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A Comparative Study of Protaper and Twisted File Nickel Titanium Instruments in Curved Canals Preparation

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SUMMARY

Introduction Root canal instrumentation is performed to achieve cleaning and shaping with maximum preservation of its original anatomy. However, in curved canals this approach may cause excessive damage or canal transportation. The present study aimed to evaluate changes in dentin wall caused by instrumentation of curved canals using two nickel titanium rotary systems, ProTaper and Twisted File.

Material and Methods Twenty five extracted human mandibular first molars with two separated mesial root canals were selected. Distal roots were amputated and 50 canals (25 mesiobuccal and 25 mesiolingual) were randomly assigned into two groups: group 1 – ProTaper, and group 2 – Twisted File. All files were used with torque control engine, following the manufacturer instructions. The final instruments were F3 (group 1) and #30/.06 (group 2). Pre and postoperative cross sections were obtained from coronal, middle, and apical portions. Changes in dentin wall were measured and evaluated using Bramante method and digital image software. Statistical analysis was performed using the Mann Whitney U test ($p<0.05$).

Results The ammount of dentin removed by ProTaper in cervical and middle canal thirds was significantly greater than with Twisted File ($p=0.040$ and $p=0.043$). ProTaper eliminated significantly greater ammount of dentin than Twisted File from mesial wall in coronal sections ($p=0.039$). Mean differences in distance from the center to other walls were not statistically significant in the middle and apical thirds of both groups ($p>0.05$).

Conclusion ProTaper system produced greater changes in cross sectional area of the root canal compared to Twisted File system.

Keywords: curved canals; ProTaper; root canal instrumentation; Twisted Files

INTRODUCTION

Cleaning and shaping of the root canal are important steps to achieve success in endodontic treatment. These include disinfection and dentin removal from canal walls, maintaining the original shape of the root canal and creating continuously tapered preparation in order to receive an adequate obturation [1]. Due to variable root canal anatomy, mechanical instrumentation of curved canals may lead to procedural errors such as ledge, zip, elbow formation, canal transportation and perforation [2, 3]. Safe preparation techniques should eliminate or minimize these procedural errors. However, several instruments have been suggested for this purpose.

Nickel titanium (NiTi) alloys for endodontic instruments were first described in 1988 [4]. Since then, several rotary NiTi instruments of different tapers and designs have been introduced in root canal preparation. Due to their flexibility and elasticity there has been an improvement in the quality of root canal shaping and less iatrogenic damage even in severely curved root canals [5].

ProTaper (Dentsply/Maillefer, Ballaigues, Switzerland) and Twisted File (SybronEndo, Orange, CA, USA) are the two NiTi rotary systems used worldwide. ProTaper has 3 shaping files and 5 finishing files. Shaping files (S) have an increasing taper from the tip to the shaft that provides more flexibility in the middle region and at the tip. Finishing files (F) have decreasing taper, they are stiffer and produce greater taper in apical region. Their convex triangular cross sectional design and grooves reduce raw material section on the rounded noncutting safety tip, and their flute design combines multiple tapers within the shaft [6, 7]. Twisted File system production is by process of heating, cooling, and twisting NiTi alloy, providing superelasticity and cyclic fatigue resistance of the instruments [8, 9]. These files have constant taper (.04, .06, .08, .10, and .12), triangular cross section, variable pitch and safe ended tip. Instrument design may also potentially influence instrumentation outcomes. Many rotary file manufacturers have incorporated different designs into their file systems to minimize apical transportation and achieve faster and more predictable preparations [10]. The

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evaluation of the efficiency of instruments and techniques is very important before their introduction to the clinical practice.

The present study aimed to compare changes in root canal dentin caused by instrumentation with two nickel titanium rotary systems, ProTaper and Twisted File in curved canals.

MATERIAL AND METHODS

The study was approved by the Research Ethics Committee at the School of Dentstry, University of Pernambuco. Twenty five extracted human mandibular first molars were selected. Inclusion criteria were: intact pulp chamber, fully formed roots, similar root lenghts (14.53±1.52 mm), two separated mesial root canals and canal curvatures between 20 and 40 degrees, measured according to Schneider's method [11].

