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ORIGINAL ARTICLE
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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	< 0.001[1]
Fragment length Dužina odlomljenog dela	4.59 ± 0.43	3.86 ± 0.48	< 0.001[2]

[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	< 0.001[1]
Fragment length Dužina odlomljenog dela	3.29 ± 0.39	2.74 ± 0.29	< 0.001[2]

[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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Condylographic evaluation of propulsive and Bennett angles in patients with temporomandibular disorders

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SUMMARY

Introduction Mandibular kinetics is composed of a series of complex movements regarding opening and closing and latero-lateral movements. The procedure for registration of this trajectory is condylography. This procedure represents a diagnostic method for monitoring and registering the movements of the mandibular condyles. The analysis starts from the most distal position of the condyle to the maximum propulsive point and latero-lateral maximum extensions. The aim of this examination is to compare the trajectory of movement of the mandibular condyle in patients with symptoms of TMD, in the acute phase and the trajectory after the treatment and corrections of intermaxillary relations.
Materials and methods The examination was carried out in 20 (10 men and 10 women) patients of PHO Denta Estetika Team Skopje. The patients were complaining about pain, limitation of movements and crepitations in the temporomandibular joint as well as difficult mastication. Condylographic measurements were made with the Kavo Arcus Digma digital condylograph. The registration of the movements was done in two sessions, before and after the treatment.
Results There was no statistically significant difference in temporomandibular condyle movement angles before and after the treatment in patients with TMD. There was a statistically significant difference in the value of Bennett's angle. Easier and more accurate movements of mandible were noticed in the patients after the treatment.
Keywords: condylography; condylar movement path; functional diagnostics; jaw movement; temporomandibular joint; temporomandibular joint disorders

INTRODUCTION

Mandibular movement patterns have been commonly used by clinicians to investigate dysfunction of the masticatory system. Restricted maximal opening (normal values range 45+/-5 mm) and deflections or deviations in the opening trajectory are one of the symptoms of TMD.

In everyday practice a dentist is confronted with problems such as tooth sensitivity, tooth fractures, luxating teeth, pain in the temporomandibular joints, muscles sensitive to palpation, facial pain etc. [1, 2]. Due to inappropriate angulation and design of the anatomy of dental cusps we get "inappropriate" and premature contacts that lead to persistent pain in the tooth and furthermore pain in the muscles after the fixation of the restauration. Form a therapeutic point of view we need to understand the occlusal concept of intercuspation and mastication, not doing so it may lead our treatment into a completely wrong approach. A first symptom that we notice are cracks or even complete fractures of dental structure. These are first indicators of some kind of disharmony in the patient's occlusion [3]. All of these complications can be prevented with a correct analysis of the occlusion and correct planning of the treatment [4].

Already in 1995 Dawson emphasized the importance of occlusion, but also of the act of mastication, which depends primarily on the neuromuscular connection of the masticatory muscles, the placement of the mandibular condyle and the angle of temporal fossa [5, 6].

Articulators are devices that help replicate the position and movements of the condyle in TMJ and are indispensable in the fabrication of restorations that match the movements of the condyles in all directions. The development of articulators has been followed by the development of methods for tracking and registering the trajectory of the condyle that help to study the degree of maximum movements mouth opening or closing, lateral movements, as well as to identify the best functional position [7]. With these results we can precisely replicate the jaw movement in the act of mastication.

Condylography is a diagnostic method for monitoring and registering the movements of the condyles. The measurements start from the most distal position of the condyle to the maximal propulsive point and latero-lateral maximal extension respectively [8]. Obtained registrations and angles are used to adjust the articulator with individual values, regardless of whether it is a virtual CAD-CAM or a mechanical articulator. This way, mandibular movements during mastication can be reproduced most accurately.

As an auxiliary diagnostic tool, condylography is used in the treatment of patients with neuromuscular problems related to head muscles [9]. Any disturbance in the degree

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of muscle contraction will move mandible out of its trajectory. Every registration is done in three dimensions and the smallest deviation is noted [10].

The aim of this study was to compare the trajectory of mandibular condyle during propulsion, opening and closing in patients with symptoms of TMD and after the treatment that eliminated symptoms.

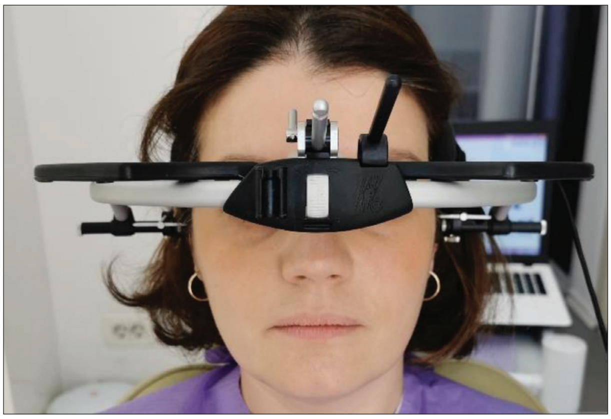

Figure 1. Anterior view of facebow with sensor
Slika 1. Obrazni luk sa senzorom sa prednje strane

MATERIALS AND METHOD

For the purposes of this study, 20 subjects (10 women and 10 men) aged from 20 to 50 years with TMD symptoms confirmed by clinical examination and a completed survey questionnaire were included. Patients who were currently undergoing orthodontic treatment, with mental disorders or neurological diseases were excluded as well as patients who had trauma in the head and neck area in the last 12 months. All patients were informed that they could cancel their participation at any time during the trial.

In order to be part of the study every patient gave a written consent, the analysis that will be done as well as the treatment plan that will follow. Each patient also filled out an ethical questionnaire in which he/she subjectively described their symptoms.

The position of the mandibular condyle and its trajectory was recorded with an Arcus Digma digital condylograph. Due to the protection of patient's personal data, all communication with laboratory was conducted under a coded record number (procedure for the protection of personal data ISO 9001:2012) according to the regulations of Denta Estetica Tim polyclinic.

Figure 2. Lateral view of face bow with sensor
Slika 2. Obrazni luk sa senzorom sa bočne strane

Procedure

Measurements and analysis

In continuation of the examination, a condylographic analysis was performed for each participant to register the trajectory of the condyle in the temporomandibular joint [11].

Measurements were made with a KAVO Arcus DIGMA condylograph.

The device consisted of:

1. Hardware part
2. Software part

The hardware part had a Face bow that was fixed on the patient's head. This part carried the receiver for the sonic emitters that emitted 40 KHz sound, with a measurement error of +/- 0.1 mm and registration frequency 50 HZ. The weight of the Face bow was 38 grams.

The placement of the facebow always followed the Camper line laterally, while the frontal placement was parallel to the bi-pupillary line. The two components for the ears rested on the external ear opening (Figures 1 and 2).

The maxillary transfer fork was fixed to the maxilla and rested on the occlusal surface of the upper dental arch. The mandibular dental arch was fixed on the buccal surface of the lower teeth, making sure that it does not hinder the movements and that there are no premature contacts on the fork.

The registration procedure started by positioning first the maxillary fork, allowing registration of the maxillary position on the virtual model as a fixed reference. The carrier was then transferred to the mandibular fork and the registration of the trajectory of the mandibular condyle started. Three sequences of propulsion left and right lateral maximal translations were recorded/ registered.

The software part of the Digma system had an algorithm for analyzing the intensity of the sonic emission, which accurately registered the position of mandible. This registration was done continuously thus registering the complete trajectory of TMJ. At the end the software provided a sketch with a schematic representation of trajectory and angles of the incisal guide and angles of the propulsive path of the condyles on the left and right side respectively. Bennet's angle and the immediate shift angle were also recorded. These parameters were important for the adjustment of the individual articulator when planning and constructing the intermaxillary relations in occlusion (Figures 3, 4, 5) [11].

Student's T-test was used to analyze the results, comparing results in the same subjects before and after occlusion

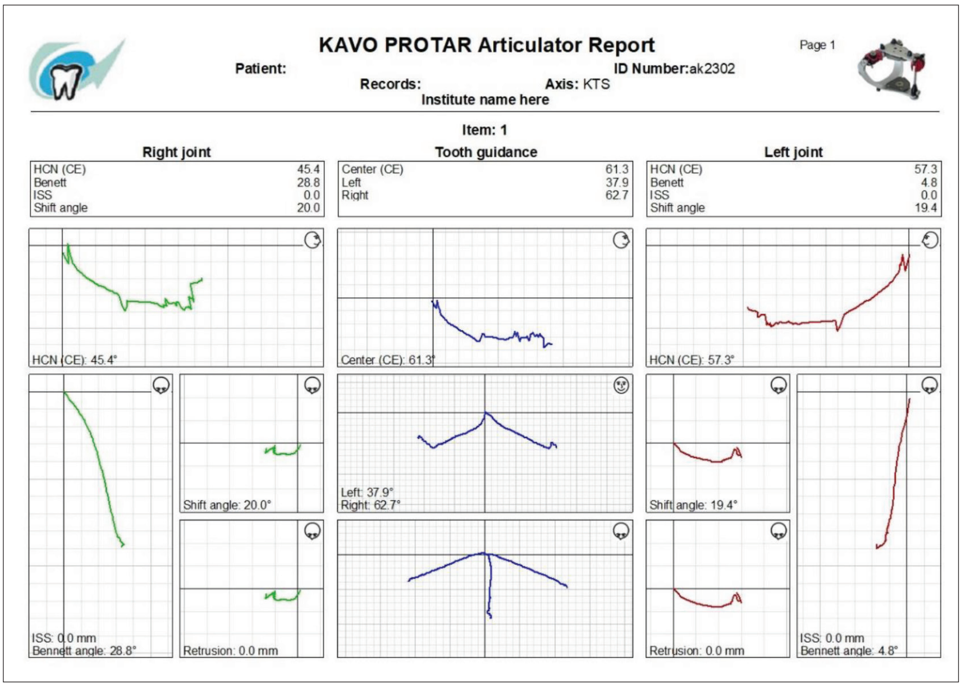

Figure 3. Scheme of condylar trajectory
Slika 3. Šema kondilarne trajektorije

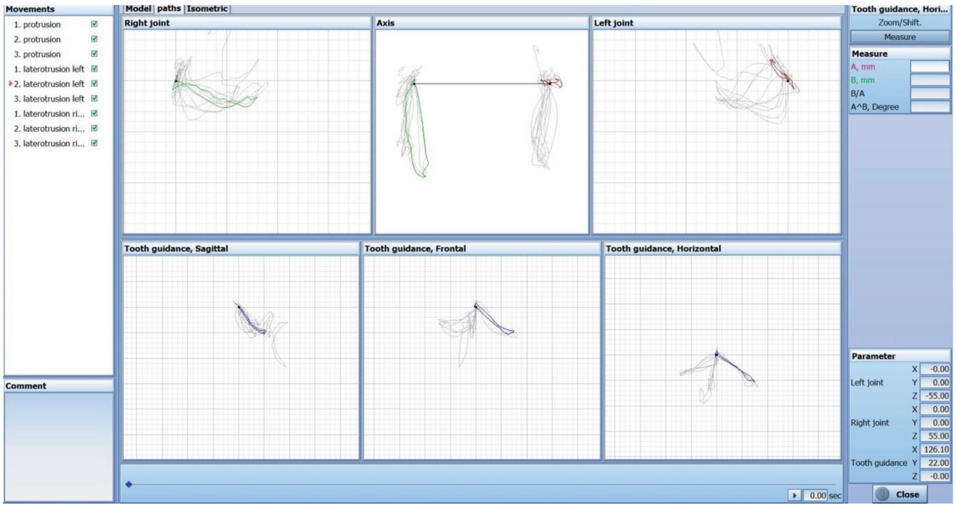

Figure 4. Graphical presentation of TMJ movement
Slika 4. Grafički prikaz pokreta TMZ

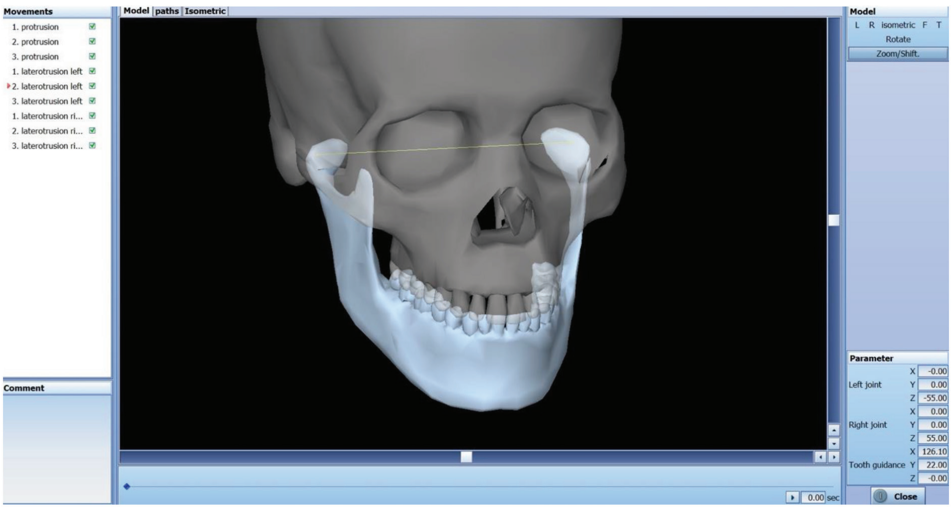

Figure 5. Virtual presentation of TMJ movement
Slika 5. Virtuelni prikaz TMZ pokreta

Table 1. Results of the analyisis before and after the treatment
Tabela 1. Rezultati analize pre i posle terapije

	Acute phase Akutna faza		After therapy Posle terapije	
Propulsion angle Ugao propulzije	Right TMJ Desni TMZ	Left TMJ Levi TMZ	Right TMJ Desni TMZ	Left TMJ Levi TMZ
Main value Glavna vrednost	31.04	30.27	30.56	33.34
Student's t-test	Right TMJ Desni TMZ p > 0.878		Left TMJ Levi TMZ p > 0.389	

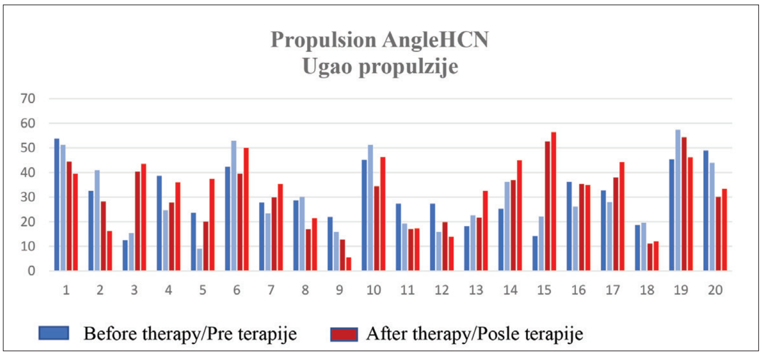

Figure 6. Graphic representation of the analysis before and after the treatment
Slika 6. Grafički prikaz analize pre i posle terapije

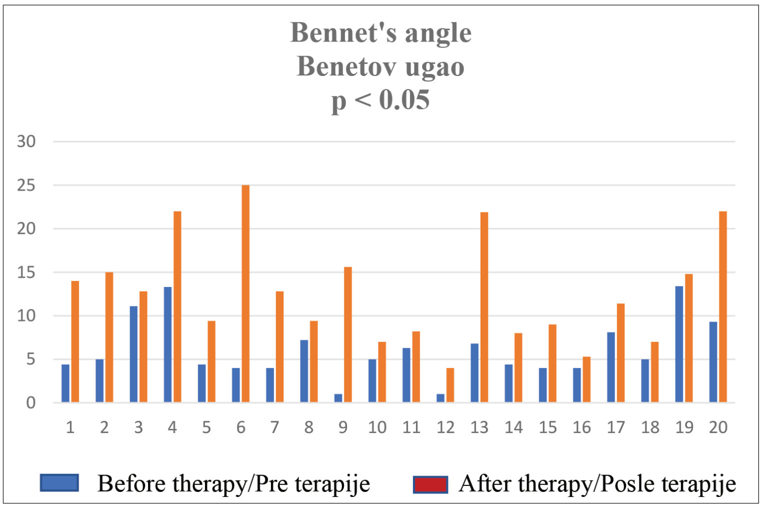

Figure 7. Graphic representation of the analysis before and after the treatment
Slika 7. Grafički prikaz analize pre i posle terapije

correction. Paired T-test analysis was used as the values were obtained in the same candidates before and after the treatment.

