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Cyclic fatigue testing of ProTaper Universal and ProTaper Next rotary instruments of different diameters

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SUMMARY

Introduction Sudden fracture of instruments without previous warning signs, which occurs due to cyclic and torsional fatigue, represents the biggest problem and one of the most difficult complications during endodontic therapy. The aim of this research was to check the influence of diameter of the instruments on the appearance of cyclic fatigue in simulated canals in full rotation.

Material and Method The study analyzed 24 ProTaper Universal instruments (12 instruments with a diameter of 25 and 12 instruments with a diameter of 30) and 24 ProTaper Next instruments (12 instruments with a diameter of 25 and 12 instruments with a diameter of 30). The instruments were tested in an artificial canal stuffed in a metal block at an angle of 45° and a corner radius of 5 mm. The operating time of each instrument until fracture was measured, and then the number of cycles to fracture (NCF) was calculated. The length of the fractured fragments (FL) was measured with a Vernier caliper.

Results The number of cycles to fracture was higher ($p < 0.001$) in instruments of the ProTaper Universal group of diameter 25 (367.83 ± 17.00) compared to instruments of diameter 30 (329.33 ± 12.86) of the same group. The number of cycles leading to the fracture in instruments of the ProTaper Next group of diameter 25 (1189.33 ± 18.97) was higher ($p < 0.001$) compared to instruments of the same group of diameter 30 (971.08 ± 15.26).

Conclusion Obtained results indicated that with an increase in the diameter of rotating endodontic instruments, there is a decrease in the resistance to cyclic fatigue.

Keywords: instrument diameter; cyclic fatigue; Neither you; ProTaper Universal; ProTaper Next

INTRODUCTION

In addition to correct diagnosis of endodontic diseases, the principles of modern endodontics are based on well-conducted chemomechanical instrumentation of root canals [1]. With the development of endodontics, the properties of the instruments used for mechanical treatment of root canals have been improved from generation to generation [2]. Due to the properties of the nickel-titanium (NiTi) alloy, rotary endodontic instruments are the standard. This "smart" feature contributes to the fact that, after the canal instrumentation, instruments can be easily returned to their original form. The use of mechanical rotating NiTi instruments in endodontic treatment enables significantly faster and more efficient preparation of the complex canal system [3].

Although fractures in nickel-titanium instruments are less common than in stainless steel instruments, instrument separation is still a serious complication of endodontic treatment. Due to the difficulty in removing the fragment from the apical third of the canal, this complication often requires additional surgical treatment (apicotomy or tooth extraction) [4].

The most common reason for fracture of endodontic instruments in the canal is cyclic fatigue [5]. Cyclic fatigue represents stress, tension and deformation, which are caused in the material by cyclic loading. It occurs in the region of the curve of the canal, due to the action of antagonistic compression and stretching forces in the bent part of the instrument [6]. Due to the elasticity of nickel-titanium, no changes in appearance are observed on the instruments after work in the canal, so that the fracture of these instruments occurs without previous change in color or shape of the instrument, such as the appearance of silver shine in stainless steel instruments [7].

There is great variation in the shape and position of the root canal. Instruments in curved canals are exposed to greater cyclic fatigue, compared to the preparation of straight canals [8]. In addition to the anatomy of the canal itself and its bending, the stress due to cyclic fatigue is also influenced by the properties and characteristics of the instrument itself [9].

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The aim of this research was to check the influence of instrument diameter on the appearance of cyclic fatigue in simulated canals in full rotation with ProTaper Universal and ProTaper Next.

MATERIAL AND METHOD

The research was conducted at the Clinic for Dental Medicine, Faculty of Medicine, University of Niš. 24 instruments of the *ProTaper Universal* group (*Dentsply Sirona, Ballaigues, Switzerland*) and 24 instruments of the *ProTaper Next group* (*Dentsply Sirona, Ballaigues, Switzerland*) were tested for cyclic fatigue. Twelve instruments of the *ProTaper Universal* group (F2) were 25 in diameter, 0.04 taper, while the remaining twelve (F3) were 30 in diameter and 0.05 taper. Twelve instruments of the *ProTaper Next* group (X2) had a diameter of 25 and a degree of conicity of 0.06, and the other twelve (X3) had a diameter of 30 and a degree of conicity of 0.07. All instruments were 25 mm long.