After distal roots amputation, occlusal surfaces of the molars were leveled using a diamond disc (Vortex, São Paulo, SP) to provide a reference point for instrumentation. Mesial root canals of all teeth were accessed using a diamond coated bur (Dentsply/Maillefer) and negotiated with 10 K files (Dentsply/Maillefer) until the tip was visible beyond the apex. Working length was set to 1 mm shorter of the apical foramen.

Fifty canals (25 mesiobuccal and 25 mesiolingual) were randomly assigned into two groups: group 1 – ProTaper and group 2 – Twisted File. Each group consisted of the same number of mesiobuccal and mesiolingual canals.

Specimens were prepared using a technique described by Bramante et al. [12]. Access cavities and apices were sealed with a small ball of utility red wax (Hygienic Corporation, Akron, OH, USA). Roots were embedded up to cementoenamel junction in a cold polymerizing acrylic resin (VIPI, Pirassununga, SP, USA). After resin cure, horizontal grooves were made on the models for subsequent segmentation. Roots were sectioned transversely at three levels: 1) 4 mm from the apical foramen, 2) middle third, and 3) coronal third of the root. A muffle system was built around each mold to ensure that, after segmentation, pieces seated in the same position. Each resin block was sectioned into four pieces using a low speed 0.15 mm stainless steel wafering blade.

Before root canal preparation, coronal side of the cross sections was scanned (HP Deskjet F4200 printer, Hewlett Packard, Palo Alto, CA, USA) at 1200 ppi and 100% scale. All digital images were analyzed using the appropriate software (Adobe Photoshop CS4 Extended, Adobe System Incorporated, San Jose, CA, USA). The conversion of pixels to millimeters was 1 pixel = 0.0211 mm. For each digital image, the canal cross sectional area was filled in black, and the center was marked in white. The cross sectional area and all distances from the center to the four walls (external, internal, mesial and distal) were measured and recorded. The buccal wall of mesiobuccal canals and the lingual wall of mesiolingual canals were classified as external walls, and the opposite walls, as internal.

The sections were reassembled and all canals instrumented by the same operator. All files were used with torque control engine, in crown down technique, and following the manufacturers' instructions. Canals were instrumented with files: group 1 – S1, SX, S2, F1, F2 and F3; group 2 – #25/.08, #25.06, #25.04 and #30/.06. Final instruments were F3 (group 1) and #30/.06 (group 2) to the working length. In both groups, 10 K file was introduced after each file to ensure patency and irrigation was performed with 2 ml of 2.5% sodium hypochlorite after each instrument. Postoperative cross sections were digitized and measured under the same conditions as during preoperative phase. Changes in dentin walls were measured in coronal, middle, and apical thirds of all canals and compared by superimposition of pre and post instrumentation digital images using image analysis software.

Statistical analysis was performed using the Mann Whitney U test in the SPSS software (SPSS Inc, Chicago, IL, USA). The level of significance was set at $p<0.05$.

RESULTS

There was statistically significant greater difference in coronal and middle thirds cross sections before and after the preparation ($p=0.040$ and $p=0.043$) between group 1 and group 2 whereas there was no difference in the apical third cross sections when the two systems were used ($p=0.992$) (Table 1).

Mean difference in distance from the center to the mesial wall in the cervical third was greater in the ProTaper group and, statistically significant compared to the Twisted File group ($p<0.05$) (Table 2). Other walls, both in middle and apical thirds, did not have any statistically significant differences between the groups ($p>0.05$) (Table 2). There was no statistically significant difference ($p>0.05$) between the two groups in cross sectional canal areas before preparation.

DISCUSSION

Root canal preparations are frequently evaluated using extracted human teeth or plastic blocks with simulated

Table 1. Mean differences (mm^2) in cross sectional area of root canals before and after instrumentation
Tabela 1. Srednje vrednosti razlike (mm^2) u poprečnoj površini kanala korena pre i posle preparacije

Root level Nivo korena	Group 1/Grupa 1 (ProTaper)		Group 2/Grupa 2 (Twisted Files)	
	$\bar{X}$	SD	$\bar{X}$	SD
Coronal Koronarni	0.32	±0.17	0.23	±0.11
Middle Središnji	0.20	±0.89	0.15	±0.07
Apical Apikalni	0.10	±0.07	0.10	±0.07

$\bar{X}$ – mean value; SD – standard deviation
$\bar{X}$ – srednja vrednost; SD – standardna devijacija

