mm^2) i Reciproc® (0,801 ± 0,140 mm^2) postigli su bolje rezultate od ostalih sustava, pri čemu su oba bila bolja od sustava od F360® i iRace®, dok je Neoniti® bio bolji od One Shapea® (Tablica 2.).

Što se tiče očuvanja anatomije korijenskog kanala (Tablica 3.), Neoniti® i Hyflex EDM® imali su veće postotke u koronalnoj trećini (100 %), Reciproc® i Wave One Gold® u srednjoj trećini (100 %) a F360®, Recipro® i Neoniti® u apikalnoj trećini. Međutim, razlike nisu bile statistički značajne ni u jednoj trećini (P > 0,05).

Što se tiče neinstrumentirane površine (Tablica 3.), ProTaper Next®, Reciproc® i Hyflex EDM® ostvarili su niže postotke u koronalnoj trećini (10 %), iako nisu postojale statistički značajne razlike. Reciproc®, Neoniti® i Wave One Gold® bili su značajno bolji (P < 0,05) u srednjoj trećini (3,33 %); ProTaper Next®, Reciproc®, Hyflex EDM®, Neoniti® i Wave One Gold® bili su statistički značajno bolji (P < 0,05) u apikalnoj trećini (0 %).

per Next®, but Neoniti® was better than Reciproc®, F6 SkyTaper® and One Shape®. In the apical third (Table 2), the cutting areas of Neoniti® and Hyflex EDM® were greater than with F360®, iRace®, ProTaper Next® or One Shape®. Those of Hyflex EDM® were also better than with Reciproc® and F6 SkyTaper®. Overall, Neoniti® system (0.805 ± 0.081 mm^2) and Reciproc® system (0.801 ± 0.140 mm^2) obtained better results than other systems, both being superior to F360® and iRace®, while Neoniti was also better than One Shape® (Table 2).

Regarding the preservation of root canal anatomy (Table 3), Neoniti® and Hyflex EDM® obtained higher percentages in the coronal third (100%), Reciproc® and Wave One Gold® in the middle third (100%), and F360®, Reciproc® and Neoniti® in the apical third. However, there were no significant differences in any of the thirds (P>0.05).

In relation to non-instrumented areas (Table 3), ProTaper Next®, Reciproc® and Hyflex EDM® scored lower percentages in the coronal third (10%), although there were not significant differences. Reciproc®, Neoniti® and Wave One Gold® were significantly better (P<0.05) in the middle third (3.33%) being significant better (P<0.05); and ProTaper Next®, Reciproc®, Hyflex EDM®, Neoniti® and Wave One Gold® were significantly superior (P<0.05) in the apical third (0%).

Tablica 3. Očuvanje anatomije korijenskog kanala (%), neinstrumentirana površina (%) i statistička analiza
Table 3. Root canal anatomy preservation (%), non-instrumented areas (%) and statistical analysis.

	Sustav • System	Koronalno • Coronal	Sredina • Middle	Apikalno • Apical
Očuvanje anatomije korijenskog kanala • Root canal anatomy preservation	F360	90	96,67	100
	F6 SkyTaper	86,67	90	90
	Hyflex EDM	100	96,67	96,67
	iRace	80	90	96,67
	Neoniti	100	93,33	100
	One Shape	93,33	90	93,33
	Protaper Next	93,33	93,33	96,67
	Reciproc	93,33	100	100
	Revo-S	93,33	96,67	93,33
	Wave One Gold	86,67	100	93,33
	Pearson's chi-squared	0.149	0.515	0.522
	Sustav • System	**Koronalno • Coronal**	**Sredina • Middle**	**Apikalno • Apical**
Neinstrumentirana površina • Non-instrumented areas	F360	33,33	23,33	13,33
	F6 SkyTaper	20	16,67	6,67
	Hyflex EDM	10	10	0
	iRace	23,33	16,67	13,33
	Neoniti	13,33	3,33	0
	One Shape	23,33	23,33	6,67
	Protaper Next	10	6,67	0
	Reciproc	10	3,33	0
	Revo-S	30	20	23,33
	Wave One Gold	20	3,33	0
	Pearson's chi-squared	0,196	0,033	0,000