In order to test the resistance to cyclic fatigue, the instruments were tested in artificial canals that were stuffed in a metal block with a curvature angle of 45 degrees and a corner radius of 5 mm in accordance with the research of Plotino et al. [10]. Glycerin was used to reduce the friction of the instruments with the walls of the artificial canal. The instruments were tested using an electric endomotor (*X-smart plus, Dentsply Sirona, Ballaigues, Switzerland*). All instruments were continuously rotated to the right, with constant resistance and speed as recommended by the manufacturer. A constant speed of 250 rpm and a torque of 2.5 N/cm were used for the instruments of the *ProTaper Universal* group, while a speed of 300 rpm and a torque of 2.0 N/cm were used for the instruments of the *ProTaper Next* group. The rotation of the instrument was analyzed visually, and the fracture was registered visually and by sound. The rotation time until the instrument broke was measured in seconds with a digital stopwatch. The number of cycles to fracture (NCF) was calculated according to the formula:

NCF = number of revolutions × time to fracture in seconds/60

The length of the broken fragment was measured with a *Vernier caliper* with an accuracy of 0.02 mm.

The statistical analysis of the obtained values was performed in the *IBM SPSS 26.0 program* using the *Mann-Whitney U test, Student's t-test and Spearman's correlation coefficient* with the degree of probability $p < 0.001$. Values are presented as arithmetic mean ± standard deviation.

RESULTS

ProTaper Universal instruments with a diameter of 25 showed higher resistance to cyclic fatigue compared to the same group of instruments with a diameter of 30. There was a significant difference in the number of cycles to fracture of the instruments in the examined groups ($Z = 3.986$; $p < 0.001$) (Table 1). The length of the fractured fragment was significantly shorter in instruments of diameter 30 compared to instruments of smaller diameter ($t = 3.921$; $p < 0.001$) (Table 1).

It was determined that the ProTaper Next instruments with a diameter of 25 showed a higher resistance to cyclic fatigue than instruments with a diameter of 30. Statistical analysis indicated significant difference in the number of cycles leading to fracture among the studied groups ($Z = 4.159$; $p < 0.001$) (Table 2). Fractured fragments of 30-diameter instruments were significantly shorter than those of 25-diameter instruments ($t = 3.876$; $p < 0.001$) (Table 2).

Table 1. Number of cycles to fracture and fragment length expressed in mm with ProTaper Universal
Tabela 1. Broj obrtaja pre preloma instrumenta i dužina odlomljenog dela u mm kod instrumenata ProTaper Universal

	F2 (#25)	F3 (#30)	p
NCF NCF	367.83 ± 17.00	329.33 ± 12.86	< 0.0011
Fragment length Dužina odlomljenog dela	4.59 ± 0.43	3.86 ± 0.48	< 0.0012

[1]Man-Witney U test
[1]Man-Vitnijev U test
[2]Student t-test
[2]Studentov t-test

Table 2. Number of cycles to fracture and fragment length expressed in mm with ProTaper Next
Tabela 2. Broj obrtaja pre preloma instrumenta i dužina odlomljenog dela u mm kod instrumenata ProTaper Next

	X_2 (#25)	X_3 (#30)	p*
NCF	1189.33 ± 18.97	971.08 ± 15.26	< 0.0011
Fragment length Dužina odlomljenog dela	3.29 ± 0.39	2.74 ± 0.29	< 0.0012

[1]Man-Witney U test
[1]Man-Vitnijev U test
[2]Student t-test
[2]Studentov t-test

The results showed that there was a negative correlation between the diameter of the instrument and the number of cycles to fracture in ProTaper Universal instruments ($\rho = -0.800$; $p < 0.001$) as well as in ProTaper Next instruments ($\rho = -0.989$; $p < 0.001$).