Table 2. Mean differences (mm^2) of distances from the center to each wall before and after instrumentation
Tabela 2. Srednje vrednosti razlika (mm^2) dužine od centra kanala do svakog zida kanala pre i posle preparacije

Root level Nivo korena	Walls Zidovi	Instrumentation Preparacija	Group 1/Grupa 1 (ProTaper)		Group 2/Grupa 2 (Twisted Files)	
			$\bar{X}$	SD	$\bar{X}$	SD
Coronal Koronarni	External Spoljašnji	Before Pre	0.34	±0.11	0.38	±0.19
		After Posle	0.38	±0.11	0.43	±0.15
	Internal Unutrašnji	Before Pre	0.41	±0.19	0.45	±0.22
		After Posle	0.59	±0.14	0.57	±0.18
	Mesial Mezijalni	Before Pre	0.21	±0.06	0.21	±0.05
		After Posle	0.37	±0.12	0.31	±0.07
	Distal Distalni	Before Pre	0.23	±0.08	0.22	±0.07
		After Posle	0.40	±0.12	0.36	±0.11
Middle Srednji	External Spoljašnji	Before Pre	0.25	±0.11	0.27	±0.15
		After Posle	0.32	±0.10	0.36	±0.19
	Internal Unutrašnji	Before Pre	0.29	±0.22	0.35	±0.26
		After Posle	0.42	±0.22	0.46	±0.23
	Mesial Mezijalni	Before Pre	0.17	±0.05	0.16	±0.03
		After Posle	0.25	±0.06	0.24	±0.07
	Distal Distalni	Before Pre	0.17	±0.06	0.17	±0.05
		After Posle	0.33	±0.14	0.28	±0.11
Apical Apikalni	External Spoljašnji	Before Pre	0.16	±0.06	0.17	±0.07
		After Posle	0.29	±0.11	0.29	±0.14
	Internal Unutrašnji	Before Pre	0.20	±0.13	0.19	±0.07
		After Posle	0.26	±0.16	0.24	±0.09
	Mesial Mezijalni	Before Pre	0.10	±0.02	0.10	±0.04
		After Posle	0.18	±0.07	0.19	±0.08
	Distal Distalni	Before Pre	0.09	±0.02	0.10	±0.04
		After Posle	0.17	±0.07	0.14	±0.05

curved root canals [13, 14]. Simulated canals have standardized canal diameter, length and curve radius, but do not simulate the coinciding bucco lingual and mesio distal curvatures often found in natural teeth [15]. Furthermore, root dentin hardness and abrasion rates may not be identical and do not reproduce the instrument stress during canal instrumentation.

Several methods have been suggested to evaluate root canal preparation such as comparative analysis of radiographic images, resin blocks, silicone impressions and micro-computed tomography [2, 16, 17, 18]. The present study used the method developed by Bramante et al. [12] because it is an established method and allows comparison of the samples before, during, and after the instrumentation [13, 19, 20]. This methodology is easy to perform and of low cost [20]. Disadvantage of such reconstructive technique is that lateral movements of cutting disc may result in some loss of material [21]. Comparison of digital images acquired before and after instrumentation using image analysis software may be an alternative to evaluate canal preparation [13, 20, 21].

Curved canals present a challenge in endodontic treatment. Mesial canals in mandibular molars are narrow and flattened making instrumentation difficult [22, 23]. In this study, both groups had the same number of specimens, and the instruments were used alternately in the buccal

and lingual canals of consecutive specimens to compensate possible differences in canal morphology. Both mesiobuccal and mesiolingual canals were included and equally distributed between groups.

The mean differences between areas before and after preparation were greater in the ProTaper group in all thirds, furthermore, this difference was statistically significant in cervical and middle thirds when compared to the Twisted File group ($p<0.05$). These findings are similar to results from other studies [24, 25].

In the present study, ProTaper removed significantly more dentin than Twisted File on mesial wall in coronal sections. Greater dentin removal may be assigned to the S shape of ProTaper instruments. According to the manufacturer's instructions, these instruments should be used without applying apical pressure, but should work laterally on the wall with the thickest dentin, in our case, mesial walls, using brushing movements [25]. Excessive dentin removal in this region may result in contact with periodontium and weakening tooth structure, which may lead to root fracture. The distal wall is the thinnest in mesial canals, and this is explained by the concavity of the distal wall of mesial roots in mandibular molars [26]. Preparing curved canals with anticurvature method might protect root against perforation and optimize access to the apical portion of canal [3].