The mean value for the propulsive angle of the right temporomandibular joint in patients in the acute phase of TMD was 31.04^0 while that of the left temporomandibular joint was 30.27^0, the propulsive incisal guidance in the acute phase had an average value of 47.05^0. After TMD treatment and reconstruction of intermaxillary relations the measurement of the propulsive path angle of the right condyle was 30.56° and 33.34° for the left joint respectively. The propulsive incisal guidance angle after the treatment was 44.25° as shown on the Table 1 and Figure 6.

Student's T-Test results showed no statistically significant difference in temporomandibular condyle movement angles before and after the treatment in patients with TMD. There was a statistically significant difference in the value of Bennett's angle. Easier and more correct and consistent movements of mandible were noticeable in the patients after the treatment (Figure 7).

DISCUSSION

This study aimed to expand our understanding of the trajectory of mandibular condyle during various movements in patients with temporomandibular disorder (TMD). Specifically, the researchers sought to compare the condylar trajectory during propulsion, opening and closing in these patients both before and after the elimination of TMD symptoms.

Previous studies conducted by Khan, Zahid Sarafas and their colleagues explored the position of the kinematic center of the condyle during opening and closing in patients without luxation. Their findings confirmed that the condyle followed the surface of the joint fossa in these individuals [12].

In 2021, Lee Won-June et al. investigated the relationship between craniofacial morphology, temporomandibular joint (TMJ) characteristics, and condylar functional movement in patients with facial asymmetry. They utilized an advanced automated real-time jaw-tracking system to analyze these factors and their correlation [13].

Another study conducted by Sojka A et al. involved the use of the Arcus Digma System to evaluate mandibular movements in healthy individuals without dental problems and TMD symptoms. The results of this study indicated that patients without TMD symptoms did not exhibit mandibular movement disorders, providing valuable insights into the normal mandibular function [14].

Additionally, Musa, Mazen conducted a study focused on exploring the quantitative and qualitative changes in the condyle following stabilization splint therapy. The study investigated various aspects such as condylar position, morphology, and bone mineral density in subjects diagnosed with temporomandibular disorders (TMD) [15]. These studies contribute to our understanding of the mandibular condyle trajectory, its correlation with craniofacial morphology and TMJ characteristics, and the effects of TMD symptoms and treatment on the condylar structure and function.

CONCLUSION

Mandibular movements are triggered by muscle contractions, controlled by the nervous system. Limited by fixed anatomical structures, the condyle-disc complex restricts translations. Muscle diseases or temporomandibular disorders often impact mandibular movement speed and trajectory. TMD treatment has minimal effect on the condyle's trajectory during opening and closing, with only facilitated latero-lateral movements. Obtained data from condylography aids in precise adjustment of mechanical and virtual articulators, enhancing control and reliability in prosthetic rehabilitation.

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Kondilografska evaluacija propulzivnog i Benetovog ugla kod pacijenata sa temporomandibularnim oboljenjima

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KRATAK SADRŽAJ

Uvod Mandibularna kinetika se sastoji od niza složenih pokreta u pogledu otvaranja i zatvaranja i latero-lateralnih pokreta. Procedura za registraciju ove trajektorije je kondilografija. Ova procedura predstavlja dijagnostičku metodu za praćenje i registrovanje kretanja kondila donje vilice.

Analize počinju od najudaljenijeg položaja kondila do tačke maksimalne propulzije i maksimalne latero-lateralne ekstenzije.

Cilj ovog ispitivanja je uporediti putanju kretanja mandibularnog kondila kod pacijenata sa simptomima temporomandibularnih poremećaja (TMD), u akutnoj fazi, kako i putanju nakon terapije i korekcije intermaksilarnih odnosa.

Materijali i metode Ispitivanje je sprovedeno na 20 pacijenata (10 muškaraca i 10 žena) iz poliklinike „Denta estetika tim" u Skoplju. Pacijenti su se žalili na bol, ograničenje pokreta, krepitacije u temporomandibularnom zglobu, kao i na otežano žvakanje. Kondilografska merenja vršena su pomoću digitalnog kondilografa Kavo Arcus Digma. Registrovanje pokreta je izvršeno u dve sesije, pre i posle tretmana.

Rezultati Rezultati Studentovog t-testa nisu pokazali statistički značajnu razliku u uglovima kretanja temporomandibularnog kondila pre i posle terapije kod pacijenata sa TMD-om. Međutim, primećena je stastistički značajna razlika u vrednosti Benetovog ugla. Uočeni su lakši i precizniji pokreti vilice kod pacijenta posle terapije.

Ključne reči: kondilografija; putanja kretanja kondila; funkcionalna dijagnostika; pokret vilice; temporomandibularni zglob; poremećaj temporomandibularnog zgloba

UVOD

Obrasci pokreta mandibule su često korišćeni od strane kliničara za istraživanje disfunkcije mastikatornog sistema. Ograničeno maksimalno otvaranje (normalne vrednosti se kreću u rasponu 45+/-5 mm) i devijacije ili odstupanja u putanji otvaranja su jedan od simptoma TMD-a.

U svakodnevnoj praksi stomatolog se susreće sa problemima kao što su osetljivost zuba, frakture zuba, luksacija zuba, bol u temporomandibularnim zglobovima, mišići osetljivi na pipanje, licevna bol itd. [1, 2].

Zbog neodgovarajućeg ugla i dizajna okluzalne morfologije i anatomije dobijamo „neodgovarajuće" i prerane kontakte koji dovode do upornih bolova u zubu, a dalje i bola u mišićima nakon fiksacije restauracije. Sa terapijskog stanovišta moramo razumeti okluzalni koncept interkuspacije i mastikacije, a ne čineći to možemo našu terapiju odvesti u potpuno pogrešnom pravcu. Prvi simptom koji primećujemo su pukotine ili čak potpuni prelomi zubne strukture. Ovo su prvi pokazatelji neke vrste disharmonije u okluziji pacijenta [3]. Sve ove komplikacije mogu se sprečiti ispravnom analizom okluzije i ispravnim planiranjem lečenja [4].

Već 1995. godine Doson naglašava važnost okluzije, ali i čina žvakanja, koji zavisi pre svega od neuromišićne veze mastikatornih mišića, položaja mandibularnog kondila i ugla temporalne jame [5, 6]. Artikulatori su uređaji koji pomažu u replikaciji položaja i pokreta kondila u temporomandibularnom zglobu i neophodni su pri izradi restauracija koje odgovaraju pokretima kondila u svim pravcima. Razvoj artikulatora pratio je razvoj metoda za praćenje i registrovanje putanje kondila koje pomažu u izučavanju stepena maksimalnih pokreta otvaranja ili zatvaranja usta, lateralnih pokreta, kao i utvrđivanju najboljeg funkcionalnog položaja [7]. Sa ovim rezultatima možemo precizno replicirati kretanje vilice pri činu žvakanja.

Kondilografija je dijagnostički metoda za praćenje i registrovanje kretanja kondila. Merenja počinju od najudaljenijeg položaja kondila do tačke maksimalne propulzije i latero-lateralne maksimalne ekstenzije [8].

Dobijene registracije i uglovi se koriste se za podešavanje artikulatora sa individualnim vrednostima, bez obzira na to da li se radi o virtuelnom CAD-CAM ili mehaničkom artikulatoru. Na taj način, pokreti mandibule pri mastikaciji se mogu najtačnije reprodukovati.

Kao pomoćno dijagnostičko sredstvo, kondilografija se koristi u lečenju pacijenata sa neuromuskularnim problemima u vezi sa mišićima glave [9]. Svaki poremećaj u stepenu mišićne kontrakcije će izmestiti mandibulu iz svoje putanje. Svaka registracija se vrši u tri dimenzije i beleži se i najmanje odstupanje [10].

Cilj ovog istraživanja je uporediti putanju mandibularnog kondila pri propulziji, otvaranju i zatvaranju kod pacijenata sa simptomima TMD-a i posle tretmana koji je eliminisao simptome.

MATERIJAL I METOD

Za potrebe ovog istraživanja uključeno je 20 ispitanika (10 žena i 10 muškaraca) uzrasta od 20 do 50 godina sa potvrđenim simptomima TMD-a na osnovu kliničkog pregleda i popunjenog upitnika.

Isključeni su pacijenti koji su trenutno na ortodontskoj terapiji, pacijenti sa mentalnim poremećajima ili neurološkim bolestima, kao i pacijenti koji su imali traume u predelu glave i vrata u poslednjih 12 meseci. Svim pacijentima je objašnjeno da mogu otkazati učešće u istraživanju u bilo kom trenutku tokom trajanja ispitivanja.

Za učešće u studiji svaki pacijent je dao pisani pristanak za učešće u ispitivanju, analizama koje se moraju izvršiti, kao i planu terapije koji će slediti. Svaki pacijent takođe mora popuniti etički upitnik u kome subjektivno opisuje simptome koje ima.

Položaj mandibularnog kondila i njegova putanja registruju se pomoću digitalnog kondilografa Arcus Digma. Zbog zaštite ličnih podataka pacijenata, sva komunikacija sa laboratorijom se vrši pod šifrovanim brojem zapisa (postupak za zaštitu ličnih podataka ISO 9001: 2012) u skladu sa propisima poliklinike „Denta estetika tim“.

Procedura

Merenja i analize

U nastavku pregleda, za svakog učesnika izvršena je kondilografska analiza kako bi se registrovala putanja kondila temporomandibularnog zgloba [15].

Merenja su izvršena pomoću kondilografa KAVO Arcus DIGMA.

Uređaj se sastoji od:

1. Hardverskog dela
2. Softverskog dela

Hardverski deo ima uređaj za fiksiranje na glavu pacijenta, poznat kao obrazni luk (*face bow*). Ovaj deo nosi prijemnik za zvučne emitere koji ispuštaju zvuk od 40 KHz, sa greškom merenja od +/- 0,1 mm i frekvencijom registracije 50 HZ. Težina *face bow*-a je 38 grama.

Postavljanje *face bow*-a uvek prati lateralnu Kamperovu liniju, dok je frontalno postavljanje paralelno sa bipupilarnom linijom. Obe komponente za uši trebalo bi da leže na spoljnom otvoru uha (slike 1 i 2).

Maksilarna viljuška za trasfer je fiksirana za maksilu i postavlja se na okluzalnoj površini gornjeg zubnog niza. Mandibularni zubni niz je fiksiran na bukalnu površinu donjih zuba, vodeći računa da ne ometa kretanje i da ne postoje prevremeni kontakti na viljušci.

Procedura registracije počinje pozicioniranjem prvo maksilarne viljuške, dozvoljavajući registraciju maksilarne pozicije na virtuelnom modelu kao fiksnu referencu. Zatim se nosač prenosi na mandibularnu viljušku i počinje se sa registracijom putanje mandibularnih kondila. Zapisuju/registruju se tri sekvence propulzivnih levih i desnih bočnih maksimalnih translacija.

Softverski deo sistema Digma ima algoritam za analizu jačine zvučnog emitera, koji precizno registruje položaj mandibule. Ova registracija se vrši kontinuirano, čime se registruje kompletna putanja temporomandibularnog zgloba. Na kraju softver prikazuje skicu sa šematskim prikazom trajektorije i uglova trajektorije, uglova propulzivnog puta kondila na levoj i desnoj strani. Takođe se registruju i Benetov ugao i ugao instantne promene. Ovi parametri su važni za prilagođavanje individualnog artikulatora pri planiranju i rekonstrukciji međumaksilarnih odnosa u okluziji [11] (slike 3, 4 i 5).

Studentov T-test je korišćen za analizu rezultata, upoređujući rezultate kod istih ispitanika pre i posle korekcije okluzije i međuviličnih relacija. Korišćena je uparena T-test analiza, tj. analizirane su vrednosti dobijene kod istih kandidata pre i posle terapije.

Srednja vrednost propulzivnog ugla desnog temporomandibularnog zgloba kod pacijenata u akutnoj fazi TMD-a bila je 31,04^0, dok je za levi temporomandibularni zglob iznosila 30,27^0. Ugao vodilje propulzivnog puta u akutnoj fazi imao je prosečnu vrednost od 47,05^0. Nakon terapije TMD-a i rekonstrukcije međumaksilarnih odnosa, merenje ugla propulzivnog puta desnog kondila bilo je 30,56°, a za levi zglob 33,34°. Ugao vodilje propulzivnog puta nakon terapije iznosio je 44,25°, kako je prikazano na Tabeli 1 i Slici 6.

Rezultati Studentovog t-testa su pokazali da nema statistički značajne razlike u uglovima kretanja temporomandibularnog kondila pre i posle terapije kod pacijenata sa TMD-om. Postojala je statistički značajna razlika u vrednosti Benetovog ugla. Nakon terapije, kod pacijenata su zabeležena lakša, ispravnija i konzistentnija kretanja mandibule (Slika 7).

DISKUSIJA

Ovo istraživanje imalo je za cilj da proširi naše razumevanje putanje mandibularnih kondila tokom različitih pokreta kod pacijenata sa TMD-om. Konkretno, istraživači su želeli da uporede putanju kondila tokom propulzivnih pokretanja, otvaranja i zatvaranja kod ovih pacijenata pre i posle uklanjanja simptoma TMD-a.

Prethodna istraživanja koja su izvršili Khan, Zahid Sarafas i saradnici bavila su se položajem kinematičkog centra kondila tokom otvaranja i zatvaranja kod pacijenata bez luksacije. Njihovi nalazi potvrđuju da kondil sledi površinu zglobne jame kod ovih osoba [12].

U 2021. godini, Lee Won-June i saradnici istraživali su odnos između morfologije kraniofacijalne regije, karakteristika temporomandibularnog zgloba i funkcionalnog pokretanja kondila kod pacijenata sa asimetrijom lica. Koristili su napredni automatizovani sistem za praćenje kondila u realnom vremenu kako bi analizirali ove faktore i njihovu korelaciju [13].