By comparing the cyclic fatigue values between ProTaper Universal and ProTaper Next of the same diameter, it was determined that the ProTaper Universal group of diameter 25 was less resistant to cyclic fatigue than ProTaper Next instruments and there was significant difference in the number of cycles leading to fracture ($Z = 4.158$; $p < 0.001$). The same results were obtained by comparing the number of cycles to fracture of ProTaper Universal instruments of diameter 30 with ProTaper Next instruments of the same diameter ($Z = 4.161$; $p < 0.001$).

The average length of the fractured fragments of the ProTaper Universal instrument of diameter 25 was greater than the average length of the fragments of ProTaper Next instruments of the same diameter ($t = 7.684$; $p < 0.001$). Also, the average length of ProTaper Universal fragments of diameter 30 was significantly higher compared to the average length of ProTaper Next fragments of the same diameter ($t = 6.859$; $p < 0.001$).

DISCUSSION

Chemomechanical intrumentation of root canal is one of the most important active phases during endodontic treatment [1]. During root canal treatment, the instruments are exposed to various forces, which have an unfavorable effect on them [6]. Numerous studies have observed that cyclic fatigue plays a significant role in the fracture of endodontic rotary instruments [5].

Literature data shows that various factors can influence the number of cycles to fracture in rotary NiTi instruments. In this study, the influence of diameter on cyclic fatigue of two different types of NiTi rotary instruments - ProTaper Universal and ProTaper Next in simulated root canals was examined.

This study indicated higher resistance of ProTaper Next instruments to cyclic fatigue, compared to ProTaper Universal instruments of the same diameter. These data are in agreement with the results of numerous studies [11]. Elnaghy et al. interpret that higher resistance of ProTaper Next instruments to cyclic fatigue is due to different design of the working part of the instrument as well as different treatment technology of the NiTi alloy [12]. Unlike the alloy from which conventional instruments are made, such as ProTaper Universal instruments, the improved M-wire alloy from which ProTaper Next instruments are made is softer and more resistant to cyclic fatigue [13].

The triangular cross-section of the ProTaper Universal instruments, created by the standard cutting technique, characteristic of conventional instruments, is more susceptible to the formation of microcracks, which ultimately lead to sudden rupture of the instrument, without prior macroscopic damage [9]. The rectangular cross-section of the ProTaper Next instruments has a higher resistance to cyclic fatigue, due to less contact with the surfaces of the canal walls during instrumentation [14].

It was found that as diameter of the instrument increases, the resistance to cyclic fatigue decreases in both types of instruments. This was also indicated by the study by Alqedairi et al. where *in vitro* testing of ProTaper Universal and ProTaper Next instruments with diameters of 25 and 30 was performed, and both types of instruments with larger diameters fractured more quickly [15]. All instruments tested in their research by Nguyen et al. (ProTaper Next, ProTaper Universal and Vortex Blue Rotary system) showed lower resistance to cyclic fatigue as the diameter of the instruments increased [16]. In the study of Hieawy et al., when testing ProTaper Universal and ProTaper Gold, the resistance to cyclic fatigue decreased with the increase in diameter [17]. Statistically significant cyclic fatigue resistance of ProTaper Next instruments compared to ProTaper Universal was also reported by Perez-Higueras et al. [18].

As the diameter of the tested instruments increases, so does their conicity, the massiveness of the instruments is probably responsible for the earlier cracking of instruments. Given that one of the significant characteristics of the design of rotating instruments is its conicity, it was shown that with increasing conicity, the stiffness of rotating instruments increases, which causes a greater twisting effect [19] and a reduction in fatigue resistance during bending [20]. Instruments of greater conicity show less flexibility due to higher metal content along its working part. Due to this, the lifetime of instruments is shorter and the resistance to cyclic fatigue is reduced. However, by increasing the diameter and cross-section of the rotating instruments, greater resistance to torsional fracture is ensured [21, 22].

A smaller number of studies dealt with the analysis of the length of fractured fragments when testing the resistance of instruments, where it was concluded that the highest number of fractures occured at ±0.5 mm from the center of the canal curve [23]. However, the results of this study showed that instruments with larger diameter had a significantly shorter fractured fragment. This indicates that larger diameter instruments will break closer to the apex than smaller instruments.