The analysis of changes in dentin wall thickness revealed that the two types of instruments did not cut dentin uniformly in all reference points, but differences were not significant, except for the mesial wall in cervical third. Other studies found symmetrical instrumentation using ProTaper system particularly in the apical third [21, 27]. However, radiographic method used in these studies might failed to detect dentin removal as accurately as analysis of cross sectional areas, as in Bramante method used in our study.

In both groups, some specimens showed areas not touched by instruments in all thirds, particularly in the internal walls of isthmuses. This finding is in agreement with the study of Hülsmann et al. [28]. We believe that combination of instrumentation techniques should be evaluated in future studies in order to provide better shaping of root canals [29, 30].

CONCLUSION

ProTaper removed more dentin than Twisted File during canal instrumentation in coronal and middle thirds of root canals. Also, ProTaper eliminated more dentin than Twisted File on the mesial wall in the coronal sections. Furthermore, ProTaper system caused greater cross sectional changes of root canals before and after instrumentation compared to Twisted File system.

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Komparativna studija nikl-titanijumskih sistema instrumenata *ProTaper* i *Twisted Files* u preparaciji zakrivljenih kanala korena zuba

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KRATAK SADRŽAJ

Uvod Svrha preparacije kanala korena zuba je čišćenje i oblikovanje kanala korena uz što je moguće veće očuvanje izvornog anatomskog izgleda. Međutim, ovaj pristup kod zakrivljenih kanala može dovesti do prevelikog uklanjanja dentina sa zidova kanala i transportacije kanala. Cilj ove studije bio je da oceni promene u obliku kanala nastale upotrebom dva nikl-titanijumska sistema rotirajućih instrumenata, *ProTaper* i *Twisted Files*, u zakrivljenim kanalima.

Materijal i metode rada U studiji je korišćeno 25 ekstrahovanih mandibularnih prvih molara koji su imali dva odvojena kanala u mezijalnom korenu. Distalni koreni su amputirani, a 50 mezijalnih kanala (25 meziobukalnih i 25 meziolingvalnih) nasumično su podeljeni u dve grupe: u grupi 1 primenjeni su instrumenti ProTaper, a u grupi 2 Twisted Files. Instrumenti su korišćeni prema uputstvu proizvođača. Kao krajnji instrument korišćen je F3 u grupi 1, odnosno 30/0,06 u grupi 2. Formirani su preseci na tri nivoa korena (koronarnom, srednjem i apikalnom) pre i posle zahvata. Promene u debljini dentinskog zida su merene i vrednovane Bramanteovom (*Bramante*) metodom i pomoću softvera za obradu digitalnih fotografija. Za statističku analizu korišćen je Man–Vitnijev (*Mann–Whitney*) U-test ($p<0,05$).

Rezultati Količina dentina koja je uklonjena pomoću sistema ProTaper u koronarnoj i srednjoj trećini kanala bila je značajno veća nego u grupi u kojoj je primenjen sistem Twisted Files ($p=0,040$ i $p=0,043$). Pomoću sistema ProTaper je takođe uklonjena veća količina dentina sa mezijalnog zida u koronarnom delu kanala nego pomoću sistema Twisted Files ($p=0,039$). Između dve grupe uzoraka nije bilo statistički značajne razlike u udaljenosti centra kanala od svih zidova u srednjoj i apikalnoj trećini ($p>0,05$).

Zaključak Sistem ProTaper izaziva veće promene u površini poprečnog preseka kanala korena nego sistem Twisted Files.

Ključne reči: preparacija kanala korena; ProTaper; Twisted Files; zakrivljeni kanali

UVOD

Čišćenje i oblikovanje kanala korena zuba je važan korak u endodontskoj terapiji. Ova faza uključuje dezinfekciju i uklanjanje dela dentina sa zidova uz održavanje izvornog oblika kanala i postizanje kontinuiranog konusa, kako bi se dobila odgovarajuća opturacija [1]. Zbog promenljivosti anatomije kanala korena, instrumentacija zakrivljenih kanala može dovesti do nastajanja proceduralnih grešaka, kao što su stepenik, *zipping*, *elbow*, transportacije i perforacije kanala [2, 3]. Sigurne tehnike preparacije kanala korena bi trebalo da eliminišu ili makar smanje ove proceduralne greške. Nekoliko sistema instrumenata je predloženo da bi se postigao ovaj cilj.