Još jedno istraživanje koje su sproveli Sojka A. i saradnici uključuje korišćenje sistema Arcus Digma za procenu mandibularnih pokreta kod zdravih osoba bez stomatoloških problema i simptoma TMD-a. Rezultati ovog istraživanja pokazali su da pacijenti bez simptoma TMD-a nisu pokazivali poremećaje mandibularnih pokreta, pružajući vredne uvide u normalnu funkciju mandibule [14].

U nastavku, Musa, Mazen i saradnici sproveli su studiju sa fokusom na istraživanje kvantitativnih i kvalitativnih promena na kondilu nakon terapije stabilizacionom pločicom. Studija je istraživala različite aspekte, kao što su položaj kondila, morfologija i mineralna gustina kosti kod osoba sa dijagnozom TMD [15].

Gledano u celini, ova istraživanja doprinose našem razumevanju putanje mandibularnih kondila, njegove korelacije sa kraniofacijalnom morfologijom i karakteristikama temporomandibularnog zgloba, kao i efekta simptoma i terapije TMD-a na strukturu i funkciju kondila.

ZAKLJUČAK

Mandibularna pokretanja nastaju kontrahovanjem mišića, koje kontroliše nervni sistem. Ograničen fiksnim anatomskim strukturama, kompleks kondila i diska ograničava te translacije. Bolesti mišića ili temporomandibularni poremećaji često utiču na brzinu i putanju mandibularnih pokreta.

Terapija TMD-a ima minimalan uticaj na putanju kondila tokom otvaranja i zatvaranja, sa postizanjem samo olakšanih lateralnih pokretanja. Podaci dobijeni kondilografijom pomažu u preciznom prilagođavanju mehaničkih i virtuelnih artikulatora, što poboljšava kontrolu i pouzdanost u protetskoj rehabilitaciji.

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Examination of the presence of periodontitis and gingivitis in rats with induced diabetes mellitus

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SUMMARY

Introduction Diabetes mellitus (DM) is a state of chronic hyperglycemia that is a predisposing factor to caries, gingivitis, inflammation of periodontium, oral candidiasis, xerostomia and many other diseases of the oral cavity. Inflammation of the supporting tissue of the tooth is a chronic disease that destroys the supporting structure of the tooth, i.e. periodontal ligament and alveolar bone. The aim of this study was to examine using histological analysis the presence of periodontitis and gingivitis in rats with experimentally induced DM that were sacrificed after 14 and 30 days.

Material and methods The research was conducted on 42 Wistar rats. DM in experimental animals was induced by the use of Alloxan intraperitoneally. The first group (Exp_14) consisted of 16 rats in which DM was induced and sacrificed after 14 days, the second group (Exp_30) consisted of 16 rats in which DM was induced and they were sacrificed after 30 days, while the control consisted of 10 healthy rats.

Results Periodontitis and gingivitis in the first group of rats (Exp_14) were determined in 54.5% of cases, while in the second group (Exp_30) in 88% of cases. In the control group no case of periodontitis and gingivitis was recorded. A highly statistically significant difference was found between the examined groups (Chi-square = 14.685; $p < 0.001$).

Conclusion In the group of rats with experimentally induced DM that were sacrificed after 30 days, a significantly higher incidence of periodontitis and gingivitis was found compared to the group of rats that were sacrificed after 14 days.

Keywords: diabetes mellitus; periodontitis and gingivitis; histological analysis

INTRODUCTION

DM is a state of chronic hyperglycemia followed by disorder of metabolism of carbohydrates, fats and proteins that occurs as a result of an absolute or relative lack of insulin action [1]. Dentists are aware of the importance of DM in their patients because various oral conditions are associated with diabetes, including xerostomia, yeast infection as well as periodontitis and gingivitis [2]. An increase in catabolic and a decrease in anabolic processes lead to changes in cells in the body, which affects the occurrence of oral diseases such as periodontitis and gingivitis. Increased concentration of glucose in saliva and hyposalivation in patients with DM encourage conditions for an acidic environment and development of pathogenic bacteria. Periodontal inflammation of a tooth is chronic, multicausal, disease in the supporting tissue around the teeth. Patients with DM can have gingivitis, pathological changes in the supporting tissue of the teeth, resorption of alveolar bone and finally complete tooth loss [3, 4].

Periodontal inflammation is an irreversible inflammatory condition and represents a significant public health burden. It is present in more than 11% of adults and is one of the causes of teeth loss, which negatively affects speech, nutrition and quality of life. Periodontal disease is one of the most common diseases today, and the number of patients is increasing with age. Good preventive measures and adequate therapy reduce the percentage of tooth loss and improve the quality of life [5–8].

Numerous studies examined correlation between DM and periodontal inflammation. Păunică et al. examined the relationship between periodontal inflammation and DM and confirmed that DM affects the onset of periodontal disease, leading to its worsening, and that periodontitis negatively affects glycemic control and the course of diabetes [9].

Pathogenic processes that connect these two diseases are the focus of many studies. DM increases the risk of periodontitis by contributing to increased inflammation in the periodontal tissue. In diabetes, there is an increased deposition of advanced glycation end products (AGE) in the periodontal tissue, and the interactions between AGEs and their receptors (RAGE, the receptor for AGEs, which is found especially on macrophages) lead to activation of local immune system and inflammatory reactions first observed on gingiva [10–14].

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MATERIAL AND METHODS

The research was conducted after the approval of the Ethics Committee of the University Clinical Center in Banja Luka no. 01-9-192.2/15, Bosnia and Herzegovina. The sample consisted of 42 Wistar rats. The animals were two months old, with a body weight of 150-200 g. They were kept in group cages made of Plexiglas, with 12 hours of light (07:00-19:00) at an air temperature of 22°C (± 2) and a humidity of 60% ± 10%, with free access to food and water during of the experiment. At the beginning of the experiment, individuals were separated into appropriate test and control groups.

Rats were divided into the two experimental groups (Exp_14 and Exp_30) and one control group. The first (Exp_14) and second (Exp_30) groups each consisted of 16 rats with experimentally induced DM. Using Alloxan the first and second groups of rats (Exp_14 and Exp_30) were brought to experimentally induced DM. Alloxan solution was applied intraperitoneally in a dose of 100 mg per kilogram of body weight of rats. The protocol was repeated every other day until the measured value of glycemia did not exceed 200 mg/dcl (animal in hyperglycemia). Glycemia was measured with a blood glucose meter (ACCU ACEH, Roche) from tail vein blood. The achieved hyperglycemia was controlled by regular measurement (every other day) and maintained for 7 days. The control consisted of 10 healthy rats.

Rats from the first group were sacrificed after 14 days and from the second group after 30 days. Rats from the control group were sacrificed also after 30 days. For histological analysis the bones of the upper jaws together with the teeth after 48h of fixation (in 10% neutral buffered formalin) were decalcified in a nitric acid solution (no longer than 90 minutes). The decalcified samples were then washed with water and processed in an automated tissue processor Leica TP 1020 (Leica Byosistems) according to a standard protocol; dehydration in increasing concentrations of ethyl alcohol (70%, 96%, 100%); clarification in xylene, impregnation with liquid paraffin, after which selected tissue samples were molded into paraffin blocks. After cooling, the paraffin blocks were cut on a sliding microtome (Leica SM 2000R, Leica Byosistems) into sections 4-5 μm thick for histological analysis. For histological analysis, the cross-sections of the periodontal tissue were collected on appropriate glass slides and dried at 60°C. In an automatic staining processor (Leica ST4040 Linear stainer, Leica Byosistems), tissue sections were deparaffinized, rehydrated and rinsed in distilled water. After that, they were stained with the standard hematoxylin-eosin (HE) method. Definitive preparations were analyzed with a light microscope (Leica DM 2500, Leica Byosistems) and photographed with a camera connected to the microscope (Figure 1).

RESULTS

In the first experimental group (Exp_14) periodontitis and gingivitis were recorded in 54.5% of cases. In the second experimental group (Exp_30) periodontitis and gingivitis are recorded in 88.0% of cases. In the control group (healthy rats without hyperglycemia) not a single case of periodontitis and gingivitis was recorded (Table 1, Figure 1). There was highly statistically significant difference in the prevalence of periodontitis and gingivitis between the studied groups (Chi-square = 14.685; $p < 0.001$) (Table 1).

Table 1. Periodontitis and gingivitis in the studied groups
Tabela 1. Periodontitis i gingivitis kod analiziranih grupa

			Periodontitis and gingivitis / Periodontitis i gingivitis: Absent / Odsutan	Periodontitis and gingivitis / Periodontitis i gingivitis: Present / Prisutan	Total / Ukupno
Group / Grupa	Exp_14 / Eksp_14	N	5	6	11
		%	45.5%	54.5%	100%
	Exp_30 / Eksp_30	N	3	22	25
		%	12%	88%	100%
	Control / Kontrolna	N	12	0	12
		%	100%	0.0%	100%
Total / Ukupno		N	20	28	48
		%	41.7%	58.3%	100%

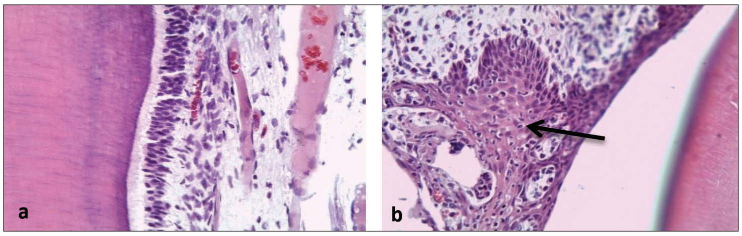

Figure 1. a) Cross-section of the periodontal ligament and jaw bone of a rat without morphological changes (HE × 400); b) View of the interdental part of the gingiva of a rat. Inflammation of the gingiva is observed (HE × 400).
Slika 1. a) Poprečni presek periodontalnog ligamenta i vilična kost pacova bez morfoloških promena (HE × 400); b) Prikaz interdentalnog dela gingive pacova. Uočava se zapaljenje gingive (HE × 400).

DISCUSSION

Periodontal inflammation is chronic inflammatory disease caused by the accumulation of dental plaque, consisted of bacteria that lead to a chronic and destructive inflammatory response resulting in tissue destruction, i.e. deterioration of the periodontal ligament, formation of periodontal pockets and resorption of alveolar bone. The risk of periodontitis is increased 2-3 times in people with DM compared to people without DM, and the level of glycemic control is crucial in determining the risk of the disease. Similar to other complications of diabetes, the risk of periodontitis increases with poorer glycemic control [15, 16].

Most of the research on inflammation of the tooth's supporting tissue and diabetes has focused on type 2 DM (probably because these diseases mainly occur in middle-aged adults), but type 1 DM is also associated with increased periodontal destruction in children and teenagers [17].

In our study, it was determined that periodontitis and gingivitis were present in groups of rats with experimentally induced DM, while no pathological changes in the periodontium were found in the group of healthy rats. In the first group of rats that were sacrificed after 14 days of introduction to DM, significantly smaller changes were observed in the supporting tissues of teeth compared to the group of rats that were sacrificed after 30 days.

A large number of research studied the relationship between DM and inflammation of the supporting tissue of the tooth and found that patients with DM (including children and young adults) had an increased risk of periodontitis. Lalla et al. compared the periodontological status in children with DM and periodontological status in healthy children of the same age of 6-18 years. The results of their study indicated higher prevalence of periodontitis and gingivitis (20%) in children with DM than in healthy children (8%), which was in accordance with the results of this study [18].

Periodontitis is now known as a risk factor for worsening glycemic control and may increase the risk of diabetes complications. Choubaya et al. also investigated the association of periodontitis with the development and progression of diabetes in Wistar rats with induced DM. The study indicated a connection between glycemic levels and changes in the periodontium, i.e. the higher the level of glucose in the blood of rats, the greater the changes in periodontium [19].

Takai et al., using histological analysis, determined that the inflammatory reaction in the gingival tissue was higher and more intense in rats with DM compared to healthy rats. These results indicate that dental plaque is also an important factor for severe inflammatory processes of the periodontium and the importance of proper maintenance of oral hygiene in patients with DM [20].

Pepelassi et al., also using histological analysis, found that alveolar bone loss was significantly greater in rats with DM and periodontitis than in rats with only periodontitis or DM [21].

In patients with DM, it is necessary to raise the level of oral hygiene, in order to prevent accumulation of dental plaque, which is one of the factors in the development of gingivitis and other periodontal diseases. Also, the level of glycemia in the blood of DM patients depends primarily on diet, which is why it is important for patients to follow the instructions given by the endocrinologist. Wang et al. as well as Preshaw et al. pointed out important roles of dental team in patients with diabetes and periodontitis, in preventing the worsening of the clinical picture [22, 23].

CONCLUSION

In the group of rats with experimentally induced DM that were sacrificed after 30 days, significantly higher prevalence of periodontitis and gingivitis was found compared to the group of rats with experimentally induced DM that were sacrificed after 14 days, as well as healthy group of rats. The results of this study indicate a connection between DM and periodontal diseases, which is why it is necessary to propose a preventive program for patients with DM that includes dental procedures such as oral hygiene training and regular visits to dentist, detection of dental plaque, removal of soft and hard dental deposits and observation of the initial pathological changes of the periodontium and their treatment.

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Ispitivanje zastupljenosti parodontitisa i gingivitisa kod pacova sa indukovanim dijabetesom melitusom

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KRATAK SADRŽAJ

Uvod Dijabetes melitus (DM) stanje je hronične hiperglikemije koje predstavlja predisponirajući faktor karijesu, gingivitisu, inflamaciji parodoncijuma, oralnoj kandidijazi, kserostomiji i mnogim drugim oboljenjima usne šupljine. Zapaljenje potpornog tkiva zuba je hronično oboljenje koje razara potpornu strukturu zuba, odnosno parodontalni ligament i alveolarnu kost.
Cilj ove studije je bio da se histološkom analizom ispita zastupljenost parodontitisa i gingivitisa kod pacova sa ekperimentalno izazvanim DM-om koji su žrtvovani posle 14 i 30 dana.

Materijal i metode rada Istraživanje je sprovedeno na 42 pacova soja Vistar. DM kod eksperimentalnih životinja indukovan je upotrebom aloksana (Alloxan) intraperitonealno. Prvu grupu (Exp_14) činilo je 16 pacova, kod kojih je indukovan DM i koji su žrtvovani posle 14 dana; drugu grupu (Exp_30) činilo je 16 pacova kod kojih je DM indukovan posle 30 dana, dok je kontrolu činilo 10 zdravih pacova.

Rezultati Parodontitis i gingivitis u prvoj grupi pacova (Exp_14) uočeni su u 54,5% slučajeva, a u drugoj u grupi (Exp_30) u 88% slučajeva. U kontrolnoj grupi nije zabeležen nijedan slučaj parodontitisa i gingivitisa. Između ispitivanih grupa utvrđena je visoko statistički značajna razlika ($\chi^2 = 14,685$; $p < 0,001$).

Zaključak Kod grupe pacova sa eksperimentalno indukovanim DM-om koji su žrtvovani posle 30 dana utvrđena je značajno veća zastupljenost parodontitisa i gingivitisa u odnosu na grupu pacova koji su žrtvovani posle 14 dana.

