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Contents / Sadržaj

Svaki novi dan je
ili nagrada ili kazna
za ono što smo juče uradili.
Duško Radović

U ovim komentarima pokušavam da oslikam našu realnost i probleme u kulturi, nauci i obrazovanju tumačeći ih aktuelnim društvenim kontekstom.

Ali tamo gde je politika „sve“, briga o nauci i obrazovanju tek „incident'“, tamo gde je kritička misao „izopštena“ iz naučnih (ali i svih drugih) segmenata života, tamo gde „sadržajna bezidejnost“ dominira društvom, bolje sutra je kao život tokom velikih pandemija (pun neizvesnosti i straha za budućnost).

Našu budućnost najbolje objašnjava citat i misao sa početka, uvek aktuelnog tumača naše svakodnevice, čija je mudrost oblikovala kulturu, a hrabrost, pamet i vera stanje svesti jednog vremena i jednog sistema.

U vremenu kada se čitav svet suočava sa pandemijom neviđenih razmera i kada je čovečanstvo ugroženo nevidljivim neprijateljem (virusom korona), naš društveni ambijent otvara mnoga pitanja, ali istovremeno „ne nudi“ prave odgovore na izazove sadašnjeg trenutka.

Najvažnije pitanje i sigurno najteži odgovor je kako „kontaminiran“ životni ambijent, koji se bazira na „izvitoperenom“ moralnom kodeksu, na apsurdima, neznanju i verbalnoj agresiji, „preokrenuti“ u posve drugačiji kontekst. Kako eliminisati govor mržnje i bahatosti, kako „isključiti“ antiintelektualizam kao stanje svesti, kako hipokriziju i laž obući u pristojno „ruho“ normalnosti – pitanje je svih pitanja u ovom momentu. U svetu u kojem živimo istina i znanje su na „stranputici“ i često „izopšteni“ iz normalnog.

A da li je lako u ovakvim okolnostima izaći na pravi put?

Naravno da nije. Danas samo plaćamo cenu neznanju i neistinama koje izviru iz brojnih „medijskih izvora“ i koje su postale prihvatljiv standard ponašanja. „Šminkanjem sramote“ i pristajanjem na laži naša stvarnost je „izletela“ na pogrešan kolosek. A da bi se zaustavila „lokomotiva besmisla“, treba valorizovati istinu, znanje i moralna načela kao najpouzdaniji „izvor“ za preokret.

Protagonisti društvene stvarnosti u teškim vremenima moraju ovakvu „civilizacijsku inverziju“ vratiti u normalu i pokušati da istinu (umesto laži), argumente (umesto manipulacija), zakon (umesto bezakonja) i znanje (umesto neukosti) uklope u društveni kontekst i blatu „spostvenog besmisla“ dati nadu i vratiti veru u bolje sutra.

U teškim vremenima (kao što je aktuelna pandemija) kada dominira strah i neizvesnost „incidentno“ sejanje istine se teško prima. U duboko kontaminiranom plodnom tlu „zaoranom“ lažima, i surova istina teško može da „proklija“. A izreka kaže: „Kako seješ, tako ćeš i žnjeti“. Ova drevna mudrost upravo daje svekolike odgovore jer potencira da istinu i znanje nikad ne treba „prekrivati“ zarad lične koristi, a uvek se vraća kao bumerang onda kada je to najmanje potrebno.

Borba za istinu je privilegija obrazovanih, slobodnih, hrabrih i nadasve čestitih ljudi. Odgovornost i kompetentnost uz visoke profesionalne standarde jedino mogu dati odgovore na brojne aktuelne probleme naše svakodnevice i ponuditi izvesniji put u budućnost.

Najvažniji kvalitet svakog čoveka je upravo on sam. Lična nadarenost da kritički misli i odgovorno stvara, unutrašnja hrabrost da produbljuje sopstvena znanja i menja „izvitoperenu“ stvarnost istovremeno su i neiscrpna energija za promene i bolje sutra, kome težimo.

Urednički komentar ću završiti onako kako sam i počeo, ali ovog puta citatom uvek aktuelnog tumača naše svakodnevice Ive Andrića: „Život nam vraća samo ono što mi drugima dajemo“ jer jasno i realno oslikava i predstavu i glumce u „teatru“ naših života.

Prof. dr Slavoljub Živković

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Salivary flow rate and oral health status in type 2 diabetics

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SUMMARY

Introduction Decreased salivary flow is frequently associated with numerous diseases such as diabetes mellitus and may lead to numerous oral diseases. The aim of this study was to compare salivary flow rate and oral health status in type 2 diabetics and healthy controls.

Material and methods The study involved 90 patients, divided into the three groups: 30 with well controlled (HbA1c<9%), 30 will poorly controlled (HbA1c≥9%) diabetes and 30 healthy subjects. The following clinical parameters were determined: decayed, missing and filled teeth (DMFT); plaque index (PI), sulcus bleeding index (SBI), probing pocket depth (PPD) and clinical attachment level (CAL). Culture of *Candida spp.* specimens were obtained from tongue dorsum and inoculated into Sabouraud Dextrose Agar. Saliva was collected using "a spit technique".

Results Highest mean of unstimulated salivary flow was in healthy subjects; however significant difference between groups was not observed. Stimulated salivary flow results indicate significant reduction in diabetics as well as significant relation between metabolic control and salivary flow. Unstimulated and stimulated salivary flows were negatively and significantly correlated with periodontal parameters and DMFT.

Conclusion The present findings indicate that decreased salivary flow rate could have a significant impact on oral health status in type 2 diabetics.

Keywords: diabetes mellitus; salivary flow; dental caries; periodontitis; candidiasis

INTRODUCTION

Diabetes mellitus (DM) is metabolic syndrome characterized by chronic hyperglycemia caused by absolute or relative lack of insulin. Chronic hyperglycemia leads to many complications, which underlines the importance of adequate metabolic control. Glucose metabolism control significantly impacts the extent and severity of diseases associated with diabetes including those in oral cavity.

Saliva is biological fluid of fundamental importance for the preservation of oral health. Consequently, decreased salivary flow is frequently associated with numerous oral diseases. There is clear evidence that the prevalence, severity and progression of periodontal disease are higher in diabetics, although mechanisms for such association are not clearly understood [1, 2]. The main etiological factor for the development of periodontal disease is dental plaque (biofilm). Increased amount of plaque in patients with diabetes is a result of increased salivary glucose and decreased salivary secretion. Bacteria from biofilm appear to act directly or indirectly, via cell and humoral components of specific and non-specific host responses [3]. It is well known that periodontal disease can have negative impact on metabolic control and the incidence of diabetes complications, but also the treatment of periodontal disease can favorably affect glycemic regulation [4, 5]. The role of saliva in the maintenance of tooth integrity is also of great importance, as confirmed by Leone et al. [6]. The authors examined the influence of saliva on the occurrence as well as development of dental caries and concluded that the flow of saliva, undoubtedly, presents most important factor for the development of cavities. Due to reduced secretion of saliva, caries lesions develop rapidly affecting even the places that are not caries susceptible. A review of the literature reveals reduced salivary flow rate in patients with diabetes [7], which could explain increased dental caries incidence in this population. Some of the early, nonspecific signs of poorly-controlled diabetes include oral candidiasis and other opportunistic infections [8]. Oral candidiasis is frequently a sign of systemic immunosuppression. In fact, reduced salivary secretion combined with high concentration of glucose in saliva can accelerate the growth of fungi and their adherence to oral mucosal epithelial cells. Oral candidiasis is reported to be more prevalent especially in diabetic denture wearers [9], who do smoke and have poor glycemic control [10].

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Table 1. Sociodemographic and clinical characteristics of patients
Tabela 1. Sociodemografske i kliničke karakteristike pacijenata

Parameter Parametar		HbA1c < 9%	HbA1c ≥ 9%	HS ZO	p
Age (years) ($\bar{X}$± SD) Starost (godine) ($\bar{X}$± SD)		59.50 ± 6.64	60.73 ± 5.89	52.50 ± 6.27	p* < 0.05
Gender (%) Pol (%)	Male Muški	53.3	43.3	30	p*** > 0.05
	Female Ženski	46.7	56.7	70	
Diabetes duration (years) ($\bar{X}$±SD) Trajanje dijabetesa (godine) ($\bar{X}$± SD)		8.57 ± 7.44	9.18 ± 6.97	-	p** > 0.05
HbA1c ($\bar{X}$± SD)		7.67 ± 1.02	10.54 ± 1.59	-	p** < 0.05

*ANOVA; **t-test; ***χ^2 test
HS – healthy subjects
ZO – zdrave osobe

The aim of this study was to compare the salivary flow rate and oral health status in type 2 diabetics and healthy controls.

METHODS

Study design and participants

The study involved 90 patients, 60 with type 2 diabetes and 30 without diabetes (control subjects), aged 45-65 years. With respect to level of HbA1c diabetic subjects were divided into the two groups: 30 better-controlled (HbA1c<9%) and 30 poorly-controlled (HbA1c≥9%), recruited from the Department of Endocrinology University Hospital Foca, Bosnia and Herzegovina. The 9% of HbA1c cut-off point has been suggested to represent an indicator for ineffective blood glucose management in type 2 diabetes [11].The control group consisted of 30 healthy subjects who visited Dental Clinic, Faculty of Medicine Foca, University East Sarajevo, for regular checkups. The study was approved by the institutional committee of ethics (No. 01-8/140) and was conducted in accordance with the Helsinki Declaration of 1975, as revised 1983. The presence of severe mental or systemic disorder, pregnancy, signs or symptoms of AIDS and antibiotic administration during the last 6 months were exclusion criteria in this study. After the study was explained to the patients, written informed consent was obtained from all patients recruited in the study.

Oral clinical examination was performed at the Dental clinic, Faculty of Medicine Foca, University of East Sarajevo, Bosnia and Herzegovina according to WHO criteria [12]. The examination was conducted using a dental mirror and both dental and periodontal probes. The following was determined: decayed, missing and filled teeth (DMFT); plaque index (PI), sulcus bleeding index (SBI), probing pocket depth (PPD) and clinical attachment level (CAL). Periodontal parameters were assessed at four sites around each tooth (mesiobuccal, distobuccal, mesiolingual and distolingual locations). Culture specimens to *Candida spp.* were obtained from dorsum of the tongue using a sterile cotton-tipped swab and inoculated into Sabouraud Dextrose Agar for 48 hours.

All patients were asked to abstain from eating for 2 hours before saliva collection [13]. Both unstimulated and stimulated saliva were collected using "a spit technique". Stimulated saliva was collected using 10% citric acid that was dropped onto the tongue [14]. Each patient was instructed to seat in dental chair with head tilted forward and instructed not to speak, do any head movements or swallow any saliva if present in the mouth during the procedure. After that, the patients were asked to spit in a sterile cup every minute for 5 minutes. Salivary flow was calculated in ml/min.

Statistical analyses

All statistical analyses were performed using SPSS version 19.0 for Windows. Results were expressed as mean values ± standard deviation (SD). The differences between the groups were assessed by ANOVA or chi-square test. Relationships between variables were evaluated by Pearson correlation coefficient. The value of p<0.05 was considered statistically significant.

RESULTS

Sociodemographic and clinical characteristics of all subjects are presented in Table 1. Study included 64 (57.8%) female and 26 (42.2%) male subjects. The mean age of the study population was 57.58±7.19. The healthy subjects had slightly more unstimulated salivary flow rate than well-controlled diabetics, although the difference was not statistically significant. Poorly-controlled diabetics had statistically significantly lower unstimulated and stimulated salivary flow rate than healthy control (Table 2).

Table 3 shows periodontal and dental health in all patients. Diabetic patients had poor periodontal health. A statistically significant difference was observed between the groups. In fact, both poorly and better-controlled diabetics had deeper periodontal pockets, more attachment loss, more bleeding on probing and higher mean value of plaque index than healthy subjects. Type 2 diabetics with poor metabolic control had significantly more decayed teeth and higher mean value of DMFT index than healthy control. Better-controlled diabetics had more decayed

Table 2. Mean values of USFR and SFR in subjects with different metabolic control of diabetes mellitus type 2 and healthy patients
Tabela 2. Srednje vrednosti PNSP i PSP kod ispitanika sa različitom metaboličkom kontrolom dijabetesa melitusa tipa 2 i zdravih pacijenata

	HbA1c < 9%	HbA1c ≥ 9%	HS ZI	p*
USFR (ml/min) (X̄±SD) PNSP (ml/min) (X̄±SD)	0.23 ± 0.14	0.19 ± 0.11	0.30 ± 0.16	1:3 > 0.05 2:3 > 0.05
SFR (ml/min) (X–±SD) PSP (ml/min) (X̄±SD)	0.70 ± 0.34	0.60 ± 0.33	0.85 ± 0.33	1:3 < 0.01 2:3 < 0.01

*ANOVA
USFR – unstimulated salivary flow; SFR – stimulated salivary flow
PNSP – protok nestimulisane pljuvačke; PSP – protok stimulisane pljuvačke

HbA1c – glycosylated hemoglobin
HbA1c – glikozilisani hemoglobin

HS – healthy subjects
ZI – zdravi ispitanici

teeth and higher mean value of DMFT index than healthy control, but statistically significant differences between the groups were not observed. Also, the difference in prevalence of missing and filled teeth was statistically significant between the groups.

Regarding the frequency of oral candidiasis, there was statistically significant difference between poorly controlled diabetics and healthy subjects. No statistically significant difference was found between well-controlled diabetics and healthy subjects in regards to candida isolation (Table 3).

Pearson correlation analyses revealed statistically significant negative correlation between unstimulated salivary flow rate (USFR) as well as stimulated salivary flow rate (SFR) and DMFT index, plaque index (PI), sulcus bleeding index (SBI), clinical attachment loss (CAL) and probing pocket depth (PPD). Negative but non-significant correlation was observed between USFR as well as SFR and oral candidiasis (Table 4).

Table 3. Oral health status of patients
Tabela 3. Stanje oralnog zdravlja ispitanika

	HbA1c<9%	HbA1c≥9%	HS/ZI	p
PI/IP	2.10 ± 0.71	2.64 ± 0.37	1.13 ± 0.68	1:3 < 0.001*
(X̄±SD)				2:3 < 0.001*
SBI/IKG	1.97 ± 0.83	2.79 ± 0.59	0.87 ± 0.77	1:3 < 0.001*
(X̄±SD)				2:3 < 0.001*
CAL/NPE	3.99 ± 1.65	4.74 ± 1.27	1.49 ± 1.32	1:3 < 0.001*
(X̄±SD)				2:3 < 0.001*
PPD/DPDŽ	4.51 ± 1.54	5.85 ± 0.81	3.10 ± 1.11	1:3 < 0.001*
(X̄±SD)				2:3 < 0.001*
Decayed teeth Karijesni zubi	2.10 ± 0.71	2.64 ± 0.37	1.13 ± 0.68	1:3 > 0.05*
(X̄±SD)				2:3 < 0.001*
Missing teeth Izvađeni zubi	1.97 ± 0.83	2.79 ± 0.59	0.87 ± 0.77	1:3 < 0.05*
(X̄±SD)				2:3 < 0.01*
Filled teeth Plombirani zubi	3.99 ± 1.65	4.74 ± 1.27	1.49 ± 1.32	1:3 < 0.05*
(X̄±SD)				2:3 < 0.001*
DMFT KEP	4.51 ± 1.54	5.85 ± 0.81	3.10 ± 1.11	1:3 < 0.05*
(X̄±SD)				2:3 < 0.001*
Positive oral candidiasis Pozitivna oralna kandidijaza	23.40	43.30	10.00	1:3 > 0.05**
(%)				2:3 < 0.05**

*ANOVA; ** χ^2 test

HS – healthy subjects; PI – plaque index; SBI – sulcus bleeding index; CAL – clinical attachment level; PPD – probing pocket depth; DMFT – decayed, missing and filled teeth

ZI – zdravi ispitanici; IP – indeks plaka; IKG – indeks krvarenja gingive; NPE – nivo pripojnog epitela; DPDŽ – dubina parodontalnog džepa; KEP – indeks karioznih, ekstrahovanih i plombiranih zuba

Table 4. Correlation of USFR and SFR with parameters of oral health
Tabela 4. Korelacija PNSP i PSP sa parametrima oralnog zdravlja

	DMFT KEP	PI IP	SBI IKG	CAL NPE	PPD DPDŽ	OC OK
USFR PNSP	-0.405**	-0.423**	-0.407**	-0.391**	-0.311**	-0.062
SFR PSP	-0.329**	-0.472**	-0.385**	-0.475**	-0.271**	-0.134

Pearson correlation; **p < 0.01
Pirsonova korelacija; **p < 0,01

USFR – unstimulated salivary flow; SFR – stimulated salivary flow; DMFT – decayed, missing and filled teeth index; PI – plaque index; SBI – sulcus bleeding index; PPD – probing pocket depth; CAL – clinical attachment level; OC – oral candidiasis

PNSP – protok nestimulisane pljuvačke; PSP – protok stimulisane pljuvačke; KEP – indeks karioznih, ekstrahovanih i plombiranih zuba; IP – indeks plaka, IKG – indeks krvarenja gingive; DPDŽ – dubina parodontalnog džepa; NPE – nivo pripojnog epitela; OK – oralna kandidijaza

DISCUSSION

Several studies reported reduced salivary secretion of both unstimulated and stimulated saliva in diabetics [15, 16]. The pathogenic mechanisms linking diabetes and hyposalivation are not fully understood. Dehydration as a result of prolonged hyperglycemia and resultant polyuria is considered to be the main cause of salivary glands hypofunction. However, dehydration by itself cannot explain functional changes in salivary glands. It is believed that the two most common degenerative complications of diabetes, neuropathy and microangiopathy are crucial for pathologic changes in the structure of salivary glands [17]. Increased concentration of calcium in parotid and submandibular saliva can explain higher prevalence of sialolithiasis in diabetics and consequently oligosialia. Also, influence of glycemic control on salivary flow is still controversy [11, 18]. The present findings show that the mean USFR was highest in healthy subjects, but there was no significant difference between groups. Similar results were presented in the study of Panchbhai et al. [19]. Results of our study indicate statistically significant SFR reduction in diabetics and significant corelation between metabolic control and salivary flow. Our results are in agreement with the study of Chavez et al. that also confirmed this relationship [20].

Recent studies clearly indicated that diabetes is an important risk factor for periodontitis [21, 22]. Diabetes is considered to promote periodontitis through an exaggerated inflammatory response to the periodontal pathogens [23]. Some studies indicate that although diabetes presents a risk factor for periodontitis, periodontitis may, on the other hand, have a negative effect on the metabolic control of diabetes. [4, 5, 24]. Results of our study demonstrated deeper periodontal pockets, more attachment loss, more bleeding on probing and higher mean value of plaque index in poorly-controlled diabetics. These results are in accordance with the findings of Mohamed et al. [25]. Moreover, our findings indicated that both, unstimulated and stimulated salivary flow rate, were negatively and significantly correlated with periodontal parameters. It has been shown that diabetic patients with xerostomia are more susceptible to periodontal infection [26]. Some studies confirmed that periodontal disease was strongly related to salivary flow rate [27].

Previous studies reported contradictory results about relationship between dental caries and diabetes mellitus. Our results showed significantly increased number of decayed teeth in poorly controlled diabetics. Similar results were obtained in study by Bakhshandeh et al. where subjects with better glycemic control had significantly lower number of decayed teeth compared to those with poor glycemic control [28]. In contrast, Syräjlä et al. revealed no association between the HbA1c level and dental caries [29]. Apart from metabolic control of diabetes, development of dental caries is affected by many other factors, among which dental plaque presence is the most important. It is well established that development of caries is a result of metabolic events in dental plaque over time and that it can be increased in terms of impaired function of saliva. High glucose level in saliva and gingival crevicular fluid can cause increase of saliva cariogenic organisms in both supragingival and subgingival plaque in diabetics [30]. Salivary flow reduction leads to impaired antimicrobial actions of saliva as well. In our study, salivary flow rate was negatively and significantly correlated with DMFT, in contrast to the results of study by Karjalainen et al. [31]. Moore et al. reported an association between a low salivary flow rate and slightly increased incidence of dental caries [32]. As a contradictory result, Collin et al. reported higher prevalence of dental caries among those with higher salivary flow rate [33].

According to the literature, prevalence of oral candidiasis was reported to be higher in patients with diabetes type 2 compared to healthy persons [34, 35]. In addition to changes in the composition and quantity of saliva, the presence of infection with *Candida spp.* in type 2 diabetics is also associated with impaired cellular immunity. The high prevalence of *Candida spp.* is especially pronounced in diabetic denture wearers. *Candida spp*. can co-aggregate with bacteria in biofilm of denture surface that than become a reservoir of aforementioned microorganisms with further potential to colonize oral mucosa. It has been estimated that 33. 3% of diabetics in our study were diagnosed with oral candidiasis and that is in accordance with the study by Shenoy et al. [36]. Similar results were reported by Guggenheimer et al. [37]. All those findings support the role of diabetes mellitus as a predisposing factor for increased *Candida spp* colonization of oral mucosa. In accordance with the study of Navazesh et al. [38], results of our study also showed negative correlation between salivary flow rate and oral candidiasis although without statistical significance.

CONCLUSION

In conclusion, within the limitation of the cross-sectional study design, our study demonstrated that decreased salivary flow rate could have a significant impact on oral health status in patients with diabetes mellitus type 2. Due to the importance of saliva in the maintenance of tooth integrity and oral health in general, management of oral diseases in diabetics should include a comprehensive evaluation of salivary function.

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Protok pljuvačke i stanje oralnog zdravlja kod obolelih od dijabetesa tipa 2

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KRATAK SADRŽAJ

Uvod Smanjen protok pljuvačke se često dovodi u vezu sa brojnim oboljenjima, kao što je dijabetes melitus, i može dovesti do brojnih oralnih bolesti.

Cilj ove studije je bio da se uporede protok pljuvačke i status oralnog zdravlja kod obolelih od dijabetesa melitusa tipa 2 i zdravih ispitanika.

Materijal i metode rada Studija je obuhvatila 90 pacijenata, podeljenih u tri grupe: 30 bolje kontrolisanih (HbA1c < 9%), 30 loše kontrolisanih (HbA1c ≥ 9%) dijabetičara i 30 zdravih ispitanika. Određeni su sledeći klinički parametri: kariozni, ekstrahovani i plombirani zubi (KEP); indeks plaka (IP), indeks krvarenja gingive (IKG), dubina parodontalnog džepa (DPDŽ) i nivo pripojnog epitela (NPE). Uzorci kulture *Candida spp.* su prikupljeni sa dorzuma jezika i kultivisani na agaru *Sabouraud Dextrose*. Pljuvačka je prikupljena metodom sukcije i pljuvanja.

Rezultati Najveća prosečna vrednost nestimulisane pljuvačke je bila kod zdravih ispitanika; međutim, značajna razlika između grupa nije primećena. Rezultati protoka stimulisane pljuvačke upućuju na značajno smanjenje kod dijabetičara, kao i značajnu vezu između metaboličke kontrole i protoka pljuvačke. Protok nestimulisane i stimulisane pljuvačke je pokazao značajnu negativnu korelaciju sa parodontalnim parametrima i KEP-om.

Zaključak Rezultati ove studije ukazuju da smanjen protok pljuvačke može imati značajan uticaj na status oralnog zdravlja kod obolelih od dijabetesa tipa 2.

Ključne reči: dijabetes melitus; protok pljuvačke; karijes zuba; parodontopatija; kandidijaza

UVOD

Dijabetes melitus (DM) metabolički je sindrom koji se karakteriše hroničnom hiperglikemijom nastalom zbog relativnog ili apsolutnog nedostatka insulina. Hronična hiperglikemija vodi mnogim komplikacijama, što ukazuje na važnost adekvatne metaboličke kontrole. Kontrola metabolizma glukoze značajno utiče na obim i težinu bolesti udruženih sa dijabetesom, uključujući i stanja u usnoj duplji.

Pljuvačka je biološka tečnost koja je od fundamentalne važnosti za očuvanje oralnog zdravlja. Shodno tome, smanjen protok pljuvačke je često udružen sa pojavom brojnih oralnih oboljenja. Postoje jasni dokazi koji upućuju da su učestalost, težina i napredak parodontopatije više izraženi kod dijabetičara, iako sami mehanizmi te povezanosti nisu potpuno razjašnjeni [1, 2]. Osnovni etiološki faktor za nastanak parodontopatije je dentalni plak (biofilm). Povećana količina plaka kod pacijenata obolelih od dijabetesa je rezultat povišenog nivoa glukoze u pljuvački i smanjene salivarne sekrecije. Bakterije iz biofilma deluju direktno ili indirektno putem celularnih i humoralnih komponenata specifičnog i nespecifičnog odgovora domaćina [3]. Dobro je poznato da parodontopatija može imati negativan uticaj na metaboličku kontrolu i učestalost komplikacija dijabetesa, ali s druge strane, terapija parodontopatije može povoljno uticati na metaboličku kontrolu [4, 5]. Uloga pljuvačke u očuvanju integriteta zuba je od velike važnosti, što je potvrđeno u studiji Leone i sar. [6]. Autori su ispitivali uticaj pljuvačke na nastanak i razvoj karijesa i zaključili da protok pljuvačke nesumnjivo predstavlja važan faktor za razvoj karioznih lezija. Zbog smanjenog protoka pljuvačke, kariozne lezije se razvijaju brzo čak i na mestima koja nisu predilekciona za nastanak karijesa. Pregledom literature uočava se smanjen protok pljuvačke kod obolelih od dijabetesa [7], što može objasniti povećanu učestalost karijesa kod ove populacije. Neki od ranih, nespecifičnih znakova loše kontrolisanog dijabetesa uključuju oralnu kandidijazu i druge oportunističke infekcije [8]. Oralna kandidijaza je često znak sistemske imunsupresije. Zapravo, smanjeno lučenje pljuvačke udruženo sa visokom koncentracijom glukoze u pljuvački može ubrzati rast gljivica i njihovo vezivanje za epitelne ćelije oralne mukoze. Oralna kandidijaza je češća kod dijabetičara koji imaju mobilne protetske nadoknade [9], koji puše i onih koji imaju lošu glikemijsku kontrolu [10]. Cilj ove studije je bio uporediti protok pljuvačke i status oralnog zdravlja kod pacijenata obolelih od dijabetesa tipa 2 i zdravih kontrolnih ispitanika.