Nikl-titanijumske (NiTi) legure za endodontske instrumente su prvi put opisane 1988. godine [4]. Otada je u endodonciju uvedeno nekoliko mašinskih NiTi sistema instrumenata različitih konusa i dizajna. Zbog njihove fleksibilnosti i elastičnosti poboljšao se kvalitet preparacije kanala korena, a jatrogena oštećenja veoma zakrivljenih kanala korena su postala ređa [5].

ProTaper (*Dentsply/Maillefer, Ballaigues*, Švajcarska) i *Twisted Files* (*SybronEndo, Orange, CA*, SAD) su dva NiTi sistema instrumenata koja se koriste širom sveta. ProTaper je sistem koji se sastoji od tri instrumenta za oblikovanje kanala i pet instrumenata za završnu obradu kanala. Instrumenti za oblikovanje kanala (S) imaju rastući konus od vrha do vrata instrumenta, koji omogućava bolju fleksibilnost u središnjoj i apikalnoj regiji. Instrumenti za završnu obradu (F) imaju manji konus, krući su i proizvode veći konus u apikalni regiji. Instrumenti ProTaper imaju poprečan presek konveksnog trouglastog oblika, koji uklanja manje dentina, kao i zaobljen vrh. Dizajn žlebova ovih instrumenata je takav da kombinuje promenljivu veličinu konusa duž instrumenta [6, 7]. Sistem Twisted Files je proizveden na specifičan način tako što je NiTi legura zagrejana, hlađena, a potom uvrnuta, dajući instrumentu superelastičnost i otpornost na ciklički zamor [8, 9]. Ovi instrumenti imaju nepromenljiv konus (0,04, 0,06, 0,08, 0,10, 0,12), na poprečnom preseku su trouglastog oblika, imaju promenljiv broj sečiva po jedinici dužine instrumenata i zatupljen, neaktivan vrh. Dizajn instrumenta je važan zato što može uticati na ishod terapije. Mnogi proizvođači uključuju različit dizajn u svoje sisteme instrumenata da bi smanjili apikalnu transportaciju kanala i postigli sigurniju preparaciju kanala [10]. Procena efikasnosti instrumenata i tehnika preparacije je veoma važna pre njihovog uvođenja u kliničku praksu.

Cilj ove studije bio je da uporedi promene na zidu kanala korena nastale obradom zakrivljenih kanala korena pomoću dva NiTi sistema mašinskih instrumenata – ProTaper i Twisted Files.

MATERIJAL I METODE RADA

Izvođenje studije odobrio je Etički komitet Stomatološkog fakulteta Univerziteta u Pernambuku. Za eksperiment je upotrebljeno 25 ekstrahovanih mandibularnih prvih molara. Kriterijumi za odabir zuba bili su: intaktna komora pulpe, potpuno formiran koren, koreni slične dužine (14,53±1,52 mm), dva odvojena mezijalna kanala i zakrivljenost korena od 20 do 40 stepeni mereno prema metodi Šnajdera (*Schneider*) [11].

Nakon amputacije distalnog korena, okluzalne površine molara su poravnate pomoću dijamantskog diska (*Vortex, São Pa-*

ulo, SP) da bi se dobila referentna tačka tokom instrumentacije kanala. Za pristup kanalima upotrebljena su dijamantska svrdla (*Dentsply/Maillefer*), a za proveru prohodnosti kanala korišćen je 10K instrument (*Dentsply/Maillefer*) dok nije postao vidljiv preko vrha korena. Radna dužina je određena 1 mm kraće od apikalnog foramena.

Pedeset kanala (25 meziobukalnih i 25 meziolingvalnih) je nasumično svrstano u dve grupe. U grupi 1 primenjen je sistem ProTaper, a u grupi 2 sistem Twisted Files. Svaka grupa se sastojala od istog broja meziobukalnih i meziolingvalnih kanala.