Ključne reči: dijabetes melitus; parodontitis i gingivitis; histološka analiza

UVOD

DM je stanje hronične hiperglikemije praćeno poremećajem metabolizma ugljenih hidrata, masti i proteina koje nastaje kao posledica apsolutnog ili relativnog nedostatka dejstva insulina [1]. Stomatolozi su svesni važnosti dijagnoze DM-a kod svojih pacijenata jer su različita oralna stanja povezana sa dijabetesom, uključujući kserostomiju, kandidoznu infekciju, kao i parodontitis i gingivitis [2]. Povećanje kataboličkih a smanjenje anaboličkih procesa dovode do promena u ćelijama u organizmu, što utiče na nastanak oralnih oboljenja kao što su parodontitis i gingivitis. Povećana koncentracija glukoze u pljuvački i hiposalivacija kod pacijenata sa DM-om podstiče uslove za kiselu sredinu i razvoj patogenih bakterija. Zapaljenje potpornog tkiva zuba je hronično, multikauzalno oboljenje u potpornom tkivu oko zuba. Pacijenti sa DM-om mogu imati gingivitis, patološke promene potpornog aparata zuba, resorpciju alveolarne kosti i na kraju potpuni gubitak zuba [3, 4].

Inflamacija parodoncijuma je ireverzibilno inflamatorno stanje i predstavlja značajan teret za javno zdravlje. Zastupljen je kod više od 11% odraslih osoba i jedan je od uzroka gubitka zuba koji negativno utiče na govor, ishranu i kvalitet života. Parodontitis je jedna od najzastupljenijih bolesti današnjice, a broj obolelih raste s godinama. Dobrim preventivnim merama i adekvatnom terapijom smanjuje se postotak gubitka zuba i dolazi do poboljšanja kvaliteta života [5–8].

Brojne studije su se bavile ispitivanjem korelacije između DM-a i inflamacije parodoncijuma. Păunică i saradnici su se bavili ispitivanjem odnosa između inflamacije parodoncijuma i DM-a i na osnovu dobijenih rezultata potvrdili su da DM utiče na nastanak parodontalnog oboljenja, dovodeći do pogoršanja, a da parodontitis negativno utiče na kontrolu glikemije i tok dijabetesa [9].

Patogeni procesi koji povezuju ove dve bolesti su u fokusu mnogih istraživanja. DM povećava rizik od parodontitisa doprinoseći pojačanoj upali u parodontalnom tkivu. Kod dijabetesa dolazi do povećanog taloženja krajnjih produkata napredne glikacije (AGE) u parodontalnom tkivu, a interakcije između AGE i njihovih receptora (RAGE, receptor za AGE, koji se nalazi posebno na makrofagima) dovode do aktivacije lokalnog imunog sistema i upalnih reakcija koje se prvo uočavaju na gingivi [10–14].

MATERIJAL I METODE

Istraživanje je sprovedeno nakon odobrenja Etičkog odbora Univerzitetskog kliničkog centra u Banjoj Luci (Bosna i Hercegovina), br. 01-9-192.2/15. Uzorak se sastojao od 42 pacova soja Vistar. Životinje su bile stare dva meseca, s telesnom težinom od 150–200 g. Čuvane su u grupnim kavezima od pleksiglasa, na 12 sati svetlosti (07.00 – 19.00 časova), na temperaturi vazduha od 22°C (± 2) i vlažnosti od 60% ± 10%, pri čemu su imali slobodan pristup hrani i vodi tokom eksperimenta. Na početku eksperimenta, individue su razdvojene u odgovarajuće test i kontrolne grupe.

Pacovi su bili podeljeni u dve eksperimentalne grupe (Exp_14 i Exp_30) i jednu kontrolnu grupu. Prvu (Exp_14) i drugu (Exp_30) grupu je činilo po 16 pacova sa eksperimentalno indukovanim DM-om. Korišćenjem aloksana, prva i druga grupa pacova (Exp_14 i Exp_30) dovedene su u eksperimentalno indukovan DM. Rastvor aloksana je aplikovan intraperitonealno u dozi od 100 mg na kilogram telesne težine pacova. Protokol se ponavljao svakog drugog dana, sve dok izmerena vrednost glikemije nije prešla 200 mg/dcl (životinja u hiperglikemiji). Glikemija je merena aparatom za merenje glikemije (ACCU ACEH, Roche) iz krvi repne vene. Postignuta hiperglikemija je kontrolisana redovnim merenjem (svakog drugog dana) i održavana sedam dana. Kontrolna grupa se sastojala od 10 zdravih pacova.

Pacovi iz prve grupe su žrtvovani posle 14 dana, a iz druge grupe posle 30 dana. Pacovi iz kontrolne grupe su žrtvovani takođe posle 30 dana. Za histološku analizu su kosti gornjih vilica zajedno sa zubima posle 48 h fiksacije (u 10% neutralnom puferovanom formalinu) dekalcifikovane u rastvoru azotne kiseline (ne duže od 90 minuta). Dekalcifikovani uzorci su potom isprani tekućom vodom i obrađeni u automatizovanom tkivnom procesoru Leica TP 1020 (Leica Byosistems) po standardnom protokolu: dehidracija u rastućim koncentracijama etil-alkohola (70%, 96%, 100%), bistrenje u ksilolu, impregnacija tečnim parafinom, nakon čega su odabrani uzorci tkiva ukalupljeni u parafinske blokove. Za histološku analizu parafinski blokovi su nakon hlađenja sečeni na kliznom mikrotomu (Leica SM 2000R, Leica Byosistems) na preseke debljine 4–5 μm, a poprečni preseci potpornog aparata sakupljani su na odgovarajuća predmetna stakalca i sušeni na 60°C. U procesoru za automatsko bojenje (Leica ST4040 Linear stainer, Leica Byosistems) tkivni preseci su deparafinisani, rehidrirani i ispirani u destilovanoj vodi. Nakon toga su obojeni standardnom metodom hematoksilin-eozina (HE). Definitivni preparati su analizirani svetlosnim mikroskopom (Leica DM 2500, Leica Byosistems) i fotografisani kamerom povezanom sa mikroskopom (Slika 1).

REZULTATI

U prvoj eksperimentalnoj grupi (Exp_14) parodontitis i gingivitis su zabeleženi u 54,5% slučajeva. U drugoj eksperimentalnoj grupi (Exp_30) parodontitis i gingivitis su zabeleženi u 88% slučajeva. U kontrolnoj grupi kod zdravih štakora (bez hiperglikemije) nije zabeležen nijedan slučaj parodontitisa i gingivitisa (Tabela 1, Slika 1). Postoji visoko statistički značajna razlika zastupljenosti parodontitisa i gingivitisa između ispitivanih grupa ($\chi^2 = 14,685$; $p < 0,001$) (Tabela 1).

DISKUSIJA

Inflamacija parodoncijuma je hronično upalno oboljenje izazvano nakupljanjem zubnog plaka, čije bakterije dovode do hroničnog i destruktivnog upalnog odgovora koje za posledicu ima razaranje tkiva tj. propadanje periodontalnog ligamenta, nastanak parodontalnih džepova i resorpciju alveolarne kosti. Rizik od parodontitisa je povećan 2-3 puta kod osoba sa DM-om u poređenju sa osobama bez DM-a, a nivo kontrole glikemije je ključan u određivanju rizika oboljevanja. Slično drugim komplikacijama dijabetesa, rizik od parodontitisa se povećava sa lošijom kontrolom glikemije [15, 16].

Većina istraživanja o zapaljenju potpornog tkiva zuba i dijabetesu fokusirana je na DM tipa 2 (verovatno zato što se ove bolesti uglavnom javljaju kod odraslih osoba srednjih godina), ali DM tipa 1 je takođe povezan s povećanom destrukcijom parodonta kod dece i tinejdžera [17].

U našoj studiji utvrđeno je da su parodontitis i gingivitis zastupljeni u grupama pacova sa eksperimentalno indukovanim DM-om, dok u zdravoj grupi pacova nisu pronađene patološke promene u parodoncijumu. Kod pacova prve grupe koji su žrtvovani posle 14 dana od uvođenja u DM, uočene su značajno manje promene na potpornim tkivima zuba u odnosu na grupu pacova koji su žrtvovani posle 30 dana.

Veliki broj istraživanja bavi se proučavanjem veze između DM-a i inflamacije potpornog tkiva zuba, jer pored mnogih kliničkih manifestacija kod pacijenata sa DM-om (uključujući decu i mlade odrasle osobe) povećan je rizik od parodontitisa. Lalla i saradnici su poredili parodontološki status kod dece obolele od DM-a i parodontološki status kod zdrave dece, iste starosne dobi – od 6 do18 godina. Rezultati njihove studije su ukazali na veću zastupljenost parodontitisa i gingivitisa (20%) kod dece sa DM-om nego kod zdrave dece (8%), što je u skladu sa rezultatima ove studije [18].

Parodontitis je danas poznat kao faktor rizika za pogoršanje kontrole glikemije i može povećati rizik od komplikacija dijabetesa. Choubaya i saradnici su takođe ispitivali povezanost parodontitisa sa razvojem i napredovanjem dijabetesa kod pacova soja Vistar sa indukovanim DM-om. Studija je ukazala na povezanost nivoa glikemije sa promenama na parodoncijumu, odnosno što je veći nivo glukoze u krvi pacova utvrđene promene na parodoncijumu su bile veće [19].

Takai i saradnici su primenom histološke analize utvrdili da je upalna reakcija u gingivalnom tkivu bila viša i intenzivnija kod pacova sa DM-om u odnosu na zdrave pacove. Ovi rezultati ukazuju na to da je i dentalni plak važan faktor za teške upalne procese parodoncijuma i na značaj pravilnog održavanja oralne higijene kod pacijenata sa DM-om [20].

Pepelassi i saradnici su, takođe koristeći histološku analizu koja je korišćena i u ovom istaživanju, utvrdili da je gubitak alveolarne kosti značajno veći kod pacova sa DM-om i parodontitisom nego kod pacova koji su imali samo parodontitis ili DM [21].

Kod pacijenata sa DM-om neophodno je podići nivo održavanja oralne higijene, kako ne bi došlo do nakupljanja dentalnog plaka, koji predstavlja jedan od faktora nastanka gingivitisa i drugih parodontoloških oboljenja. Takođe, nivo glikemije u krvi kod pacijenata obolelih od DM-a zavisi prevashodno od ishrane, zbog čega je važno da se pacijenti pridržavaju uputstava dobijenih od endokrinologa. Wang i saradnici i Preshaw i saradnici ukazali su na značaj uloge stomatološkog tima kod pacijenata s dijabetesom i parodontitisom u sprečavanju pogoršanja kliničke slike navedenih oboljenja i njenom poboljšanju [22, 23].

ZAKLJUČAK

Kod grupe pacova sa eksperimentalno indukovanim DM-om koji su žrtvovani posle 30 dana utvrđena je značajno veća zastupljenost parodontitisa i gingivitisa u odnosu na grupu pacova sa ekperimentalno indukovanim DM-om koji su žrtvovani posle

14 dana, kao i u odnosu na zdravu grupu pacova. Rezultati ove studije ukazuju na povezanost DM-a i parodontalnih oboljenja, zbog čega je neophodno predložiti preventivni program za pacijente sa DM-om koji obuhvata stomatološke procedure od obuke održavanja oralne higijene i redovnih poseta stomatologu, detekciju zubnog plaka, uklanjanje mekih i tvrdih zubnih naslaga te uočavanje početnih patoloških promena parodoncijuma i njihovo lečenje.

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An influence of finishing procedures and protective coating on the ultrastructure of conventional and hybrid glass ionomer cement restorations

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SUMMARY

Introduction In addition to the advantages of glass ionomer cements that have led to their wide application, hybrid glass ionomer cements have been developed to overcome the shortcomings in mechanical resistance. The aim of the study was to perform an ultrastructural analysis of restorations made from conventional and hybrid glass ionomer cements after recommended finishing procedures and application of a protective coating.

Materials and Methods This study analyzed 30 samples of conventional glass ionomer cement Fuji IX™ and 30 samples of hybrid glass ionomer cement EQUIA Forte HT Fil™. The samples were prepared in cylindrical molds and divided into the three groups. The first group of samples, after adaptation, was left untreated and served as a control group. The second group consisted of samples that were finished with a cylindrical diamond bur with water cooling. The samples in the third group were finished and protected with appropriate coatings (G-COAT PLUS™ and EQUIA Forte Coat™). The samples were analyzed using scanning electron microscopy.

Results The finishing procedures of Fuji IX™ samples significantly reduced crack width ($t = 3.42$, $p < 0.005$; $Z = 3.25$, $p = 0.001$). Similarly, the crack width in EQUIA Forte HT Fil™ samples was also significantly smaller in treated samples ($t = 4.78$, $p < 0.001$; $Z = 4.28$, $p < 0.001$). Ultrastructural analysis of both materials showed the complete absence of cracks in finished samples protected by coatings.

Conclusion Finishing of conventional and hybrid glass ionomer cements results in a reduction in the number of cracks as well as a decrease in their widths, and the protective coatings completely cover remaining cracks.

Keywords: glass ionomer cement; porosity; cracks; ultrastructure; SEM

INTRODUCTION

Numerous positive properties of glass ionomer cements, as well as the constant overcoming of their disadvantages, from their creation in the early 1970s until today, have led to the fact that these materials have become one of the most popular in dentistry [1]. In addition to the most important advantages such as good adhesion to hard dental tissues and fluoride release, the biggest disadvantages of restorations made of these cements are weak mechanical resistance, low wear resistance and high porosity compared to restorations made of composite and amalgam [2]. Porosity is manifested in the presence of voids, pores or cracks inside the material, which results in reduced mechanical properties and increased permeability of material [3].

The need for material based on glass ionomer cement, which would satisfy all patient requirements, contributed to the presentation of the hybrid glass ionomer cement for permanent fillings – EQUIA Forte HT Fil™. The quality of its performance compared to its predecessor EQUIA Forte Fil™ has been confirmed in numerous studies [4]. The manufacturer points out the wide indications of these materials, including class I and II fillings, which are applied in one piece and whose longevity is described by numerous studies [5, 6]. A ten-year follow-up of a patient with EQUIA fillings did not observe a statistically significant difference between these fillings and composite fillings [5]. Due to poor aesthetic properties and possible toxic effects, the suppression of amalgam in many countries has imposed the EQUIA system as a suitable alternative to this mercury alloy, when it comes to class I and II cavities [7]. A study by Moshaverinio et al. [8] indicated that the EQUIA material has higher flexural strength and hardness compared to previous generations of glass ionomers, which makes it a very promising material in restorative dentistry.

Finishing procedures of the material is a treatment during which the surface roughness of the filling and possible irregularities, created during the restoration, are eliminated [9]. The aim of removing these irregularities is to reduce the porosity of the material as well as the accumulation of plaque, which can lead to the colonization of bacteria that has the effect of impairing the aesthetics of the filling itself, but also increasing the chance of tooth decay [10].