MATERIJAL I METODE RADA

Dizajn studije i učesnici

U studiju je uključeno 90 pacijenata, 60 obolelih od dijabetesa tipa 2 i 30 bez dijabetesa (kontrolnih ispitanika) starosti 45–65 godina. U odnosu na nivo HbA1c ispitanici sa dijabetesom su podeljeni na dve grupe: 30 bolje kontrolisanih (HbA1c < 9%) i 30 loše kontrolisanih (HbA1c ≥ 9%), upućenih sa Odeljenja za endokrinologiju Univerzitetske bolnice Foča, Republika Srpska, Bosna i Hercegovina. Presek nivoa HbA1c od 9% je korišćen jer predstavlja indikator neefektivne kontrole glukoze u krvi dijabetesa tipa 2 [11]. Kontrolna grupa je obuhvatila 30 zdravih ispitanika koji su posetili Stomatološku kliniku Medicinskog fakulteta u Foči, Univerziteta u Istočnom Sarajevu radi redovnih kontrolnih pregleda. Studija je odobrena od strane institucionalnog etičkog komiteta (No. 01-8/140) i sprovedena je u skladu sa Helsinškom deklaracijom iz 1975, revidiranom 1983. Prisustvo teških mentalnih ili sistemskih poremećaja, trudnoća, znaci ili simptomi AIDS-a i primena antibiotika tokom poslednjih šest meseci su bili kriterijumi za isključenje u ovoj studiji.

Nakon što je studija objašnjena pacijentima, pacijenti uključeni u ovo istraživanje su potpisali saglasnost za učešće u studiji.

Oralni klinički pregled je obavljen na Stomatološkoj klinici Medicinskog fakulteta u Foči, Univerziteta u Istočnom Sarajevu, Bosna i Hercegovina, u skladu sa kriterijumima SZO [12]. Pregled je obavljen uz korišćenje stomatološkog ogledalca kao i obe, i stomatološke i parodontalne, sonde. Određeni su sledeći parametri: kariozni, ekstrahovani i plombirani zubi (KEP); indeks plaka (IP), indeks krvarenja gingive (IKG), dubina parodontalnog džepa (DPDŽ) i nivo pripojnog epitela (NPE). Parodontalni parametri su procenjeni na četiri mesta oko svakog zuba (meziobukalnoj, distobukalnoj, meziolingvalnoj i distolingvalnoj lokalizaciji). Kulture uzoraka *Candida spp.* su prikupljene sa dorzuma jezika upotrebom sterilnog štapića sa vrhom obloženim vatom i kultivisane na agar *Sabouraud Dextrose* 48 sati.

Svi pacijenti su zamoljeni da se suzdrže od jela dva sata pre prikupljanja pljuvačke [13]. Obe, i nestimulisana i stimulisana pljuvačka, prikupljene su metodom sukcije i pljuvanja. Stimulisana pljuvačka je prikupljena posle aplikovanja 10% limunske kiseline na jezik [14]. Svaki pacijent je upućen da sedne na stomatološku stolicu sa glavom nagnutom napred, da ne priča, ne čini nikakve pokrete glavom, niti da guta pljuvačku prisutnu u ustima tokom procedure. Posle toga, pacijenti su zamoljeni da pljuju u sterilnu čašu svake minute tokom pet minuta. Protok pljuvačke je meren u ml/min.

Statistička analiza

Statistička analiza je izvedena u verziji SPSS 19.0 za Windows. Rezultati su izraženi kao srednje vrednosti ± standardna devijacija (SD). Razlike između grupa su procenjene sa testovima ANOVA ili hi-kvadrat. Veze između varijabli su procenjene Pirsonovim koeficijentom korelacije. Vrednost $p < 0{,}05$ je smatrana statistički značajnom.

REZULTATI

Sociodemografske i kliničke karakteristike svih ispitanika su predstavljene u Tabeli 1. Studija je obuhvatila 64 (57,8%) ženska i 26 (42,2%) muških ispitanika. Srednja vrednost starosti populacije studije je bila 57,58 ± 7,19.

Zdravi ispitanici su imali nešto veći protok nestimulisane pljuvačke nego dobro kontrolisani dijabetičari, iako razlika nije bila statistički značajna. Loše kontrolisani dijabetičari su imali značajno niži protok nestimulisane i stimulisane pljuvačke nego zdrave kontrole (Tabela 2).

Tabela 3 pokazuje parodontalno i dentalno zdravlje kod svih pacijenata. Pacijenti sa dijabetesom su imali lošije parodontalno zdravlje. Između grupa je primećena statistički značajna razlika. Međutim, i loše i dobro kontrolisani dijabetičari su imali dublje parodontalne džepove, veći nivo pripojnog epitela, izraženije krvarenje na sondiranje i veće vrednosti indeksa plaka od zdravih kontrolisanih. Bolesnici sa dijabetesom tipa 2 i lošom metaboličkom kontrolom su imali značajno više karioznih zuba i veće vrednosti indeksa KEP od zdravih ispitanika. Dobro kontrolisani dijabetičari su imali više karioznih zuba i veće vrednosti indeksa KEP od zdravih ispitanika, ali nisu primećene statistički značajne razlike između grupa. Takođe, razlika u učestalosti ekstrahovanih i plombiranih zuba je bila statistički značajna između grupa.

Posmatrajući učestalost oralne kandidijaze, uočena je statistički značajna razlika između loše kontrolisanih dijabetičara i zdravih ispitanika. Statistički značajna razlika nije nađena između dobro kontrolisanih dijabetičara i zdravih ispitanika u odnosu na izolaciju kandide (Tabela 3).

Analiza Pirsonove korelacije je otkrila statistički značajnu negativnu korelaciju između PNSP, kao i PSP i indeksa KEP, indeksa plaka (IP), indeksa krvarenja gingive (IKG), nivoa pripojnog epitela (NPE) i dubine parodontalnog džepa (DPDŽ). Negativna korelacija je uočena između PNSP, kao i PSP i oralne kandidijaze, ali nije bila statistički značajna (Tabela 4).

DISKUSIJA

Nekoliko studija je objavilo prisustvo smanjene sekrecije i nestimulisane i stimulisane pljuvake kod dijabetičara [15, 16]. Patološki mehanizmi koji povezuju dijabetes i hiposalivaciju nisu potpuno razjašnjeni. Dehidratacija koja nastaje kao rezultat produžene hiperglikemije i posledična poliurija se smatraju glavnim uzrokom smanjene funkcije pljuvačnih žlezda. Međutim, dehidratacija sama po sebi ne može objasniti funkcionalne promene u pljuvačnim žlezdama. Veruje se da su dve najčešće degenerativne komplikacije dijabetesa, neuropatija i mikroangiopatija, od presudnog značaja za patološke promene u strukturi pljuvačnih žlezda [17]. Povećana koncentracija kalcijuma u parotidnoj i submandibularnoj pljuvački može objasniti veću učestalost sijalolitijaze kod dijabetičara i posledičnu oligosijaliju. Takođe, uticaj glikemijske kontrole je još uvek nerazjašnjen [11, 18]. Rezultati ove studije pokazuju da je vrednost nivoa nestimulisane pljuvačke bila najveća kod zdravih ispitanika, ali značajna razlika između grupa nije primećena. Slične rezultate su u svojoj studiji objavili Panchbhai i sar. [19]. Rezultati naše studije pokazuju statistički značajno smanjenje protoka stimulisane pljuvačke kod dijabetičara i značajnu vezu između metaboličke kontrole i protoka pljuvačke. Naši rezultati su u skladu sa rezultatima studije koju su objavili Chavez i sar., koji takođe potvrđuju ovaj odnos [20].

Nedavne studije nedvosmisleno upućuju na to da je dijabetes važan faktor rizika u nastanku parodontopatije [21, 22]. Smatra se da dijabetes doprinosi razvoju parodontopatije kroz izražen inflamatorni odgovor na parodontalne patogene [23]. Neke studije upućuju na to da, iako dijabetes predstavlja faktor rizika za parodontopatiju, parodontopatija može, s druge strane, imati negativan uticaj na metaboličku kontrolu dijabetesa [4, 5, 24]. Rezultati naše studije pokazuju dublje parodontalne džepove, veći nivo pripojnog epitela, izraženije krvarenje na sondiranje i veće srednje vrednosti indeksa plaka kod loše kontolisanih dijabetičara. Ovi rezultati su u skladu sa navodima Mohameda i sar. [25]. Nadalje, naši rezultati upućuju da su oba, PNSP i PSP, u negativnoj i značajnoj korelaciji sa parodontalnim parametrima. Pokazalo se da su bolesnici oboleli od dijabetesa koji imaju kserostomiju podložniji parodontopatiji [26]. Neke studije potvrđuju da je parodontopatija snažno povezana sa protokom pljuvačke [27].

Prethodne studije izveštavaju kotradiktorne rezultate o vezi odnosa zubnog karijesa i dijabetesa melitusa. Rezultati naše studije su pokazali značajno povećan broj karioznih zuba kod loše kontrolisanih dijabetičara. Slične rezultate su prikazali Bakhshandeh i sar. u svojoj studiji, gde su ispitanici sa boljom glikemijskom kontrolom imali manje karioznih zuba u poređenju sa ispitanicima sa lošom glikemijskom kontrolom [28]. Suprotno navedenom, Syräjlä i sar. nisu našli povezanost između nivoa HbA1c i zubnog karijesa [29]. Pored metaboličke kontrole dijabetesa, na razvoj karijesa utiču i mnogi drugi faktori, od kojih prisustvo dentalnog plaka ima najveći značaj. Poznato je da je razvoj karijesa posledica metaboličkih dešavanja u dentalnom plaku u funkciji vremena i da može biti povećan u uslovima poremećene funkcije pljuvačke. Visoki nivoi glukoze u pljuvački i gingivalnoj tečnosti mogu dovesti do povećanja salivarnih kariogenih mikroorganizama u supragingivalnom i subgingivalnom plaku kod dijabetičara [30]. Smanjenje protoka pljuvačke takođe vodi ka slabljenju antimikrobne aktivnosti pljuvačke. U našoj studiji protok pljuvačke je bio u negativnoj i značajnoj korelaciji sa KEP-om, nasuprot rezultatima koje su u svojoj studiji prikazali Karjalainen i sar. [31]. Moore i sar. su u svojoj studiji objavili vezu između slabijeg protoka pljuvačke i neznatno povećane učestalosti karijesa [32]. Suprotno tome, Collin i sar. su objavili veću učestalost karijesa među ispitanicima sa većim protokom pljuvačke [33].

Prema navodima iz literature, učestalost oralne kandidijaze je veća kod pacijenata obolelih od dijabetesa tipa 2 u poređenju sa zdravim ispitanicima [34, 35]. Uz promene u sastavu i količini pljuvačke, prisustvo infekcije gljivicama iz roda kandida kod obolelih od dijabetesa tipa 2 dovodi se u vezu sa poremećenim celularnim imunitetom. Velika učestalost *Candida spp.* je posebno izražena kod dijabetičara koji nose mobilne protetske nadoknade. *Candida spp*. može koegzistirati sa bakterijama iz biofilma na površini proteza, koje tako postaju rezervoar gorepomenutih mikroorganizama sa daljim potencijalom za koloniziranje oralne mukoze. Oralna kandidijaza je potvrđena kod 33,3% dijabetičara naše studije, što je u skladu sa navodima koje u svojoj studiji daju Shenoy i sar. [36]. Slične rezultate su objavili Guggenheimer i sar. u svojoj studiji [37]. Svi ovi navodi podržavaju ulogu dijabetesa melitusa kao predisponirajućeg faktora za povećanu kolonizaciju oralne mukoze gljivicama iz roda kandida. Kao što su objavili Navazesh i sar. [38], rezultati i naše studije su pokazali negativnu korelaciju između protoka pljuvačke i oralne kandidijaze, iako bez statističke značajnosti.

ZAKLJUČAK

U zaključku, u okviru ograničenja dizajna studije preseka, naša studija ukazuje da smanjen protok pljuvačke može imati značajan uticaj na status oralnog zdravlja kod bolesnika obolelih od dijabetesa melitusa tipa 2. Zbog važnosti pljuvačke u očuvanju integriteta zuba i oralnog zdravlja uopšte, tretman oralnih bolesti kod dijabetičara bi trebalo da uključi i sveobuhvatnu evaluaciju salivarne funkcije.

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Sem analysis of working surface in new manual endodontic instruments

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SUMMARY

Introduction The aim of this study was to analyze working surfaces of new hand endodontic instruments and to check possible existence of dirt or defects on working surface that resulted from manufacturing process using SEM.

Material and methods Three sets of new hand instruments: K-File (KF), (18 instruments) (Dentsply Maillefer, Switzerland) and Hedstorm Files (HF), (18 instruments) (SybronEndo Co, USA) were used. Instruments were analyzed by SEM method at 170× magnification while semi-quantitative EDS analysis was used to determine chemical composition of dirt particles. Fisher test ($p < 0.05$) was applied in statistical analysis.

Results Results showed that none of the instruments was defect-free. The most common defects were metal strips and fretting noticed at the surface of all tested instruments. Debris was present on all KF (100% in apical and middle third) and HF (56% in apical and 56% in middle third) instruments. Pitting was noticed in KF (33% in apical and 39% in middle third) and HF (11% in apical and 6% in middle third) instruments. Corrosion of working surface, metal flash and disruption of cutting edge were marked only in KF group.

Conclusion Manufacturing defects were noticed in all instruments and the most common type of irregularity were metal strips and fretting.

Keywords: stainless-steel hand endodontic instruments; defects SEM; debris

INTRODUCTION

Chemomechanical root canal treatment is usually performed with hand endodontic instruments (made of stainless steel or Ni-Ti alloy) or engine-driven Ni-Ti rotary endodontic instruments with adequate and abundant irrigation of canal system [1]. Despite the fact that Ni-Ti rotary instruments have become widely used in endodontic practice due to its efficacy when compared to stainless steel hand instruments (speed, simplicity and instrumentation uniformity), hand instruments are still used in standard endodontic procedure [2, 3]. Most manufacturers recommend a combination of hand stainless steel instruments and Ni-Ti rotary instruments when establishing initial patency for curved and / or narrow canals [4]. Stainless steel hand files are much better choice than Ni-Ti rotary instruments for preparation of initial patency mainly due to better tactile sensation of complicated canal morphology, low fracture risk and economic efficiency. Flaws of hand instruments are greater fatigue of practitioner, longer procedure and more frequent instrumentation mistakes (irregularity in intracanal dentin, apical transportation, over-extension, apical perforation, ledging, zipping and canal obtrusion and apical blockage by dentine debris) [2]. Canal preparation with Ni-Ti endodontic instruments secures more appropriate canal shape with less frequent faults caused by instrumentation when compared to hand instruments. Nonetheless, complications such as unexpected deformation and fracture are more frequent [5]. Great number of studies analyzed percentage of fracture incidence of rotary Ni-Ti instruments and their results vary from 0.3% to 23% (Sattapan et al. 2000 [6], Ankrum et al. 2004 [7], Spili et al. 2005 [8], Iqbal et al. 2006 [9], Wu et al. 2011 [10]) while fracture incidence in stainless steel instruments ranges from 0.25% to 6% [8, 11, 12, 13]. Fractured instrument is a serious threat to treatment, irrigation and filling of root canals and it may significantly affect the outcome of endodontic therapy [14].

The most common reason for avoiding engine-driven endodontic treatment in dental practice is higher frequency and unpredictability of rotary Ni-Ti instrument fractures. On the top of that, root canal anatomy itself might make engine-driven treatment even more difficult. This relates to mandibular incisors (due to mesiodistal flattened root canals), very wide canals and apical deltas. In all these situations, hand endodontic technique prevails over engine-driven [15].

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Table 1. Chemical analysis of points from Picture 1a (analysis normalized at 100wt%)
Tabela 1. Hemijska analiza u tačkama prikazanim na Slici 1a (analize normalizovane na 100 wt%)

Spectrum Spektrum	C	N	O	Na	Si	S	Cl	K	Cr	Mn	Fe	Ni	Cu	Total Ukupno
Spectrum 1 Spektrum 1	7.15				0.47				18.03	1.16	65.93	7.27		100.00
Spectrum 2 Spektrum 2	11.03				0.57				17.18	1.08	62.79	7.35		100.00
Spectrum 3 Spektrum 3	34.71	4.36	13.45	1.57	0.25	0.26	0.68	0.35	9.11	0.44	31.19	3.19	0.43	100.00
Max.	34.71	4.36	13.45	1.57	0.57	0.26	0.68	0.35	18.03	1.16	65.93	7.35	0.43	
Min.	7.15	4.36	13.45	1.57	0.25	0.26	0.68	0.35	9.11	0.44	31.19	3.19	0.43	

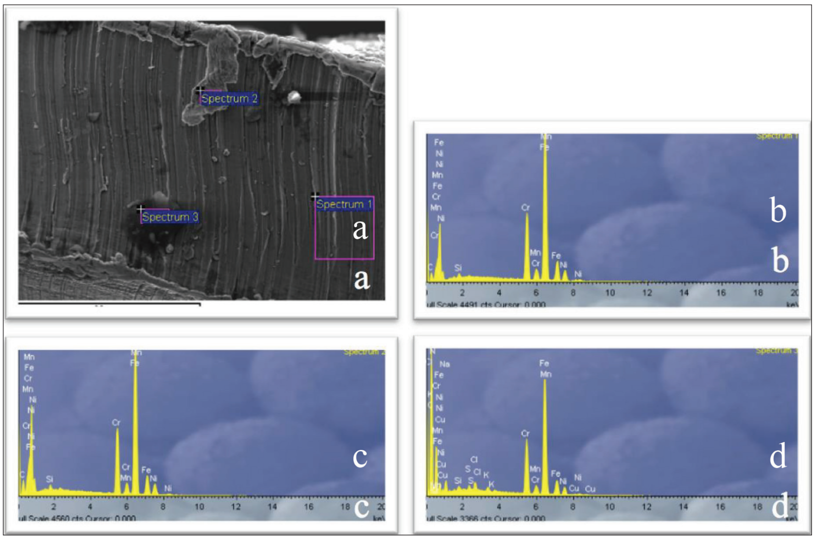


Figure 1. EDS analysis of KF instruments (ISO 20): a) SE image with marked points which were analyzed (Spectrum 1–3); b) Diagram of EDS analysis Spectrum 1; c) Diagram of EDS analysis Spectrum 2; d) Diagram of EDS analysis Spectrum 3
Slika 1. EDS analiza instrumenta KF (ISO 20): a) SE snimak sa obeleženim tačkama u kojima su rađene analize (Spektrum 1–3); b) Dijagram EDS analize Spektar 1; c) Dijagram EDS analize Spektar 2; d) Dijagram EDS analize Spektar 3

The majority of new endodontic instruments are not sterile. Various metal debris and dirt of organic and non-organic origin can be found on their surface. Stainless steel endodontic instruments manufacture process might cause metal strips which, to some extent, stay on the surface of endodontic instruments working parts [16].

It is confirmed that endodontic instruments, due to their design and different manufacture process, may significantly impact deformation and fracture during root canal instrumentation [7–10].

Stainless steel endodontic instruments are usually made by twisting of various steel profiles around longitudinal axis thus forming blades from vertical wire edges [17]. Irregularities at the instrument surface might increase its vulnerability to fracture. Surface defects seem to be points of tension and can initiate and spread cracks thus potentially highly contributing to possible fractures during instrument activation [18].

The aim of this study was to analyze working surfaces of new hand endodontic instruments and check possible existence of manufacture dirt or defects on working surface using SEM.

MATERIAL AND METHOD

This research was performed on three basic sets (each set consisting of 6 instruments) of new hand stainless steel instruments: K-File, KF (Dentsply Maillefer, Switzerland) and Hedstorm Files, HF (SybronEndo Co, USA). SEM analysis was performed in SEM-EDS laboratory of the Faculty of Mining and Geology, University of Belgrade (JEOL JSM-6610LV, Japan), without any prior preparation.

Microphotographs were taken at 170× magnification but in case of noticeable changes on the instruments and for the purpose of more detailed analysis, they were magnified up to 800×. Apical and middle third of the files were analyzed from two different directions and each side of instrument was analyzed by three images.

Analysis of different irregularities and faults during manufacturing process implied the criteria proposed by Eggert et al. [19]: Score 1 – No visible defect, Score 2 – Pitting, Score 3 – Fretting, Score 4 – Micro fractures, Score 5 – Complete fracture, Score 6 – Metal flash, Score 7 – Metal strips, Score 8 – Blunt cutting edge, Score 9 – Disruption of cutting edge, Score 10 – Corrosion, Score 11 – Debris. Qualitative analysis was performed though obtained results were not quantified. Semi-quantitative EDS analysis determined chemical composition of found dirt. Fisher test ($p < 0.05$) was used for statistical analysis.

RESULTS

Obtained results were presented in Tables 1–5, Graphs 1 and 2 and Pictures 1–8.

Analysis of SEM microphotographs determined contamination of working surface of tested instruments and subsequent EDS analysis defined its chemical composition. Thus, we divided instruments into two types – instruments contaminated with metal strips and contaminated with debris.

EDS analysis of KF instrument (ISO 20) (Figure 1, Table 1) for Spectrum 1 was performed on a clean part of

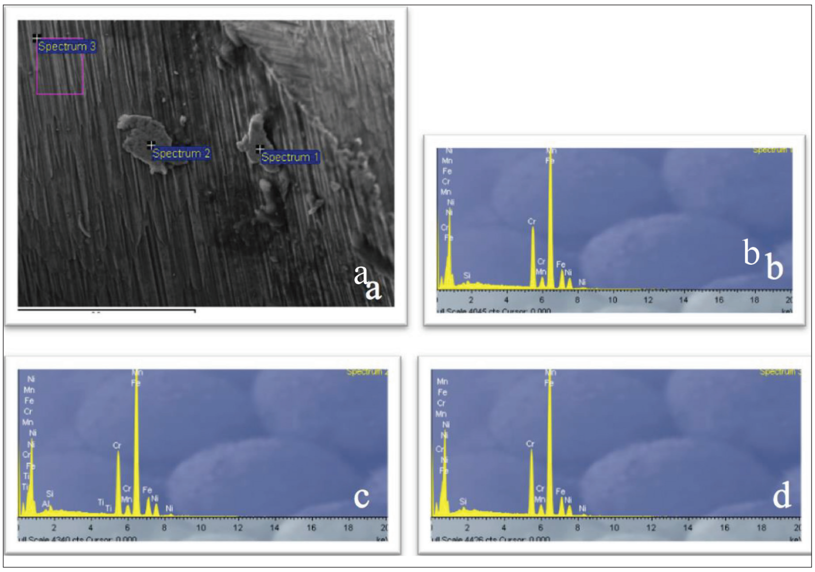


Figure 2. EDS analysis of HF instrument (ISO 25): a) SE image with marked points which were analyzed (Spectrum 1–3); b) Diagram of EDS analysis Spectrum 1; c) Diagram of EDS analysis Spectrum 2; d) Diagram of EDS analysis Spectrum 3
Slika 2. EDS analiza instrumenta HF (ISO 25): a) SE snimak sa obeleženim tačkama u kojima su rađene analize (Spektrum 1–3); b) Dijagram EDS analize Spektar 1; c) Dijagram EDS analize Spektar 2; d) Dijagram EDS analize Spektar 3

Table 2. Chemical analysis of points from Picture 2a (analysis normalized at 100wt%)
Tabela 2. Hemijska analiza u tačkama prikazanim na Slici 2a (analize normalizovane na 100 wt%)

Spectrum Spektrum	Al	Si	Ti	Cr	Mn	Fe	Ni	Total Ukupno
Spectrum 1 Spektrum 1		0.60		18.76	1.44	71.12	8.08	100.00
Spectrum 2 Spektrum 2	0.39	0.88	0.30	18.78	1.20	69.53	8.92	100.00
Spectrum 3 Spektrum 3		0.57		18.95	1.39	70.78	8.30	100.00
Max.	0.39	0.88	0.30	18.95	1.44	71.12	8.92	
Min.	0.39	0.57	0.30	18.76	1.20	69.53	8.08	

Table 3. Presence of defects and dirt on working parts of tested instruments
Tabela 3. Prisustvo defekata i nečistoća na radnom delu testiranih instrumenata

Type of defect Tip defekta	KF		HF	
	Apical third Apikalna trećina	Middle third Srednja trećina	Apical third Apikalna trećina	Middle third Srednja trećina
Pitting JaMIČasta udubljenja	33%	39%	11%	6%
Fretting Žlebovi	100%	100%	100%	100%
Metal flash Metalne uglačane površine	11%	6%	/	/
Metal strips Metalni opiljci	100%	100%	100%	100%
Disruption of cutting edge Prekid sečivne ivice	6%	/	/	/
Corrosion Korozija	11%	17%	/	/
Debris Debris	100%	100%	56%	56%

instrument surface, while Spectrums 2 and 3 were performed on a contaminated surface. The most abundant element in the analysis of Spectrums 1 and 2 was iron with maximum abundance of 65.93 mas%. Apart from carbon (maximum 11.03 mas%), there were also silicon, chrome, manganese and nickel in different mass concentration. Analysis of Spectrum 2 indicates contamination with metal strips. Carbon (34.71 mas%) and iron (31.19 mas%) were the most abundant elements in Spectrum 3. Oxygen was also detected (13.45 mas%) as well as chrome, nitrogen, nickel, sodium, chlorine, copper, potassium and sulfur but to a lesser extent. Results from Spectrum 3 show contamination with organic debris.

EDS analysis of HF instrument (ISO 25) (Picture 2, Table 2) for Spectrum 1 was performed on a clean part of instrument surface, while Spectrum 2 and 3 were performed on a contaminated surface. The most abundant element in the analysis of all three Spectrums was iron with maximum presence of 71.12 mas% and minimum of 69.53 mas%. Aluminum, silicon, titanium, chrome, manganese and nickel were detected in different mass concentrations. EDS analysis of Spectrums 2 and 3 showed contamination with metal strips.

All tested instruments had some kind of defect on their working surface. New hand instruments did not show any signs of micro fractures, fractures or blunt cutting edges (Tables 3, 4, 5). The most frequent defect types were metal strips and fretting which were detected on the surface of all tested instruments (in 100% of cases) (Tables 3, 4, 5, Figure 3). Fisher test did not show any statistically significant differences between tested instruments at their ends or apical and middle thirds.

Debris was noticed on all KF instruments (100% apical and middle third) and half of the HF instruments (56% apical and middle third) (Table 3, Graph 1, Figure 4 and 5). After the comparison of debris on different hand instruments (KF and HF), statistically significant difference was noted ($p = 0.0029$ in apical and $p = 0,0029$ in middle third).