Rasprava

U ovom istraživanju uspoređivani su učinci deset endodontskih sustava (F360®, F6 SkyTaper®, Hyflex EDM®, iRace®, Neoniti®, One Shape®, ProTaper Next®, Reciproc®, RevoS® i Wave One Gold®) iste veličine, ali s razlikama u kretnjama, koničnosti, obliku, broju instrumenata, brzini i okretnom momentu na reznu površinu, očuvanje anatomije korijenskog kanala i neinstrumentiranu površinu. Tri područja korijenskih kanala (koronalna, srednja i apikalna trećina) procijenjena su na sličan način kao i kod Testa i sur. (25). Nekoliko istraživanja bavilo se učinkovitošću oblikovanja u blokovima smole, ali problem tih blokova je njihova distorzija (26, 27). Zbog toga su u ovom istraživanju korišteni izvađeni ljudski zubi, kao kod Pedullà i sur. (28).

Što se tiče korištenja AutoCAD-a u endodonciji, ovaj softver korišten je za usporedbu učinkovitosti ručne instrumentacije te rotacijskih i recipročnih instrumenata za uklanjanje materijala za punjenje iz korijenskog kanala u revizijama endodontskog liječenja (29, 30), analizu kvalitete brtvljenja različitih sustava (31, 32), gubitka radne duljine (33) i transportacije apeksnog foramena (34, 35).

Što se tiče sličnih istraživanja učinkovitosti oblikovanja korijenskih kanala, Cabanillas i sur. (36) usporedili su ručnu instrumentaciju sa sustavima ProTaper Universal®, ProTaper Next® i Wave One®. Zaključili su da nema značajnih razlika u srednjim i apikalnim trećinama te da je Wave One® bio znatno lošiji u koronalnoj trećini ($P < 0,05$), vjerojatno zbog oblika instrumenta. Iqbal i sur. (37) proučavali su postotak instrumentiranih površina primjenom sustava ProFile®

Discussion

This study compared the effects of ten endodontic systems (F360®, F6 SkyTaper®, Hyflex EDM®, iRace®, Neoniti®, One Shape®, ProTaper Next®, Reciproc®, Revo-S® and Wave One Gold®)of the same size but with different movements, tapers, designs, file numbers, speeds and torques in the cutting area, root canal anatomy preservation and non-instrumented areas. Three areas of root canal (the coronal, middle and apical thirds) were assessed in a similar fashion to that of Testa et al. (25). Several studies have investigated the shaping ability in resin blocks, but the problem of these blocks is their distortion (26, 27). For this reason, the extracted human teeth were used in this study, likewise in Pedullà et al. (28).

Regarding the use of AutoCAD in endodontics, this software was has been used to compare the efficacy of manual instrumentation and rotary and reciprocating instruments for removing root canal filling material in retreatments (29, 30,) the sealing quality of different systems (31, 32) and the working length loss (33) and apical transportation of multiple instrumentation systems (34, 35).

With regard to similar investigations into the shaping ability, Cabanillas et al. (36) compared manual instrumentation, ProTaper Universal®, ProTaper Next® and Wave One®. They concluded that there were no significant differences in the middle and apical thirds, and that Wave One® was significantly worse in the coronal third ($P<0.05$), probably due to the design of the file. Iqbal et al. (37) studied the percentage of instrumented areas with ProFile® and a hybrid technique

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i hibridne tehnike koristeći se instrumentima lqFiles i H-instrumentima 1 i 3 mm od radne dužine; hibridna tehnika s instrumentima lqFiles bila je značajno bolja od ostalih tehnika (P < 0,05), ali nije bilo statistički značajne razlike između dviju hibridnih tehnika na 3 mm (P > 0,05). Godine 2015. (23) autori ovog istraživanja koristili su se sličnom metodologijom za usporedbu sustava F360®, RaCe®, Mtwo® i Hyflex CM®, bez statistički značajnih razlika (P > 0,05). Međutim, instrumenti korišteni u istraživanju 2015. imali su isti konus (4 %) i veličinu (#35), koji su važni čimbenici u istraživanju učinkovitosti oblikovanja. Za razliku od Iqbala i sur. (37), nisu korištene hibridne tehnike. Za razliku od Cabanillas i sur. (36), u ovom su istraživanju zapažene statistički značajne razlike u srednjoj i apikalnoj trećini.