Uzorci su pripremljeni primenom tehnike koju je opisao Bramante (*Bramante*) sa saradnicima [12]. Pristupni kaviteti i apeksi su zatvoreni pomoću crvenog voska (*Hygienic Corporation, Akron, OH*, SAD). Koreni su utopljeni u hladno polimerizujuću akrilnu smolu (*VIPI, Pirassununga, SP*, SAD) do gleđnocementnog spoja. Nakon polimerizacije smole napravljeni su horizontalni žlebovi, da bi se dobila tri dela na svakom korenu, i to: 4 mm od apikalnog foramena, u srednjoj i koronarnoj trećina korena. Oko svakog kalupa je napravljen dodatni sloj, kako bi se omogućilo vraćanje svih delova korena u prvobitnu poziciju nakon sečenja. Svaki blok smole je presečen na četiri dela pomoću oštrice od nerđajućeg čelika debljine 0,15 mm pri maloj brzini.

Pre preparacije kanala korena koronarna strana svakog dela je skenirana (*HP Deskjet F4200 printer, Hewlett Packard, Palo Alto, CA*, SAD) koristeći 1200 ppi i veličinu 100%. Sve digitalne fotografije su analizirane pomoću odgovarajućeg softvera (*Adobe Photoshop CS4 Extended, Adobe System Incorporated, San Jose, CA*, SAD). Jedan piksel je pretvoren u 0,0211 mm. Na svakoj digitalnoj fotografiji poprečni presek kanala je bio obojen crno, a centar je označen belom bojom. Potom su izmereni površina poprečnog preseka i udaljenost zidova (spoljašnjeg, unutrašnjeg, mezijalnog i distalnog) od centra kanala. Bukalni zid meziobukalnog kanala i lingvalni zid meziolingvalnog kanala su klasifikovani kao spoljašnji zidovi, a naspramni kao unutrašnji zidovi.

Preseci zuba su nakon opisanog merenja ponovo sastavljeni i jedan stomatolog je izveo preparacije svih kanala motorom s kontrolisanim obrtnim momentom i primenom tehnike *crown-down* prema preporuci proizvođača. Kanali su obrađeni na sledeći način: grupa 1 – S1, SX, S2, F1, F2 i F3; grupa 2 – 25/0,08, 25,06, 25,04 i 30/0,06. Zadnji instrumenti su bili F3 (grupa 1) i 30/0,06 (grupa 2) do radne dužine. U svakoj grupi primenjen je 10K instrument da bi se osigurala prohodnost kanala, a za irigaciju je korišćeno 2 ml dvoipoprocentnog natrijum-hipohlorita nakon svakog instrumenta. Merenje istih parametara pod istim okolnostima kao i pre preparacije vršeno je i na postoperacionim presecima korena. Promena u debljini zidova kanala pre i posle preparacije dobijena je superimpozicijom fotografija poprečnog preseka u koronarnoj, srednjoj i apikalnoj trećini pre i posle preparacije.

Za statističku analizu korišćen je Man–Vitnijev (Mann–Whitney) U-test u softveru SPSS (*SPSS Inc, Chicago, IL*, SAD). Značajnost je postavljena na $p<0,05$.

REZULTATI

Postojala je statistički značajno veća razlika poprečnih preseka u koronarnoj i srednjoj trećini pre i posle preparacije kanala korena zuba ($p=0,040$ i $p=0,043$) između grupe 1 i 2, dok razlike nije bilo između preseka u apikalnoj trećini nakon korišćenja sistema ProTaper i Twisted Files ($p=0,992$) (Tabela 1).

Srednja udaljenost od centra kanala do mezijalnog zida u koronarnom delu bila je veća u grupi uzoraka gde je korišćen ProTaper i statistički značajno različita u odnosu na grupu u kojoj je primenjen sistem Twisted Files ($p>0,05$) (Tabela 2). Udaljenost ostalih zidova u koronarnoj trećini, kao i svih zidova u srednjoj i apikalnoj trećini, nije bila statistički značajno različita u grupi 1 u odnosu na grupu 2 ($p>0,05$) (Tabela 2). Statistički značajne razlike između ove dve grupe nije bilo ($p>0,05$) ni u poprečnim presecima kanala pre preparacije.

DISKUSIJA

Preparacija kanala korena se često procenjuje korišćenjem ekstrahovanih zuba ili plastičnih blokova sa simuliranim zakrivljenim kanalima [13, 14]. Simulirani kanali imaju standardni prečnik, dužinu i stepen zakrivljenja, ali ne oponašaju dobro krivinu koja postoji u bukolingvalnom i meziodistalnom pravcu kod prirodnih zuba [15]. Osim toga, nije moguće simulirati tvrdoću i abraziju dentina, niti stres koji pretrpi instrument tokom preparacije kanala.