Scanning electron microscopy (SEM) is recognized as an extremely effective technique for detailed examination

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Table 1. Classification of tested samples according to the method of preparation
Tabela 1. Klasifikacija uzoraka prema metodi pripreme

Ia group/grupa	Untreated Fuji IX™ samples Netretirani uzorci Fuji IX™	Untreated Fuji IX™ samples Netretirani uzorci Fuji IX™
Ib group/grupa	Untreated EQUIA Forte HT Fil™ samples Netretirani uzorci EQUIA Forte HT Fil™	Untreated EQUIA Forte HT Fil™ samples Netretirani uzorci EQUIA Forte HT Fil™
IIa group/grupa	Fuji IX™ samples – finished with superfine diamond bur with water cooling Fuji IX™ uzorci – ispolirani superfinim dijamantom sa vodenim hlađenjem	Fuji IX™ samples – finished with superfine diamond bur with water cooling Fuji IX™ uzorci – ispolirani superfinim dijamantom sa vodenim hlađenjem
IIb group/grupa	EQUIA Forte HT Fil™ samples – finished with superfine diamond bur with water cooling EQUIA Forte HT Fil™ uzorci – ispolirani superfinim dijamantom sa vodenim hlađenjem	EQUIA Forte HT Fil™ samples – finished with superfine diamond bur with water cooling EQUIA Forte HT Fil™ uzorci – ispolirani superfinim dijamantom sa vodenim hlađenjem
IIIa group/grupa	Fuji IX™ samples – finished and covered with coating G-COAT PLUS™ Fuji IX™ uzorci – ispolirani i premazani G-COAT PLUS™	Fuji IX™ samples – finished and covered with coating G-COAT PLUS™ Fuji IX™ uzorci – ispolirani i premazani G-COAT PLUS™
IIIb group/grupa	EQUIA Forte HT Fil™ samples – finished and covered with coating EQUIA Forte Coat™ EQUIA Forte HT Fil™ uzorci – ispolirani i premazani EQUIA Forte Coat™	EQUIA Forte HT Fil™ samples – finished and covered with coating EQUIA Forte Coat™ EQUIA Forte HT Fil™ uzorci – ispolirani i premazani EQUIA Forte Coat™

of the ultrastructure of materials, due to the possibility of visualizing the microscopic structure of surfaces [11].

The aim of this study was to perform an ultrastructural analysis of the restoration surface of conventional and hybrid glass ionomer cement after recommended finishing procedures and application of protective coatings.

MATERIAL AND METHODS

The research was conducted at the Clinic for Dental Medicine in Niš. The research used a representative of conventional glass cements Fuji IX™ (GC Dental, Tokyo, Japan) and the latest hybrid glass cement EQUIA Forte HT Fil™ (GC Dental, Tokyo, Japan), which were prepared according to the manufacturer's instructions.

Fuji IX™ was manually mixed with a spatula on a paper surface by combining one drop of liquid with one scoop of powder, and then adapted into cylindrical molds measuring 8x3mm using a plastic filling instrument. Individual EQUIA Forte HT Fil™ capsules were mixed for 10 seconds in a mixer (Silamat, Vivadent). After preparation, the material was introduced into cylindrical molds with dimensions of 8x3mm using a capsule applicator and adapted with a placement instrument according to the manufacturer's instructions.

Sixty prepared samples of glass ionomer cements (30 samples of Fuji IX™ and 30 samples of EQUIA Forte HT Fil™) were divided into the three groups. The first group consisted of 20 samples (Ia group – 10 Fuji IX™ samples; Ib group – 10 EQUIA Forte HT Fil™ samples), which were not treated after adaptation and setting. The second group consisted of 20 samples (IIa group – 10 Fuji IX™ samples; IIb group – 10 EQUIA Forte HT Fil™ samples), which, after adaptation and setting, were finished according to the manufacturer's instructions with a superfine cylindrical diamond bur with water cooling. Twenty samples of the third group (IIIa group – 10 Fuji IX™ samples; IIIb group – 10 EQUIA Forte HT Fil™ samples) were, after finishing according to the manufacturer's instructions, protected with a coating that was polymerized with a LED lamp after application. G-COAT PLUS™ coating (GC Dental, Tokyo, Japan) was used to coat Fuji IX™ specimens (IIIa group), while EQUIA Forte Coat™ (GC Dental, Tokyo, Japan) was used to coat EQUIA Forte HT Fil™ specimens (IIIb group) (Table 1).

The preparation of all samples was carried out by one therapist, in order to achieve uniformity in the preparation of samples and the effect of processing. During the treatment, the therapist's movements were even from left to the right. Processing was completed at the moment when the smoothness of the sample was visually assessed by the therapist. After the final processing, the samples were slightly dried for 30 seconds.

Samples were prepared for SEM analysis by first being attached to cylindrical supports with a fixative (Dotite paint xc 12 Carbon JEOL, Tokyo, Japan). In an ion sputtering device (JFC 1100E Ion Sputter JEOL), a thin layer of gold was applied to the samples after vacuuming. For each sample, three micrographs were made at ×500 magnification, on which the crack width was analyzed. ImageJ software was used to estimate the width of the cracks. The distance between the edges of the crack was measured. Thirty distances were measured on each micrograph. Statistical analysis was performed using Mann-Whitney U and Student's t-test in IBM SPSS version 26.0.

RESULTS

Figures 1–3 show micrographs of Fuji IX™ material. Figure 1 shows the ultrastructure of the control sample of group Ia, where rare cracks and pores that dominate the material between the filler particles can be observed. In the samples of group IIa, uniform traces of finishing can be observed over the entire surface and the cracks are significantly reduced. However, pores that penetrate deeper layers of the material are still visible (Figure 2). In Figure 3, which shows the ultrastructure of the sample of group IIIa, a smooth surface covered with a coating can be observed,

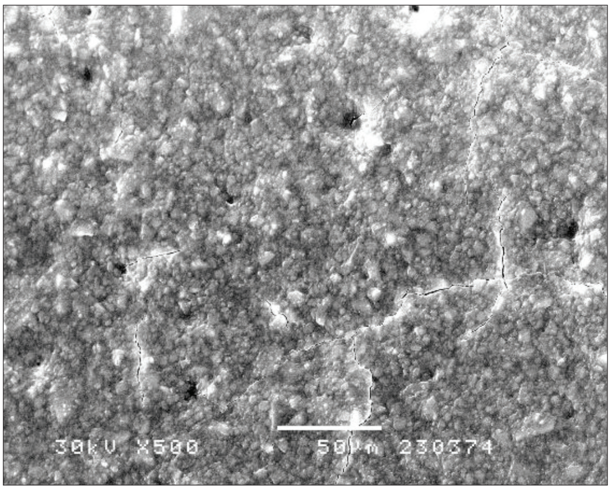

Figure 1. SEM of untreated Fuji IX™ sample
Slika 1. SEM prikaz neobrađenog uzorka Fuji IX™

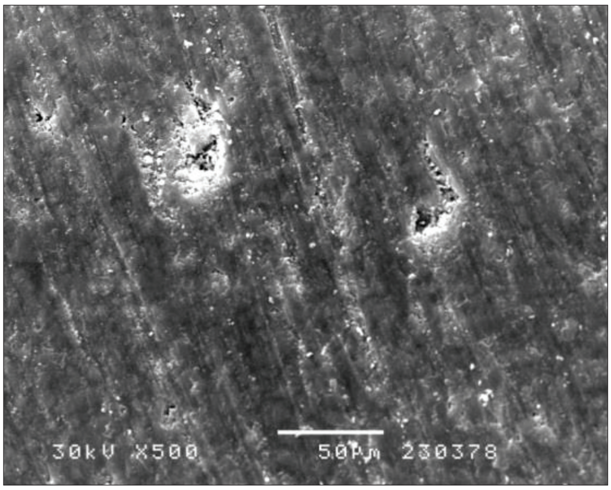

Figure 2. SEM of finished Fuji IX™ sample
Slika 2. SEM prikaz obrađenog uzorka Fuji IX™

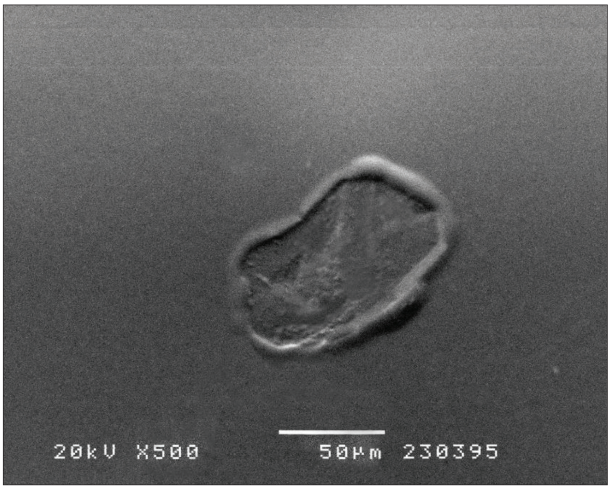

Figure 3. SEM of treated sample of Fuji IX™ with G-COAT PLUS™
Slika 3. SEM prikaz obrađenog uzorka Fuji IX™ premaznog G-COAT PLUS™

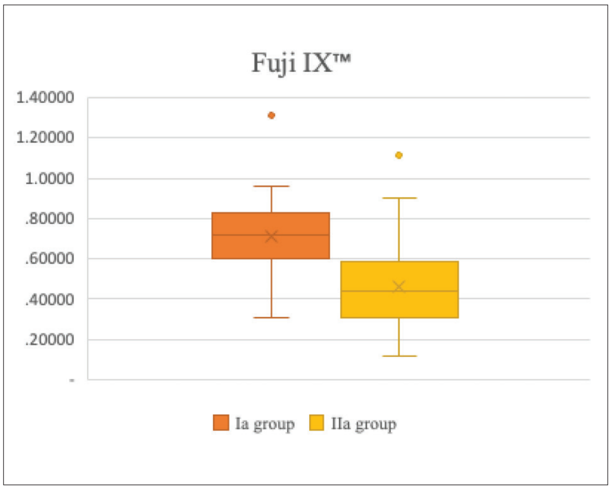

Figure 4. Crack size distribution of untreated and finished Fuji IX™ samples, expressed in µm
Slika 4. Raspodela veličina pukotina na neobrađenim i obrađenim uzorcima Fuji IX™, koje su izražene u µm

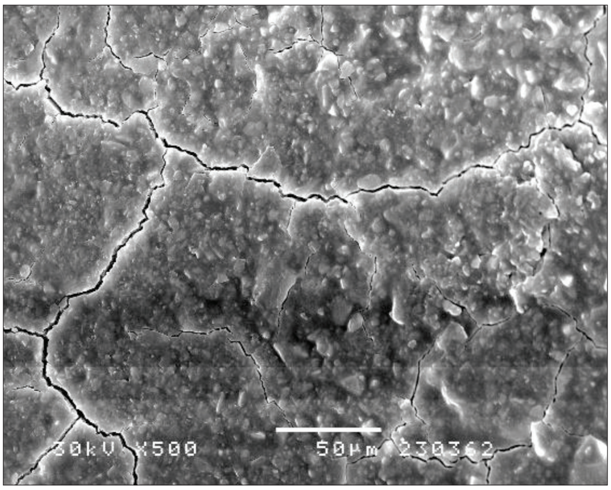

Figure 5. SEM of untreated EQUIA Forte HT Fil™ sample
Slika 5. SEM prikaz neobrađenog uzorka EQUIA Forte HT Fil™

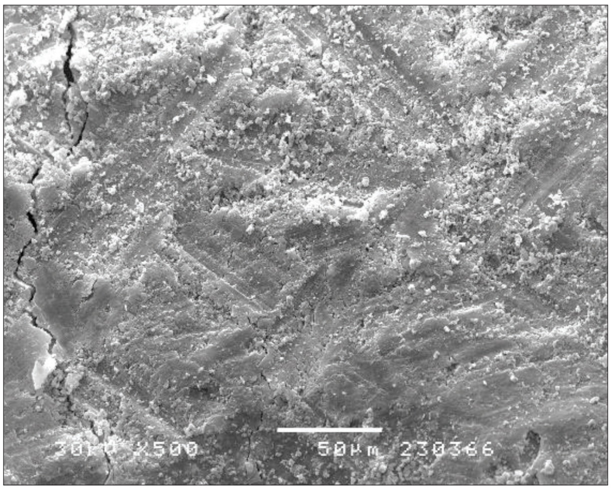

Figure 6. SEM of finished sample of EQUIA Forte HT Fil™
Slika 6. SEM prikaz obrađenog uzorka EQUIA Forte HT Fil™

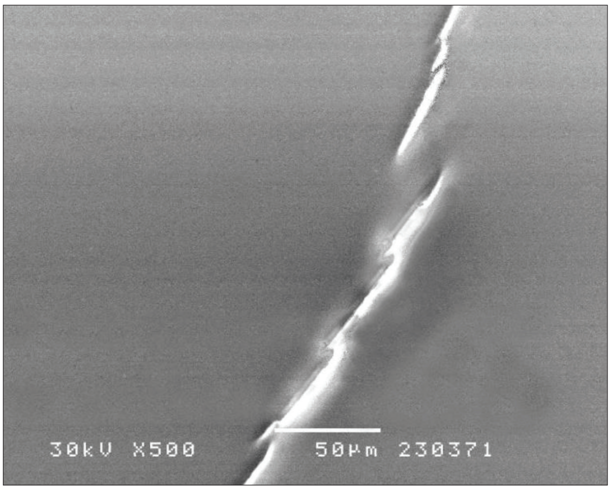

Figure 7. SEM of the treated sample of EQUIA Forte HT Fil™ with EQUIA Forte Coat™
Slika 7. SEM prikaz obrađenog uzorka EQUIA Forte HT Fil™ premaznog EQUIA Forte Coat™

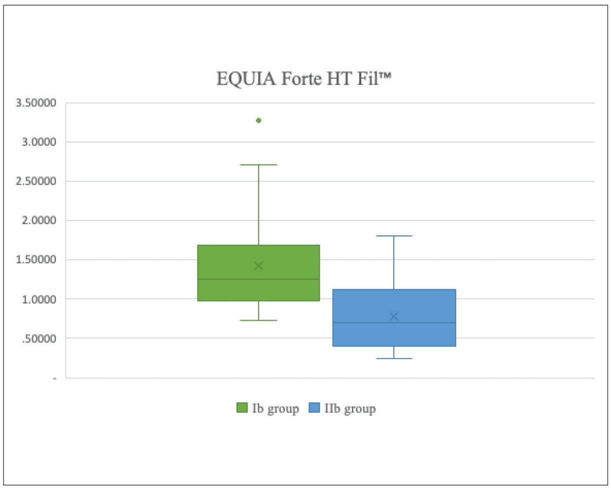

Figure 8. Crack size distribution of untreated and finished EQUIA Forte HT Fil™ samples, expressed in µm
Slika 8. Raspodela veličina pukotina na neobrađenim i obrađenim uzorcima EQUIA Forte HT Fil™, koje su izražene u µm

and rare, clearly delimited places of former pores filled with coat. SEM analysis indicated the reduction of cracks after processing the material, but also the complete filling of pores and cracks after applying the appropriate coating. Figure 4 shows the distribution of crack widths, which were measured on untreated and finished Fuji IX™ samples and expressed in µm. The finishing of the samples resulted in a statistically significant reduction in the width of the cracks ($t = 3.42, p < 0.005; Z = 3.25, p = 0.001$).