Što se tiče rezultata rezne površine (Tablica 1.), Reciproc® i ProTaper Next® postigli su najveće prosječne vrijednosti u koronarnoj trećini: 1,510 ± 0,275 mm^2 i 1,586 ± 0,301 mm^2. Istodobno, Neoniti® i Hyflex EDM® postigli su najveće vrijednosti u srednjoj i apikalnoj trećini: 0,789 ± 0,112 mm^2 - 0,707 ± 0,109 mm^2 i 0,475 ± 0,059 mm^2 - 0,538 ± 0,071 mm^2. Reciproc® (0,801 ± 0,140 mm2) i Neoniti® (0,805 ± 0,081 mm2) bili su sveukupno statistički značajno bolji. Ahmetoglu i sur. (38) uspoređivali su Reciproc®, Revo-S® i Self-Adjusting File® (SAF) primjenom µ-CT-a na gornjim prvim kutnjacima i nisu pronašli statistički značajne razlike između instrumenata (P > 0,05). U drugom istraživanju, Saleh i sur. (39) istraživali su Reciproc®, Wave One®, One Shape® i F360® veličine 25, koristeći se blokovima smole i preklapajući preoperativne i postoperativne slike. Autori su zaključili da su Reciproc® i Wave One® znatno bolji od sustava One Shape® i F360® (P < 0,05), vjerojatno zbog konusa (8 %) i recipročne kretnje. Nadalje, Zeng i sur. (40) proučavali su reznu površinu postignutu sustavima Reciproc®, One Shape®, Mtwo® i Revo-S® veličine instrumenta 25 u apikalnoj trećini kutnjaka s pomoću µ-CT-a i zabilježili najbolje rezultate za Reciproc® (P < 0,05). Zaključili su da je sustav s jednim instrumentom dao bolje rezultate od sustava s kontinuiranim rotacijskim kretnjama. U ovom istraživanju korišteni su izvađeni ljudski zubi, kao i u istraživanjima Ahmetoglua i sur. te Zenga i sur., ali različito od Saleha i sur.

Očuvanje anatomije korijenskog kanala vrlo je važno za trodimenzionalnu obturaciju. Rezultati (Tablica 3.) su pokazali da su Neoniti® i Hyflex EDM® najbolji u koronarnoj trećini (100 %), Reciproc® i Wave One Gold® bili su najstabilniji (100 %), a F360®, Reciproc® i Neoniti® postigli su najbolje postotke u apikalnoj trećini (100 %). Neinstrumentirana područja mogu ugroziti uspjeh endodontske terapije. Zbog toga je instrumentacija koja obuhvaća sve stijenke vrlo važna. U ovom istraživanju ProTaper Next®, Reciproc® i Hyflex EDM® postigli su najbolji postotak (10 %) u koronarnoj trećini. U srednjoj trećini, Recipro®, Neoniti® i Wave One Gold® bili su bolji (3,33 %) od ostalih sustava. ProTaper Next®, Reciproc®, Hyflex EDM®, Neoniti® i Wave One Gold® postigli su najbolji postotak u apikalnoj trećini (0 %) (Tablica 3.). Gergi i sur. (41) uspoređivali su očuvanje anatomije korijenskog kanala i neinstrumentiranu površinu s instrumentima veličine 25 sustava Reciproc®, Wave One® i TF®, bez statistički značajnih razlika (P > 0,05), ali s boljim očuvanjem anatomije korijen-

using lqFiles and H-files at 1 and 3mm from working length; the hybrid technique with lqFiles was significantly better than the other techniques (P<0.05), but there were no significant differences between the two hybrid techniques at 3mm (P>0.05). In 2015 (23), the authors of the present study used similar methodology to compare (21) F360®, RaCe®, Mtwo® and Hyflex CM® files, obtaining and no significant differences (P>0.05). However, all of the files used in the 2015 study had the same taper (4%) and size (#35), which are important factors in any investigations into the ability. Unlike in Cabanillas et al. (36), significant differences in the middle and apical thirds were observed in the present study.