Predloženo je nekoliko metoda za procenu preparacije kanala korena, kao što su uporedna analiza radiografskih snimaka, blokovi od smole, silikonski otisci i mikrokompjuterizovana tomografija [2, 16, 17, 18]. U našoj studiji je korišćena metoda koju su razvili Bramante i saradnici [12], jer je to proverena metodologija koja omogućava poređenje uzoraka pre, tokom i nakon instrumentacije kanala [13, 19, 20]. Takođe, lako se izvodi i nije skupa [20]. Nedostatak ove metode je u tome da tokom rezanja zuba lateralni pokreti diska mogu dovesti do gubitka materijala [21]. Poređenje digitalnih fotografija napravljenih pre i posle obrade kanala pomoću programa za analizu slika može biti alternativa u proceni preparacije kanala [13, 20, 21].

Zakrivljeni kanali su problem u endodontskom lečenju. Mezijalni kanali mandibularnih molara su uski i spljošteni, što otežava obradu kanala [22, 23]. U našoj studiji obe grupe su imale isti broj uzoraka, a instrumenti su korišćeni naizmenično u bukalnim i lingvalnim kanalima da bi se nadomestile eventualne razlike u morfološkom izgledu kanala. Meziobukalni i meziolingvalni kanali su bili podjednako raspoređeni u obe grupe.

Srednje razlike između površina kanala pre i posle obrade kanala bile su veće u grupi 1 (ProTaper) u svim trećinama; ta razlika je bila statistički značajna ($p<0,05$) u koronarnoj i srednjoj trećini u odnosu na grupu 2 (Twisted Files). Ovi rezultati su u saglasnosti s nalazima sličnih studija [24, 25].

U našoj studiji ProTaper je uklonio znatno više dentina nego sistem Twisted Files na mezijalnom zidu u koronarnom delu kanala. Uklanjanje veće količine dentina može biti zbog oblika ProTaper instrumenata, koji su u vidu slova S. Prema uputstvima proizvođača, ovi instrumenti se koriste bez apikalnog pritiska, ali sa lateralnim pokretima četkanja uz zidove kanala, naročito onog gde je dentin najdeblji – u našem eksperimentu to je bio mezijalni zid [25]. Prekomerno uklanjanje dentina u ovoj regiji može dovesti do kontakta s parodoncijumom ili slabljenja zubnog tkiva, što povećava rizik od preloma korena. Distalni zid je najtanji zid kod mezijalnih kanala zbog zastupljenog konkaviteta na distalnom zidu mezijalnog korena mandibularnih mo-

lara [26]. Obrada zakrivljenih kanala metodom *anticurvature* može sprečiti perforaciju korena i omogućiti pristup apikalnom delu kanala [3].

Analiza promena u debljini zida dentina je pokazala da dve vrste instrumenata ne uklanjaju dentin podjednako u svim referentnim tačkama; ipak, razlike nisu bile statistički značajne, osim za mezijalni zid u koronarnoj trećini. Druge studije su uočile simetrično uklanjanje dentina sa svih zidova kanala tokom primene sistema instrumenta ProTaper, naročito u apikalnoj trećini [21, 27]. Moguće je da radiografska metoda korišćena u ovim studijama nije tačno izmerila uklonjeni dentin, kao što je to moguće analizom poprečnog preseka kanala u Bramanteovoj metodi, primenjenoj u našoj studiji.

U obe grupe je bilo kanala sa delovima zidova u svim trećinama koji nisu dotaknuti instrumentima, naročito u unutrašnjim zidovima istmusa. Ovaj nalaz je u skladu s rezultatima studije Hilsmana (*Hülsmann*) i saradnika [28]. Trebalo bi obaviti istraživanja o tome kakav efekat imaju kombinacije metoda preparacije na oblikovanje kanala korena [29, 30].

ZAKLJUČAK

Pomoću sistema ProTaper je tokom preparacije kanala korena zuba uklonjeno više dentina u koronarnoj i srednjoj trećini kanala nego primenom Twisted Files. Takođe, ProTaper je uklonio više dentina nego sistem Twisted Files sa mezijalnog zida u koronarnoj trećini. ProTaper dovodi do nastanka većih promena poprečnog preseka kanala korena pre i posle instrumentacije nego sistem Twisted Files.