The limitation of the study was that the study was done on a model and *in vitro* conditions where only cyclic fatigue parameters were measured. Given that in clinical work, the cyclic and torsional loading of the instruments used to instrument the canal is alternated, it is possible that different results would be obtained in clinical conditions and instruments with larger diameter may not have a shorter life compared to those with a smaller diameter.

CONCLUSION

In accordance with the limitations of the study, it was determined that with an increase in the diameter of the rotating endodontic instruments ProTaper Universal and ProTaper Next, their resistance to cyclic fatigue decreased and, therefore, the instrument broke faster. Fractured fragments were significantly shorter with increasing diameter in instruments of both types. ProTaper Next showed greater resistance to cyclic fatigue compared to ProTaper Universal instruments of the same diameter.

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Ispitivanje otpornosti na ciklični zamor kod rotirajućih instrumenata ProTaper Universal i ProTaper Next različitih dijametara

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KRATAK SADRŽAJ

Uvod Iznenadni prelom instumenata bez prethodnih znakova upozorenja, koji se dešava usled cikličnog i torzionog zamora, predstavlja najveći problem i jednu od težih komplikacija u toku endodontske terapije.
Cilj ovog istraživanja je bio da se proveri uticaj dijametra instrumenata na pojavu cikličnog zamora u simuliranim kanalima u punoj rotaciji.

Metodologija U studiji su analizirana 24 ProTaper Universal instrumenta (12 instrumenata dijametra 25 i 12 instrumenata dijametra 30) i 24 ProTaper Next instrumenta (12 instrumenata dijametra 25 i 12 instrumenata dijametra 30). Instrumenti su testirani u artificijelnom kanalu preparisanom u metalnom bloku pod uglom od 45° i radijusom ugla od 5 mm. Mereno je vreme rada svakog instrumenta do pojave frakture, a zatim je urađeno izračunavanje broja ciklusa do frakture (NCF). Dužina frakturisanih fragmenata (FL) merena je kaliperom po Vernijeru.

Rezultati Vrednost broja ciklusa do frakture je bila veća ($p < 0,001$) kod instrumenata grupe ProTaper Universal dijametra 25 (367,83 ± 17,00) u odnosu na instrumente dijametra 30 (329,33 ± 12,86) iste grupe. Broj ciklusa koji dovodi do frakture kod instrumenata grupe ProTaper Next dijametra 25 (1189,33 ± 18,97) veći je ($p < 0,001$) u odnosu na instrumente iste grupe dijametra 30 (971,08 ± 15,26).

Zaključak Dobijeni rezultati su ukazali da se sa povećanjem dijametra kod rotirajućih endodontskih instrumenata dolazi do smanjenja otpornosti na ciklični zamor.

Ključne reči: dijametar instrumenta; ciklični zamor; NiTi; ProTaper Universal; ProTaper Next

UVOD

Pored pravilne dijagnostike endodontskih oboljenja, principi moderne endodoncije počivaju na kvalitetno sprovedenoj hemomehaničkoj obradi kanala korena zuba [1]. Razvojem endodoncije, osobine instrumenata koji se koriste za mehaničku obradu kanala korena unapređivane su iz generacije u generaciju [2]. Zahvaljujući osobinama legure od nikl-titanijuma (NiTi), rotirajući endodontski instrumenti predstavljaju standard. Ova „pametna" osobina doprinosi tome da se instrumenti posle instrumentacije u kanalima mogu vrlo lako vratiti u prvobitan oblik. Primenom mašinskih rotirajućih NiTi instrumenata u endodontskom lečenju omogućena je znatno brža i efikasnija preparacija kompleksnog kanalnog sistema zuba [3].

Iako su prelomi kod instrumenata od nikl-titanijuma ređi nego kod instrumenata od nerđajućeg čelika, fraktura instrumenta i dalje predstavlja ozbiljnu komplikaciju endodontskog tretmana. Zbog teškoća u uklanjanju fragmenta iz apeksne trećine kanala ova komplikacija često iziskuje dodatno hirurško lečenje (apikotomije ili ekstrakcije zuba) [4].