The presence of pitting was noted in apical and middle third of KF instruments (33% apical and 39% middle third) and HF instruments (11% apical and 6% middle third) (Tables 3, 4, 5, Graph 2, Picture 6). After the comparison of pitting on different hand instruments (KF and HF), both apical and middle thirds showed statistically significant difference ($p = 0.0051$ end) ($p = 0,0045$ middle).

Table 4. Presence of defects and dirt on working surfaces of KF instruments
Tabela 4. Prisustvo defekata i nečistoća na radnom delu testiranih KF instrumenata

# ISO	First group PRVA GRUPA		Second group Druga GRUPA		Third group treća GRUPA	
	Apical third Apikalna trećina	Middle third Srednja trećina	Apical third Apikalna trećina	Middle third Srednja trećina	Apical third Apikalna trećina	Middle third Srednja trećina
15	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal flash Metalne uglačane površine				Metal flash Metalne uglačane površine	Metal flash Metalne uglačane površine
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Disruption Prekid					
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
20	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja
	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
				Corrosion Korozija		
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
25	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci strips	Metal strips Metalni opiljci strips	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Corrosion Korozija	Corrosion Korozija				
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
30	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
			Corrosion Korozija			
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
35	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja
	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
40		Pitting Jamičasta udubljenja				
	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri

Table 5. Presence of defects and dirt on working surface of tested HF instruments
Tabela 5. Prisustvo defekata i nečistoća na radnom delu testiranih HF instrumenata

# iso	First group PRVA GRUPA		Second group Druga GRUPA		Third group treća GRUPA	
	Apical third Apikalna trećina	**Middle third Srednja trećina**	**Apical third Apikalna trećina**	**Middle third Srednja trećina**	**Apical third Apikalna trećina**	**Middle third Srednja trećina**
15	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
					Pitting	
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
20	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
25	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
					Pitting Jamičasta udubljenja	Pitting Jamičasta udubljenja
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
30	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
			Corrosion Korozija			
	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri	Debris Debri
35	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
40	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi	Fretting Žlebovi
	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci	Metal strips Metalni opiljci
					Debris Debri	Debris Debri

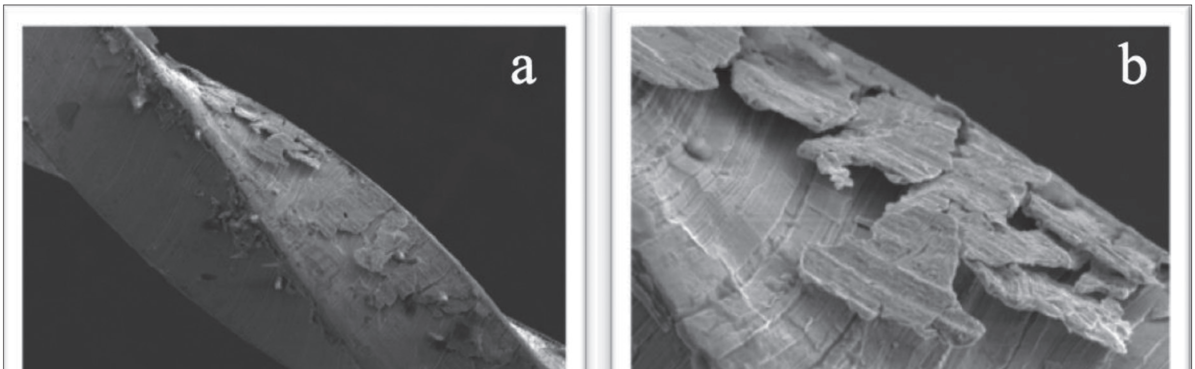
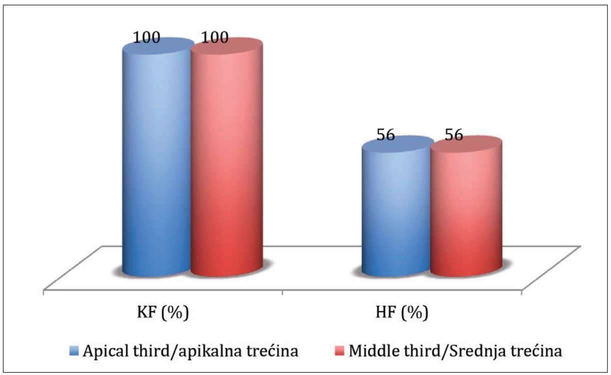
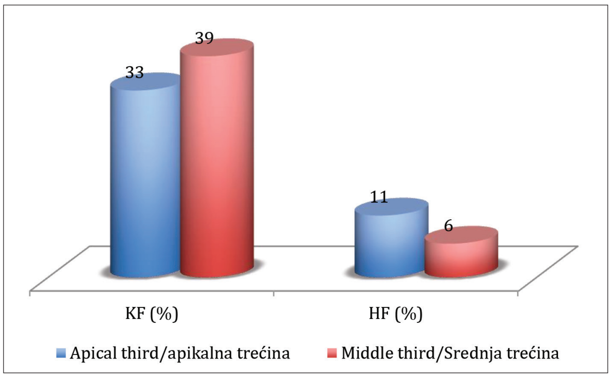


Figure 3. SEM analysis of working surface (middle third) of KF instruments with metal strips and fretting: a) magnification 170×, b) magnification 800×
Slika 3. SEM analiza radnog dela (srednja trećina) instrumenta KF sa metalnim opiljcima i žljebovima: a) uvećanje 170×, b) uvećanje 800×



Graph 1. Presence of debris on working surface of tested instruments
Grafikon 1. Prisustvo debrisa na radnom delu testiranih instrumenata



Graph 2. The presence of pitting on working surface of tested instruments
Grafikon 2. Prisustvo jamičastih udubljenja na radnom delu testiranih instrumenata

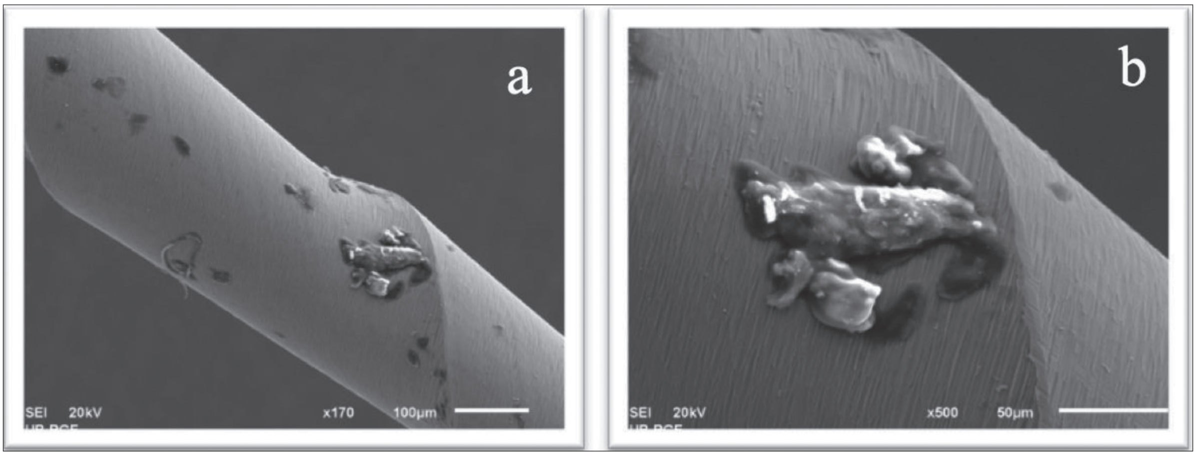


Figure 4. SEM of middle third of KF 20 instrument with debris: a) magnification 170×, b) magnification 500×
Slika 4. SEM srednje trećine instrumenta HF 20 sa debrisom: a) uvećanje 170×, b) uvećanje 500×

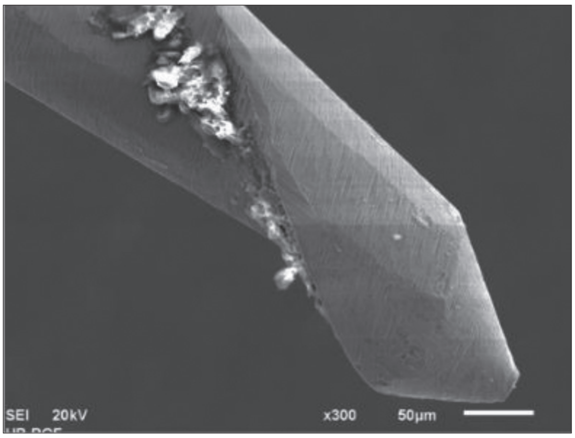


Figure 5. SEM of apical third of KF 25 instrument with debris (magnification 300×)
Slika 5. SEM apikalne trećine instrumenta KF 25 sa debrisom (uvećanje 300×)

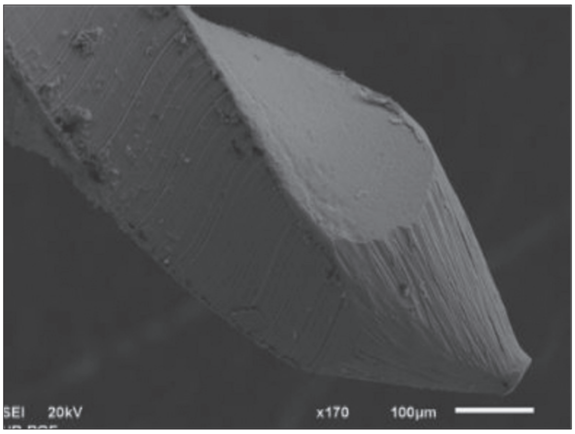


Figure 6. SEM of apical third of HF 35 instrument with pitting
Slika 6. SEM apikalne trećine instrumenta HF 35 sa jamičastim udubljenjima

Metal flash, corrosion of working surface and disruption of cutting edge were detected only in KF instruments (corrosion 11% apical and 17 % in middle third; metal flash surface 11% apical, 6% in middle third; disruption of cutting edge 2% apical) (Table 3, 4, 5, Figures 7 and 8).

In HF instrument group, there were no corrosion, metal flash or disruption of cutting edge.

DISCUSSION

Above all, success of endodontic therapy depends on proper instrumentation i.e. biomechanical treatment and tridimensional hermetic root canal obturation.

Design of endodontic instruments, their metallurgical characteristics and surface may complicate endodontic treatment in case instrument deforms or fractures during

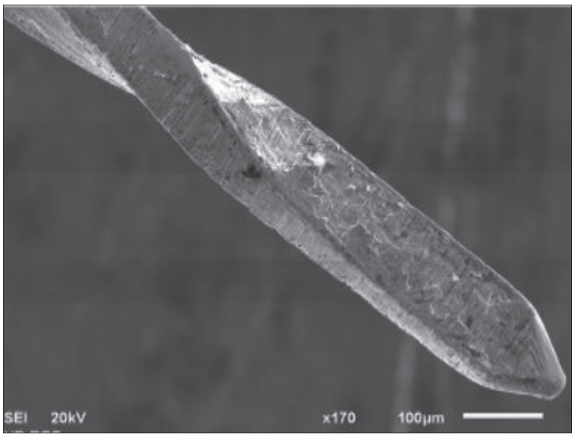


Figure 7. SEM of apical third in KF15 instrument with metal flash and disruption of cutting edge
Slika 7. SEM apikalne trećine instrumenta KF15 sa metalnom uglačanošću i prekidom sečivne ivice

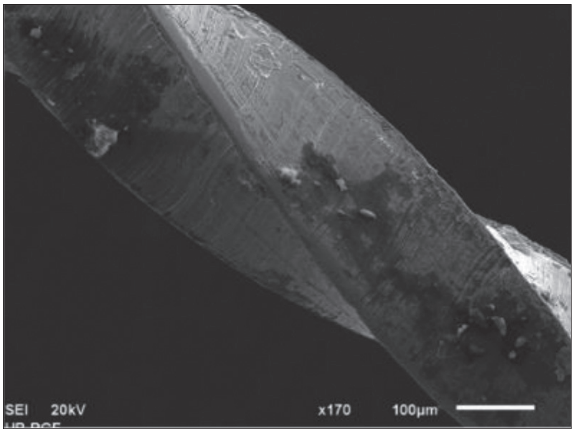


Figure 8. SEM of middle third of KF 25 instrument with corrosion
Slika 8. SEM srednje trećine instrumenta KF 25 na kom se uočava korozija

use. It is proven that manufacturing defects might cause fracture of new instruments even during their first clinical use [20]. During manufacturing process, working surface of instruments, especially its threads, might have residuals of metal strips and organic and non-organic debris which might have infective and non-specific irritating potential [21–24].

Results of this study showed that all analyzed instruments had minimum two and maximum five different defects prior to any use. Such results comply with literature data reporting frequent defects of endodontic instruments during their manufacturing process [5, 16, 19, 25, 26]. The most common defects on working surfaces of new endodontic stainless steel instruments (KF and HF) in our study were fretting and metal strips.

Fretting on working surface of an instrument during the manufacturing process was noticed in all tested hand stainless steel instruments. Conventional manufacture of instruments by twisting the wire (of quadrangular profile for K-type file and milling of circular profile for Hedstorm file) causes surface irregularities such as traces of milling and metal flash (especially on blades) which might compromise efficiency of instrument blade and potentially cause problems related to corrosion and fracture [20, 25, 26]. Clinical importance of fretting on instrument surface reflects in its easy screwing (due to friction that is present because of uneven surface) which as a consequence leads to greater incidence of fracture [27]. Greater incidence of HF file fracture is explained with different design of this file which implies different activation in root canal. HF instruments have increased incline of blades compared to the instrument axis (60° and 65°) while KF has significantly smaller angle (25° and 40°), therefore, manipulation must be very careful [28].

Presence of metal strips, shown in all tested groups in 100 percent, just confirms the complexity of endodontic instrument manufacture. This finding complies with the result of Chianella et al. study that confirmed the presence of such contamination in 96.3% of all new tested instruments [28]. This type of defect is very significant since it decreases the blade efficacy. Apart from that, metal strips on active surface of instrument might stick to dentin root canal walls or slip into periapical tissue during instrumentation. Van Eldik reported possible contamination of periapical tissue with metal strips that were transferred by instruments which significantly reduced tissue reparation [29].

Pitting on working surface of instrument was noticed in small percentage of instruments (KF, HF), and it could be explained by specific technological process of manufacturing just like the presence of metal flash and blade damage in KF grupi. Bonetti Filho et al. also draw attention to potential pitting on new instruments [30].

Debris was present in KF tested groups in 100% and HF in 56% (apical and middle) which confirmed that manufacturing clean endodontic instruments was a very complex procedure. As opposed to the study of Lopes et al. which combined acetone and ultrasonic cleaning to obtain clean and dry instruments, this study analyzed the instruments immediately after the removal of their packaging and without any prior preparation [25]. Thus, SEM analysis tested the quality of their final processing and packaging conditions. Remains of grease (used in manufacture process), epithelial cells, hair and parts of fabrics might be found on the surface of new instruments after the manufacturing process and inadequate packaging. This potentially may compromise the success of endodontic treatment. Study of Roth et al. determined biological contamination in 13% of new hand stainless steel endodontic instruments made by different manufacturers thus proving the possibility of new instrument contamination by live microorganisms. (*S. epidermidis*, *Paenibacillus species* and three fungal species) [31].

Problems in manufacturing process might arise due to the quality of wire used, since oxide and carbides particles might be incorporated in alloy during manufacturing, thus creating more brittle zones that represent key points for micro defects development [32]. Corrosion factors (irrigators, disinfects and sterilization solutions) and torsion and cyclic pressure during instrumentation might cause corrosion and further propagation of these defects [32].

Review of EDS analysis showed mass percentage of elements present in stainless steel alloy and exact composition of contamination found on new instrument surface. Great abundance of chrome on spectrum of clean surface (18.03 mas% and 18.76 mas%) and nickel (7.27 mas% and 8.08 mas%) confirms the significance of these elements in improvement of instrument features. This type of alloy provides good mechanical features and is resistant to corrosion. In order to avoid unwanted effects during instrumentation, manufacturers developed new stainless steel alloys which are characterized by greater flexibility. As a result, state of the art ferritic steel has 12–18% of mass share of chrome [30]. Due to great affinity of chrome to bond carbon and create brittle chromium carbide, increase in mass share of carbon leads to decrease in corrosion resistance. In order to prevent unwanted chrome carbide, new alloys are enriched with titanium which has a greater affinity toward carbon that results in stabilization of ferritic steel [30].

CONCLUSION

The results of this study showed that all tested instruments had manufacturing defects (two or more), and that the most common types of defects were metal strips and fretting. Debris on working surface indicated the necessity to sterilize instruments before their first use. These facts could be warning sign to all practitioners to carefully manipulate files even during first use and perform good observation of working surface in order to prevent possible complications during endodontic treatment.

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SEM analiza površine radnog dela novih ručnih endodontskih instrumenata

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KRATAK SADRŽAJ

Uvod Cilj ovog rada je bio da se primenom skenirajuće elektronske mikroskopije analiziraju površine novih ručnih endodontskih instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata na radnom delu.

Materijal i metod U istraživanju su korišćena po tri seta novih ručnih instrumenata: K-File (KF), (18 instrumenata) (Dentsply Maillefer, Switzerland) i Hedstorm Files (HF), (18 instrumenata) (SybronEndo Co, USA). Instrumenti su podvrgnuti SEM analizi sa uvećanjem 170×, a semikvantitativnom EDXS analizom utvrđivan je hemijski sastav nečistoće. Statistička analiza je urađena primenom Fišerovog testa ($p < 0,05$).

Rezultati Rezultati su pokazali da ne postoji nijedan instrument bez defekta. Najučestaliji tip defekta je bilo prisustvo metalnih opiljaka i žlebova, koji su uočeni na površini svih ispitivanih instrumenata. Debri je uočen na svim KF (100% apikalno i u srednjoj trećini) i HF (56% apikalno i 56% u srednjoj trećini). Prisustvo udubljenja zabeleženo je kod KF (33% apikalno i 39% u srednjoj trećini) i HF (11% apikalno i 6% u srednjoj trećini). Korozija radne površine, pojava uglačane površine i prekid sečivne ivice su uočeni samo u grupi KF.

Zaključak Na svim ispitivanim ručnim instrumentima su uočeni proizvodni defekti, a najučestaliji tip nepravilnosti je bilo prisustvo metalnih opiljaka i žlebova.

Ključne reči: čelični ručni endodontski instrumenti; defekti; SEM; debris

UVOD

Hemomehanička obrada kanala se najčešće realizuje ručnim endodontskim instrumentima (od nerđajućeg čelika ili Ni-Ti legure) ili mašinskim Ni-Ti rotirajućim endodontskim instumentima uz adekvatnu i obilnu irigaciju kanalskog sistema [1]. Iako su Ni-Ti rotirajući instrumenti postali deo svakodnevne endodontske prakse zbog svoje veće efikasnosti u odnosu na ručne instrumente od nerđajućeg čelika u gotovo svim aspektima (brzina, jednostavnost i ujednačenost instrumentacije), endodontski instrumenti od nerđajućeg čelika se još uvek koriste u standardnoj endodontskoj proceduri [2, 3]. Većina proizvođača preporučuje kombinovanu upotrebu ručnih instrumenata od nerđajućeg čelika i Ni-Ti rotirajućih instrumenata prilikom uspostavljanja inicijalne prohodnosti za povijene i/ili uske kanale [4]. Prednosti upotrebe ručnih turpija od nerđajućeg čelika u odnosu na Ni-Ti rotirajuće instrumente pri preparaciji primarne prohodnosti uključuju bolji taktilni osećaj komplikovane kanalne morfologije, manji rizik od preloma i ekonomsku isplativost. Nedostaci upotrebe ručnih instrumenata se ogledaju u većem zamoru terapeuta, dužem vremenu rada i češćoj pojavi grešaka tokom instrumentacije (formiranje stepenika na intrakanalnom dentinu, transportacija, tj. izmeštanja (zipa) apeksnog dela, preekstendiranje apeksne matrice, perforacija (probijanje) zida kanala, blokada kanala i prebacivanja detritusa u periapeks, odnosno, njegovo sabijanje u apeksne delte) [2]. Preparacija kanala rotirajućim Ni-Ti endodontskim instrumentima obezbeđuje poželjniji oblik kanala sa manje grešaka pri instrumentaciji u odnosu na ručne instrumente, ali sa češćom komplikacijom u vidu neočekivane deformacije i frakture [5]. Veliki broj studija se bavio procentualnom incidencijom frakture rotirajućih Ni-Ti instrumenata i njihovi rezultati variraju od 0,3% do 23% (Sattapan i saradnici, 2000 [6], Ankrum i saradnici, 2004 [7], Spili i saradnici, 2005 [8], Iqbal i saradnici, 2006 [9], Wu i saradnici, 2011 [10]), dok su stope frakture instrumenata od nerđajućeg čelika u rasponu od 0,25% do 6% [8, 11, 12, 13]. Zalomljen endodontski instrument je ozbiljna smetnja pri obradi, irigaciji i opturaciji kanala korena i može značajno uticati na nepovoljan ishod endodontske terapije [14].

Veća učestalost i nepredvidivost frakture rotirajućih Ni-Ti instrumenata je najčešći razlog izbegavanja mašinske endodontske terapije u stomatološkoj praksi. Osim toga, zatečene karakteristike anatomskog prostora mogu otežati mašinsku preparaciju. To se odnosi na mandibularne sekutiće (zbog mezio-distalno spljoštenih kanala), jako široke kanale i endodontske prostore u vidu delti. U ovim slučajevima je ručna endodontska tehnika efikasnija od mašinske [15].

Većina novih endodontskih instrumenata nije sterilna i na njihovoj površini se mogu naći različiti metalni ostaci, nečistoće, organskog i neorganskog porekla. Proces proizvodnje endodontskih instrumenata od nerđajućeg čelika može dovesti do prisustva sitnih opiljaka –metala koji se u manjoj ili većoj meri zadržavaju na površinama radnih delova endodontskih instrumenata [16].

Potvrđeno je da endodontski istrumenti, zbog svog različitog dizajna i proizvodnog procesa, mogu imati značajan uticaj na pojavu deformacija i fraktura tokom instrumentacije kanala [7–10].

Endodontski instrumenti od nerđajućeg čelika se uglavnom izrađuju postupkom uvrtanja različitih profila žice po uzdužnoj osovini, formirajući sečiva od vertikalnih ivica žice [17]. Prisustvo nepravilnosti na površini instrumenta može povećati njegovu vulnerabilnost na frakturu. Defekti na površini deluju kao tačke koncentracije napona i izazivaju inicijaciju i širenje pukotina, sa velikom mogućnošću pojave frakture tokom aktivacije instrumenta [18].

Cilj ovog rada je bio da se primenom skenirajuće elektronske mikroskopije analiziraju površine novih ručnih endodontskih instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata na radnom delu.

MATERIJAL I METOD

U istraživanju su korišćena po tri osnovna seta (svaki set po šest instrumenata) (15–40) novih ručnih instrumenata od nerđajućeg čelika: K-File, KF (Dentsply Maillefer, Switzerland) i Hedstorm Files, HF (SybronEndo Co, USA). SEM analiza je realizovana u laboratoriji za SEM-EDS Rudarsko-geološkog fakulteta Univerziteta u Beogradu (JEOL JSM-6610LV, Japan), bez ikakve prethodne pripreme instrumenata.

Mikrofotografije su relizovane na uvećanju od 170×, a kod izraženijih promena na instrumentima, radi detaljnije analize, na uvećanju do 800×. Analizirana je apeksna i srednja trećina instrumenta iz dva različita pravca, a svaka strana instrumenta je analizirana sa po tri snimka.

Analiza prisustva različitih nepravilnosti i grešaka tokom procesa izrade je obuhvatila kriterijume koje je predložila Eggert sa saradnicima [19]: ocena 1 – bez vidljivog defekta, ocena 2 – jamičasta udubljenja, ocena 3 – žlebovi, ocena 4 – mikrofrakture, ocena 5 – potpune frakture, ocena 6 – metalna uglačanost, ocena 7 – metalni opiljci, ocena 8 – tupe sečivne ivice, ocena 9 – prekid sečivne ivice, ocena 10 – korozija, ocena 11 – prisustvo debrija. Urađena je kvalitativna analiza ali bez kvantifikovanja dobijenih rezultata. Semikvantitativnom, EDXS analizom utvrđen je hemijski sastav zatečene nečistoće.

Statistička analiza dobijenih rezultata je urađena primenom Fišerovog testa ($p < 0,05$).

REZULTATI

Dobijeni rezultati prikazani su u tabelama 1–5, grafikonima 1 i 2 i slikama 1–8.

Analizom SEM mikrofotografija utvrđeno je postojanje kontaminacije na površini radnog dela ispitivanih instrumenata, a naknadnom EDXS analizom je utvrđen njen hemijski sastav. Na taj način je urađena podela na instrumente kontaminirane metalnim opiljcima i instrumente sa debrisom.

EDXS analiza instrumenta KF (ISO 20) (Slika 1, Tabela 1) za spektar jedan je urađena na čistom delu površine instrumenta, dok je za spektar dva i tri urađena na kontaminiranoj površini. Najzastupljeniji element u analizi prvog i drugog spektra je gvožđe sa maksimalnom zastupljenošću od 65,93 mas%. Pored ugljenika (maksimalno 11,03 mas%), prisutni su bili silicijum, hrom, mangan i nikl u različitim masenim koncentracijama. Analiza za drugi ispitivani spektar ukazuje na kontaminaciju metalnim opiljcima. U trećem spektru najzastupljeniji elementi su ugljenik (34,71 mas%) i gvožđe (31,19 mas%). Prisutni su bili kiseonik (13,45 mas%) i u manjoj meri hrom, azot, nikl, natrijum, hlor, bakar, kalijum, sumpor. Rezultati trećeg spektra ukazuju na kontaminaciju organskim debrisom.

EDXS analiza instrumenta HF (ISO 25) (Slika 2) za prvi spektar je uzeta na čistoj površini instrumenta, dok je za drugi i treći urađena na kontaminiranoj površini. Najzastupljeniji element u analizi sva tri spektra je gvožđe sa maksimalnom zastupljenošću od 71,12 mas% i minimalnom od 69,53 mas%. Prisutni su i aluminijum, silicijum, titanijum, hrom, mangan i nikl u različitim masenim koncentracijama. EDXS analiza za drugi i treći spektar ukazuje na kontaminaciju metalnim opiljcima.