Figures 5–7 show micrographs of the EQUIA Forte HT Fil™ material. Figure 5 shows the ultrastructure of the control sample of group Ib, in which a compact surface of the material without pores can be seen, but with the presence of cracks that bypass the filler particles. Figure 6, which presents the ultrastructure of the group IIb sample, shows traces of material finishing and surfaces with rare cracks of smaller width compared to the control samples. On the micrograph of the IIIb group sample, the borders of the cracks are barely visible, and their space is completely filled with coating along its entire length (Figure 7). SEM analysis showed a significant reduction of cracks in the material after finishing and a complete filling of cracks after applying the coating.

Figure 8 shows the distribution of crack widths, which were measured on untreated and finished EQUIA Forte HT Fil™ samples and expressed in µm. The measurements showed that the processing of the samples led to a statistically significant reduction in the crack width ($t = 4.78, p < 0.001; Z = 4.28, p < 0.001$).

DISCUSSION

Thanks to the unique combination of properties, conventional glass ionomer cements are the materials of choice in everyday dental practice. In order to overcome mechanical deficiencies, glass hybrid was developed - innovative materials that combine positive mechanical properties of composites with the fluor protective effect and good adhesion of glass ionomer cement. However, research shows that, dimples and defects can be observed on the surface of these materials after setting, which can negatively affect the clinical properties and durability of the filling [2, 12]. Determining the presence and size of pores in glass ionomer cement-based materials is highly dependent on the type and resolution of the experimental technique used. In the literature, the method of scanning electron microscopy is described for the two-dimensional examination of the surface and the measurement of the width of cracks and pores, while for the three-dimensional examination of porosity, the application of a micro-CT study is more precise [13].

In this study, scanning electron microscopy was used to examine surface defects in materials, which gave a clear insight into the ultrastructure of untreated and treated samples. Analysis of control group samples revealed the presence of microcracks, which is in agreement with numerous studies [8, 14]. Cohesive cracks were observed on samples of both materials, which is in agreement with studies that found cracks in glass ionomer cements occur in the material itself, and not at the junction of the material and the tooth [15]. The appearance of cracks can be explained by the imbalance of water, which occurred in acid-base reactions during cement hardening [16].

The results of this study showed significant occurrence of cracks and pores on the surface of control samples. Data from literature showed that glass ionomer cements proved to be more porous than composites and amalgams [2, 17], so the obtained results were as expected. Porosity testing of EQUIA by Cabello Malagon et al. [18] showed that about 3% of the surface of material was filled with pores. In the mentioned research, it was concluded that porosity of the material was related to the increase in the viscosity of cement. Despite wider cracks on the EQUIA Forte HT Fil™ samples, compared to the Fuji IX™ samples, the absence of pores was also observed in the EQUIA Forte HT Fil™ samples, which is in agreement with the claims from the literature that preparation has the effect on reducing the porosity of cements. Cements prepared in a mixer proved to be less porous than those prepared by hand [19].

Swift et al. [20] pointed out the possibility that the preparation of samples for SEM analysis, may lead to the appearance of additional cracks due to the vacuuming process and the evaporation of water from the cements. However, the same preparation method, which was applied to untreated and finished samples of both groups of materials in this study, did not show a significant effect on the ultrastructure.

The results showed that the recommended finishing procedures with a diamond bur after the cement hardening process resulted in a reduction in the width of microcracks, as well as their removal. Considering that minor irregularities, such as surface protrusions and unevenness [9], are removed during finishing with a diamond bur, it follows that the observed cracks on the untreated samples of EQUIA Forte HT Fil™ and Fuji IX™ were in the surface layers of the material. In the case that the cracks penetrated deeper into the material, diamond bur treatment would not be effective in removing them. The importance of microcracks is reflected in the fact that they can act as stress concentrators that may contribute to material fracture [21]. From this, it follows that stress concentrators, in this case cracks, represent places that should be taken into consideration in order to ensure adequate resistance to stress and to reduce the risk of material cracking. The importance of finishing treatment is also reflected in the reduction of bacterial adhesion to fillings. In an *in vitro* study by Ismail et al. [22], it was determined that resin-modified cements, regardless of the finishing technique, have a smoother surface than conventional glass ionomer cements.

SEM analysis of processed samples with appropriate coatings showed that the cracks were completely filled. This indicates the great importance of the final coating, which can eliminate the problem caused by dehydration during material bonding [23]. The nanofiller coating improves the primary stabilization of the material during curing, but also improves infiltration as well as the closure of surface defects [24]. EQUIA Forte Fil HT™ samples, with a suitable coating, in the study by Brkanović et al. [25] proved to be more resistant to wear compared to those without coating, but no statistical significance was observed. In addition, it has been shown that the appropriate coating affects the reduction of water sorption and the solubility of almost all glass ionomer cement restorations [26]. A study by Ezoji et al. [27] pointed out that treated glass ionomer cement fillings with a suitable coating had significantly less microleakage compared to those without coating protection.

The role of coatings, based on light-curing monomers, that are applied over cement restorations to reduce porosity, can be explained by their property of building a barrier that prevents water exchange during the acid-base reaction of cement hardening. After the subsequent dissolution of the surface layer of the coating after the hardening of the glass ionomer, the cement undergoes secondary maturation under the influence of saliva, and the result is a better restoration [28]. Despite the studies which, in addition to better mechanical properties, highlight the greater resistance of EQUIA Forte HT Fil™ to acid-induced erosions compared to conventional cements such as Fuji IX™ and zinc-reinforced glass ionomer cements such as ChemFil Rock™ [8], the obtained SEM images of this material indicate on the need for additional improvement.

CONCLUSION

The finishing process of the Fuji IX™ and EQUIA Forte HT Fil™ materials leads to reduction in the width of microcracks, as well as to their elimination. The application of appropriate protective coatings affects the filling of the remaining pores and cracks, and obtaining a completely smooth filling surface for both types of cement.

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Uticaj završne obrade i zaštitnog premaza na ultrastrukturu ispuna od konvencionalnog i hibridnog glasjonomernog cementa

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KRATAK SADRŽAJ

Uvod Pored prednosti i jedinstvenih osobina glasjonomernih cemenata koje su dovele do njihove široke primene, radi prevazilaženja nedostataka u mehaničkoj otpornosti razvijeni su hibridni glasjonomerni cementi.
Cilj ovog rada je bio da se uradi ultrastrukturna analiza površine ispuna od konvencionalnog i hibridnog glasjonomernog cementa nakon preporučene završne obrade i nanošenja zaštitnog premaza.

Materijali i metode U istraživanju je analizirano 30 uzoraka konvencionalnog glasjonomernog cementa Fuji IX™ i 30 uzoraka hibridnog glasjonomernog cementa EQUIA Forte HT Fil™. Uzorci su pripremani u cilindričnim kalupima i podeljeni u tri grupe. Prva grupa uzoraka nakon adaptacije nije obrađivana i služila je kao kontrola. Drugu grupu su činili uzorci koji su nakon adaptacije obrađeni cilindričnim dijamantskim borerom sa vodenim hlađenjem, dok su uzorci treće grupe nakon adaptacije i završne obrade zaštićeni odgovarajućim premazima (G-COAT PLUS™ i EQUIA Forte Coat™). Uzorci su analizirani pomoću skenirajućeg elektronskog mikroskopa.

Rezultati Obrada uzoraka Fuji IX™ je značajno uticala na smanjenje širine pukotina ($t = 3,42$, $p < 0,005$; $Z = 3,25$, $p = 0,001$). Širina pukotina kod uzoraka EQUIA Forte HT Fil™ je takođe bila statistički značajno manja kod obrađenih uzoraka ($t = 4,78$, $p < 0,001$; $Z = 4,28$, $p < 0,001$). Ultrastrukturna analiza oba materijala je ukazala na potpuno odsustvo pukotina kod obrađenih uzoraka zaštićenih premazima.

Zaključak Završna obrada konvencionalnih i hibridnih glasjonomernih cemenata dovodi do smanjenja broja pukotina, kao i do smanjenja njihovih širina, a zaštitni premazi potpuno prekrivaju preostale pukotine.

Ključne reči: glasjonomerni cementi; poroznost; pukotine; ultrastruktura; SEM

UVOD

Veliki broj pozitivnih osobina glasjonomernih cemenata kao i konstantno prevazilaženje njihovih nedostataka, od svog nastanka početkom 1970-ih pa sve do danas, doveli su do toga da ovi materijali postanu jedni od najpopularnijih u stomatologiji [1]. Pored najvažnijih prednosti kao što su dobra adhezija za tvrda zubna tkiva i otpuštanje fluorida, najveći nedostaci restauracija od ovih cemenata su slaba mehanička otpornost, mala otpornost na trošenje i velika poroznost u poređenju sa restauracijama od kompozita i amalgama [2]. Poroznost se ogleda u prisustvu praznina, pora ili pukotina unutar materijala, što rezultira smanjenjem mehaničkih osobina i povećanom propustljivošću materijala [3].

I pored široke primene konvencionalnih glasjonomernih cemenata, potrebe za materijalom na bazi glasjonomernog cementa, koji bi zadovoljio sve zahteve pacijenata, doprinele su tome da bude predstavljen hibridni glasjonomerni cement za trajne ispune – EQUIA Forte HT Fil™. Kvalitet njegovih performansi u odnosu na prethodnika EQUIA Forte Fil™ potvrđen je u brojnim studijama [4]. Proizvođač ističe široke indikacije ovih materijala, među kojima su i ispuni I i II klase, koji se nanose u jednom komadu i čiju dugovečnost opisuju brojne studije [5, 6]. Desetogodišnje praćenje pacijenta sa ispunima od EQUIA-e nije uočilo statistički značajnu razliku između ovih ispuna i ispuna od kompozita [5]. Zbog loših estetskih osobina i mogućih toksičnih efekata, potiskivanje amalgama u mnogim zemljama nametnulo je EQUIA sistem kao odgovarajuću alternativu ovoj leguri žive, kada su u pitanju kaviteti I i II klase [7]. Studija koju su sproveli Moshaverinia i saradnici [8] ukazuje da materijal EQUIA ima veću čvrstoću na savijanje i veću tvrdoću u poređenju sa prethodnim generacijama glasjonomera, što ga čini veoma perspektivnim materijalom u restaurativnoj stomatologiji.

Završna obrada materijala predstavlja postupak prilikom kog se eliminišu površinska hrapavost ispuna i eventualne nepravilnosti nastale tokom restauracije [9]. Uklanjanje ovih neravnina ima za cilj da smanji poroznost materijala i akumulaciju plaka, koja može dovesti do kolonizacije bakterija, što za posledicu ima narušavanje estetike samog ispuna, ali i povećanje šanse za nastanak karijesa [10].

Skenirajuća elektronska mikroskopija (SEM) priznata je kao izuzetno efikasna tehnika za detaljno ispitivanje ultrastrukture materijala, zbog mogućnosti vizualizacije mikroskopske strukture površina [11].

Cilj ovog rada je bio da se uradi ultrastrukturna analiza površine ispuna od konvencionalnog i hibridnog glasjonomernog cementa nakon preporučene završne obrade i nanošenja zaštitnog premaza.

MATERIJAL I METODE

Istraživanje je obavljeno na Klinici za dentalnu medicinu u Nišu. U istraživanju su korišćeni predstavnik konvencionalnih glasjonomernih cemenata Fuji IX™ (GC Dental, Tokyo, Japan) i najnoviji hibridni glasjonomerni cement EQUIA Forte HT Fil™ (GC Dental, Tokyo, Japan), koji su pripremljeni po uputstvu proizvođača.

Fuji IX™ je ručno zamešan špatulom na papirnoj podlozi sjedinjavanjem jedne kapi tečnosti sa jednom mericom praha, a nakon toga pomoću šestice adaptiran u cilindrične kalupe dimenzija 8 × 3 mm. Pojedinačne kapsule EQUIA Forte HT Fil™ su mešane 10 sekundi u mikseru (Silamat, Vivadent). Nakon pripreme, materijal je pomoću aplikatora za kapsule unesen u cilindrične kalupe dimenzija 8 × 3 mm i adaptiran šesticom i nabijačem po uputstvu proizvođača.

Šezdeset pripremljenih uzoraka glasjonomernih cemenata (30 uzoraka Fuji IX™ i 30 uzoraka EQUIA Forte HT Fil™) podeljeno je u tri grupe. Prvu grupu sačinjavalo je 20 uzoraka (Ia grupa – 10 uzoraka Fuji IX™; Ib grupa – 10 uzoraka EQUIA Forte HT Fil™) koji nakon adaptacije nabijačem i vezivanja nisu obrađivani. Druga grupa se sastojala od 20 uzoraka (IIa grupa – 10 uzoraka Fuji IX™; IIb grupa – 10 uzoraka EQUIA Forte HT Fil™) koji su nakon adaptacije nabijačem i vezivanja obrađivani po uputstvu proizvođača superfinim cilindričnim dijamantskim borerom sa vodenim hlađenjem. Dvadeset uzoraka treće grupe (IIIa grupa – 10 uzoraka Fuji IX™; IIIb grupa – 10 uzoraka EQUIA Forte HT Fil™) nakon adaptacije nabijačem i obrade prema uputstvu proizvođača zaštićeni su premazom koji je nakon aplikovanja polimerizovan LED lampom. Premaz G-COAT PLUS™ (GC Dental, Tokyo, Japan) korišćen je za premazivanje uzoraka Fuji IX™ (IIIa grupa), dok je za premazivanje uzoraka EQUIA Forte HT Fil™ (IIIb grupa) korišćen premaz EQUIA Forte Coat™ (GC Dental, Tokyo, Japan) (Tabela 1).

Pripremu svih uzoraka je realizovao jedan terapeut, kako bi se postigla ujednačenost u pripremi uzoraka i efektu obrade. Prilikom obrade pokreti terapeuta su bili ravnomerni sleva nadesno. Obrada je završena u trenutku kada je terapeut vizuelno procenio glatkoću uzorka. Nakon finalne obrade, uzorci su blago posušeni pusterom u trajanju od 30 sekundi.

Uzorci su pripremljeni za SEM analizu tako što su prvo pričvršćeni za cilindrične nosače uz pomoć sredstva za fiksiranje (Dotite paint xc 12 Carbon JEOL, Tokyo, Japan). U uređaju za jonsko raspršivanje (JFC 1100E Ion Sputter JEOL) na uzorcima je posle vakuumiranja nanesen tanak sloj zlata. Za svaki uzorak su napravljene po tri mikrografije na uvećanju ×500, na kojima je analizirana širina pukotina. Za procenjivanje širine pukotina korišćen je softver ImageJ, uz pomoć kog je mereno rastojanje između ivica pukotine. Na svakoj mikrografiji izmereno je 30 rastojanja. Statistička analiza je izvršena korišćenjem Man-Vitnijevog i Studentovog t-testa u programu IBM SPSS, verzija 26.0.

REZULTATI

Na slikama 1, 2 i 3 prikazane su mikrografije materijala Fuji IX™. Slika 1 prikazuje ultrastrukturu kontrolnog uzorka Ia grupe, na kome se uočavaju retke pukotine i pore koje dominiraju u materijalu između čestica punioca. Na uzorcima IIa grupe zapažaju se ujednačeni tragovi obrade po čitavoj površini, pukotine su značajno smanjene, međutim, i dalje se uočavaju blazne koje zadiru u dublje slojeve materijala (Slika 2). Na Slici 3, koja prikazuje ultrastrukturu uzorka IIIa grupe, uočavaju se glatka površina prekrivena premazom i retka, jasno ograničena mesta nekadašnjih pora ispunjena lakom. SEM analiza je ukazala na smanjenje pukotina posle obrade materijala, ali i na potpuno ispunjavanje pora i pukotina posle nanošenja odgovarajućeg premaza.