Najčešći razlog frakture endodontskih instrumenta u kanalu je ciklični zamor [5]. Ciklični zamor predstavlja stres, nategnutost i deformaciju, koji su u materijalu izazvani cikličnim opterećenjem. Javlja se u predelu krivine kanala, zbog dejstva antagonističkih sila zbijanja i istezanja u savijenom delu instrumenta [6]. Zbog elastičnosti nikl-titanijuma, na instrumentima se ne primećuju promene u izgledu posle rada u kanalu, tako da fraktura ovih instrumenata nastaje bez prethodne promene boje ili oblika instrumenta, kao što je pojava *silver shine*-a kod instrumenata od nerđajućeg čelika [7].

Postoje velike varijacije oblika i položaja kanala korena. Instrumenti su u povijenim kanalima izloženi većem cikličnom zamoru, u poređenju sa preparacijom pravih kanala [8]. Pored anatomije samog kanala i njegove povijenosti, na stres usled cikličnog zamora utiču i svojstva i osobine samog instrumenta [9].

Cilj ovog istraživanja je bio da se proveri uticaj dijametra instrumenata na pojavu cikličnog zamora u simuliranim kanalima u punoj rotaciji kod instrumenata ProTaper Universal i ProTaper Next.

MATERIJAL I METOD

Istraživanje je obavljeno na Klinici za dentalnu medicinu Medicinskog fakulteta Univerziteta u Nišu. Na ciklični zamor testirana su 24 instrumenta grupe ProTaper Universal (*Dentsply Sirona, Ballaigues, Switzerland*) i 24 instrumenta grupe ProTaper Next (*Dentsply Sirona, Ballaigues, Switzerland*). Dvanaest instrumenata grupe ProTaper Univesal (F_2) bilo je dijametra 25, stepena koničnosti 0,04, dok je preostalih dvanaest (F_3) bilo dijametra 30 i stepena koničnosti 0,05. Dvanaest instrumenata grupe ProTaper Next (X_2) bilo je dijametra 25 i stepena koničnosti 0,06, a ostalih dvanaest (X_3) dijametra 30 i stepena koničnosti 0,07. Svi instrumenti su bili dužine 25 mm.

Radi ispitivanja otpornosti na ciklični zamor, instrumenti su testirani u artificijalnom kanalu koji je bio preparisan u metalnom

bloku sa uglom zakrivljenosti od 45 stepeni i radijusom ugla od 5 mm u skladu sa istraživanjem Plotina i saradnika [10]. Za smanjenje trenja instrumenata sa zidovima artificijalnog kanala korišćen je glicerin. Instrumenti su testirani korišćenjem električnog endomotora (*X-smart plus, Dentsply Sirona, Ballaigues, Switzerland*). Svi instrumenti su kontinuirano rotirani udesno, sa konstantnim otporom i brzinom prema preporuci proizvođača. Za instrumente grupe ProTaper Universal korišćena je konstantna brzina od 250 rpm i tork od 2,5 Ncm, dok je kod instrumenata grupe ProTaper Next korišćena brzina od 300 rpm i tork od 2,0 Ncm. Rotacija instrumenta je analizirana vizuelno, a prelom je registrovan vizuelno i zvukom. Vreme rotacije do preloma instrumenta mereno je u sekundama digitalnom štopericom. Broj ciklusa do frakture (*NCF*) računat je prema formuli:

NCF = broj obrtaja × vreme do frakture u sekundama/60

Dužina prelomljenog fragmenta merena je kaliperom po Vernijeru sa tačnošću 0,02 mm.

Statistička analiza dobijenih vrednosti je odrađena je u programu IBM SPSS 26.0 pomoću Man-Vitnijevog U testa, Studentovog t-testa i Spirmanovog koeficijenta korelacije sa stepenom verovatnoće $p < 0,001$. Vrednosti su prikazane kao aritmetička sredina ± standardna devijacija.