Concerning the cutting area results (Table 1), Reciproc® and ProTaper Next® obtained the highest means in the coronal third: 1.510 ± 0.275 mm^2 and 1.586 ± 0.301 mm^2 respectively. On the other hand, Neoniti® and Hyflex EDM® achieved the highest means in the middle and apical thirds: 0.789 ± 0.112 mm^2 – 0.707 ± 0.109 mm^2 and 0.475 ± 0.059 mm^2 – 0.538 ± 0.071 mm^2, respectively. Finally, Reciproc® (0.801 ± 0.140 mm^2) and Neoniti® (0.805 ± 0.081 mm^2) were significantly better overall. Ahmetoglu et al. (38) compared Reciproc®, Revo-S® and Self-Adjusting File® (SAF) by micro-computed tomography (µ-CT) in maxillary first molars, and found no significant differences between instrumentation systems (P>0.05). In another study, Saleh et al. (39) investigated Reciproc®, Wave One®, One Shape® and F360® 25 files using resin blocks and superimposing preoperative and postoperative images. The authors observed that Reciproc® and Wave One® were significantly better than One Shape® and F360® (P<0.05), probably because of the taper (8%) and the reciprocating movement. Moreover, Zeng et al. (40) studied the cutting area of apical third of Reciproc®, One Shape®, Mtwo® and Revo-S® size 25 files in the apical third of mature molars with µ-CT and observed better results for Reciproc® (P<0.05), concluding that the reciprocating single-file system gave better results than continuous rotary systems. Extracted human teeth were used in this study as in those of Ahmetoglu et al. and Zeng et al. although unlike in Saleh et al., which superimposed preoperative and postoperative images, as in the present study.

Root canal anatomy preservation is very important for three-dimensional obturation. The results (Table 3), showed that Neoniti® and Hyflex EDM® were the best systems in the coronal third (100%), Reciproc® and Wave One Gold® were the most stable (100%), and in apical thirds F360®, Reciproc® and Neoniti® obtained the best percentages in the apical thirds (100%). Non-instrumented areas can also jeopardize the endodontic treatment. For this reason, circumferential instrumentation is very important, and was used in all the groups. In this investigation the present study, ProTaper Next®, Reciproc® and Hyflex EDM® obtained the best percentage (10%) in the coronal third. In the middle third, Reciproc®, Neoniti® and Wave One Gold® were better (3.33%) than the other systems. Finally, ProTaper Next®, Reciproc®, Hyflex EDM®, Neoniti® and Wave One Gold® obtained the best percentage in the apical third (0%), (Table 3). Gergi et al. (41) compared the root canal anatomy preservation and non-instrumented areas with Reciproc®, Wave One® and TF®

skog kanala kada je korišten sustav TF® (P < 0,05). De-Deus i sur. (42) analizirali su neinstrumentirane površine nakon instrumentacije instrumentima veličine 25 i 40 sustava Reciproc®, Wave One® i BioRace® te zaključili da između sustava nije bilo statistički značajnih razlika (P > 0,05). Za razliku od Gergija i sur. i De-Deusa i sur., ovo istraživanje pokazalo je statistički značajne razlike s obzirom na neinstrumentiranu površinu u srednjoj i apikalnoj trećini, pri čemu je Reciproc® bio bolji (P < 0,05), vjerojatno zbog presjeka u obliku slova S i konusa.