Svi ispitivani instrumenti su pokazali prisustvo defekata na svojoj površini. Na novim ručnim instrumentima nije uočeno prisustvo mikrofraktura, fraktura i zatupljenih sečivnih ivica (tabele 3, 4, 5). Najučestaliji tip defekta je bila pojava metalnih opiljaka i žlebova koja je uočena na površini svih ispitivanih instrumenata (ova zastupljenost je bila u 100% slučajeva) (tabele 3, 4, 5, Slika 3). Statistička analiza Fišerovim testom nije ukazala na statistički značajne razlike između testiranih instrumenata, niti između njihovih apikalnih i srednjih trećina.

Prisustvo debrisa je uočeno na svim KF instrumentima (100% apikalna i srednja trećina) i polovini HF instrumenata (56% apikalna i srednja trećina) (Tabela 3, Grafikon 1, slike 4 i 5). Poredeći pojavu debrisa na različitim ručnim instrumentima (KF i HF), uočena je statistički značajna razlika ($p = 0,0029$ u apikalnoj i $p = 0,0029$ u srednjoj trećini).

Prisustvo udubljenja zabeleženo je u apikalnoj i srednjoj trećini KF instrumenata (33% apikalna i 39% srednja trećina) i HF instrumenata (11% apikalna i 6% srednja trećina) (tabele 3, 4, 5, Grafikon 2, Slika 6). Poredeći pojavu jamičastih udubljenja na različitim ručnim instrumentima (KF i HF), u apikalnoj trećini uočena je statistički značajna razlika ($p = 0,0051$ apikalno), koja je zabeležena i u srednjoj trećini ($p = 0,0045$).

Pojava uglačane površine, korozija radne površine i prekid sečivne ivice su uočeni samo na KF instrumentima (korozija – 11% apikalno i 17% u srednjoj trećini; uglačana površina – 11% apikalno i 6% u srednjoj trećini; prekid sečivne ivice – 2% apikalno) (tabele 3, 4, 5, slike 7 i 8).

U grupi KH instrumenata nisu uočeni prisustvo korozije, uglačanost površine, kao ni prekid sečivne ivice.

DISKUSIJA

Uspeh endodontske terapije zavisi pre svega od pravilne instrumentacije, odnosno od biomehaničke obrade i trodimenzionalne hermetičke opturacije kanala korena. Endodontski instrumenti svojim dizajnom, metalurškim karakteristikama, izgledom površine mogu uzrokovati pojavu komplikacija endodontskog tretmana, usled svoje deformacije i frakture tokom instrumentacije. Dokazano je da proizvodni defekti mogu dovesti do preloma novog instrumenta čak i pri prvoj kliničkoj aktivaciji [20]. Tokom proizvodnog procesa na radnoj površini instrumenata, a posebno na navojima, mogu zaostati metalni opiljci, ali i organski i neorganski debris, koji mogu imati infektivni i nespecifični iritirajući potencijal [21–24].

Rezultati ove studije su pokazali da je na svakom analiziranom instrumentu postojalo minimum dva i maksimalno pet različitih defekata pre bilo kakve upotrebe. Ovakav rezultat je u saglasnosti sa literaturnim podacima koji izveštavaju o velikoj učestalosti oštećenja endodontskih instrumenata tokom procesa njihove izrade [5, 16, 19, 25, 26]. Najzastupljeniji defekti na radnim površinama novih endodontskih instrumenata od nerđajućeg čelika (KF i HF) u ovoj studiji su bili pojava žlebova i metalnih opiljaka.

Prisustvo žlebova na radnom delu instrumenata koji nastaju tokom proizvodnog procesa uočeno je kod svih ispitivanih ručnih instrumenata od nerđajućeg čelika. Konvencionalna izrada instrumenata uvrtanjem žice različitog profila (četvorougaonog za turpiju K tipa i okruglog za turpiju Hedstorm) izaziva pojavu površinskih nepravilnosti, kao što su tragovi glodanja i pojava uglačanih površina (posebno na sečivnim ivicama), koje mogu kompromitovati sečivnu efikasnost instrumenata i potencijalno izazvati probleme vezane za koroziju i pojavu frakture [20, 25, 26]. Klinički značaj pojave žlebova na površini instrumenta je u povećanju mogućnosti njegovog ušrafljivanja (usled trenja koje postoji zbog neravne površine), čime se, posledično, povećava učestalost loma [27]. Veća mogućnost loma turpija tipa HF se objašnjava različitim dizajnom ove turpije, koja iziskuje i različitu aktivaciju u korenskom kanalu. HF instrumenti imaju povećan nagib sečiva u odnosu na osu instrumenta (60° i 65°), dok je za KF ovaj ugao značajno manji (25° i 40°), te iziskuju veoma pažljivu manipulaciju [28].

Prisustvo metalnih opiljaka, koje je uočeno u svim ispitivanim grupama u stopostotnom procentu, potvrđuje komplikovanost izrade endodontskih instrumenata. Ovakav nalaz je u saglasnosti sa rezultatima studije koju su objavili Chianella i saradnici, koji su potvrdili prisustvo ovakve kontaminacije u 96,3% ispitivanih novih instrumenata [28]. Značaj pojave ovog tipa defekta na površini novih instrumenata ogleda se u smanjenju sečivne efikasnosti. Osim toga, metalni opiljci na aktivnoj površini instrumenta se tokom instrumentacije mogu zadržati u dentinskim zidovima kanala ili mogu biti prebačeni u periapeksno tkivo. Van Eldik je dokazao mogućnost kontaminacije periapeksnog tkiva metalnim opiljcima unetim preko instrumenata, čime se značajno može redukovati reparacija tkiva [29].

Pojava jamica ili udubljenja na radnom delu instrumenta je primećena na malom procentu instrumenata (KF, HF), i može se objasniti specifičnim tehnološkim procesom izrade, kao i pojava metalnog fleša (uglačane površine) i oštećenja na sečivnim ivicama u grupi KF. Bonetti Filho i saradnici su takođe izneli mogućnost nastanka jamica i brazdastih udubljenja na novim instrumentima [30].

Prisustvo debrisa, koje je uočeno u ispitivanim grupama KF u stopostotnom procentu i HF u procentu od 56% (apikalno i srednje) potvrđuje komplikovanost izrade čistih endodontskih instrumenata. Za razliku od studije Lopesa i saradnika (2002), u kojoj je aceton u ultrazvuku korišćen za dobijanje čistih i suvih instrumenata, u ovoj studiji su instrumenti analizirani neposredno po otvaranju fabričkog pakovanja, bez ikakve prethodne pripreme [25]. SEM analiza je na ovaj način imala mogućnost ispitivanja kvaliteta njihove završne obrade i uslova pakovanja. Ostaci maziva (korišćenog tokom proizvodnje), epitelnih ćelija, dlaka, delovi tkanina mogu zaostati na površini novih instrumenata posle procesa proizvodnje i neadekvatnog pakovanja i kompromitovati uspešnost endodontske terapije. Roth i saradnici su u svom istraživanju utvrdili biološku kontaminiranost od 13% novih ručnih endodontskih instrumenata od nerđajućeg čelika različitih proizvođača, čime su dokazali mogućnost kontaminacije novih instrumenata održivim mikroorganizmima (*S. epidermidis*, *Peenibacillusspecies* i tri gljivična soja) [31].

Problemi tokom proizvodnog procesa mogu nastati i zbog kvaliteta same žice od koje se izrađuju, jer čestice oksida i karbida mogu ostati inkorporirane u leguri tokom proizvodnje, stvarajući krtije zone koje mogu biti nukleaciona mesta za pojavu mikrošupljina [32]. Pod dejstvom korozivnih faktora (irigacionih rastvora, dezinfekcije i sterilizacije) i pod dejstvom torzionih i cikličnih opterećenja tokom instrumentacije može doći do korozije i dalje propagacije ovih defekata [32].

Analiziranjem rezultata EDXS analize dobio se uvid u maseni procenat zastupljenih elemenata u leguri nerđajućeg čelika i tačan sastav zatečene kontaminacije na površini novog instrumenta.

Velika zastupljenost hroma na spektrima čiste površine (18,03 mas% i 18,76 mas%) i nikla (7,27 mas% i 8,08 mas%) potvrđuje značaj ovih elemenata u poboljšavanju osobina instrumenata. Ovakav sastav legure obezbeđuje dobre mehaničke osobine uz otpornost na koroziju. Proizvođači su razvili nove legure od nerđajućeg čelika koje karakteriše veća fleksibilnost kako bi se izbegli neželjeni efekti tokom instrumentacije, te savremeni feritni čelici imaju 12–18% masenog udela hroma [30].

Usled velikog afiniteta hroma za vezivanje sa ugljenikom i stvaranja krtog hrom-karbida, sa povećanjem masenog udela ugljenika dolazi do smanjenja otpornosti prema koroziji. Da bi se sprečilo stvaranje nepoželjnog hrom-karbida, u nove legure se dodaje titanijum, koji ima veći afinitet prema ugljeniku, čime se postiže stabilizacija feritnih čelika [30].

ZAKLJUČAK

Na osnovu rezultata ovog istraživanja može se zaključiti da su na svim ispitivanim instrumentima uočeni proizvodni defekti (po dva ili više), i da je najučestaliji tip nepravilnosti bilo postojanje metalnih opiljaka i žlebova na radnom delu instrumenata. Zbog prisustva debrisa na radnom delu instrumenta neophodna je njihova sterilizacija pre prve upotrebe. Ove činjenice bi mogle biti upozoravajući faktor praktičarima da i pre prve primene dobro analiziraju radni deo instrumenta kako bi se izbegle moguće komplikacije tokom endodontskog tretmana.

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The flow rate of endodontic sealers in various consistencies

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SUMMARY

Introduction The flow of endodontic sealer (ES) is the property that characterizes its velocity along the certain surface and depends on the friction force. The aim of this research was to measure the flow rate of three zinc oxide eugenol based ES's in various consistencies exposed to the load of 2 kg.

Material and methods The experimental group included prepared samples of sealers protocoled by ADA specification No. 57 A) Endomethasone N in liquid:powder ratio of 1:5, 1:6, 1:7 (standard), 1:8 and 1:9 according to the manufacturer brochure depending on the clinical situation; B) Roth 801 as 1:7 (standard) and 1:8 mixtures C) Tubliseal EWT as standard preparation (base-catalyst 1:1). A volume of 0.05 ml sealer was spread on the glass plate and upon applying the load of 2 kg the diameter of sealer was measured. In the control group the sealer samples were loaded only by the weight of glass plate (0.1kg).

Results Based on measured diameters of sealers, all of them satisfied ADA requirements for the flow (d>20mm) (Endomethasone – 20.7–27.8 mm; Roth 801- 29.6–30.0 mm; Tubliseal -39.9 mm). The thin consistency of sealers (1:5, 1:6) showed significantly higher flow than standard mixture (1:7) ($p < 0.05$).

Conclusion Tubliseal EWT sealer showed the highest flow rate, significantly different than standard mixtures (1:7) of Endomethasone N and Roth 801.

Keywords: flow; viscosity; sealer; endodontic sealer; zinc oxide eugenol

INTRODUCTION

One of the main roles of endodontic sealer (ES) is lubricating canal instruments and gutta-percha cones during its insertion and compaction. This feature is directly dependent on its velocity over the surface (dentin). The appropriate flow of ES is important to be able to reach the most distant labyrinth spaces (apical ramification, recurrent canals, pulpoperiodontal communications, cul de sac, irregular ampular spaces and fracture gaps etc.) and hermetically seal endodontic space [1]. One study has confirmed that presence of residual irrigant could accelerate sealer's setting time and slow down the sealer flow. Temperature rise during gutta-percha compaction has similar effect on setting time of ES resulting in slowing down the flow rate (warm compaction technique) [2]. The flow rate of ES is also dependent on material nature. In general, thinner consistency creates the higher flow rate and vice versa [3].

One study confirmed that denser ES had lower flow, where higher viscosity increased possibility of creating pools (reservoirs) within sealer itself and prevented sealer to line all canal walls affecting homogeneity of root canal filling. This study also showed that thinner ES created pores on dentinal wall-sealer junction as well as between canal wall and gutta-percha cones [4]. Sealer's flow is also correlated to the canal shape, width and convergence where for very narrow accessory canals and dentin tubules of diameter < 500 μm capillarity rule may be applied. The flow rate is also dependent on dentin structure. It is known that dentinal tubules become narrower with age but ES flow is also affected in vital tooth (filled by tubular liquor) [5].

Some authors reported different ES flow rate of AH Plus along dentinal walls after the use of different irrigants where Chlorhexidine improved while Cetrimide decreased sealer flow. The explanation for higher flow is the presence of liquid vehicular-carrier incorporated in Chlorhexidine while powder component of Cetrimide likely caused higher friction [6]. Some authors examined different compaction forces on gutta-percha cones (3.0–24.3 kg, 8N, 10–25 N, 20 N) where higher values were attributed to the compaction techniques and lower ones to mono-cone method. Higher values of ES flow rates were to be expected with higher compaction forces [3, 7–10].

A variety of experimental models have been used to measure the ES flow rates. One of them is microscope examination of dentinal tubules and pulp-periodontal communications filled by ES of different fluidity [2, 11, 12]. Kontakiotis et al. investigated the values of contact angle for Roth 801, AH26, RSA, Gutta Flow dropped onto the dentin surface indicating inverse correlation of their flow and contact angle (higher the flow, lower the contact angle) [13]. Japanese authors compared two study models for the same sealer: flow of sealer down the vertical glass slab (time and length) and spreading the sealer drop between two horizontally pressed plates (diameter of circle). A discrepancy in obtained results with these two methods for tested sealers (Sealapex, AH26, Canals and CH61)

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has been found [14]. Some authors used passive leaking through the rotational viscometer (round in shape) and examined rheological parameters: pseudoplasticity, i.e. increase of viscosity stress due to the increase of fluidity shear rate [15, 16].

The aim of this research was to evaluate the flow of three zinc oxide-eugenol endodontic sealers of different consistency (density) under the load of 2 kg. The null hypothesis was that there was no difference between the flow rates among three standardly prepared sealers and no differences in flow rate between standard mixture and mixtures with different powder to liquid ratios.

MATERIAL AND METHOD

Materials

The study included the following endodontic sealers: Endomethasone N (Septodont, St. Maur, France), Roth 801 (Roth Inter. Limit.) and Tublisel EWT (Kerr Romulus, Michigan, USA), all being zinc-oxide-eugenol based materials. The materials were mixed according to the manufacturer recommendation; eight samples of each ES were prepared. The powder to liquid ratio for standard mixture of Endomethasone N samples was 1.5 gr: 3.0 gr (standard mixture assumed one scoop powder and two oil drops that was the ratio of w/w = 1:7). The next Endomethasone N mixtures were made in very thin (1:5), thin (1:6), thick (1:8) and very thick consistency (1:9). Roth 801 sealer was prepared as standard mixture (1:7) and thicker mixture (1:8) with weight ratio powder/liquid (w/w) 0.13 gr: 0.03 gr. Tubliseal EWT was prepared by mixing equal parts of base and catalyst from original tubes. This variant was chosen due to the prolonged setting time that experiment required. The accurate weights of sealers' components were measured using the digital scale (with error of ±0.0005 gr) – Mettler PE 360, Germany.

Groups

The experiment was done using a pair of glass plates according to ADA specification No.57. and ISO standard number 6876/2001 [17]. The sealers were aspirated by insulin-graduated syringe with barrel of 2 mL. The amount of 0.05 ± 0.025 mL sealer was immediately injected after mixing on the middle portion of glass plate and spread in circle using dental probe to the size of 10 mm in diameter. Three minutes later another glass plate (120 gr) was gently placed over sealer (Figure 1). The weight of 2 kg was then placed over second plate for each sample. Two-plates system was fixed by metal rings for the next 7 minutes.

The following experimental groups were formed: Endomethasone N: a) 1:5+2 kg; b) 1:6+2 kg; c) 1:7+2 kg; d) 1:8+2 kg; e) 1:9+2 kg; Roth 801; f) 1:7+2 kg; g) 1:8+2 kg; Tubliseal EWT: h) 1:1+2 kg. In control group the samples were loaded with the weight of glass plate (120 gr). The experiment was done under the standard laboratory conditions, temperature and humidity (t = 22 ± 1°C, 60–65%).

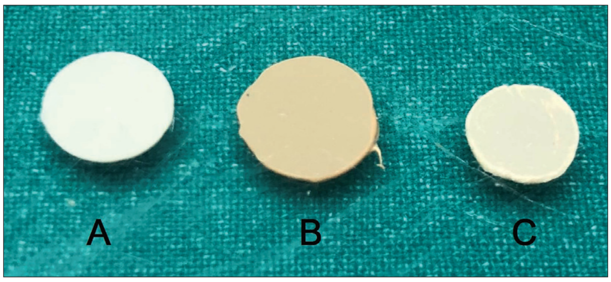

Figure 1. Control group with sealers A) Tulbliseal EWT, B) Endomethasone N and C) Roth 801 without extra load
Slika 1. Kontrolna grupa sa silerima: A) Tulbliseal EWT, B) Endometazon N i C) cement bez opterećenja Roth 801

Measurments

The biggest and the smallest diameter of each sample of spread sealer was measured using orthodontic ruler during 11th minute after mixing the sealer and immediately after removing the 2 kg weight. ADA standard required 10 minutes to display real flow rate. The sample that exhibited discrepancy of maximal and minimal diameter more than 1 mm was discarded. An orthodontic ruler was used to measure sealer diameters with accuracy of 0.5 mm ± 0.025 mm (error).

Statistical calculation

Student t-test, Boniferroni and Post-hoc test were used for statistical comparison of results within the control and experimental groups at the confidence level of 0.05.

RESULTS

The mean values of sealers diameters are presented in Table 1 and 2.

The highest mean value of diameter of spread sealer after loading with 2 kg weight for Endomethasone N (component ratio 1:6) was 27.8 mm, 25.1 mm (1:5) and 24.1 mm (1:7), respectively. Slightly smaller diameter was measured for the ratio 1:9 (22.4 mm) and 1:8 (22.1 mm). Statistically significant difference was noted between 1:5, 1:8 and 1:9 mixtures ($p < 0.05$). Roth 801 exposed mean diameter of spread sealer of 32.8 mm for 1:7 mixture and 34.0 mm for 1:8 preparation. The mean diameter for Tubliseal EWT cement was 39.9 mm.

There was statistically significant difference in sealer diameter between Endomethasone N and other two sealers as well between Roth 801 and Tubliseal EWT ($p < 0.05$).

The obtained results of spread sealers diameter loaded by the glass plate weight only (control group) are shown in the Table 2. The mean values of sealer diameters were: Endomethasone N- 15.5 mm, Roth 801- 19.7 mm and Tubliseal EWT-19.8 mm. The statistically significant difference between the diameter values of spread sealers was noted between Endomethasone N and both, Roth 801 and Tubliseal EWT ($p < 0.05$) while there was no significant difference between Roth 801 and Tubliseal EWT.

Table 1. The mean values of spread sealers diameter under the load of 2 kg in experimental groups
Tabela 1. Prosečne vrednosti prečnika ispitivanih silera pod opterećenjem od 2 kg u eksperimentalnoj grupi

Sealers Sileri	Endomethasone N 1:5 *	Endomethasone N 1:6*	Endomethasone N Stand 1:7*	Endomethasone N 1:8*	Endomethasone N 1:9*	Roth 801 Stand 1:7*	Roth 801 1:8*	Tubliseal EWT Stand 1:1**
Diameter Prečnik (mm)	27.8 ± 1.9	25.1 ± 3.0	24.1 ± 1.2	22.1 ± 1.7	22.4 ± 1.7	32.8 ± 1.9	30.0 ± 1.9	39.9 ± 1.3
Groups Grupe	a	b	c	d	e	f	g	h

components ratio: * liquid–powder, ** base–catalyst
težinski odnos komponenata: * tečnost–prah, ** baza–katalizator

Table 2. The disk diameter values of spread sealers without extra load (only 100 gr weight of glass slab)
Tabela 2. Vrednosti dijametra diska razlivenog silera bez opterećenja (samo 100 gr težina staklene pločice)

Sealers Sileri	Diameter values Vrednosti prečnika (mm)	Mean diameter Prosečna vrednost prečnika (mm) ± SD
Endomethasone N	15.5 16.0 16.5	16.0 ± 2.2
Roth 801	19.0 20.0 20.0	19.7 ± 5.5
Tubliseal EWT	18.8 20.2 20.2	19.8 ± 3.4

DISCUSSION

Our results showed the difference in the flow rate among tested sealers with the load of 2 kg, therefore, the null hypothesis can be rejected. In addition, the null hypothesis stating there was no difference in the flow rate between standard mixture and mixtures with different powder to liquid ratios was rejected due to found statistically significant difference between flow rate of 1:5 and 1:8 mixtures.

The study used protocol similar to the Grossman model [18] that is simple and allows easy comparison of results [3,19–21]. The calculated SD values were less than 30% for experimental (13.0–29.8%) and control group (15.5–19.8%). This indicates homogeneity of the results and satisfactory measuring precision.

Literature data for root canal pressure during obturation was within the span of 8 to 35 N (0.8–3.5 kg) therefore we used 2 kg weight to be comparable to the similar literature results [3,7–10]. In our study ISO protocol for the endodontic sealer flow was respected hence minimum 20 mm of diameter of spread sealer was noted [17]. Gambarini et al. results for the sealers: Roeko Seal Automix (Polyvynilsiloxan) 32.7 mm, Bioseal (ZOE sealer) 38.5 mm and Real Seal (composite resin) 37.9mm, are also in accordance to ISO requirements and similar to results in our study [19]. The differences in final results of the flow in different studies are the consequence of the experimental condition and can be correlated to the weight of cover glass plate (30-120-500 gr), additional load (1.0–3.5 kg), the amount of placed sealer on the plate (0.05 ± 0.005 – 0.5 ± 0.05ml), pressure exposure time (30 sec to 10 min) and humidity values [3,7–10].

Considering the depth of tubular penetration, Balaguerie et al. using SEM analysis found deeper flow of AH Plus sealer than Acroseal, RSA, Endobtur and Ketac-Endo. The authors explained lower flow of these sealers due to warm gutta-percha that created coagulant particles in hot sealers resulting in harder penetration along the dentinal tubules [20]. Our investigation satisfied ADA Number 57 standard (d > 20 mm) for each sealer in all experimental groups (22.1–39.9 mm) with loads of 2 kg.

In vitro study of Candeiro et al. revealed better flow of calcium-silicate sealer Endosequence BC Sealer (27 mm) than AH Plus (21 mm). The authors explained superior flow of first sealer due to its smaller particles although both satisfied ISO 6876/2001 standard [21].

The different ratio of powder in tested sealers in the current study resulted in corresponding diameter values for spread sealers (flow). Endomethasone N showed significantly lower diameter (around 30%) than Roth 801 that is in accordance to the results of Camps et al. [22]. They also compared the flow of ZOE-based sealer Esthesone and Pulp Canal Sealer (thicker and thinner mixtures) and obtained higher flow rate in thinner samples. Furthermore, they found significantly lower fluidity of tested sealers (31 mm and 40 mm) than manufacturers' referent values. Their study also showed that very fluid mixture of sealer (of low density) placed in root canal during application of mono-cone technique required around 80% lower pressure than in cases of the same sealer of higher density. This fact indicates the choice of obturation technique (that exerts different stress values to dentin canal walls) in various canal systems (wide opened apical foramen and thin root canal walls) [22].

Balaguer et. al. explained high flow rate of sealer in cases of thin prepared mixture by more present liquid (oil) constituent that lowers the friction i.e. viscosity (shear stress) over the surface [20]. Analyzing the mixtures with component ratio from 1:5 to 1:9 samples where the powder percentage is different for about 50%, statistically significant difference was found in sealer's diameters. Mendonca et al. reported similar findings in their study using comparable variations of powder and liquid components in ZOE-based sealers (Endomethasone N, Grossman sealer and Tubliseal). In low-density sealer samples they found smaller sealer penetration into dentinal tubules due to less resistance related to higher liquid percentage [23] and that was in accordance with other investigations [3, 24].

Manufacturers instructions suggest using different density of sealers (thicker or thinner) (Endomethasone N, Roth 801 cement), what was included in experimental, mostly in *in vitro* studies [3, 22, 24]. To achieve more efficient and accurate dosing in standard manual mixing of ZOE-based sealers, it is mostly used as two-component paste (Tubliseal, TublisealEWT).

The SEM study of Mamootil et al. found slightly lower penetration of ZOE-based Pulp Canal Sealer into dentinal tubules in comparison to resin-based endodontic sealers [25] that is not in accordance to Gambarini et al. results [19]. The discrepancy might be due to different methodologies of these two studies. Namely, SEM examination of dentinal histological sections in the study of Mamotil et al. was analyzed used high magnification while Gambarini et al. used loupes only. Mamotil et al. in their methodology protocol did not mention patient's age (teeth donors) or teeth age (deciduous or permanent dentition) as well as angle of dentin section in coronal area that may have significant influence on tubule diameter and consequently flow rate of ES.

Mutal et al. stressed out the importance of gas bubbles that were created more in sealers with lower flow rate during obturation. They noted pores and vacuoles in diameter of around 500 µm, more present in thicker sealers (resin-based and glassionomer-based) than in ZOE-based sealers. They concluded that good obturation requires denser sealers because bubbles become entrapped within sealer and do not reach the canal wall. Therefore, the chance of microbial percolation between oral cavity and dentin tubules is then lower [2]. One study reported expansion of gutta-percha cones after using different eugenol concentration in ZOE-based sealer (Pulp Canal Sealer EWT). The increase of eugenol oil resulted in volumetric change of gutta-percha cones and higher sealer flow, i.e. better tubular penetration confirmed by spiral computerized tomography [26]. Tiwari found that AH Plus samples had optimal values for sealer penetration into dentin tubules as well as improved hermetic and antimicrobial effect compared to Perma Evolution paste (mixture of calcium silicate and calcium phosphate). This study analyzed the size of particles and concludes that flow rate is inversely proportional to the granule size [27].

Passing the sealer through the round opening is interesting model for flow analysis and it did not show significant difference between Roth 801 and TubliSeal EWT [16] while experimental model with two glass slabs (ISO 6876/2001) displayed different "flow" values in sealers regardless of 2 kg weight.

The differences in flow values are only to be explained by different experimental protocol. The differences in viscosity of sealers resulted in corresponding diameter of spread sealer (flow). In addition, Ono et al. involved gravity force as an important factor in fluidity of sealer placed to roll down the vertical glass slab. Our study included only friction factor without gravity due to its horizontal position as ADA standard required [17]. In our study humidity and heat factor (cold/warm gutta-percha) were not analyzed but they are known to affect flow and penetration of sealer (warm compacted gutta-percha vs. mono-cone technique or Thermafil) [27, 28]. Relatively new calcium phosphate and calcium-silicate mixture, Capseal, showed lower flow values than AH Plus and Sealapex sealers using ISO 6876 standard. This result is caused by material structure itself. Namely, AH Plus and Sealapex have significantly smaller granulation of particles than Capseal resulting in better flow and spreading power [29].