Na Slici 4 je prikazana raspodela širina pukotina, koje su izmerene na obrađenim i neobrađenim uzorcima Fuji IX™ i izražene u μm. Obradom uzoraka došlo je do statistički značajnog smanjenja širine pukotina ($t = 3,42$, $p < 0,005$; $Z = 3,25$, $p = 0,001$).

Na slikama 5, 6 i 7 prikazane su mikrografije materijala EQUIA Forte HT Fil™. Slika 5 prikazuje ultrastrukturu kontrolnog uzorka Ib grupe, na kome se vidi kompaktna površina materijala bez pora, ali sa prisutnim pukotinama koje mimoilaze čestice punioca. Na Slici 6, koja prikazuje ultrastrukturu uzorka IIb grupe, vide se tragovi obrade materijala i površina sa retkim pukotinama manje širine u poređenju sa kontrolnim uzorcima. Na mikrografiji uzorka IIIb grupe granice pukotina su slabo vidljive, a njihov prostor je celom dužinom potpuno ispunjen premazom (Slika 7). SEM analiza je pokazala značajno smanjivanje pukotina u materijalu posle obrade i potpuno odsustvo pukotina posle aplikovanja premaza.

Na Slici 8 je prikazana raspodela širina pukotina, koje su izmerene na obrađenim i neobrađenim uzorcima EQUIA Forte HT Fil™ i izražene u μm. Merenja su pokazala da je obrada uzoraka dovela do statistički značajanog smanjenja širine pukotina ($t = 4,78$, $p < 0,001$; $Z = 4,28$, $p < 0,001$).

DISKUSIJA

Zahvaljujući jedinstvenoj kombinaciji osobina, konvencionalni glasjonomerni cementi predstavljaju materijale izbora u svakodnevnoj stomatološkoj praksi. U cilju prevazilaženja mehaničkih nedostataka, razvijeni su glashibridi – inovativni materijali koji objedinjuju pozitivne mehaničke osobine kompozita sa fluoroprotektivnim dejstvom i dobrom adhezijom glasjonomernih cemenata. Međutim, istraživanja pokazuju da se nakon vezivanja na površini ovih materijala mogu uočiti jamice i defekti koji mogu negativno uticati na kliničke osobine i trajnost ispuna [2, 12]. Određivanje prisustva i veličine pora u materijalima na bazi glasjonomernih cemenata u velikoj meri zavisi od tipa i rezolucije eksperimentalne tehnike koja se koristi. U literaturi je za dvodimenzionalno ispitivanje površine i merenje širine pukotina i pora opisana metoda skenirajuće elektronske mikroskopije, dok je za trodimenzionalno ispitivanje poroznosti preciznija primena mikro-CT studije [13].

U ovoj studiji je za ispitivanje površinskih defekata u materijalima korišćena skenirajuća elektronska mikroskopija, koja je dala jasan uvid u ultrastrukturu netretiranih i tretiranih uzoraka. Analizom uzoraka kontrolne grupe uočeno je prisustvo mikropukotina, što je u saglasnosti sa brojnim istraživanjima [8, 14]. Na uzorcima oba materijala uočene su kohezivne pukotine, što je u saglasnosti sa studijama u kojima je zaključeno da se pukotine kod glasjonomernih cemenata događaju u samom materijalu, a ne na spoju materijala i zuba [15]. Pojava pukotina se može objasniti disbalansom vode, do kog dolazi tokom acidobaznih reakcija prilikom stvrdnjavanja cemenata [16].

Rezultati ove studije su pokazali značajnu pojavu pukotina i pora na površini kontrolnih uzoraka. Podaci iz literature govore da su se glasjonomerni cementi pokazali poroznijim od kompozita i amalgama [2, 17], tako da su dobijeni rezultati bili i očekivani. Cabello Malagon i saradnici su ispitivali poroznosti EQUIA-e [18] i pokazali da je oko 3% površine materijala bilo ispunjeno porama. U pomenutom istraživanju je zaključeno da je poroznost materijala povezana sa porastom viskoznosti cemenata. Uprkos širim pukotinama na uzorcima EQUIA Forte HT Fil™, u poređenju sa uzorcima Fuji IX™, u uzorcima EQUIA Forte HT Fil™ je zapaženo i odsustvo pora, što je u saglasnosti sa tvrdnjama iz literature, koje sugerišu da na uticaj na smanjenje poroznosti cemenata ima i način pripreme cemenata. Cementi pripremljeni u mikseru pokazali su se manje poroznijim od onih koji se spremaju ručno [19].

Swift i saradnici [20] ukazali su da priprema uzoraka za SEM analizu, usled procesa vakuumiranja, može da dovede do pojave dodatnih pukotina zbog evaporacije vode iz cemenata, međutim ista metoda pripreme kojoj su bili podvrgnuti i obrađeni i neobrađeni uzorci obe grupe materijala u ovoj studiji nije pokazala značajan uticaj na ultrastrukturu.

Rezultati su pokazali da je preporučena obrada dijamantskim borerom nakon procesa stvrdnjavanja cementa rezultirala smanjenjem širine mikropukotina, kao i njihovim uklanjanjem. S obzirom na to da se prilikom obrade dijamantskim borerom uklanjaju manje nepravilnosti poput površinskih izbočina i neravnina [9], iz ovog proizilazi da su uočene pukotine na neobrađenim uzorcima EQUIA Forte HT Fil™ i Fuji IX™ bile u površinskim slojevima materijala. U slučaju da su pukotine prodirale dublje u materijal, obrada dijamantskim borerom ne bi bila efikasna u njihovom uklanjanju. Značaj mikropukotina ogleda se u tome što one mogu da deluju kao koncentratori naprezanja koji mogu doprineti lomu materijala [21]. Iz ovog proizilazi da koncentratori naprezanja, u ovom slučaju pukotine, predstavljaju mesta koja treba posebno uzeti u razmatranje, kako bi se obezbedila adekvatna otpornost na naprezanje i kako bi se smanjio rizik od pucanja materijala. Značaj završne obrade ogleda se i u smanjenju adhezije bakterija za ispune. U *in vitro* studiji Ismaila i saradnika [22], utvrđeno je da smolom modifikovani cementi, bez obzira na tehniku obrade, imaju glađu površinu od konvencionalnih glasjonomernih cemenata.

SEM analiza obrađenih uzoraka sa odgovarajućim premazima pokazala je kako su pukotine u potpunosti ispunjene. Ovo ukazuje na veliki značaj završnog premaza, kojim se može eliminisati problem izazvan dehidratacijom tokom vezivanja materijala [23]. Premaz od nanopunioca poboljšava primarnu stabilizaciju materijala tokom stvrdnjavanja, ali i infiltraciju i zatvaranje površnih defekata [24]. Uzorci EQUIA Forte Fil HT™, sa odgovarajućim premazom, u studiji Brkanović i saradnika [25] pokazali su se otpornijim na habanje u poređenju sa onima bez premaza, ali nije uočena statistička značajnost. Pored toga, pokazalo se da odgovarajući premaz utiče i na smanjenje sorpcije vode i rastvorljivost gotovo svih restauracija od glasjonomernih cemenata [26]. Studija Ezoji i saradnika [27] istakla je da su obrađeni ispuni glasjonomernih cemenata sa odgovarajućim premazom imali značajno manje mikrocurenje u odnosu na one koji nisu zaštićeni premazom.

Uloga premaza na bazi svetlosnopolimerizujućih monomera koji se aplikuju preko cementa radi prevencije poroznosti može da se objasni njihovom osobinom da grade barijeru koja sprečava razmenu vode tokom acidobazne reakcije stvrdnjavanja cementa. Nakon kasnijeg rastvaranja površnog sloja premaza posle stvrdnjavanja glasjonomera, cement podleže sekundarnoj maturaciji pod dejstvom pljuvačke, a rezultat svega predstavlja kvalitetnija restauracija [28]. Uprkos studijama koje pored boljih mehaničkih osobina ističu i veću otpornost EQUIA Forte HT Fil™ na erozije izazvane kiselinom u poređenju sa konvencionalnim cementima poput Fuji IX™ i cinkom ojačanim glasjonomernim cementima poput ChemFil Rock™ [8], dobijeni SEM prikazi ovog materijala ukazuja na potrebe za dodatnim usavršavanjem.

ZAKLJUČAK

Postupak završne obrade materijala Fuji IX™ i EQUIA Forte HT Fil™ dovodi do smanjenja širine mikropukotina, kao i do njihove eliminacije. Aplikacija odgovarajućih zaštitnih premaza utiče na ispunjavanje preostalih pora i pukotina i dobijanje potpuno glatke površine ispuna kod obe vrste cemenata.

Da li ste pažljivo čitali radove?

1. Ciklični zamor je proveravan:
   a) u simuliranim kanalima
   b) u kliničkim uslovima
   c) na akrilatnim zubima

2. Kondilografska evaluacija je istraživana:
   a) u Beogradu
   b) u Nišu
   c) u Skoplju

3. Dijabetes melitus je predisponirajući faktor za nastanak karijesa?
   a) Da
   b) Ne
   c) Isključivo kod kardiovaskularnih bolesnika

4. Ultrastrukturna analiza je realizovana kod ispuna od:
   a) kompozitnog materijala
   b) amalgama
   c) GJC-a

5. Ciklični zamor je proveravan:
   a) u punoj rotaciji instrumenata
   b) sa recipročnim pokretima
   c) u ekscentričnim pokretima instrumenata

6. Kondilografsko ispitivanje je rađeno na:
   a) lakatnom zglobu
   b) kolenom zglobu
   c) TM zglobu

7. Zastupljenost parodontitisa i gingivitisa je ispitivana:
   a) bakteriološkom analizom
   b) histološkom analizom
   c) kliničkom evaluacijom

8. Ultrastrukturna analiza je urađena posle:
   a) završne obrade
   b) nanošenja zaštitnog premaza
   c) završne obrade i nanošenja zaštitnog premaza

9. Na pojavu cikličnog zamora proveravan je uticaj:
   a) legure
   b) broja navoja
   c) dijametra instrumenta

10. Broj ciklusa do pojave frakture NiTi intrumenata je određivan na osnovu:
    a) brzine rotacije
    b) povijenosti kanala
    c) vremena

11. Kondilografska evaluacija je realizovana kod:
    a) 10 pacijenata
    b) 20 pacijenata
    c) 30 pacijenata

12. Zastupljenost parodontitisa i gingivitisa je proveravana na:
    a) pacovima
    b) kunićima
    c) eksperimentalnim svinjama

13. Parodontitis i gingivitis u grupi do 30 dana je uočen u:
    a) 54,5% slučajeva
    b) 65,4% slučajeva
    c) 88% slučajeva

14. Analiza površine ispuna je realizovana kod:
    a) 15 uzoraka
    b) 30 uzoraka
    c) 40 uzoraka

15. Zaštitni premaz na ispunima od GJC:
    a) potpuno pokriva pukotine ispuna
    b) delimično pokriva pukotine ispuna
    c) samo u manjem broju pokriva pukotine ispuna

16. Otpornost na ciklični zamor je proveravana kod:
    a) 5 setova NiTi
    b) 3 seta NiTi
    c) 2 seta NiTi

17. Kondilografska ispitivanja su merena kondilografom firme:
    a) Kavo
    b) Simens
    c) Toshiba

18. Zastupljenost parodontitisa i gingivitisa je proveravana:
    a) posle 7 i 14 dana
    b) posle 14 i 30 dana
    c) posle 15 i 21 dan

19. Parodontitis u kontrolnoj grupi:
    a) nije zabeležen
    b) bio je identičan kao u grupi do 14 dana
    c) bio je identičan kao u grupi do 30 dana

20. Uzorci za analizu površine ispuna podeljeni su u:
    a) dve grupe
    b) tri grupe
    c) pet grupa

21. Ultrastrukturna analiza testiranih GJC je ukazala na:
    a) potpuno odsustvo pukotina na ispunima
    b) delimično odsustvo pukotina na ispunima
    c) pojavu pukotina kod nekoliko uzoraka

22. Kod svakog seta NiTi otpornost na ciklični zamor je testirana:
    a) na svim instrumentima u setu
    b) kod 3 intrumenta u setu
    c) kod 2 instrumenta u setu

23. Ciklični zamor je proveravan kod:
    a) 8 ProTaper Next instrumenata
    b) 12 ProTaper Next instrumenata
    c) 24 ProTaper Next instrumenata

24. Registrovanje pokreta TM zgloba je urađeno:
    a) u jednoj poseti
    b) u dve posete
    c) u tri posete

25. Zastupljenost parodontitisa i gingivitisa je bila:
    a) veća u grupi do 30 dana
    b) manja u grupi do 30 dana
    c) veća u grupi do 14 dana

26. Za analizu površine ispuna korišćeni su uzorci:
    a) klasičnog kompozita
    b) klasičnog GJC-a
    c) klasičnog i hibridnog GJC-a

27. Testiranje otpornosti na ciklični zamor je realizovano:
    a) u kliničkim uslovima
    b) u akrilatnom bloku
    c) u metalnom bloku

28. Pukotina kod uzoraka FUJI IX je iznosila:
    a) 3,42
    b) 4,78
    c) 5,32

29. Kod instrumenata ProTaper Universal (#25) broj ciklusa do frakture je iznosio:
    a) 367,83
    b) 329,33
    c) 971,08

30. Registrovanje pokreta TM zgloba je rađeno:
    a) pre terapije
    b) posle terapije
    c) pre i posle terapije

31. Terapija TM disfunkcija ima:
    a) minimalan efekat na trajektoriju kondila tokom otvaranja i zatvaranja
    b) maksimalan efekat na trajektoriju kondila tokom otvaranja i zatvaranja
    c) značajan efekat na trajektoriju kondila tokom otvaranja i zatvaranja

32. Kod pacova žrtvovanih posle 30 dana zastupljenost parodontitisa je bila:
    a) značajno veća nego kod pacova žrtvovanih posle 14 dana
    b) veća nego kod pacova žrtvovanih posle 14 dana
    c) identična kao kod pacova žrtvovanih posle 14 dana

33. FUJI IX predstavlja:
    a) konvencionalni GJC
    b) hibridni GJC
    c) GJC ojačan smolom

34. Arteficijalni kanal u metalnom bloku je bio:
    a) pod uglom od 5o i radijusom ugla od 45 mm
    b) pod uglom od 45o i radijusom ugla od 5 mm
    c) pod uglom od 30o i radijusom ugla od 5 mm

35. Kod instrumenta ProTaper Universal (#30) broj ciklusa do frakture je iznosio:
    a) 367,83
    b) 329,33
    c) 971,08

36. Merenjem Benetovog ugla kod TM disfunkcija:
    a) uočena je značajna razlika
    b) nije bilo razlike
    c) vrednosti ugla su bile identične