Zaključci

Što se tiče rezne površine, ProTaper Next® i Reciproc® bili su najbolji u koronarnoj trećini, Neoniti® i Hyflex EDM® u srednjoj i apikalnoj trećini, a ukupno su bili najbolji Neoniti® i Reciproc®. Što se tiče očuvanja anatomije korijenskog kanala, svi sustavi su postigli slične rezultate. S obzirom na neinstrumentiranu površinu, sustavi su bili slični u koronarnoj trećini, no Reciproc®, Neoniti® i Wave One Gold® bili su bolji u srednjoj trećini, a ProTaper Next®, Recipro®, Hyflex EDM®, Neoniti® i Wave One Gold® u apikalnoj trećini.

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Sukob interesa

Nema sukoba interesa.

size 25 files, finding no significant differences in non-instrumented areas (P>0.05), but better root canal anatomy preservation results with TF® (P<0.05). De-Deus et al. (42) investigated non-instrumented areas for size 25 and 40 Reciproc®, Wave One® and BioRace® files and concluded that there were no significant differences between all any of the systems (P>0.05). Unlike Gergi et al. and De-Deus et al., the present study found significant differences in non-instrumented areas in the middle and apical thirds, but Reciproc® was significantly better (P<0.05), probably due to its S cross-section, reciprocating movement and taper.

Conclusions

In cutting area, ProTaper Next® and Reciproc® were superior in the coronal third, Neoniti® and Hyflex EDM® in the middle and apical thirds, and Neoniti® and Reciproc® overall. Regarding root canal anatomy preservation, all the systems obtained similar results. In non-instrumented areas, the systems were similar in the coronal third, but Reciproc®, Neoniti® and Wave One Gold® were better in the middle third, and ProTaper Next®, Reciproc®, Hyflex EDM®, Neoniti®, and Wave One Gold® were better in the apical third.

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Conflict of Interest

None declared

Abstract

Objective: The aim of this study was to compare the cutting are, root canal anatomy preservation and non-instrumented areas of F360®, F6-SkyTaper®, Hyflex-EDM®, iRACE®, Neoniti®, O.Shape®, P.Next®, Reciproc®, Revo-S® and Wave-One-Gold® size 25 files. **Materials and Methods:** 300 teeth with a single straight root and a circular or elliptical root canal were divided into 10 groups (1-F360®, 2- F6-SkyTaper®, 3-Hyflex-EDM®, 4-iRACE®, 5-Neoniti®, 6-O.Shape®, 7-P.Next®, 8-Reciproc®, 9-Revo-S® and 10-Wave-One-Gold®) cut into 3 cross sections using an ultrafine cutting disc. They were photographed under a stereo microscope and preinstrumentation analyses were made before rebuilding the teeth with# 10 K- File and epoxy glue. A glide path was created with #10 and #15 K files and each group was instrumented using rotary or reciprocating systems. Cutting areas, root canal anatomy preservation and non-instrumented areas were analyzed using the AutoCAD 2015 Levene's test, the Welch´s test, and the Games-Howell´s test. The Pearson's chi-squared test was used for statistical analysis. **Results:** Levene's test showed **no** equality of variances (P<0.05), therefore Welch´s and Games-Howell's tests were applied to cutting areas, showing significant differences in all thirds and overall (P<0.05). No differences in root canal anatomy preservation were observed (P>0.05). In non-instrumented areas, significant differences were found (P<0.05) in middle third being better in Reciproc®, Neoniti® and WaveOneGold®, and in apical thirds being higher P.Next®, Reciproc®, HyflexEDM®, Neoniti® and WaveOneGold®. **Conclusions:** In cutting area, P.Next® and Reciproc® were superior in coronal third, Neoniti® and Hyflex EDM® medially and apically and Neoniti® and Reciproc® overall. Regarding the root canal anatomy preservation, all systems were similar. For non-instrumented areas, all systems achieved similar results coronally, but Reciproc®, Neoniti® and Wave One Gold® were superior in middle third and P.Next®, Reciproc®, Hyflex EDM®, Neoniti® and Wave One Gold® were superior in apically.

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