One of the promising calcium-silicate sealers, MTA Obtura, did not show statistically significant difference in flow rate compared to Sealer 26 although both satisfied ADA No. 57 requirements [30]. Kyung et al. found that only bioceramic-based sealer Endosequence BC created smaller diameter of around 18 mm, while others (AH-Plus, AD Seal, Radic-Sealer, EndoSeal MTA, MTA Fillapex, AD Seal i Radic-Sealer) showed satisfying diameters (more than 20 mm) [31]. Jeanneau C et al. investigated anti-inflammatory effect of Endomethasone N and Pulp Canal Sealer and found that only standard or thick consistency (adequate saturation of powder with eugenol) had effect on lessening the secretion of interleukine-6 [32].

Some authors analyzed the sealer flow using ISO standard and viscosity of sealers using rheometer device and found the latter one to be more accurate ($\rho = -0.8618$). The greatest flow was found for Pulp Canal Sealer EWT and then for AH Plus, Sealapex and Capseal sealer [33].

It is to note that heterogeneity of results about flow rate of various sealers indicates to follow the proposed standard protocols in order to get comparable results. As for clinical aspect, the density of ES should be in function of every single case and chosen obturation technique.

CONCLUSION

All tested sealers showed satisfactory flow level. The greatest flow was observed in Tubliseal EWT paste, then Roth 801 cement and the lowest in Endomethasone N.

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Ispitivanje fluidnosti endodontskih silera različitih konzistencija

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KRATAK SADRŽAJ

Uvod Fluidnost endodontskog silera (ES) osobina je koja karakteriše njegovu brzinu kretanja na određenoj podlozi i zavisi od otpora koji ova podloga pruža.

Cilj ovog istraživanja je bio da se ispita fluidnost tri ES na bazi cink-oksid eugenola različitih konzistencija pod dejstvom opterećenja od 2 kg.

Materijal i metode U eksperimentalnoj grupi su pripremljeni uzorci prema specifikaciji ADA No. 57 za ispitivanje fluidnosti zamešanih silera: A) Endometazon N sa odnosom prah : tečnost 1 : 5, 1 : 6, 1 : 7 – standardno, 1 : 8 i 1 : 9; B) Roth 801 1 : 7 – standardno i 1 : 8 i C) Tubliseal EWT prema standardnoj preskripciji proizvođača. Posle opterećenja silom tegom od 2 kg preko staklene pločice izmereni su prečnici razlivenih silera. Kod kontrolne grupe sileri su bili opterećeni samo težinom staklene pločice (100 gr).

Rezultati Posle merenja i statističke obrade rezultata svi zamešani sileri su pokazali zadovoljavajući nivo fluidnosti – d > 20 mm [A) Endometazon N 20,7–27,8 mm; B) Roth 801 29,6–30 mm; C) Tubliseal 39,9 mm]. Ređe zamešan Endometazon N (1 : 5, 1 : 6) pokazao je znatno veću fluidnost od standardno pripremljenog (1 : 7) ($p < 0,05$).

Zaključak Najveću fluidnost pokazao je siler Tubliseal EWT, koja je bila značajno veća u odnosu na standardno zamešane (1 : 7) Endometazon N i Roth 801.

Ključne reči: fluidnost; viskoznost; siler; endodontski siler; cinkoksid-eugenol

UVOD

Jedna od glavnih uloga endodontskog silera (ES) za opturaciju je njegovo lubrikantno (podmazujuće) svojstvo prema instrumentima i gutaperka kočićima prilikom njihovog umetanja i komprimovanja. Ovo svojstvo zavisi od fluidnosti paste za opturaciju u odnosu na podlogu na koju je nanešen. Primenjeno na endodontski siler (ES), povoljna fluidnost treba da mu omogući da dosegne do najudaljenijih nepristupačnih prostora (apikalne ramifikacije, rekurentni kanali, pulpoperiodontalne komunikacije, slepi i ampularni nepravilni prostori, frakturne pukotine itd.) [1]. Potvrđeno je da prisustvo zaostalog irigansa ubrzava očvršćavanje ES, čime se smanjuje brzina toka (fluidnost), a na sličan način utiče i povećanje temperature (tople kompakcione tehnike) [2]. Brzina fluidnosti ES je takođe zavisna od prirode (teksture) materijala, pa se uopšteno može reći da je ona veća kod ređe pripremljenih, a manja kod gušćih preparata [3].

Jedno ispitivanje je pokazalo da gušći sileri pokazuju manju fluidnost, tj. nepovoljnu viskoznost i mogućnost stvaranja bazenčića (rezervoara) unutar samog silera, koji ne dosežu do svih površina kanalskog zida, što nepovoljno utiče na kompaktnost kanalskog ispuna. Ovo ispitivanje pokazuje da ređi siler stvara nepoželjne pore na spoju silera i dentinskog zida, kao i između kanalskog zida i gutaperka konusa [4]. Fluidnost silera je takođe u korelaciji sa oblikom kanala, njegovom širinom i konvergencijom, pa se za veoma uske akcesorne kanale i dentinske kanaliće manjeg promera od 500 μm na fluidnost silera može primeniti zakon kapilariteta koji zavisi od sastava silera i širine dentinskih kanalića. Fluidnost ES takođe zavisi od strukture dentina jer se vremenom dijametar tubula smanjuje, a mogućnost prodora u tubule je otežan, naročito ako su oni ispunjeni tečnošću [5].

Neki autori beleže različitu fluidnost, odnosno prodor AH Plus, u dentinske zidove posle tretmana dezinficijensima, pri čemu predtretman hloreksidinom poboljšava, a cetrimidom pogoršava ovu osobinu. Objašnjenje za veću fluidnost najverovatnije leži u prisustvu tečnog vehikuluma (nosioca) kod prvog kondicionera. Kao objašnjenje za manju fluidnost AH Plus kod predtretmana sa cetrimidom autori ukazuju na njegovu praškastu komponentu, koja pruža veći otpor prilikom prekrivanja dentinskog zida kanala [6]. Pojedini autori beleže veliki raspon za vrednosti različitih sila kompakcije gutaperke (3,0–24,3 kg, 8 N, 10–25 N, 20 N), pri čemu su one znatno jače kod kompakcionih tehnika u poređenju sa monokonim tehnikama zbog pojave hidrodinamskog efekta, pa se shodno tome mogu očekivati veće vrednosti za fluidnosti kod primenjenih većih kompakcionih sila [3, 7–10].

Da bi ispitali fluidnost ES, autori su primenjivali različite metode. Jedna od njih je mikroskopiranje dentinskih tubula i pulpoperiodontalnih komunikacija ispunjenih silerom različite fluidnosti [2, 11, 12]. Kontakiotis i sar. su ispitivali vrednosti kontaktnog ugla silera Roth 801, AH26, RSA, Gutta Flow na dentinu i ukazali na korelaciju nivoa fluidnosti testitanih materijala i kontaktnog ugla (veća fluidnost korelirala je sa manjim uglom) [13]. Japanski autori su poredili dva modela na istom sileru: slivanje silera, tj. napon tečenja niz vertikalnu pločicu i merenje veličine prečnika razlivenog silera pritisnutog horizontalno postavljenom pločicom. Za primenjene silere (Sealapex, AH26, Canals i CH61) dobili su sasvim različite vrednosti testiranim metodama [14]. Pojedini autori su koristili pasivno istiskivanje silera kroz rotacioni viskometarski uređaj, tj. kroz okrugli otvor i posmatrali reološke osobine, pseudoplastičnost, odnosno porast viskoznog stresa sa povećanjem njegovog napona tečenja [15, 16].

Cilj ovog istraživanja je bio da se proveri fluidnost tri endodontska silera na bazi cink-oksid eugenola različitih konzistencija (gustina) pri opterećenju od 2 kg.

Postavljena je nulta hipoteza da ne postoji razlika u fluidnosti između tri standardno pripremljena silera, kao i između standardno zamešanih silera i onih sa različitim odnosom praha i tečne komponente.

MATERIAL I METOD

Materijali

U eksperimentu su ispitivani sileri Endometazon N (Septodont, St. Maur, Francuska), Roth 801, (Roth Inter. Limit.) i Tubliseal EWT (Kerr Romulus, Mičigen, USA) na bazi cink-oksid eugenola. Materijali su zamešani prema uputstvu proizvođača, za svaku grupu po osam uzoraka. Odnos praha i ulja za standardno pripremljen Endometazon N je bio 1,5 gr : 3,0 gr (standardna mešavina 1 : 7 podrazumevala je odnos jedne kašičice praha prema dve kapi tečnosti, što je predstavljao volumenski odnos w/w = 1 : 7). Zatim je Endometazon N pripremljen kao veoma retka (1 : 5), retka (1 : 6), gusta (1 : 8) i veoma gusta konzistencija (1 : 9). Siler Roth 801 je zamešan kao standardna preskripcija (1 : 7) i gusto zamešana masa (1 : 8) sa težinskim odnosom prah/tečnost (w/w) 0,13 gr : 0,03 gr. Tubliseal EWT je pripremljen mešanjem jednakih delova paste baze i katalizatora istisnutih iz tuba. Ova nova varijanta je izabrana za studiju zbog produženog vremena očvršćavanja. Tačna odmeravanja urađena su digitalnim uređajem sa greškom merenja od 0,0005 g (Mettler PE 360, Nemačka).

Grupe

Eksperiment je urađen primenom dveju staklenih pločica slično ADA specificaciji No. 57, odnosno prema standardu ISO 6876/2001 [17]. Sileri su usisani u insulinski graduisani špric (2 mL), a količina od 0,05 ± 0,025 mL odmah je posle mešanja istisnuta na sredinu staklene pločice i cirkularno pomoću sonde postavljena kružno do velicine 10 mm u prečniku. Posle tri minuta druga staklena pločica težine 120 gr je nežno postavljena preko silera. Teg od 2 kg za svaki uzorak postavljen je posebno. Pomoću metalnih prstenova pločice su fiksirane sledećih 7 min. (Slika 1).

Tako su formirane eksperimentalne grupe: Endometazon N: a) 1 : 5 + 2 kg; b) 1 : 6 + 2 kg; c) 1 : 7 + 2 kg; d) 1 : 8 + 2 kg; e) 1 : 9 + 2 kg; Roth 801; f) 1 : 7 + 2 kg, g) 1 : 8 + 2 kg; Tubliseal EWT; h) 1 : 1 + 2 kg. U kontrolnoj grupi uzorci silera su opterećivani samo težinom pokrovne pločice (120 gr). Eksperiment je izveden u stabilnim laboratorijskim uslovima temperature i vlažnosti (t = 22 ± 1°C, 60–65%).

Merenje

Za svaki uzorak od tri primenjena silera ortodontskim lenjirom je meren najveći i namanji dijametar u 11. minutu od početka mešanja, odnosno posle uklanjanja tegova (Slika 1), jer se prema standardu razlivanje (fluidnost) ispoljava u okviru 10 minuta. Ukoliko disk razlivenog silera nije bio uniformno kružan (razlika najvećeg i najmanjeg prečnika je bila veća od 1 mm), formiran je novi uzorak. Ortodontski lenjir je imao veličinu rastera od 0,5 mm (0,025 mm greška merenja), a posle merenja izračunavana je srednja vrednost dobijenih prečnika.

Statistička obrada

Korišćeni su Student t-test, Boniferroni i test Post-hoc za statističko poređenje veličine dijametara silera kod kontrolne i eksperimentalne grupe na nivou značajnosti od 0,05.

REZULTATI

Dobijeni rezultati prikazani su u tabelama 1 i 2.

Najveća prosečna vrednost prečnika razlivenog silera za Endometazon N bila je pri odnosu 1 : 6 (27,8 mm), potom pri odnosu 1 : 5 (25,1 mm), zatim pri odnosu 1 : 7 (24,1 mm), a nešto manji prečnik je uočen pri odnosu 1 : 9 (22,4 mm) i odnosu 1 : 8 (22,1 mm). Poređenjem dobijenih rezultata uočena je statistički značajna razlika između grupe sa odnosom mešavine 1 : 5 prema zamešanoj masi u odnosu 1 : 8 i 1 : 9 ($p < 0,05$). Kod paste za opturaciju Roth 801 prosečna vrednost razlivenog silera posle opterećenja je iznosila 32,8 mm za odnos 1 : 7, a za odnos 1 : 8 34 mm. Prosečna vrednost prečnika kod cementa Tubliseal EWT je iznosila 39,9 mm. Poređenjem prečnika standardno zamešanih uzoraka testiranih silera uočena je statistički značajna razlika između Endometazona N i ostala dva silera, kao i između silera Roth 801 i Tubliseal EWT ($p < 0,05$).

Dobijeni rezultati merenja prečnika razlivenih silera opterećenih samo težinom pokrovne staklene pločice u ovoj grupi prikazani su u Tabeli 2. Prosečne vrednosti prečnika razlivenih silera iznosile su za Endometazon N 15,5 mm, Roth 801 19,7 mm i Tubliseal EWT 19,8 mm. Značajna statistička razlika u veličini prečnika razlivenih silera je zabeležena poređenjem Endometazona N prema silerima Roth 801 i Tubliseal EWT ($p < 0,05$), dok između silera Roth 801 i Tubliseal EWT nije zabeležena statatistički značajna razlika.

DISKUSIJA

Dobijeni rezultati su pokazali da postoji razlika u fluidnosti između testiranih silera pri opterećenju od 2 kg, pa se nulta hipoteza može odbaciti.

U eksperimentu je korišćen protokol sličan Grosmanovom modelu zbog jednostavnosti izvođenja i mogućnosti poređenja rezultata [18]. Dobijene vrednosti SD su bile manje od 30% (13,0–29,8%) u eksperimentalnoj i kontrolnoj grupi (15,5–19,8%), što ukazuje na homogenost rezultata i zadovoljavajuću preciznost merenja.

Literaturne vrednosti za kanalski pritisak kod opturacije su se kretale u rasponu od 8 do 35 N (0,8–3,5 kg), pa su zato za ovaj eksperiment izabrane vrednosti od 2 kg kako bi rezultati bili uporedivi sa dostupnom literaturom [3, 7–10]. Za ispitivanje fluidnosti primenjen je ISO protokol koji zahteva minimalnu veličinu prečnika razlivenog silera veću od 20 mm [17]. Rezultati Gambarinija i sar. za silere Roeko Seal Automix (Polivinilsiloksan) 32,7 mm, Bioseal (ZOE siler) 38,5 mm i Real Seal (kompozitna smola) 37,9 mm su takođe u saglasnosti sa ISO zahtevima i realizovani su po sličnom protokolu kao i ovo naše istraživanje [19]. Različiti rezultati brojnih autora najčešće su rezultat uslova eksperimenata vezanih za težinu pokrovne pločice (30–120–500 gr), primenjeno dodatno opterećenje (1,0–3,5 kg), količinu istisnutog silera (0,05 ± 0,005–0,5 ± 0,05 ml), vreme izlaganja pritisku (30 sec. do 10 min.), odnosno uslove vlažnosti [3, 7–10].

Posmatrajući dubinu tubularne penetracije, Balaguerie i saradnici SEM analizom nalaze da siler AH Plus pokazuje dublji prodor nego sileri Acroseal, RSA, Endobtur i Ketac-Endo. Ovi autori daju objašnjenje za manju fluidnost ova četiri silera, što tumače činjenicom da zagrejana gutaperka utiče na stvaranje gromuljice kod zagrejanog silera, koji teže prodire u dentinske tubule [20]. Naše istraživanje je zadovoljilo ADA no. 57 standard (d > 20 mm) kod svih silera u svim eksperimentalnim podgrupama (22,1–39,9 mm) sa korišćenim opterećenjima od 2 kg.

U *in vitro* studiji Candeiro i sar. nalaze da kalcijum-silikatni siler Endosequence BC pokazuje bolju fluidnost (27 mm) nego AH Plus (21 mm). Autori ovo objašnjavaju veličinom čestica silera i potvrđuju da oba zadovoljavaju postavljen ISO 6876/2001 standard [21].

Različit udeo praha u silerima u ovim istraživanjima dao je i srazmerne vrednosti prečnika razlivenih materijala odnosno fluidnosti. Poređenje fluidnosti standardno zamešanih silera (1 : 7) Endometazon N i Roth 801 u našoj studiji je pokazalo značajno manje dijametre (oko 30%) kod Endometazona N, što je u saglasnosti sa rezultatima koje su objavili Camps i sar. [22]. Ovi autori su poredili fluidnost kod ZOE silera Esthesone i silera Pulp Canal (sa gušćom i ređom varijantom), pri čemu su dobili znatno veću fluidnost kod ređe zamešanih uzoraka. Camps i sar. su dobili značajno manje vrednosti fluidnosti testiranih silera nego što sam proizvođač navodi u brošuri (31 mm odnosno 40 mm). Rezultati njihove studije takođe pokazuju da je jako fluidna masa (male gustine) silera u kanalu pri aplikaciji monokonusa zahtevala oko 80% manji pritisak nego primena istog silera veće gustine. Ova činjenica ukazuje na značaj izbora opturacione tehnike koja rezultuje različitim pritiscima na kanalski zid kod različitih kanalskih sistema (široko otvorenog apeksa ili tankih zidova kanala korena) [22].

Balaguer i sar. daju objašnjenje za bolju fluidnost ukazujući da se kod retko zamešanog silera zbog procentualno više zastupljene uljne komponente smanjuje trenje, odnosno napon tečenja i time povećava njegova fluidnost [20]. Analizirajući mešavine silera sa odnosom komponenata od 1 : 5 prema 1 : 9, gde se udeo praha razlikuje oko 50%, uočene su statistički značajne razlike u prečnicima razlivenih silera. Slične nalaze beleže Mendoncasa i sar. u studiji sa sličnim varijacijama praha i tečnosti kod ZOE-nih silera Endometazon, silera Grossman i Tubliseal. Oni kod fluidnih silera sa manjom gustinom dobijaju i manji prodor paste u tubule dentina jer masa silera pruža manji otpor pri kliženju po podlozi usled većeg prisustva tečne komponente [23], što potvrđuju i druga istraživanja [3, 24].

Na mogućnost primene različitih gustina silera (gušće i ređe smese) ukazuju uputstva proizvođača (Endometazon N, cement Roth 801), kao i eksperimentalni, uglavnom *in vitro* radovi [3, 22, 24]. Upravo radi efikasnijeg rada i tačnog doziranja standardne perskripcije pri manuelnoj pripremi cink-oksid eugenolnih silera, proizvedeni su preparati sa setom od dve tube (Tubliseal, Tubliseal EWT).

U SEM studiji Mamootil i sar. uočavaju nešto slabiju penetraciju u dentinske tubule silera ZOE-Pulp Canal u poređenju sa endodontskim silerima na bazi smola [25], što nije u saglasnosti sa rezultatima Gambarinija [19]. Ovo bi se moglo objasniti različitim metodološkim postupcima. Naime, SEM studija na histološkim presecima dentina Mamotila i sar. koristi za uočavanje prodora silera velika uveličanja, dok Gambarini i sar. koriste lupu. Mamotil i sar. pritom ne navode starost pacijenata od kojih su dobijeni ekstrahovani zubi (mlečni, stalni), kao ni ugao sečenja dentina u kruničnom delu zuba, što takođe može znatno da utiče na dijametar dentinskih tubula, a shodno tome i na fluidnost silera.

Mutal i sar. naglašavaju značaj gasnih mehurića tokom opturacije, koji se više stvaraju kod silera sa nižom fluidnošću. Oni primećuju pore i vakuole veličine čak do 500 mikrona, koje su više zastupljene kod gušćih silera (smolastih i glasjonomernih cemenata) nego kod cink-oskid eugenolnih silera. Oni zaključuju da je za kvalitetnu opturaciju bolji izbor gušćih silera jer ovde mehurići ostaju zarobljeni i ne dosežu do kanalskog zida i time smanjuju mogućnost mikrobne perkolacije između usne duplje i kanalskih dentinskih tubula [2]. Jedno istraživanje otkriva ekspanziju gutaperka mase primenom različitih koncentracija eugenola kod ZOE-nog silera (Pulp Canal Sealer EWT), gde je porast udela eugenola rezultovao volumetrijskom promenom gutaperke, većom fluidnošću paste, odnosno boljim tubularnim prodorom potvrđenim spiralnom kompjuterizovanom tomografijom [26].

Tiwari nalazi kod uzoraka AH Plus optimalne vrednosti penetracije u dentinske tubule i poboljšanu hermetičnost i antimikrobni efekat u odnosu na pastu Perma Evolution (mešavina kalcijum-silikata i kalcijum-fosfata). Ovo studija uzima u obzir granulaciju čestica silera i zaključuje da je nivo fluidnosti obrnuto proporcionalan veličini čestica [27].

Istiskivanje silera kroz otvor kao model za merenje fluidnosti nije pokazao značajne razlike između Roth 801 i Tubliseal EWT [16], dok je eksperimentalni model sa dve staklene pločice (ISO 6876/2001) pokazao različite vrednosti fluidnosti između ovih silera bez obzira na primenjenu silu od 2 kg.

Razlike u fluidnosti silera jedino se mogu objasniti različitim metodološkim postavkama u eksperimentu. Različit viskozitet silera rezultovao je odgovarajućom veličinom dijametra razlivenog silera. Shodno tome, Ono i sar. uključuju i gravitacionu silu kao važan faktor fluidnosti silera na vertikalno postavljenoj staklenoj pločici [14]. U našoj studiji prisutan je bio samo faktor trenja silera na staklenoj pločici jer je ona bila po ADA standardu postavljena horizontalno [17]. Naša studija nije uključila parametar toplote gutaperka mase (hladna ili topla gutaprka) na veličinu fluidnosti, kao ni uticaj vlage. Na značaj ovih činilaca ukazuju rezultati ispitivanja koji govore o većoj fluidnosti i dubljem prodoru silera kod slučajeva toplo komprimovane gutaperke u odnosu na monokonu tehniku ili Thermafil opturaciju [27, 28]. Relativno nova kalcijum-fosfatna i kalcijum-silikatna mešavina u sileru Capseal pokazala je niže vrednosti fluidnosti od silera AH Plus i Sealapex primenom ISO 6876 standarda. Ovakav rezultat je uslovljen samom strukturom materijala (silera). Zapravo, AH Plus i Sealapex poseduju znatno manju granulaciju čestica u odnosu na siler Capseal, što rezultuje većom fluidnošću materijala, tj. njegovim boljim razlivanjem [29].

Jedan od obećavajućih kalcijum-silikatnih silera, MTA Obtura, nije pokazao statistički značajnu razliku u fluidnosti poređenjem sa preparatom Sealer 26, iako su oba zadovoljila zahteve ADA No. 57 [30]. Kyung i sar. nalaze da jedino siler na bazi biokeramičkih čestica EndoSequence BC stvara nezadovoljavajući dijametar od oko 18 mm, dok ostali (AH-Plus, AD Seal, Radic-Sealer i tri biokeramička silera EndoSequence BC Sealer, EndoSeal MTA, MTA Fillapex, AD Seal i Radic-Sealer) pokazuju prečnike zadovoljavajućih vrednosti (većih od 20 mm) [31]. Jeanneau C. i sar. ispituju antiinflamatorno dejstvo Endometazona N i silera Pulp Canal i zaključuju da samo standardno zamešan (ili kao gušća konzistencija) ovaj siler omogućava pravilno očvršćavanje i zasićenje cink-oksida eugenolom i na taj način ispoljava i svoje antiinflamatorno dejstvo smanjenjem lučenja interleukina-6 [32].

Grupa autora poredi i fluidnosti ISO standardom i viskozitet silera uz pomoću reometra, označava ovu drugu metodu kao precizniju (ρ = -0,8618) i ističe najveću fluidnost za Pulp Canal Sealer EWT, potom kod silera AH Plus, Sealapex i Capseala [33].

Može se primetiti da heterogenost rezultata o nivou fluidnosti ES u bogatoj literaturi iz ove problematike ukazuje na potrebu pridržavanja standardno propisanih protokola, kako bi rezultati mnogobrojnih studija bili verodostojno uporedivi.

Što se tiče kliničkog aspekta, gustina zamešanog silera treba da je u funkciji svakog pojedinačnog slučaja i naravno u funkciji izabrane tehnike opturacije.

ZAKLJUČAK

Na osnovu rezultata ovih istraživanja može se zaključiti da svi testirani sileri pokazuju zadovoljavajući nivo fluidnosti. Najveću fluidnost pokazala je pasta Tubliseal EWT, potom Roth 801 cement, a najmanju Endometazon N.

sciendo

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Review of lasers application in dentistry

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SUMMARY
In this paper the mechanism of stimulated emission is described as the fundamental of laser technology. The types of lasers from the aspect of their operation are also given. The particular attention is paid to dental lasers and their effect on healing processes in bone, dentin, enamel etc.
Keywords: lasers; dental lasers; bone regeneration; hard dental tissue; soft tissue

INTRODUCTION

Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation, Maiman developed the first laser prototype in 1960 [1]. His device used a crystal medium of ruby that emitted a coherent light when it was stimulated by energy. A bit later, in 1961, Snitzer published his paper with the prototype of the Nd:YAG laser [2]. The first application of laser on dental tissue was reported by Goldman et al. and Stern and Sognnaes [3, 4]. In their papers, the effects of the ruby laser on enamel and dentin were described. Further application of lasers in dentistry was studied in the paper published in 1985 by Myers and Myers, where *in vivo* removal of dental caries using a modified ophthalmic Nd:YAG laser was presented [5]. Several years later, it was recommended that Nd:YAG laser could be used for oral soft tissue surgery, due to its effect on healing of various dental diseases [6].

The purpose of this review was to analyze wide area of laser applications and principle of its specific functions, as well as application of lasers in treating common oral soft and hard tissue problems.

Basic laser theory

Laser is the acronym of the words "Light Amplification by Stimulated Emission of Radiation". Lasers have come a long way since Albert Einstein described the theory of stimulated emission in 1917. Einstein in his theory of stimulated emission predicted that excited atoms could convert stored energy into light in the process by which an incoming photon of a specific frequency can interact with an excited atomic electron (or other excited molecular state), causing it to drop to a lower energy level. The generated energy transfers to electromagnetic field, creating a new photon. This process has two important characteristics. First, it is multiplicative, because one photon induces two photons. If these two photons interact with two other excited atoms, this will yield a total of four photons, and so forth (Figure 1). Second and most importantly, these two photons have identical properties: wavelength, direction, phase, and polarization. This ability to "amplify" light in the presence of a sufficient number of excited atoms leads to "optical gain" that is the basis of the laser operation [7].