37. EQUIA FORTE predstavlja uzorak:
    a) konvencionalnog GJC-a
    b) hibridnog GJC-a
    c) GJC-a ojačanog smolom

38. U studiji o cikličnom zamoru je analizirano:
    a) 24 instrumenta ProTaper Universal
    b) 12 instrumenata ProTaper Universal
    c) 8 instrumenata ProTaper Universal

39. Kod instrumenata ProTaper Next (#25) broj ciklusa do frakture je iznosio:
    a) 367,83
    b) 329,33
    c) 1189,33

40. Posle terapije TM disfunkcija pokreti u zglobu su bili:
    a) oštri i grubi
    b) laki i precizni
    c) bolni i sa teškoćama

41. Pukotina kod uzoraka EQUIA FORTE je iznosila:
    a) 3,42
    b) 4,78
    c) 5,32

42. Kod instrumenata ProTaper Next (#30) broj ciklusa do frakture je iznosio:
    a) 367,83
    b) 1189,33
    c) 971,08

43. Parodontitis i gingivitis u grupi do 14 dana je uočen u:
    a) 54,5% slučajeva
    b) 65,4% slučajeva
    c) 88% slučajeva

44. Normalne vrednosti zgloba pri otvaranju usta se kreću u rangu:
    a) 45 ± 5 mm
    b) 50 ± 5 mm
    c) 60 ± 5 mm

45. Sa povećanjem dijametra NiTi otpornost na ciklični zamor:
    a) povećava se
    b) smanjuje se
    c) ostaje isti

46. Kondilografska evaluacija je obuhvatila:
    a) 10 žena i 10 muškaraca
    b) 15 žena i 5 muškaraca
    c) 5 žena i 15 muškaraca

47. Ispitivanje zastupljenosti parodontitisa i gingivitisa je sprovedeno na:
    a) 30 pacova
    b) 40 pacova
    c) 42 pacova

48. Uzrast ispitanika za kondilografska ispitivanja je bio:
    a) 15–30 godina
    b) 20–50 godina
    c) 30–60 godina

49. Eksperimentalnu grupu pacova je činilo:
    a) 16 pacova za period od 14 dana
    b) 32 pacova za period od 14 dana
    c) 42 pacova za period od 14 dana

50. Kontrolnu grupu pacova za eksperiment o gingivitisima i parodontitisima je činilo:
    a) 8 pacova
    b) 10 pacova
    c) 12 pacova

Odgovore slati na email adresu Uredništva časopisa „Stomatološki glasnik Srbije“ ili na adresu Stomatološke komore Srbije (Uzun Mirkova 3/3). Tačni odgovori na pitanja će se vrednovati u skladu s Pravilnikom o kontinuiranoj medicinskoj edukaciji zdravstvenih radnika.

UPUTSTVO AUTORIMA ZA PRIPREMU RADA

Stomatološki glasnik Srbije (SGS) časopis je Srpskog lekarskog društva osnovan 1953. godine. Časopis objavljuje originalne naučne i stručne radove, prikaze iz prakse, pregledne radove, saopštenja, istoriografske radove, prikaze knjiga, komentare i pisma uredništvu, društvenu hroniku.

Pre podnošenja rukopisa Uredništvu časopisa SGS svi autori treba da pročitaju Uputstvo za autore (Instructions for Authors), gde će pronaći sve potrebne informacije o pisanju i pripremi rada u skladu sa standardima časopisa. Ukoliko rukopis ne bude usklađen s ovim zahtevima, Uredništvo će odložiti ili odbiti njegovo publikovanje.

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Radovi se štampaju na englekom i srpskom jeziku.

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Pri pisanju teksta na engleskom jeziku treba se pridržavati jezičkog standarda American English i koristiti kratke i jasne rečenice. Za nazive lekova koristiti isključivo generička imena. Uređaji (aparati) se označavaju fabričkim nazivima, a ime i mesto proizvođača treba navesti u oblim zagradama. Ukoliko se u tekstu koriste oznake koje su spoj slova i brojeva, precizno napisati broj koji se javlja u superskriptu ili supskriptu (npr. 99Tc, IL-6, O2, B12, CD8). Ukoliko se nešto uobičajeno piše kurzivom (italic), tako se i navodi, npr. geni (BRCA1). Ukoliko je rad deo magistarske teze, odnosno doktorske disertacije, ili je urađen u okviru naučnog projekta, to treba posebno naznačiti u Napomeni na kraju teksta.

KLINIČKA ISTRAŽIVANJA. Klinička istraživanja se definišu kao istraživanja uticaja jednog ili više sredstava ili mera na ishod zdravlja. Registarski broj istraživanja se navodi u poslednjem redu sažetka.

ETIČKA SAGLASNOST. Rukopisi o istraživanjima na ljudima treba da sadrže izjavu u vidu pisanog pristanka ispitivanih osoba u skladu s Helsinškom deklaracijom i odobrenje nadležnog etičkog odbora da se istraživanje može izvesti i da je ono u skladu s pravnim standardima. Eksperimentalna istraživanja na humanom materijalu i ispitivanja vršena na životinjama treba da sadrže izjavu etičkog odbora ustanove i treba da su u saglasnosti s pravnim standardima.

IZJAVA O SUKOBU INTERESA. Uz rukopis se prilaže potpisana izjava u okviru obrasca Submission Letter kojom se autori izjašnjavaju o svakom mogućem sukobu interesa ili njegovom odsustvu. Za dodatne informacije o različitim vrstama sukoba interesa posetiti internet-stranicu Svetskog udruženja urednika medicinskih časopisa (World Association of Medical Editors – WAME; http://www.wame.org) pod nazivom „Politika izjave o sukobu interesa".

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Autori treba da prilože opis doprinosa pojedinačno za svakog koautora u okviru obrasca Submission Letter. Finansiranje, sakupljanje podataka ili generalno nadgledanje istraživačke grupe sami po sebi ne mogu opravdati autorstvo. Svi drugi koji su doprineli izradi rada, a koji nisu autori rukopisa, trebalo bi da budu navedeni u Zahvalnici s opisom njihovog doprinosa radu, naravno, uz pisani pristanak.

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SAŽETAK. Uz originalni rad, prethodno i kratko saopštenje, metaanalizu, pregled literature, prikaz slučaja (bolesnika), rad iz istorije medicine, aktuelnu temu, rad za rubriku jezik medicine i rad za praksu, na drugoj po redu stranici dokumenta treba priloži ti sažetak rada obima 100–250 reči. Za originalne radove, prethodno i kratko saopštenje, metaanalize i pregledne radove, sažetak treba da ima sledeću strukturu: Uvod/Cilj, Metode, Rezultati, Zaključak; svaki od navedenih segmenata pisati kao poseban pasus koji počinje boldovanom reči. Navesti najvažnije rezultate (numeričke vrednosti) statističke analize i nivo značajnosti. Zaključak ne sme biti uopšten, već mora biti direktno povezan sa rezultatima rada. Za prikaze bolesnika sažetak treba da ima sledeće delove: Uvod (u poslednjoj rečenici navesti cilj), Prikaz bolesnika, Zaključak; segmente takođe pisati kao poseban pasus koji počinje boldovanom reči. Za ostale tipove radova sažetak nema posebnu strukturu.

KLJUČNE REČI. Ispod Sažetka navesti od tri do šest ključnih reči ili izraza. U izboru ključnih reči koristiti Medical Subject Headings – MeSH (http://www.nlm.nih.gov/mesh).

PREVOD NA SRPSKI JEZIK. Na posebnoj stranici dokumenta priložiti naslov rada na srpskom jeziku, puna imena i prezimena autora (bez titula) indeksirana brojevima, zvaničan naziv ustanova u kojima autori rade, mesto i državu. Na sledećoj stranici dokumenta priložiti sažetak (100–250 reči) s ključnim rečima (3–6), prevod naziva priloga (tabela, grafikona, slika, shema) i celokupni tekst u njima i legendu.

STRUKTURA RADA. Svi podnaslovi se pišu velikim masnim slovima (bold). Originalni rad, metaanaliza, prethodno i kratko saopštenje obavezno treba da imaju sledeće podnaslove: Uvod (Cilj rada navesti kao poslednji pasus Uvoda), Metode rada, Rezultati, Diskusija, Zaključak, Literatura. Pregled literature čine: Uvod, odgovarajući podnaslovi, Zaključak, Literatura. Prvoimenovani autor metaanalize i preglednog rada mora da navede bar pet autocitata (kao autor ili koautor) radova publikovanih u časopisima s recenzijom. Koautori, ukoliko ih ima, moraju da navedu bar jedan autocitat radova takođe publikovanih u časopisima s recenzijom. Prikaz slučaja ili bolesnika čine: Uvod (Cilj rada navesti kao poslednji pasus Uvoda), Prikaz bolesnika, Diskusija, Literatura. Ne treba koristiti imena bolesnika, inicijale, niti brojeve istorija bolesti, naročito u ilustracijama. Prikazi bolesnika ne smeju imati više od pet autora. Priloge (tabele, grafikone, slike itd.) postaviti na kraj rukopisa, a u samom telu teksta jasno naznačiti mesto koje se odnosi na dati prilog. Krajnja pozicija priloga biće određena u toku pripreme rada za publikovanje.

SKRAĆENICE. Koristiti samo kada je neophodno, i to za veoma dugačke nazive hemijskih jedinjenja, odnosno nazive koji su kao skraćenice već prepoznatljivi (standardne skraćenice, kao npr. DNK, sida, HIV, ATP). Za svaku skraćenicu pun termin treba navesti pri prvom navođenju u tekstu, sem ako nije standardna jedinica mere. Ne koristiti skraćenice u naslovu. Izbegavati korišćenje skraćenica u sažetku, ali ako su neophodne, svaku skraćenicu objasniti pri prvom navođenju u tekstu.

DECIMALNI BROJEVI. U tekstu rada na engleskom jeziku, u tabelama, na grafikonima i drugim prilozima decimalne brojeve pisati sa tačkom (npr. 12.5 ± 3.8), a u tekstu na srpskom jeziku sa zarezom (npr. 12,5 ± 3,8). Kad god je to moguće, broj zaokružiti na jednu decimalu.

JEDINICE MERA. Dužinu, visinu, težinu i zapreminu izražavati u metričkim jedinicama (metar – m, kilogram (gram) – kg (g), litar – l) ili njihovim delovima. Temperaturu izražavati u stepenima Celzijusa (°C), količinu supstance u molima (mol), a pritisak krvi u milimetrima živinog stuba (mm Hg). Sve rezultate hematoloških, kliničkih i biohemijskih merenja navoditi u metričkom sistemu prema Međunarodnom sistemu jedinica (SI).

OBIM RADOVA. Celokupni rukopis rada – koji čine naslovna strana, sažetak, tekst rada, spisak literature, svi prilozi, odnosno potpisi za njih i legenda (tabele, slike, grafikoni, sheme, crteži), naslovna strana i sažetak na srpskom jeziku – mora iznositi za originalni rad, prethodno i kratko saopštenje, rad izistorije medicine i pregled literature do 5000 reči, a za prikaz bolesnika, rad za praksu, edukativni članak i rad za rubriku „Jezik medicine“ do 3000 reči; radovi za ostale rubrike mogu imati najviše 1500 reči.

PRILOZI RADU su tabele i slike (fotografije, crteži, sheme, grafikoni).

TABELE. Svaka tabela treba da bude sama po sebi lako razumljiva. Naslov treba otkucati iznad tabele, a objašnjenja ispod nje. Tabele se označavaju arapskim brojevima prema redosledu navođenja u tekstu. Tabele crtati isključivo u programu Word, kroz meni Table–Insert–Table, uz definisanje tačnog broja kolona i redova koji će činiti mrežu tabele. Desnim klikom na mišu – pomoću opcija Merge Cells i Split Cells – spajati, odnosno deliti ćelije. Kucati fontom Times New Roman, veličinom slova 12 pt, s jednostrukim proredom i bez uvlačenja teksta. Korišćene skraćenice u tabeli treba objasniti u legendi ispod tabele. Ukoliko je rukopis na srpskom jeziku, priložiti nazive tabela i legendu na oba jezika. Takođe, u jednu tabelu, u okviru iste ćelije, uneti i tekst na srpskom i tekst na engleskom jeziku (nikako ne praviti dve tabele sa dva jezika!).

SLIKE. Slike su svi oblici grafičkih priloga i kao „slike“ u SGS se objavljuju fotografije, crteži, sheme i grafikoni. Slike označavaju se arapskim brojevima prema redosledu navođenja u tekstu. Primaju se isključivo digitalne fotografije (crno-bele ili u boji) rezolucije najmanje 300 dpi i formata zapisa tiff ili jpg (male, mutne i slike lošeg kvaliteta neće se prihvatati za štampanje!). Ukoliko autori ne poseduju ili nisu u mogućnosti da dostave digitalne fotografije, onda originalne slike treba skenirati u rezoluciji 300 dpi i u originalnoj veličini. Ukoliko je rad neophodno ilustrovati sa više slika, u radu će ih biti objavljeno nekoliko, a ostale će biti u e-verziji članka kao PowerPoint prezentacija (svaka slika mora biti numerisana i imati legendu). Ukoliko je rukopis na srpskom jeziku, priložiti nazive slika i legendu na oba jezika.

GRAFIKONI. Grafikoni treba da budu urađeni i dostavljeni u programu Excel, da bi se videle prateće vrednosti raspoređene po ćelijama. Iste grafikone prekopirati i u Word-ov dokument, gde se grafikoni označavaju arapskim brojevima prema redosledu navođenja u tekstu. Svi podaci na grafikonu kucaju se u fontu Times New Roman. Korišćene skraćenice na grafikonu treba objasniti u legendi ispod grafikona. U štampanoj verziji članka verovatnije je da grafikon neće biti štampan u boji, te je bolje izbegavati korišćenje boja u grafikonima, ili ih koristiti različitog intenziteta. Ukoliko je rukopis na srpskom jeziku, priložiti nazive grafikona i legendu na oba jezika.

SHEME (CRTEŽI). Crteži i sheme se dostavljaju u jpg ili tiff formatu. Sheme se mogu crtati i u programu CorelDraw ili Adobe Illustrator (programi za rad sa vektorima, krivama). Svi podaci na shemi kucaju se u fontu Times New Roman, veličina slova 10 pt. Korišćene skraćenice na shemi treba objasniti u legendi ispod sheme. Ukoliko je rukopis na srpskom jeziku, priložiti nazive shema i legendu na oba jezika.

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Reference se citiraju prema Vankuverskom stilu (uniformisanim zahtevima za rukopise koji se predaju biomedicinskim časopisima), koji je uspostavio Međunarodni komitet urednika medicinskih časopisa (http://www.icmje.org), čiji format koriste U.S. National Library of Medicine i baze naučnih publikacija. Primeri navođenja publikacija (članaka, knjiga i drugih monografija, elektronskog, neobjavljenog i drugog objavljenog materijala) mogu se pronaći na internet-stranici http://www.nlm.nih.gov/bsd/uniform_requirements.html. Prilikom navođenja literature veoma je važno pridržavati se pomenutog standarda, jer je to jedan od najbitnijih faktora za indeksiranje prilikom klasifikacije naučnih časopisa.

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Za sve dodatne informacije, molimo da se obratite na dole navedene adrese i broj telefona:

ADRESA:
Srpsko lekarsko društvo
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INSTRUCTIONS FOR AUTHORS

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