REZULTATI

Instrumenti ProTaper Universal dijametra 25 pokazali su veću otporost na ciklični zamor u odnosu na istu grupu instrumenata dijametra 30. Postoji značajna razlika u broju ciklusa do frakture instrumenata ispitivanih grupa ($Z = 3,986$; $p < 0,001$) (Tabela 1). Dužina prelomljenog fragmenta je bila značajno kraća kod instrumenata dijametra 30 u odnosu na instrumente manjeg dijametra ($t = 3,921$; $p < 0,001$) (Tabela 1).

Utvrđeno je da su instrumenti ProTaper Next dijametra 25 pokazali veću otpornost na ciklični zamor od instrumenata dijametra 30. Statistička analiza je ukazala na značajnu razliku u broju ciklusa koji dovode do frakture među ispitivanim grupama ($Z = 4,159$; $p < 0,001$) (Tabela 2). Frakturisani fragmenti instrumenata dijametra 30 bili su značajno kraći od fragmenata instrumenta dijametra 25 ($t = 3,876$; $p < 0,001$) (Tabela 2).

Rezultati su pokazali da je postojala negativna korelacija između dijametra instrumenta i broja ciklusa do frakture kod instrumenata ProTaper Universal ($\rho = -0,800$; $p < 0,001$), kao i kod instrumenata ProTaper Next ($\rho = -0,989$; $p < 0,001$).

Poređenjem vrednosti cikličnog zamora između instrumenata ProTaper Universal i ProTaper Next istih dijametra, utvrđeno je da je grupa ProTaper Universal dijametra 25 manje otporna na ciklični zamor od instrumenata ProTaper Next i da postoji značajna razlika u broju ciklusa koji dovode do frakture ($Z = 4,158$; $p < 0,001$). Isti rezultati su dobijeni upoređivanjem vrednosti broja ciklusa do frakture instrumenata ProTaper Universal dijametra 30 sa instrumentima ProTaper Next istog dijametra ($Z = 4,161$; $p < 0,001$).

Prosečna dužina frakturisanih fragmenata instrumenta ProTaper Universal dijametra 25 veća je od prosečne dužine fragmenta instrumenata ProTaper Next istog dijametra ($t = 7,684$; $p < 0,001$). Takođe, prosečna dužina fragmenta instrumenata ProTaper Universal dijametra 30 značajno je veća od prosečne dužine fragmenta instrumenata ProTaper Next istog dijametra ($t = 6,859$; $p < 0,001$).

DISKUSIJA

Hemomehanička obrada kanala korena zuba je jedna od najvažnijih aktivnih faza tokom endodotskog tretmana zuba [1]. Prilikom obrade kanala korena, instrumenti su izloženi različitim silama, koje nepovoljo deluju na njih [6]. Brojna istraživanja su pokazala da ciklični zamor igra značajnu ulogu u frakturi endodontskih rotirajućih instrumenata [5].

Literaturni podaci pokazuju da različiti faktori mogu da utiču na broj ciklusa do frakture kod rotirajućih NiTi instrumenata. U ovoj studiji je urađena provera uticaja dijametra na ciklični zamor kod dva različita tipa NiTi rotirajućih instrumenata – ProTaper Universal i ProTaper Next u simuliranim kanalima korenova.

Ova studija je ukazala na postojanje veće otpornosti instrumenata ProTaper Next na ciklični zamor, u odnosu na instrumente ProTaper Universal istog dijametra. Ovi podaci su u saglasnosti sa rezultatima brojnih istraživanja [11]. Elnaghy i saradnici tumače da je za veću otpornost instrumenata ProTaper Next na ciklični zamor odgovoran drugačiji dizajn radnog dela instrumenta, ali i drugačija tehnologija tretmana NiTi legure [12]. Za razliku od legure od koje su napravljeni konvencionalni instrumenti, poput instrumenata ProTaper Universal, unapređena legura M-wire, od koje su izgrađeni instrumenti ProTaper Next, mekša je i otpornija na ciklični zamor [13].