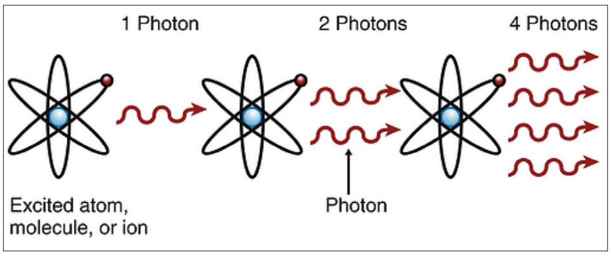

Figure 1. Light amplification by stimulated emission of radiation
Slika 1. Amplifikacija svetlosti stimulisanom emisijom zračenja

Figure 2 shows three and four level lasers. In three level lasers, a burst of energy excites electrons in more than half of atoms from their ground state to a higher state, creating a population inversion. The electrons then drop into a long-lived state with slightly less energy, where they can be stimulated to quickly shed excess energy as a laser burst, returning electrons to a stable ground state. In four level lasers a sustained laser beam can be achieved by using atoms that have two relatively stable levels between their ground state and a higher-energy excited state. As in a three-level laser, atoms first drop to a long-lived metastable state where they can be stimulated to emit excess energy. However, instead of dropping to the ground state, they stop at another state above the ground state from which they can easily be excited back up to the higher metastable state, thereby maintaining the population inversion needed for continuous laser operation.

A wide range of solid, liquid and gas-phase materials have been discovered that exhibit gain under appropriate pumping. A laser generally contains *laser* resonator (or *la-*

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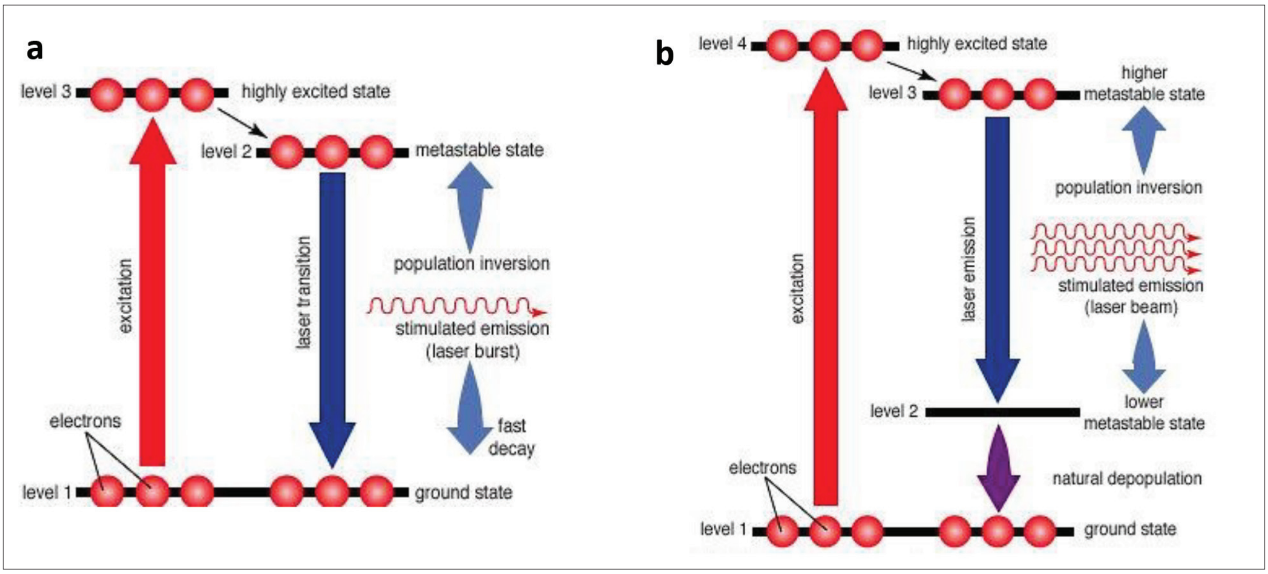

Figure 2. a) Three-level laser, b) Four-level laser
Slika 2. a) Laser sa tri nivoa energije, b) Laser sa četiri nivoa energije

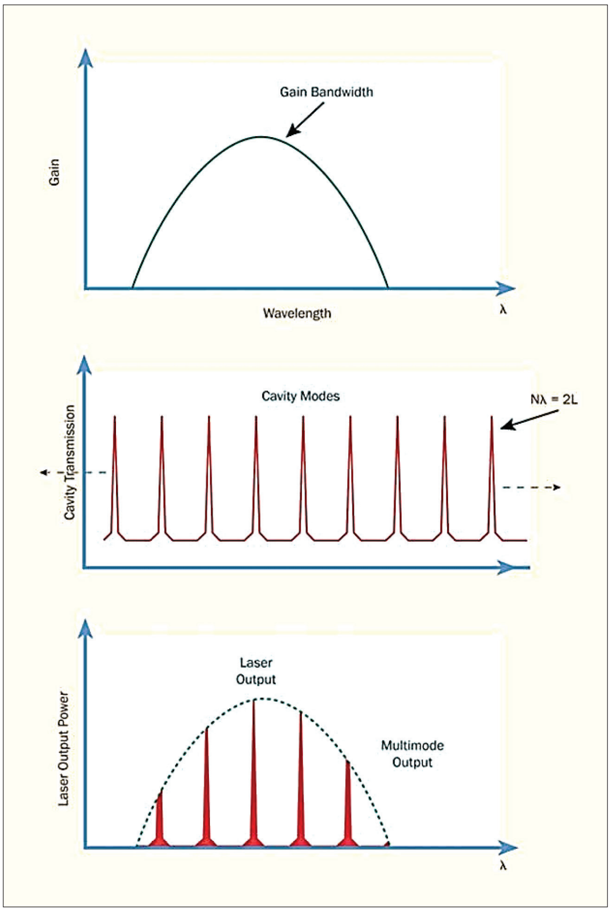

Figure 3. A resonant cavity supports only modes that meet the resonance condition, for cavity length. The output of a CW laser is defined by the overlap of the gain bandwidth and these resonant cavity modes.
Slika 3. Rezonantna kutija podržava samo modove koji postižu rezonantne uslove, za datu dužinu kutije. Izlazna snaga kontinualnog lasera definisana je preklapanjem opsega i modova rezonantne kutije.

ser cavity), in which laser radiation can circulate and pass a gain medium that compensates optical losses (Figure 3). Exceptions are a few cases where a medium with very high gain is used, so that amplified spontaneous emission extracts significant power in a single pass through the gain medium, such as excimer laser. Additionally, a laser resonator typically contains multiple laser mirrors, enabling multiple pass of generating photons, through its gain medium, and additional optical elements e.g. for wavelength tuning, Q switching mode, or locking. The laser mediums can be crystals, semiconductors, or gas enclosed in an appropriate confinement structure. It is placed along the optical axis of the resonator. This unique axis with very high optical gain becomes also the direction of propagation of the laser beam. A somewhat different example of a uniquely long (and flexible) gain axis is the fibre laser [8, 9].

Types of lasers

Lasers, from the aspect of its way of operation can be divided in three basic categories: continuous wave (CW), pulsed and ultrafast.

Continuous lasers

Continuous wave lasers produce a continuous, uninterrupted beam of light, with high stable output power. The exact wavelength of laser beam is determined by the characteristics of the laser medium. For example, CO_2 molecules readily excite at 10.6 μm, while neodymium-based crystals (like YAG or vanadate) produce wavelengths in the range between 1047 and 1064 nm. Additionally, each laser wavelength is followed by corresponding line-width, which depends mainly on the gain bandwidth of the lasing medium, filters and design of optical resonator. The specific wavelengths of the output beam within this gain bandwidth are determined by the longitudinal modes of the cavity. A laser that produces multiple longitudinal modes has a limited coherence, because different wavelengths cannot stay in phase over extended distances [10].

For some laser types with a narrow gain bandwidth, single-mode output is achieved with a very short resonant cavity. Generally, filtering elements are used to provide a preferential pass for only one mode generated into the cavity. The most common type of filter is called an etalon. Using various sophisticated design enhancements, it is possible to restrict the line-width of a laser to less than 1 kHz, useful for scientific applications. Some solid-state lasers have extremely broad bandwidths (order of hundreds of nanometers). This broad bandwidth enables the design of tunable and ultrafast (femtosecond and picosecond pulse width) lasers. Most applications of CW lasers require its stable power over long time (hours or weeks), as well as over short time durations (microseconds), depending on the specific application. To ensure this stability appropriate control of temperature and vibration, the aging of the laser itself and microprocessor control loops are very important factors [10, 11].

Pulsed lasers

Pulsed lasers are defined as laser devices that produce pulses of 0.5 to 500 ns (Figure 4). Some excited dimers (or "excimers") of a noble gas with halogen, such as ArF and XeCl, show quick laser action for only a several nanoseconds. Other lasers, like Nd or Yb diode-pumped solid-state (DPSS) lasers, also can operate both in CW or puls regime, while laser diodes, are not suitable at all for pulsed operations. The most important characteristic of a nanosecond-pulsed laser is the capability to "store" and release energy very rapidly; i.e., on a nanosecond scale so that the laser output can achieve tens of kilowatts to megawatts of peak power. This high-energy peak enables ablation of processing materials. Nanosecond-pulsed laser is substantially different from CW laser. The key to producing these energetic pulses is storing energy from the pump in atoms or molecules of the lasing medium by preventing the laser gain and the amplification process. Then, when the stored energy is at its maximum, lasing action is rapidly enabled [12].

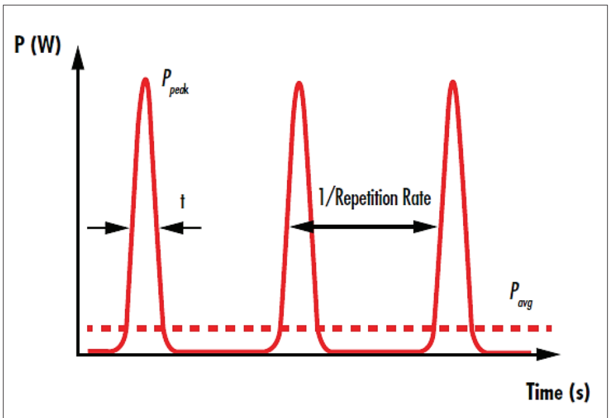

Figure 4. The pulses of a pulsed laser are temporally separated by the inverse of the repetition rate.
Slika 4. Pulsevi kod pulsnog lasera su privremeno razdvojeni inverzijom ponavljajuće frekvence.

The stored energy induces in extremely high laser amplification during only a few round trips, when giant pulse builds up. This regime is called Q-switched operation and can be presented as a two-mirror cavity with an optical gate located between one of the mirrors and laser medium. When the gate is closed and the laser medium is pumped, photons cannot circulate in the cavity, and the excitation of the atoms builds up, while when the gate is opened, photons start to build up via stimulated emission with a very large gain at each round trip. Typical pulse duration is 1 to 200 ns. It depends on the type of gain medium and how much energy it can store, the cavity length, the repetition rate of the pulses and the pump energy [13]. Excimer lasers do not require a Q-switch to produce nanosecond pulses, which are produced by exciting the noble gas-halogen mixture with powerful and short electric discharge.

Ultrafast lasers

Ultrafast lasers are lasers that produce pulses in the range of 5 fs to 100 ps (1 femtosecond = 10^{-15} seconds). Such short pulses can be produced with so-called mode-locking technique. With this technique, the modes are locked in phase (mode-locking regime) and their coherent interference causes the intra-cavity optical field to collapse into a single pulse traveling back and forth in the laser cavity. Generally, it is shown that as more as interfering modes, the pulse duration is shorter. Since larger lasing bandwidths support a larger number of oscillating modes, the pulse duration is inversely proportional to the bandwidth of the laser gain material. Ultrafast pulses are highly useful in research, due to short pulse duration and high peak power [14]. Recently developed femtosecond lasers enabled ground breaking research leading to Nobel prizes for femto-chemistry. Femtosecond lasers enabled multiphoton excitation (MPE) techniques that deliver three-dimensional imaging of live tissue. MPE is now widely used in several areas of biological research, presumably in neuroscience. In the case of femtosecond lasers, the high peak power of the amplified pulses can damage the laser optics. For this reason, the amplification is usually preceded by stretching the pulse (chirping) from 50 to 200 ps. The amplified pulse is then re-compressed to the fs domain. This is commonly referred to as chirped pulse amplification, or CPA (Figure 5).

In scientific research, amplified ultrafast pulses are used in photochemistry, pump-probe spectroscopy, terahertz (THz) generation and creating accelerated electrons and other small charged particles. The pulses can also drive nonlinear generation of extreme-UV light with pulse widths of tens of attoseconds [14, 15]. Ultrafast lasers are mainly based on titanium:sapphire (Ti:sapphire) because of its large bandwidth and broad tuning range, enabling them delivering pulses as short as 6 fs. Ti:sapphire lasers are typically pumped using a green-wavelength CW pump laser. Typical repetition rates of Ti:sapphire oscillators are 50 to 100 MHz, and peak powers several hundred kilowatts. The most common CPA systems based on Ti:sapphire operate at 1 to 10 kHz with the amplifier stages energized by nanosecond green lasers. It has ability to produce pulse

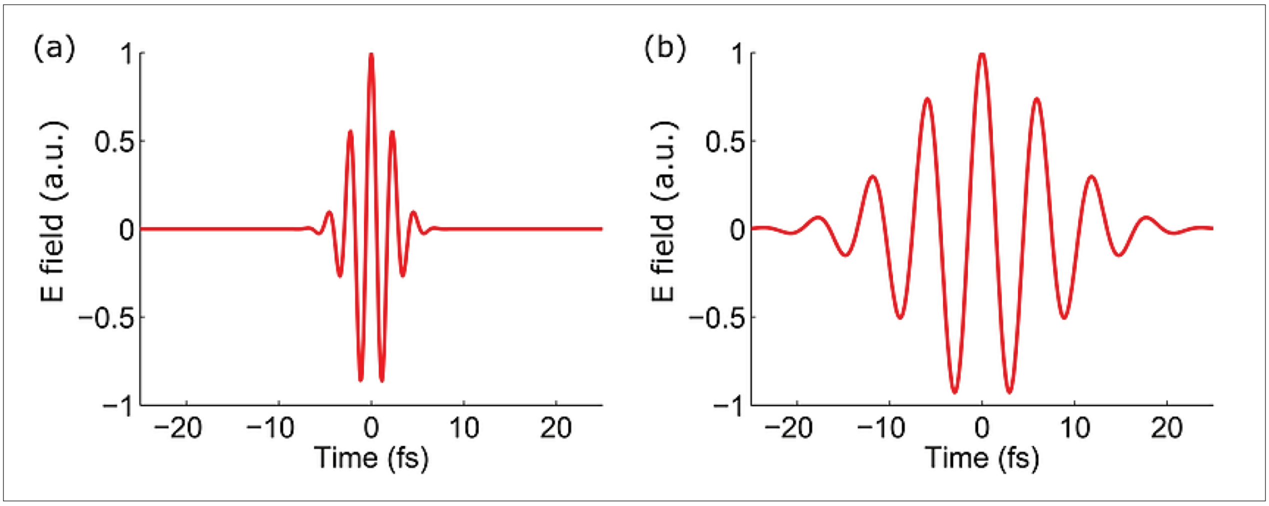

Figure 5. Calculated electric field evolution of the laser pulses used in experiment. (a) Pulse duration: 5 fs, central wavelength: 700 nm, (b) Pulse duration: 18 fs, central wavelength: 1800 nm

Slika 5. Izračunata evolucija električnog polja pulsa lasera tokom ogleda. (a) Trajanje pulsa: 5 fs, središnja talasna dužina: 700 nm, (b) Trajanje pulsa: 18 fs, središnja talasna dužina: 1800 nm.

energies of several milijoules with pulse widths as short as 20 fs. These systems can produce power of petawatt range [16]. Most of these systems recently are based on Nd-doped bulk materials (e.g., YAG or glass) or fiber, or a combination of the two, although smaller gain bandwidth of Nd limited the ps regime [17].

Yb-doped materials combine to some extent the advantages of Ti:sapphire scientific lasers and Nd-based industrial lasers. For scientific research, the gain bandwidth of Yb means oscillator pulses can be as short as 50 fs, which is more than adequate for many applications, particularly in MPE microscopy [18]. As for the scientific applications extremely short (>6 fs) pulse widths and/or high pulse energies are needed, Ti:sapphire remains the preferred gain material for such purposes. Femtosecond laser pulses have two advantages over picosecond pulses for materials processing. First, the material interaction involves many simultaneous photons and becomes reasonably wavelength insensitive, unlike with nanosecond linear absorption. Second, the short pulses and nonlinear interaction influence that fs pulses can deliver even better edge quality and precision than ps pulses.

Typical laser properties

The photons inside the laser beam are all in phase, or "coherent," causing propagation of electric field with a uniform wave front. Because a laser beam is highly directional, its brightness is much more intense than other light sources. An ideal laser should emit all photons with exactly the same energy and wavelength, and it would be perfectly monochromatic, but due to several broadening mechanisms as it is Doppler broadening frequently, frequency is often widened. Consequently, YAG lasers can have line widths of hundreds of gigahertz, while stabilized diode-pumped YAG lasers can have a line width <1 kHz [19].

Today, lasers enable for the first time DNA sequencing, and freezing the motion of electrons around atoms as it can generate very short pulses (below 10^{-16} s), and measurements of the absolute frequencies with an accuracy of ~10^{-15}. The input energy can take many forms. Among them, two most frequent are optical and electrical. For optical pumping, lamp or another laser as energy source are used, while for electrical pumping DC current (as in laser diodes) electrical discharge (noble gas lasers and excimer lasers), or a radio-frequency discharge (some CO_2 lasers) are used [20].

There are several kinds of lasers used in dental practice, which are divided according to active medium that is stimulated. This medium can be gas (e.g. argon, carbon dioxide), liquid (dyes) or solid state crystal rod as in the case of the neodymium yttrium aluminum garnet (Nd:YAG), erbium yttrium aluminum garnet (Er:YAG) or a semi conductors (diode lasers). As it was explained above the active mediums contain atoms which electrons can be excited to a metastable energy level by an energy source: optical (e.g. xenon flash lamps, other lasers), electrical (e.g. gas discharge tubes, electric current in semi-conductors) or chemical method. Due to the high level of coherency of monochromatic laser beam, its energy can be delivered on to target tissue as a continuous wave, gated-pulse mode (laser is periodically in an on and off mode) or free running pulse mode (energy is emitted for an extremely short span, in microseconds followed by a relatively long time which the laser is off). Fibre optics for visible and near infrared lasers is used for more efficient transfer energy to the corresponding tissue, while the articulated arms, with mirrors at joints, was used for UV, visible and infrared lasers, and hollow waveguides (flexible tube with reflecting internal surfaces), for middle and far infrared lasers [21].

Recently, fibre optic delivery systems are mostly used, as they can deliver laser energy to most parts of the oral cavity, even within the complex root canal system. This system can deliver energy in forward direction, with minimal dissipation from the bare end of a plain tip. Therefore, it is applied in cases of cavity preparation or soft tissue surgery. In some cases, this drawback related to the energy dissipation may cause some difficulties in lateral transfer energy, limiting its use for applications in root canal treatment. Recently, a number of fibre optic modifications are suggested to overcome this limitation. Other factors that influence the laser choice for dental hard and soft tissue are absorption of laser beam by chromophores (water, apatite minerals, and various pigmented substances) inside of the target tissue because better absorption allows more efficient photo-thermal sterilization, ablation of dentin, etc. Besides, rapid heating of water molecules within enamel can cause rapid vaporization of water and build-up of steam that induce huge expansion of dental structures, leading to material breaks by exploding, through this process of ablation. In the case of high-powered lasers, tissue vaporization or coagulation through absorption in a major tissue component is known as photo-thermal ablation. Photomechanical ablation includes tissue disruption due to shock wave formation, cavitation, etc. The photochemical effects are induced by light-sensitive substances, and today are used for its antibacterial effect and in cancer treatment. The typical variables in laser application are wavelength, pulse energy or power output, exposure time, spot size (and thus energy density), and the tissue physical and chemical composition (e.g. water content, density, thermal conductivity and thermal relaxation) [22].

Lasers are grouped into seven classes depending on the potential for the beam to cause harm. The hazard and classification depend on the wavelength, power, energy and pulse characteristics. These groups are: class 1 and 1M (inherently safe); class 2 and 2M (where the eye is protected by the blink reflex); class 3R and 2B (where direct viewing is hazardous); and class 4 (where the laser power is above 0.5 Watts, and the laser is classed as extremely hazardous) [23].

Dental lasers

Most dental and medical lasers belong to class IV, and thus, compliance with safety standards is necessary to protect the dentist, patient and supporting staff. Lasers used in dentistry vary from ultraviolet light (100-400 nm), to infrared spectrum (750 nm-1 mm). The visible spectrum lies between these two wavelengths (400-750 nm). Lasers used in dentistry cover a broad range of procedures, from diagnosis of caries or cancer to soft tissue and hard tissue procedure.

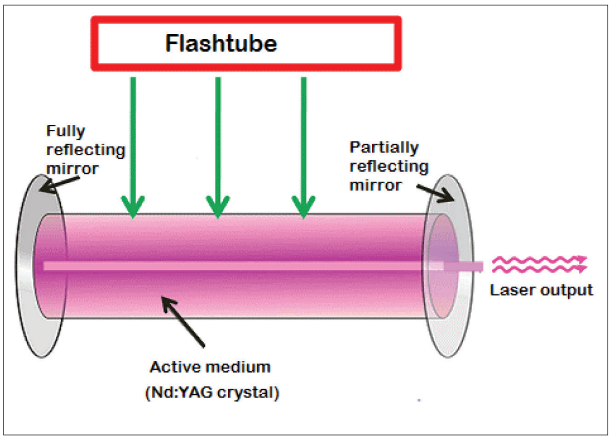

Figure 6. Typical schematic appearance of Nd: YAG laser
Slika 6. Tipični šematski prikaz lasera Nd:YAG

The first application of laser on dental tissue was reported by Goldman et al. and Stern and Sognnaes, when the effects of the ruby laser on enamel and dentin were described [3, 4]. Many studies were done after 1985, after publishing the paper by Myers that described *in vivo* removal of dental caries using modified ophthalmic Nd:YAG laser (Figure 6) [5]. Four years later, Nd:YAG laser (neodymium doped yttrium aluminum garnet) was used for oral soft tissue surgery, and that introduced the use of these lasers in clinical periodontics [24]. Lasers commonly used in dentistry consist of a variety of wavelengths delivered as either a continuous, pulsed (gated), or running pulse waveform, e.g., CO_2, Nd:YAG, Ho:YAG, Er:YAG, Er, Cr:YSGG, Nd:YAP, GaAs, diode laser and argon laser (Figure 7). Lasers with shorter wavelengths and pulse widths combined with higher-power densities are not currently relevant to dental applications [25].

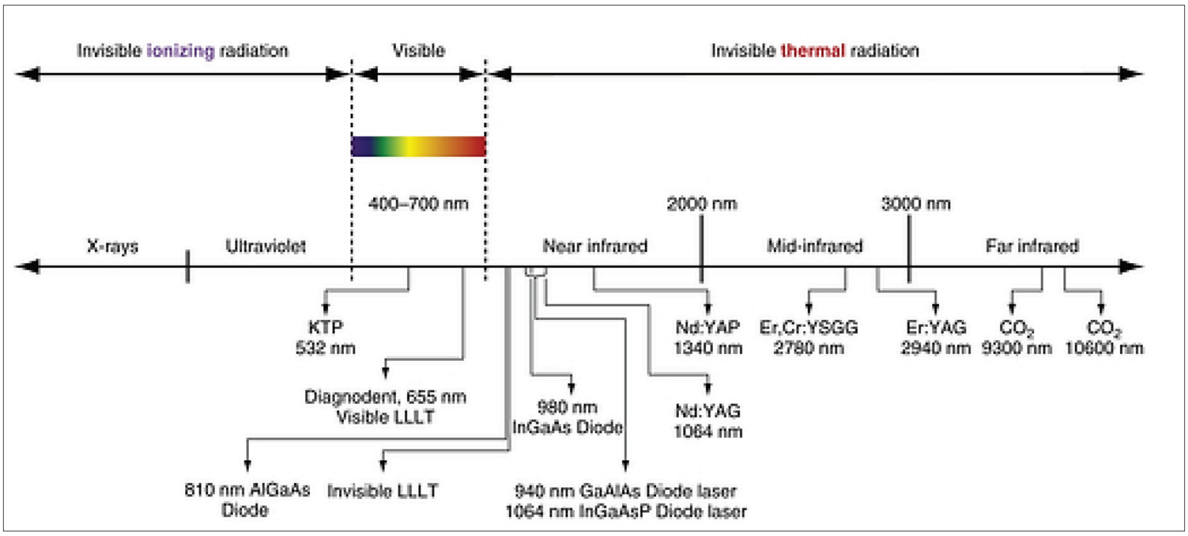

Figure 7. Dental lasers wavelengths in the electromagnetic spectrum
Slika 7. Laseri u stomatologiji po talasnim dužinama prema elektromagnetnom spektru

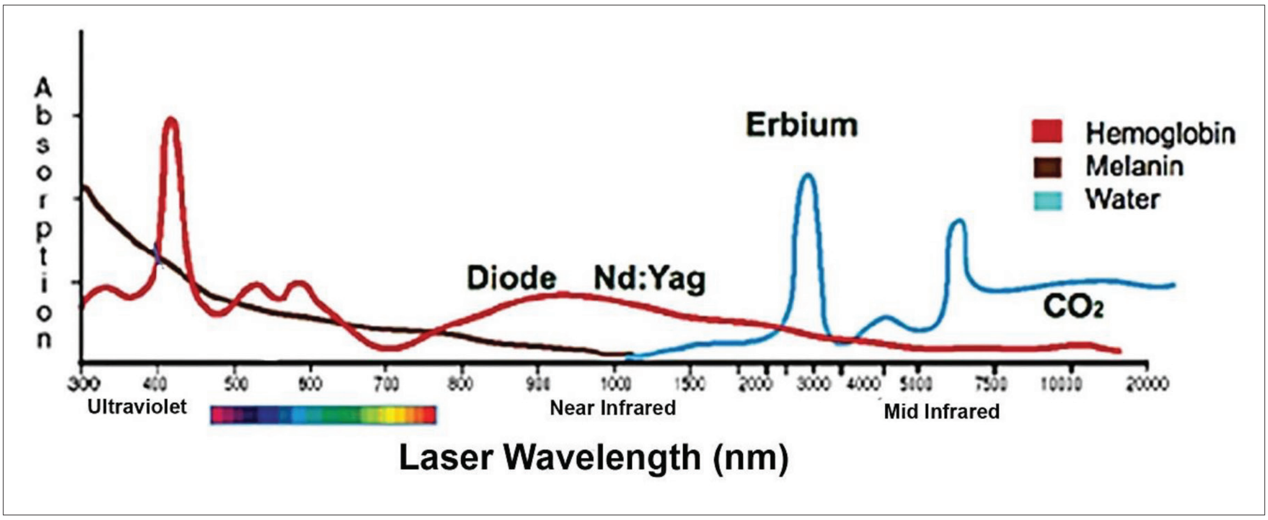

Figure 8. Lasers used in dentistry and their affinity to oral materials
Slika 8. Laseri primenjeni u stomatologiji i njihov afinitet ka oralnim tkivima

In biologic tissues, the laser energy is absorbed by surface tissues and will only exhibit scattered penetration in deep tissues. Absorbed light energy is converted to heat and cause various photo thermal events like warming, coagulation, or excision and incision through tissue vaporization. The energy absorption depends on various parameters like emission wavelength, power (watts), waveform (continuous or pulsed), pulse duration, energy/pulse, energy density, duration of exposure, peak power of pulse, angulation of the energy delivery tip to the target surface, and optical properties of the tissue (Figure 8) [26].

Optical properties of a tissue influence the interaction with specific laser wavelengths. In the case of periodontium, optical properties of tissues depend on its pigmentation, water content, mineral content, heat capacity that accounts for both thermal conductivity and tissue density, and latent heat transformation (i.e., denaturation of proteins, vaporization of water, and melting of mineral). Taking into account that bone is the classic composite tissue, consisting of 67% inorganic minerals (calcium hydroxyapatite) and 33% collagen and non-collagenous proteins, or gingiva which is constituted from various densities of fibrous connective tissue, associated extracellular matrix components, and a high content of water (70%), their optical properties are also determined by its specific composition. Additionally, gingiva frequently exhibits melanin pigmentation. Other factors that are included in laser-tissue interactions are processes of heat conduction and dissipation, the degree of tissue inflammation and vascularity, and availability of progenitor cells to participate in the healing process. Each wavelength of laser energy is absorbed to a greater or lesser degree in their components, like water, pigment, or hydroxyapatite [27].

Knowing that CO_2 laser (10600 nm wavelength) has a high absorption coefficient in water, it is suitable for soft tissue surgery but recently it has no scientifically well-supported clinical application to mineralized tissues. Nd:YAG (1064 nm wavelength) and diode lasers (800 to 950 nm wavelength) have lower absorption coefficients in water than CO_2 lasers, but they are preferentially absorbed in pigmented tissues, while the Er,Cr:YSGG and Er:YAG wavelengths (2780 and 2940 nm, respectively) are highly absorbed in both water and hydroxyapatite [28]. Therefore, the clinicians should, in each case, determine the specific clinical treatment aims and then select the adequate technology (laser or otherwise) to achieve the desired endpoint(s).

For many intraoral soft tissue surgical procedures, the laser is suitable alternative to scalpel. The CO_2, Nd:YAG, and diode lasers are primarily used for intraoral soft tissue procedures, such as frenectomy, gingivectomy and gingivoplasty, epithelization of reflected periodontal flaps, removal of granulation tissue, second stage exposure of dental implants, lesion ablation, incisional and excisional biopsies of both benign and malignant lesions, irradiation of aphthous ulcers, coagulation of free gingival graft donor sites, and gingival depigmentation. Besides, there are evidences of faster healing after using laser on soft tissue wounds that are wavelength specific and highly sensitive to energy density. Most studies used CO_2, Nd:YAG, or diode lasers. A comparison of wound healing induced by Nd:YAG and CO_2 lasers indicates that CO_2 laser used in oral, oropharyngeal and laryngeal mucosa caused significantly faster healing than Nd:YAG laser, but conventional scalpel-induced wound healed faster then after laser use. Wound healing was comparable between scalpel and Nd:YAG laser when laser was used at lower power of 1.75 W and 20 Hz. However, investigations based on tissue histology showed that high power (watts), long pulse duration, high repetition rates (hertz), and long interaction times (duration of target exposure) all increased the risk of negative outcomes. Comparison of laser and scalpel surgery was broadly investigated in numerous medical and veterinary journals. From the aspect of laser wavelengths and various tissue parameters like incision time, blood loss, swelling and oedema, pain, and general wound healing, great diversity of data has been reported. However, in most papers laser technology showed numerous advantages, like higher level of clinician control, operating efficiency, tip flexibility and accessory selection [27, 28].

Figure 9. Representative radiological images of tibia bone after artificial fracture
Slika 9. Reprezentativni rendgenski snimci tibije posle preloma

Effect of lasers on bone healing

Laser-biologic tissue interactions are wavelength dependent photo-thermal events, as most of dental laser effects on bone are potentially damaging. It seems that only wavelengths of Er:YAG and Er,Cr:YSGG lasers are suitable for such application. It has been shown that bone surface exposed to the same total laser energy showed temperature increase for CO_2 from 1.4^{0}C to 2.1^{0}C and for Nd:YAG laser, it was 8.0^{0}C to 11.1^{0}C [29, 30]. These results indicate that for ablation relatively thin soft tissues supported by adjacent bone is needed (e.g. mandibular facial, gingival and alveolar mucosa). If the Nd:YAG laser is used it should have relatively low energy densities emitted in short time intervals to prevent risk of irreversible bone damage. It was found that Er:YAG laser, when used at a peak pulse energy of 100 mJ/pulse and 10 Hz, produced well-defined intrabony cuts with no evidence of melting or carbonization [29–32]. Figure 9 shows that laser-treated group exhibited earlier new bone formation compared to non treated group [33].

Fourier transform infrared spectroscopy (FTIR), energy dispersive x-ray spectroscopy (EDX), and x-ray diffraction analysis revealed normal collagen/hydroxyapatite relationship with thin surface layer characterized by slight increase in calcium/phosphate ratio due to formation of tetracalcium phosphate, which was similar chemical composition formed after the use of rotary bur method. On the other hand CO_2 laser–induced osteotomies exhibited extensive carbonization, melting of mineral phase, and delayed healing [29]. Also, some recent studies suggested that Er, Cr:YSGG wavelength is suitable for use on bone, as EDX analysis showed no change in calcium/phosphate ratio, and there was no evidence of charring or melting. Surface modification of cement and dentin exposed to variety of laser wavelengths, primarily CO_2, Nd:YAG, and Er:YAG lasers showed that they can be efficiently used for removing calculus, if wavelength characterized by minimal penetration depth in mineralized tissue was selected. This is important to suppress both thermal damage to the pulp tissue and undesired removal of sound root structure. The mineral phase of both cement and dentin is carbonated hydroxyapatite that has intense absorption bands in the mid-infrared region [27–32].

Consequently, of all lasers studied, the Er:YAG laser would appear to be the laser of choice for effective removal of calculus, root etching, and creation of a biocompatible surface for cells and tissue reattachment. Contrary, if CO_2 laser it used, even at the low energy, FTIR analysis showed presence of toxic chemical residues of cyanamide and cyanate, followed by lack of flap reattachment to the surface of treated root area. Therefore, CO_2 lasers have restricted application in subgingival periodontal therapy. At energy densities of 100 to 400 J/cm^2 for CO_2 and 286 to 1,857 J/cm^2 for Nd:YAG lasers, the certain degree of morphologic change in root surfaces induced by laser irradiation, like cavitation defects, globules of melted and re-solidified mineral, changes in root structure proteins, surface crazing, and production of superficial layer directly dependent on energy density is observed. In contrast to studies reporting unfavourable results, Nd:YAG laser with low energy densities or combination of low energy density with a defocused beam, showed to be suitable for removing root surface smear layers without causing collateral damage to underlying cement and/or dentin, or increasing temperatures to a level that might trigger irreversible pulpal damage [34, 35, 36].

A relatively new laser, Nd:YAP with a wavelength of 1,340 nm, tested on root surfaces of extracted teeth, showed the presence of heat-induced damages at energy densities ranging from 509 to 1,274 J/cm^2. The degree of damage was directly related to increasing energy density and progressively grew from simple surface cracking of cement to deep cratering, melting and deep ablation of cement with exposure of underlying dentin. Recently, the Er,Cr:YSGG laser, and to a lesser extent the Er:YAG laser, have been promoted for clinical crown lengthening without gingival flap reflection for both aesthetic and prosthetic reasons. Obviously, aesthetic crown lengthening can easily be managed with lasers if clinically short crowns are the result of gingival overgrowth or lack of passive eruption. In such cases increased probing depth (PD) is caused by excessive amounts of soft tissue [34–37].

The use of dental laser in the treatment of chronic periodontitis is based on regeneration of mucogingival attachment, cement, periodontal ligament, and supporting alveolar bone, and significant decrease in sub-gingival pathogenic bacteria. There is limited evidence suggesting that lasers cause greater reductions in subgingival bacteria than that achieved by traditional treatment. Most laser bactericidal studies report a dose/response relationship. However, in many studies, energy densities are often not reported or cannot be calculated due to incomplete listing of parameters. Finally, the angle of irradiation can vary from 0 to 90^0, making computation of energy densities nearly impossible [38–41].

One of the first *in vivo* studies reporting reductions in pathogenic bacteria following irradiation with Nd:YAG laser showed decrease in *Porphyromonas gingivalis* (Pg), Prevotella *intermedia* (Pi) and *Actinobacillus actinomycetemcomitans* (Aa) [38]. However, teeth extracted 7-days post-treatment exhibited recolonization of laser-irradiated subgingival root surfaces by multiple morphotypes of bacteria. *In vitro* studies using Nd:YAG laser at low power settings have reported calculus ablation without detrimental effects to underlying cement or dentin. A linear relationship between energy level, microbial numbers, and concentration of hemoglobin (blood) has been found as well as minimal energy required for bactericidal effect, different susceptibility of various microbes to laser energy, different susceptibility to damage of calculus, cement, and dentin, even within the same specimen. It also showed variability in color, thickness, composition, texture, and water content [38–41]. The diode laser (805 nm), when used adjunctively with traditional scaling and root planning method (SRP), have shown an additive effect in reducing subgingival bacterial populations in periodontal pockets of 4 mm depth. However, many *in vivo* studies showed the persistence of viable bacteria following subgingival laser irradiation [38, 40, 41].

CONCLUSIONS

In this paper irradiation of biologic tissues by a specific wavelength of laser was studied. Based on this review, interaction of dental tissue with laser depends on the type, energy and wavelength of lasers used. This knowledge should be implemented for the right choice of laser parameters, without destruction of treated soft and hard dental tissues. Beside specific laser applications, our review described basic elements of stimulated emission; principles of laser function, main types of laser instrumentation, advantages and disadvantages of certain types of laser applications.

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Primena lasera u stomatologiji – pregled literature

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KRATAK SADRŽAJ

U ovom radu opisan je mehanizam stimulisane emisije, kao osnova tehnologije rada lasera. Navedeni su i tipovi lasera sa aspekta njihove primene. Posebna pažnja je posvećena laserima u stomatologiji, kao i uticaju njihovih karakteristika na mogućnost regeneracije kosti, dentina i drugih oralnih tkiva.

Ključne reči: laseri; laseri u stomatologiji; regeneracija kosti; čvsto zubno tkivo; meko tkivo

UVOD

Na osnovu teorije o spontanoj i stimulisanoj emisiji zračenja Alberta Ajnštajna, Majman je napravio prvi prototip lasera 1960. godine [1]. Njegov uređaj je koristio kristalni medijum rubina, koji je emitovao koherentno svetlo kada je bilo stimulisano energijom. Nešto kasnije, 1961. godine, Šnicer je objavio rad koji je opisivao prototip lasera Nd:YAG [2]. Prva primena lasera na oralnim tkivima opisana je od strane Goldmana i sar., kao i Sterna i Sognesa [3, 4]. Opisana je primena rubinskog lasera u nagrizanju gleđi i dentina. Dalja primena lasera u stomatologiji zabeležena je u radu publikovanom 1985. od strane Majersa i Majersa, u kome je prikazano *in vivo* uklanjanje zubnog karijesa korišćenjem modifikovanog oftalmološkog lasera Nd:YAG [5]. Nekoliko godina kasnije preporučena je upotreba lasera Nd:YAG u mekotkivnoj hirurgiji za lečenje mnogobrojnih oralnih oboljenja [6].

Cilj ovog preglednog rada je analiza veoma širokog polja primene lasera i principa njihovog funkcionisanja, u nameri da se da kratki pregled današnjih stavova u stomatološkim naukama u vezi sa primenom lasera na tvrdim i mekim oralnim tkivima.

Osnovna teorija lasera

Laser je akronim nastao od engleskih reči za amplifikaciju svetla stimulisanom emisijom zračenja (eng. *Light Amplification by Stimulated Emission of Radiation*). Laseri su u svom razvoju prošli veliki put od kad je Albert Ajnštajn opisao teoriju stimulisane emisije 1917. godine. Ajnštajn je u svojoj teoriji predvideo da pobuđeni atomi mogu pretvoriti nastalu energiju u svetlost tokom procesa u kome foton određene frekvencije interaguje sa pobuđenim elektronom (ili nekim drugim pobuđenim molekularnim stanjem), dovodeći do smanjenja nivoa energije atoma. Energija/foton nastala pri tome prenosi se u elektromagnetnom polju stvarajući novi foton. Ovaj proces ima dva važna svojstva. Prvi je svojstvo mutliplikacije, jer jedan foton indukuje stvaranje dva fotona. Ukoliko ova dva fotona dođu u interakciju sa druga dva pobuđena atoma, kao rezultat će nastati četiri fotona, i tako dalje (Slika 1). Drugo, veoma važno svojstvo je to što nastali fotoni imaju identične karakteristike: talasnu dužinu, usmerenost, fazu i polarizaciju. Ovo svojstvo „umnožavanja“ svetla u prisustvu dovoljnog broja pobuđenih atoma vodi u „optičku dobit“, koja je osnova funkcionisanja lasera [7].

Slika 2 prikazuje lasere sa tri i četiri nivoa energije (a, b). Kod lasera sa tri nivoa snop energije pobuđuje elektrone u preko pola atoma i prevodi ih iz osnovnog u više stanje, stvarajući inverznu populaciju elektrona. Elektroni se zatim spuštaju u dugopostojeće stanje sa nešto nižom energijom, iz koga lako mogu biti stimulisani da brzo oslobode višak energije u vidu laserskog snopa, vraćajući elektron u stabilno osnovno stanje. Kod lasera sa četiri nivoa energije kontinuiran laserski zrak može se postići primenom atoma koji imaju dva relativno stabilna stanja između osnovnog i visokoenergetskog pobuđenog stanja. Kao kod lasera sa tri nivoa energije, atomi prvo prelaze u dugopostojeće međustanje, u kom mogu biti stimulisani da emituju višak energije. Međutim, oni se umesto prelaska u osnovno stanje zadržavaju u stanju iznad osnovog, iz kog lakše mogu biti pobuđeni nazad u međuenergetsko stanje, tako održavajući inverziju populacije potrebnu za kotinuirani rad lasera.

Otkriven je veliki broj materijala u čvrstom, tečnom i gasovitom stanju koji mogu ući u stanje pobuđenosti pod dejstvom odgovarajućeg snopa energije. Laser se obično sastoji od rezonatora (laserskog kućišta), u kom lasersko zračenje može da se prostire i prolazi kroz ciljani medijum, čime se kompenzuje optički gubitak (Slika 3). Izuzetak predstavljaju pojedini slučajevi u kojima se koristi medijum visoke energije, tako da umnožena spontana emisija oslobađa veliku energiju u jednom prolazu kroz ciljani medijum, kao što je slučaj sa egzajmer laserima. Pored toga, rezonator obično sadrži u sebi sistem ogledala, omogućavajući višestruki prolaz stvorenih fotona kroz ciljani medijum, i dodatne optičke elemente, odnosno elemente za podešavanja talasne dužine, Q prelazni mod ili zaključavanje. Laserski medijumi su kristali, poluprovodnici, ili gasovi smešteni u odgovarajuću zatvorenu strukturu. Smešteni su duž optičke osovine rezonatora. Ova jedinstvena osovina sa visokim nivoom optičke energije postaje pravac širenja laserskog svetla. Nešto drugačiji primer jedinstvene, duge (ili savitljive) energetske osovine nalazi se u vlaknu lasera [8, 9].

Vrste lasera

Laseri se, sa aspekta rada, mogu podeliti u tri osnovne kategorije: laseri u kontinuiranom (neprekidnom) radu (CW), pulsni i ultrabrzi pulsni.

Kontinualni mod lasera

Kontinualni talasni laseri proizvode kontinualni, neprekidni laserski zrak, uz veoma stabilnu izlaznu snagu. Tačna talasna dužina laserskog snopa je određena karakteristikama laserskog medijuma. Na primer, CO_2 molekuli ekscituju zrak na 10,6 μm, dok kristali zasnovani na neodimijumskim kristalima (kao što je YAG ili vanadati) produkuju zrak talasnih dužina između 1047 i 1064 nm. Dodatno, svaka talasna dužina praćena je odgovarajućim promerom, koji uglavnom zavisi od protoka kroz medijum, filtera i dizajna optičkog rezonatora. Specifična talasna dužina izlaznog zraka u okviru datog frekventnog opsega određena je longitudinalnim modovima kutije. Laseri koji produkuju višestruke longitudinalne modove imaju ograničenu koherentnost, jer različite talasne dužine ne mogu ostati u fazi tokom velikih rastojanja [10].

Za neke tipove lasera sa uzanim poljem frekventnog opsega, pojedinačni izlazni mod je postignut uz veoma kratku rezonantnu kutiju. Uopšteno, filtrirajući elementi se koriste kako bi se omogućio prolaz samo željenog moda u kutiju. Najčešći tip filtera naziva se etalon. Koristeći različite sofisticirane dizajne pojačivača, moguće je ograničiti promer snopa lasera na manje od 1 kHz, što je korisno za naučnu primenu. Pojedini laseri sa medijumom u čvrstom stanju imaju izrazito široke opsege (izražene u stotinama nanometara).

Široka polja frekventnog opsega omogućavaju dizajn izrazito brzih pulsnih lasera (pauze između pulsa izražene su u femtosekundama i pikosekundama). Primena kontinuiranih lasera zahteva stabilnu snagu tokom dužeg perioda vremena (sati ili nedelje), kao i tokom kraćih perioda (mikrosekunde), zavisno od primene. Kako bi se osigurala adekvatna kontrola temperature i vibracija, vreme starenja samog lasera i mikroprocesora su veoma bitni faktori [10, 11].

Pulsni mod lasera

Pulsni laseri su definisani kao uređaji koji produkuju pulseve između 0,5 do 500 ns (Slika 4). Pojedini ekscitovani dimeri (ekscimeri) plemenitih gasova sa halogenom, kao što su ArF i XeCl, omogućuju veoma brzo dejstvo lasera, koje odgovara vremenu od samo nekoliko nanosekundi. Drugi laseri, kao Nd ili Yb diodni pumpani laseri čvrstog stanja (DPSS), mogu raditi i u kontinualnom i pulsnom modu, dok diodni laseri nisu pogodni za sve pulsne operacije. Najvažnija karakteristika nanosekundnih pulsnih lasera je sposobnost da skladište i oslobode energiju vrlo brzo, pri čemu na nanosekundnoj skali izlazna snaga lasera može postići reda desetine kilovata do megavata snage. Ovaj pik visoke energije omogućava ablaciju materijala, kada se laser koristi u proizvodnji. Nanosekundni pulsni laseri značajno su drugačiji od lasera koji rade u kontinualnom modu. Ključ proizvodnje energetskih pulseva leži u uskladištenoj energiji pumpenjem atoma ili molekula medijuma, što doprinosi aktivnosti lasera i pojačava/ amplifikuje proces prenosa energije. Pritom, kada je skladištena energija na maksimumu, omogućeno je brzo dejstvo lasera [12].

Skladištena energija uslovljava ekstremno velika laserska pojačanja tokom nekoliko ponavljanja, u kojima se proizvodi gigantski puls. Ovaj režim podrazumeva primenu Q-prekidača, koji je smešten u šupljini sa dva ogledala i optičkim izlazom, radi pumpanja energije, koji vodi ka laserskom medijumu. Kada je izlaz zatvoren, fotoni ne cirkulišu u kutiji, te ekscitacija atoma raste, dok posle otvaranja izlaznog dela nastaju fotoni stimulisanom emisijom uz veliku koncentraciju tokom svakog ciklusa. Standardno trajanje pulsa iznosi od 1 do 200 ns. Ono zavisi od vrste medijuma i količine sačuvane energije, dužine kutije, ponavljanja pulsnih talasa i energije [13]. Ekcimer laseri ne zahtevaju Q-prekidače da bi produkovali nanosekundne pulseve, koji u ovom slučaju nastaju ekscitacijom mešavine plemenitog gasa i halogena, koji poseduje moćna kratka električna pražnjenja.

Ultrabrzi laseri

Ultrabrzi laseri produkuju pulseve u rangu između 5 fs do 100 ps (1 femtosekund = 10^{-15} sekundi). Tako kratki pulsevi mogu se razviti tokom takozvane tehnike zaključavanja moda. Tokom ove tehnike modovi su zaključani u fazi (režim zaključanog moda) i njihova koherentna interferencija prouzrokuje da unutar kutije kolapsira optičko polje u jedinstveni puls koji se kreće nazad-napred u kutiji. Pokazano je da što je više interferentnih modova puls je kraći. Pošto veća širina frekventnog opsega podstiče veći broj oscilirajućih modova, dužina pulsa je obrnuto proporcionalna širini frekventnog opsega medijuma lasera. Ultrabrzi laseri su veoma korisni u istraživanjima zbog svojstava kratkog trajanja pulsa i postizanja visokih snaga [14]. Nedavno razvijen femtosekundni laser za koji je dobijena Nobelova nagrada u oblasti hemije omogućio je veoma značajna istraživanja u oblasti medicine. Femtosekundni laseri omogućavaju tehnike multifotonske ekscitacije, koje dalje daju trodimenzionalne slike živih tkiva. Tehnika multifotonske ekscitacije je danas široko primenjena u nekoliko oblasti bioloških istraživanja, posebno u neuronauci. U slučaju femtosekundnih lasera, visoki pik snage umnoženih pulseva može oštetiti optički sistem lasera. Usled toga, umnožavanje je obično praćeno produžavanjem pulsa (pojačanje) od 50 do 200 ps. Umnoženi puls se zatim rekompresuje u fs domen, što se naziva pojačanje pulsiranog impulsa (CPA) (Slika 5).

U istraživanjima, umnoženi ultrabrzi pulsevi se primenjuju u fotohemiji, spektroskopiji, terahercnoj generaciji ubrzanih elektrona i ostalih naelektrisanih čestica. Pulsevi mogu dovesti i do nastanka nelinearnog ekstremnog UV zračenja uz trajanje pulsa od nekoliko desetina atosekundi [14, 15].

Ultrabrzi laseri su uglavnom bazirani na titanijum:safiru (Ti:safir) zahvaljujući velikoj širini frekventnog opsega i opsegu podešavanja frekvencije, što omogućava produkovanje kratkog pulsa dužine 6 fs. Laseri Ti:safir su obično povezani sa laserima koji pripadaju opsegu frekvencija zelenog svetla u kontinuiranom modu rada. Prosečno ponavljanje oscilatora Ti:safir iznosi od 50 do 100 MHz, dok se najveće snage mere u stotinama kilovata. Najčešći CPA sistemi su zasnovani na radu lasera Ti:safir pri 1 do 10 kHz uz nanosekundni zeleni laser za amplifikaciju energije. Može da produkuje pulsne energije od nekoliko milidžula uz trajanje pulsa od samo 20 fs. Ovi sistemi mogu produkovati snagu u rangu veličine petavata [16].

U poslednje vreme većina ovih sistema zasnovana je na Nd-dopiranim materijalima (YAG ili staklo) ili vlaknu, ili kombinaciji ova dva, mada se niža širina frekventnog opsega Nd ograničava na pikosekundni režim [17].

Yb-dopirani materijali kombinuju određene prednosti Ti:safira primenjenih u naučnim istraživanjima i Nd-dopiranih materijala, koji se najčešće koriste u industriji. Za naučna istraživanja širina frekventnog opsega pulsa Yb oscilatora može iznositi samo 50 fs, što je više nego pogodno za razne primene, posebno u MPE mikroskopiji [18]. Usled potrebe da se u istraživanjima primenjuju ekstremno kratki (> 6 fs) pulsevi velikih energija, Ti:safir ostaje najpoželjniji laserski medij/material u ovoj oblasti istraživanja.

Femtosekundne pulsne lasere karakterišu dve prednosti u odnosu na pikosekundne lasere za obradu materijala. Prvo, interakcija materijala podrazumeva mnoge simultane fotone, te materijal postaje neosetljiv na talasnu dužinu, za razliku od nanosekundne linearne apsorpcije. Drugo, kratki pulsevi i nelinearna interakcija utiču da fs pulsevi mogu biti kvalitetniji i precizniji od ps pulseva.

Osnovne karakteristike lasera

Fotoni u laserskom svetlu su svi u fazi, odnosno koherentni, prouzrokujući prolaz električnog polja sa uniformnim talasnim frontom. Usled velike usmerenosti laserskog zraka, jačina svetla je značajno intenzivnija u odnosu na druge izvore svetlosti. Idealni laser trebalo bi da emituje sve fotone potpuno iste energije i talasne dužine, koji bi bili savršeno monohromatski, ali usled nekoliko mehanizama širenja, kao što je Dopler efekat, frekvenca je proširena. Posledično, laseri YAG mogu imati širine od nekoliko stotina gigaherca, dok laseri YAG stabilizovani diodnom nadogradnjom mogu imati širinu <1 kHz [19].