Trouglasti poprečni presek instrumenata ProTaper Universal, nastao standardnom tehnikom rezanja, karakterističnom za konvencionalne instrumente, podložniji je nastanku mikropukotina, koje za krajnji ishod imaju iznenadno pucanje instrumenta, bez prethodne makroskopske naznake [9]. Pravougaoni poprečni presek instrumenata ProTaper Next ima veću otpornost na ciklični zamor, zbog manjeg kontakta sa površinama zidova kanala tokom obrade [14].

Ustanovljeno je da sa porastom dijametra instrumenta opada otpornost na ciklični zamor kod oba tipa instrumenata. Na ovo ukazuje i studija koju su sproveli Alqedairi i saradnici, u kojoj je vršeno *in vitro* testiranje instrumenata ProTaper Universal i ProTaper Next dijametra 25 i 30, gde je kod oba tipa instrumenata većeg dijametra brže dolazilo do frakture [15]. Svi instrumenti, koje su u svom istraživanju testirali Nguyen i saradnici (ProTaper Next, ProTaper Universal i Vortex Blue Rotary system), sa povećanjem dijametra instrumenata pokazali su manju otpornost na ciklični zamor [16]. U studijama koje su sproveli Hieawy i saradnici, prilikom testiranja instrumenata ProTaper Universal i ProTaper Gold, sa porastom dijametra došlo je do smanjenja otpornosti na ciklični zamor [17]. Statistički značajnu otpornost na ciklični zamor instrumenata ProTaper Next u odnosu na ProTaper Universal objavili su i Perez-Higueras i saradnici [18].

Kako sa povećanjem dijametra testiranih instrumenata raste i njihova koničnost, verovatno je masivnost instrumenata odgovorna za ranije pucanje instrumenata. S obzirom na to da je jedna od značajnih karakteristika dizajna rotirajućih instrumenta i njegova koničnost, pokazalo se da sa povećanjem koničnosti dolazi do povećanja krutosti rotirajućih instrumenta, što uslovljava i veći efekat uvrtanja [19] i smanjenje otpornosti na zamor pri savijanju [20]. Instrumenti veće koničnosti pokazuju manju fleksibilnost zbog većeg sadržaja metala duž njegovog radnog dela. Zahvaljujući tome, životni vek instrumenata je kraći, odnosno otpornost na ciklični zamor je smanjena. Međutim, povećanjem

prečnika i poprečnog preseka rotirajućih instrumenta, obezbeđuje se veća otpornost na torzioni prelom [21, 22].

Manji broj studija se bavio analizom dužine prelomljenih fragmenata kod testiranja otpornosti instrumenata, pri čemu je zaključeno da se najveći broj fraktura dešava na ±0,5 mm od centra krivine kanala [23]. Međutim, rezultati ove studije su pokazali da instrumenti većeg dijametra imaju značajnije kraći frakturisani fragment. Ovo ukazuje da će se instrumenti koji su većeg dijametra prelomiti bliže apeksu nego instrumenti manjih veličina.

Ograničenje studije je bilo u tome što je studija urađena na modelu i u *in vitro* uslovima gde su isključivo mereni parametri cikličnog zamora. S obzirom na to da se u kliničkom radu naizmenično smenjuju ciklično i torziono opterećenje instrumenata kojim se kanal obrađuje, moguće je da bi se u kliničkim uslovima dobili drugačiji rezultati, koji bi pokazali da nije nužno da instrumenti većeg dijametra imaju kraći rok upotrebe u odnosu na one sa manjim dijametrom.

ZAKLJUČAK

U skladu sa ograničenjima studije, utvrđeno je da sa povećanjem dijametra kod rotirajućih endodontskih instrumenata ProTaper Universal i ProTaper Next dolazi do smanjenja njihove otpornosti na ciklični zamor i samim tim do brže frakture instrumenta. Frakturisani fragmenti su sa povećanjem dijametra bili značajnije kraći kod instrumenata oba tipa. ProTaper Next su pokazali veću otpornost na ciklični zamor u poređenju sa instrumentima grupe ProTaper Universal istog dijametra.

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