Danas, laseri prvi put omogućavaju sekvenciranje DNK molekula, „zamrzavanje“ elektrona u pokretu oko atoma usled mogućnosti produkovanja veoma kratkih pulseva (ispod 10^{-16} s), kao i merenja apsolutnih frekvencija sa tačnošću od ~10^{-15}. Primljena energija može uzeti mnoge oblike. Među njima, dva najznačajnija su optički i električni izbor energije. Kao optički izvor energije koristi se lampa ili drugi laser, dok se kao električni izvor koristi DC struja (kao u diodnim laserima), električno pražnjenje (laseri plemenitih gasova i egzajmer laseri), ili radiofrekventno pražnjenje (pojedini CO_2 laseri) [20].

Nekoliko vrsta lasera se primenjuje u stomatologiji, a dele se prema aktivnom medijumu koji je stimulisan. Medijumi mogu biti gasovi (argon, ugljen-dioksid), tečnost (neke organske boje), čvrsto kristalno stanje (Nd:YAG, Er:YAG) i poluprovodnici (diodni laseri). Kao što je ranije objašnjeno, aktivni medijumi sadrže atome čiji elektroni mogu biti ekscitovani do metastabilnog nivoa energije primenom različitih energetskih izvora: optičkih (ksenon lampe, drugi laseri), električnih (električno pražnjenje, električna struja u poluprovodnicima) ili hemijskih. Usled visokog nivoa koherentnosti monohromatskog laserskog svetla energija može biti isporučena do ciljanog tkiva u vidu kontinuiranog talasa, u pulsnom modu (laser je periodično u modu uključeno-isključeno), ili slobodnom pulsnom modu (energija je emitovana u veoma kratkom periodu, u mikrosekundama, praćena relativno dugim periodom u kome je laser neaktivan). Za zrak iz vidljivog spektra i lasere koji rade u opsegu bliskog infracrvenog spektra koriste se optička vlakna za efikasniji prenos energije do ciljanog tkiva, dok se uzglobljeni nastavci sa ogledalima i spojevima koriste za lasere sa UV, vidiljivim i infracrvenim spektrima laserskog zraka, dok se šuplji provodnik radiotalasa (savitljiva cev sa refleksivnom unutrašnjom površinom) koristi za lasere iz srednjeg spektra i spektra udaljenog od infracrvenog [21].

U poslednje vreme se najčešće koriste optička valkna jer mogu dostaviti energiju lasera do većine oralnih tkiva, čak i u kompleksni kanalni sistem korena zuba. Optički sistem isporučuje energiju sa distalnog kraja nastavka u usmerenom zraku uz minimalno bočno rasipanje. Stoga se primenjuje u preparaciji kaviteta ili mekotkivnoj hirurgiji. U određenim slučajevima nedostatak koji proizilazi iz minimalnog bočnog rasipanja energije može dovesti do poteškoća tokom bočnog prenosa energije, što ograničava primenu u endodontskom tretmanu. Nedavno su predložene različite modifikacije optičkog vlakna kako bi se prevazišli pomenuti nedostaci. Ostali faktori koji utiču na odabir lasera za rad na tvrdim i mekim oralnim tkivima su apsorpcija laserskog zraka od strane tkivnih hromofora (voda, apatit, pigmenti) u ciljanom tkivu, jer je bolja apsorpcija praćena efikasnijom fototermalnom sterilizacijom, ablacijom dentina, i ostalim dejstvima. Pored toga, brzo zagrevanje molekula vode u gleđi može uzrokovati vaporizaciju vode i stvaranja pare, što izaziva brzo širenje dentalnih tkiva, te vodi do minieksplozija u tkivu kroz process ablacije. U slučaju lasera velike snage, vaporizacija ili koagulacija tkiva kroz apsorpciju energije u tkivnim komponentama naziva se i fototermalna ablacija. Fotomehanička ablacija podrazumeva ukanjanje tkiva posredstvom stvaranja šok talasa, kavitacije. Fotohemijsko dejstvo nastaje posredstvom supstanci osetljivih na svetlo, i danas se primenjuje u antibakterijskom dejstvu i lečenju kancera. Indikacije za primenu lasera najčešće zavise od talasne dužine, pulsne energije i izlazne snage, vremena izlaganja, površine dejstva (samim tim i gustine energije), i tkivnog fizičkog i hemijskog sastava (sadržaja vode, gustine, toplotne provodljivosti i vremena oslobađanja od stvorene toplote) [22].

Svi laseri su grupisani u sedam klasa zavisno od potencijala izlaznog zraka da uzrokuje povredu. Oštećenje, i stoga i klasifikacija, zavise od talasne dužine, snage, energije i karakteristika pulsa. Laseri su grupisani u: klasu 1 i 1M (nizak nivo mogućnosti oštećenja), klasu 2 i 2M (oči mogu da se zaštite od zraka refleksom treptanja), klasa 3, 3R i 2B (direktno gledanje u zrak može dovesti do oštećenja), i klasa 4 (snaga lasera je iznad 0,5 vati i laser je klasifikovan kao izrazito štetan) [23].

Laseri u stomatologiji

Većina lasera u stomatologiji i medicini pripadaju klasi 4 i stoga je neohodno sprovesti standarde adekvatne zaštite da bi se zaštitili stomatolog, pacijent i pomoćno osoblje. Laseri u stomatologiji variraju od ultravioletnog svetla (100–400 nm) do infracrvenog spektra (750 nm – 1 mm). Vidljivi spektar se nalazi između dve talasne dužine (400–750 nm). Laseri se u stomatologiji primenjuju pri raznim procedurama, od dijagnoze karijesa ili kancera do mekotkivnih i procedura na tvrdim zubnim tkivima.

Goldman i sar. i Stern i Sognas su prvi opisali primenu lasera na oralnim tkivima, gde je rubi laserom delovano na tkiva gleđi i dentina [3, 4]. Naredna ekspanzija istraživanja iz ove oblasti desila se 1985. godine, posle publikacije Majersa, u kojoj je opisano *in vivo* uklanjanje zubnog karijesa primenom modifikovanog lasera Nd:YAG za primenu u oftalmologiji (Slika 6) [5]. Četiri godine kasnije laser Nd:YAG je primenjen u oralnoj hirurgiji na mekom tkivu, što je uticalo na dalja istraživanja primene ovog lasera u kliničkom lečenju parodontopatija [24]. Laseri u stomatologiji danas odlikuju se različitim talasnim dužinama i dejstvom zraka u kontinuiranom, pulsnom modu sa vratima i slobodnom pulsnom modu, odnosno primenjuju se CO_2, Nd:YAG, Ho:YAG, Er:YAG, Er, Cr:YSGG, Nd:YAP, GaAs, diodni laseri i argonski laseri (Slika 7). Laseri kraćih talasnih dužina i pulsnog opsega kombinovani sa gustinama velikih snaga trenutno nisu od interesa za primenu u stomatologiji [25].

U slučaju bioloških tkiva, energija lasera je apsorbovana na površini tkiva izloženom laseru i u slučaju dubljeg prolaska zraka dolazi do ožiljavanja. Apsorbovana energija se prevodi u toplotu i izaziva različite fototermalne efekte kao što su zagrevanje, koagulacija, ekscizija i incizija tokom vaporizacije tkiva. Apsorpcija energije zavisi od talasne dužine zraka, snage, moda rada (kontinuirani ili pulsni), dužine trajanja pulsa, odnosa energija/puls, gustine energije, dužine izlaganja, najvećeg pika snage pulsa, angulacije distalnog kraja optičkog vlakna u odnosu na tkivo, kao i optičkih svojstava tkiva (Slika 8) [26].

Optička svojstva tkiva utiču na interakciju tkiva sa laserskim zracima specifičnih talasnih dužina. U slučaju tkiva parodoncijuma, optička svojstva zavise od stepena pigmentacije, sadržaja vode, mineralnog sastava, toplotnog kapaciteta, koji se odnosi i na toplotnu provodljivost i gustinu tkiva, i posledica transformacije toplote (denaturacija proteina, vaporizacija vode, topljenje minerala). Kako se zna da je kost klasično kompozitno tkivo koje u svom sastavu ima 67% neorganskih minerala (kalcijum-hidroksiapatita) i 33% kolagena i nekolagenih proteina, dok je gingiva izgrađena od fibroznog tkiva različitih gustina povezanih međusobno komponentama vanćelijskog matriksa uz veliki procenat vode (70%), njihova optička svojstva su određena navedenim specifičnim sastavom. Dodatno, gingiva može biti hiperpigmentisana u slučaju velikog nakupljanja melanina u podsluzokožnom sloju. Ostali faktori koji određuju interakciju lasera i tkiva uključuju procese provođenja toplote i rasipanja, stepen prokrvljenosti i mogućeg zapaljenja tkiva, kao i sposobnosti progenitornih ćelija da učestvuju u regeneraciji tkiva. Svaka talasna dužina energije lasera apsorbovana je u većem ili manjem obimu u komponentama oralnih tkiva, kao što su voda, pigmenti ili hidroksiapatit [27].

Znajući da CO_2 laser (10600 nm talasne dužine) ima visok koeficijent apsorpcije u vodi, pogodan je za primenu u mekotkivnoj hirurgiji, dok nema dovoljno kvalitetnih podataka u literaturi o opravdanoj kliničkoj primeni na čvrstim tkivima usne duplje. Zrak lasera Nd:YAG (1064 nm talasne dužine) i diodnih lasera (talasne dužine od 800 do 950 nm) ima manji koeficijent apsorpcije u vodi u odnosu na CO_2 lasere, a značajno su apsorbovani u pigmentnim tkivima, dok su laseri Er,Cr:YSGG i Er:YAG (2780 i 2940 nm talasnih dužina) visoko apsorbovani i u vodi i hidroksiapatitu [28]. Stoga bi trebalo da kliničari za svaki klinički slučaj zasebno utvrde specifične ciljeve lečenja i zatim odaberu odgovarajuću tehnologiju (laser ili neku drugu) kako bi se postigli najbolji rezultati.

Za mnoge intraoralne mekotkivne hirurške procedure laser je adekvatna zamena skalpelu. CO_2, Nd:YAG i diodni laseri se najčešće koriste za mekotkivne procedure kao što su frenektomija, gingivektomija i gingivoplastika, epitelizacija periodontalnog režnja, uklanjanje granulacionog tkiva, oslobađanje dentalnih imlantata, ablacija, incizione i ekscizione biopsije benignih i malignih tumora, zračenje aftoznih ulceracija, koagulacija donorskog mesta slobodnog gingivalnog grafta i gingivalna depigmentacija. Pored toga, dokazi bržeg zarastanja mekih tkiva zavisni su od talasne dužine lasera i veoma osetljivi na gustinu energije. Većina studija koje istražuju zarastanje u ispitivanju koriste talasne dužine CO_2, Nd:YAG i diodnih lasera. Poređenjem zarastanja tkiva između Nd:YAG i CO_2 lasera pokazano je da CO_2 laser primenjen na oralnoj, orofaringealnoj i laringealnoj mukozi dovodi do značajno bržeg zarastanja u odnosu na laser Nd:YAG, ali je u oba slučaja zarastanje sporije u odnosu na rane nastale skalpelom [25]. Zarastanje je bilo podjednako za skalpel i laser Nd: YAG kada je upotrebljena niža snaga lasera od 1,75 W i 20 Hz. Dodatno, histološka istraživanja pokazala su da laseri velike snage (snaga u vatima), dugog pulsa, velikog broja ponavljanja (herci) i dugog vremena interakcije (dužina intervencije) povećavaju rizik od neželjenih efekata. Poređenje hirurških procedura laserom i skalpelom je široko istraženo u brojnim medicinskim i veterinarskim časopisima. Sa aspekta talasne dužine i različitih tkivnih parametara kao što su vreme incizije, krvarenje, otok, bol, i uopšteno zarastanje tkiva, objavljen je veliki broj različitih podataka, ali je u većini radova tehnologija lasera pokazala brojne prednosti, kao što su visok nivo kontrole radnog polja, efikasnost sprovođenja procedure, fleksibilnost nastavka i dodatnih opcija rada [27, 28].

Dejstvo lasera na zarastanje koštanog tkiva

Interakcija lasera i bioloških tkiva zavisna je od talasne dužine i posledičnog fototermalnog efekta, usled čega je većina efekata lasera velike snage na koštano tkivo potencijalno štetna. Čini se da su samo talasne dužine lasera Er:YAG i Er,Cr:YSGG pogodne za rad u kosti. Rezultati povećanja temperature na površini kosti izloženoj istoj ukupnoj energiji lasera pokazuju rang 1,4–2,1^{0}C za CO_2 laser, dok za laser Nd:YAG iznose 8,0–11,1^{0}C [29, 30]. Ovi rezultati ukazuju da je za ablaciju potreban relativno tanak sloj mekog tkiva poduprt okolnom kosti (bukalna, gingivalna i alveolarna mukoza). Ukoliko se koristi laser Nd:YAG relativno niske gustine energije, treba emitovati zrak u kratkim intervalima kako bi se sprečilo oštećenje kosti. Utvrđeno je da ukoliko se koristi laser Er:YAG u pulsnom modu pri energiji od 100 mJ/puls i 10 Hz, dobijaju se dobro definisani intrakoštani isečci bez tragova topljenja ili karbonizacije [29–32]. Slika 9 pokazuje da je grupa tretirana laserom izazvala brže formiranje kosti u odnosu na kontrolu [33].

Tehnika infracrvene spektroskopije sa Furijeovom transformacijom, razlučujuća/disperzivna energetska rendgenska spektrometrija i rendgenska difrakciona analiza pokazale su adekvatan odnos kolagena i hidroksiapatita u tankom sloju, koji se karakteriše blagim povećanjem u odnosu kalcijumi/fosfati ozračene površine usled stvaranja tetrakalcijum-fosfata, pokazujući da je hemijska struktura kosti slična onoj posle rada u kosti borerom, dok osteotomije CO_2 laserom dovode do izrazite karbonizacije, topljenja mineralne faze i odloženog zarastanja [29]. Takođe, nedavne studije govore u prilog talasnoj dužini Er, Cr:YSGG kao veoma pogodnoj za rad u kosti, jer energetskom rendgenskom spektrometrijom nije zabeležena promena u odnosu kalcijuma/fosfata, niti su nađeni znakovi karbonizacije ili topljenja. Promene površina cementa i dentina ispitivane su posle primene različitih talasnih dužina lasera CO_2, Nd:YAG i Er:YAG. Pokazano je da navedeni laseri mogu uspešno biti korišćeni za uklanjanje čvrstih naslaga ukoliko se odabere talasna dužina sa minimalnom apsorpcijom od strane mineralnih tkiva. Ovo je važno sa aspekta termalnog oštećenja pulpnog tkiva i neželjenog uklanjanja čvrstih struktura korena zuba. Mineralna faza cementa i dentina, karbonatni hidroksiapatit, ima intenzivnu apsorpciju zraka iz srednjeg infracrvenog spektra [27–32].

Posledično, od svih ispitivanih talasnih dužina, laser Er:YAG bi bio instrument izbora za efikasno uklanjanje tvrdih zubnih naslaga, nagrizanje mineralnog tkiva kosti i stvaranja biokompatibilne površine za ponovni pripoj ćelija i tkiva. Suprotno, ukoliko bi se upotrebio CO_2 laser, čak i pri niskoj energiji, analiza infracrvenom spektroskopijom sa Furijeovom transformacijom pokazuje prisustvo toksičnih hemijskih ostataka cijanamida i cijanata, praćenih nedosatkom pripoja režnja na tretiranoj površini zuba. Stoga CO_2 laseri imaju ograničenu primenu u subgingivalnoj parodontalnoj terapiji. Pri energijama od 100 do 400 J/cm^2 za CO_2 i 286 do 1,857 J/cm^2 za laser Nd:YAG opisan je određen stepen morfoloških promena na površini korena nastalih dejstvom lasera, kao što su efekat kavitacije, topljenje i remineralizovanje globula, promene u strukturi proteina korena, površinskih pukotina, i stvaranje površinskog sloja, što je direktno bilo zavisno od gustine primenjene energije. Suprotno u odnosu na navedene rezultate, kada je primenjen laser Nd:YAG, pri manjim gustinama energije ili kombinaciji niže gustine energije uz defokusiran zrak, pokazano je da je pogodan za uklanjanje razmaznog sloja na površini korena bez izazivanja posledica po tkivo cementa i/ili dentina, ili povećanja temperature do nivoa koji bi uzrokovao ireverzibilno oštećenje pulpe [34, 35, 36].

Relativno nov laser, Nd:YAP sa talasnom dužinom 1340 nm, ispitivan na površini izvađenih zuba, pokazuje prisustvo promena na tkivu uzrokovanih toplotom pri gustinama primenjenih energija od 509 do 1274 J/cm^2. Stepen oštećenja je direktno povezan sa povećanjem gustine energije i progresivno raste od nastajanja pukotina na površini cementa do razvoja dubokih pukotina, topljenja i duboke ablacije cementa uz izlaganje dentina ispod.

Nedavno su laser Er,Cr:YSGG i u manjem obimu laser Er:YAG promovisani za primenu u produženju kliničke krune bez podizanja gingivalnog režnja, iz estetskih i protetskih razloga. Očigledno, estetsko produženje krune može se jednostavno izvesti laserima ukoliko su klinički kratke krune rezultat izražene gingive ili nedostatka pasivne erupcije zuba. U takvim slučajevima povećanje dubine gingivalnog sulkusa se javlja usled izraženog volumena mekih tkiva [34–37].

Primena lasera u lečenju hronične parodontopatije zasniva se na regeneraciji mekotkivnog pripoja, cementa, periodontalnog ligamenta i okolne alveolarne kosti, uz značajno smanjenje broja subgingivalnih patogenih bakterija. Ograničen je broj istraživanja koja govore u prilog efikasnijem laserskom uklanjanju subgingivalnih bakterija u odnosu na standardno lečenje. Većina studija koja ispituje baktericidni efekat opisuje dozno zavisnu vezu. Međutim, u mnogim studijama gustina energije često nije navedena ili ne može biti izračunata usled nekompletnog spiska parametara. Konačno, ugao zračenja može varirati od 0 do 90^0, čime je izračunavanje gustine energije gotovo nemoguće [38–41].

Jedna od prvih *in vivo* studija koja je opisala smanjenje broja patogenih bakterija posle zračenja laserom Nd:YAG pokazuje smanjenje bakterija *Porphyromonas gingivalis*, *Prevotella intermedia* i *Actinobacillus actinomycetemcomitans* [38]. Međutim, na zubima izvađenim sedam dana posle + tretmana nađena je rekolonizacija površina korena ozračenih laserom mnogobrojnim bakterijama. *In vitro* studije primenom lasera Nd:YAG uz niže primenjene energije opisale su ablaciju čvrstih naslaga bez neželjenih efekata po dentin ili cement. Takođe je nađena linearna veza između nivoa energije, broja mikroorganizama i koncentracije hemoglobina i minimalne energije potrebne za baktericidni efekat, odnosa prijemčivosti mikroba za energiju lasera i oštećenja čvrstih zubnih naslaga, cementa, dentina, čak i na pojedinačnom uzorku. Takođe, pokazana je raznolikost u boji, debljini, sastavu, teksturi i sadržaju vode [38–41]. Diodni laser (805 nm), primenjen uz standardnu kauzalnu terapiju parodontopatije, doprinosi smanjenju subgingivalnih bakterija u parodontalnom džepu dubine 4 mm. Međutim, mnoge *in vivo* studije opisale su zastupljenost vijabilnih bakterija posle subgingivalnog zračenja laserom [38, 40, 41].

ZAKLJUČCI

U ovom radu opisano je zračenje bioloških tkiva specifičnim talasnim dužinama lasera. U pregledu literature su proučene interakcija zubnih tkiva i različitih tipova lasera, energija i talasne dužine, a prikazani rezultati mogu poslužiti za odabir adekvatnijih parametara za primenu lasera, bez izazivanja destrukcije tretiranih mekih i tvrdih zubnih tkiva. Pored specifične primene lasera, u ovom radu su opisane i osnove stimulisane emisije, principi rada lasera, glavni tipovi instrumentacije lasera, prednosti i nedostaci primene određenih vrsta lasera, kao osnova za bolje razumevanje veoma zahtevnih oblasti primene lasera u dentalnoj medicini.

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Doctor-patient communication in medicine and dental medicine

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SUMMARY

Doctor-patient communication is a type of institutional communication which distinct linguistic features can significantly affect patient satisfaction and treatment outcome. A medical encounter has a clearly defined structure that has been shifting from *clinician-centred* to *patient-centred.* Therefore, it is of utter importance for prospective doctors and dentists to be aware of the role of language when communicating with their patients. Given the fact that working in a medical/dental practice has become increasingly international, the paper focuses on the role of the English language. New communicative models and environments such as Computer-Mediated Medical Communication (CMMC) and Video Interaction Guidance (VIG) are also presented.

Keywords: computer-mediated communication; English for Medical Purposes; institutional communication; medical encounter

INTRODUCTION

Doctor-patient communication as a type of institutional communication has been analysed within various disciplines over the past few decades – conversation analysis, critical discourse analysis, sociology, sociolinguistics, psychology, anthropology, and medicine itself. Research results from this field of communication are considered to be highly applicable in medical practice as they can improve interactions between doctors and patients and contribute to better treatment outcomes. It has been reported that the communicative style a doctor adopts highly affects both patient satisfaction and treatment outcome [1]. Besides, patients who have good communication with their doctors and are adequately informed of their condition seem to recover faster and more successfully after complex surgical procedures and are rarely depressed in comparison with other patients [2]. Studying doctor-patient interaction also reveals potential problems in this type of communication, helps solving these problems and results in better informed patients who can follow doctors' advice more precisely. Research results from this field are also valuable for teaching English for medical (academic) purposes (EMAP) as they provide practical examples and illustrate important characteristics of doctor-patient communication that can help prospective doctors/dentist communicate efficiently with foreign patients in an era of medical/dental tourism expansion.

This paper provides an insight into doctor-patient communication and its characteristics through the prism of medical encounters and encounters in dental medicine. First, institutional communication is briefly presented and contrasted to ordinary communication. The characteristics of a medical encounter, as a typical representative of institutional communication, are given. Finally, the importance of contemporary communication in dentistry is emphasised, including computer-mediated communication (CMC).

Institutional talk

This type of communication is usually accomplished through the exchange of talk between *professionals* (i.e. institutional representatives) and *lay people* (i.e. institutional clients) and it takes place in an institution such as a school, a police station, a courtroom or a hospital/examination room [3]. Such interaction: (1) involves participants in specific goal orientations which are connected with their institution-relevant identities (e.g. doctor-patient), (2) it includes specific constraints on what will be taken as allowable contributions to a particular business, and (3) it is associated with inferential frameworks and procedures that are specific for institutional contexts at hand [3, 4, 5].

Institutional talk is distinct from ordinary conversation in several different ways: turn-taking organization, word choice, and asymmetry being the most important ones [3, 6]. Turn-taking procedure is rather similar to that in ordinary conversation except that participants could be sanctioned for their contributions, e.g. if they answer when they are not supposed to, when they are expected to answer a question and they do not do it or when they talk when somebody else is talking [6]. Besides, turn-taking organization can differ considerably in various institutions.

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Institutional representatives can sometimes organize their turns in such a way that they achieve a particular goal in communication with their clients. For example, in order to prepare their patient for a piece of bad news they are about to receive, a doctor might ask the patient for their own opinion of that problem and by doing this they prepare the patient for the information by changing their perspective of the problem, which makes it easier for the patient to understand the information [3]. In another example, a paediatrician asks parents how they see their child and only then presents the intended information partly relying on parents' own impressions [7].

Unlike ordinary conversation, which is fluid and prone to variations, institutional communication has a specific structural organization [3]. In institutional talk, participants usually choose more formal lexis than in ordinary conversations. They more often opt for descriptive terms [6] and it has also been noticed that institutional representatives frequently choose the first person plural (*we*) instead of the first person singular (*I*) with the aim of presenting themselves as institutional representatives rather than individuals [4]. Institutional euphemisms are also frequently used in order to downplay potentially problematic issues [6]. For example, references to pain are often euphemistic in a way that the words *pain* and *painful* are often avoided and replaced by something softer (e.g. *sore*) [8].

Asymmetry is one of the main characteristics of institutional talk and according to Heritage it is visible on different levels: (1) participation, (2) interactional and institutional *knowhow,* (3) epistemological caution and asymmetry of knowledge, and (4) rights of access to knowledge [6]. When it comes to asymmetry in participation, it can be illustrated by the fact that institutional representatives usually hold initiative throughout the conversation and they thus have greater power than their clients. However, Sinadinović and Polovina's research showed that the patient's initiative was very often accepted, which is contrary to some previous findings [9]. This means that patients do possess some power although doctors undoubtedly dominate the entire communication.

Institutional *knowhow* implies different attitudes that participants have towards the problem because of which a client has come to the institution; in other words, what is extremely important to the client may be just another routine case for the institutional representative. Asymmetry of knowledge can take two different forms – institutional representative may be cautious in expressing their opinion on something or they might openly show their superiority (this is often the case in doctor-patient interaction where doctors emphasize the possession of knowledge in a particular field). On the other hand, patients might miss asking important questions just because they do not have knowledge in the field and for the same reason, they might misunderstand doctor's agenda [6, 10]. Finally, rights of access to knowledge manifest themselves in the fact that institutional clients have no right to have the same knowledge that institutional representative possess owing to their position, education and profession. In doctor-patient interaction, this would mean that a patient should not reveal to their doctor if they have previously informed themselves on their problem on Internet websites or elsewhere. Similarly, it has been reported that doctors who take their children to paediatricians try not to behave like doctors in such situations, but like parents who know nothing and they try to hide what they know in order not to offend their colleague [6, 11].

Medical encounter

A medical encounter is considered to be a typical representative of the institutional communication being a "tightly organized event" which is almost completely ritualized [12, 13]. Authors in both *discourse literature* and *praxis literature*[1] agree that there are several phases of a medical encounter, but the number of phases and their content vary considerably. Byrne and Long were the first linguists to research the six-phase model known as the *biomedical model* containing the following steps: (1) establishing a relationship with a patient, (2) discovering the reason for the patient's visit, (3) conducting a verbal and/or physical examination of the patient, (4) considering the patient's condition with the help of the patient if necessary, (5) discussing further treatment or suggesting further investigation, and (6) ending the conversation (this is usually done by the doctor) [14]. Heritage and Maynard accepted these six phases, elaborating further on their content. They recommended that the first phase should be cordial and relaxing for the patient and they also insisted that in the fifth phase the patient's condition should not be discussed only by the doctor but that the patient should be involved as well and that their opinion on any further steps should be respected [15]. Almost identical models are found with Heath and also with Gill and Roberts [16, 17], whereas Mishler insisted on a three-part model – (1) doctor's question, (2) patient's answer to the question, and (3) doctor's assessment of patient's answer (e.g. *a-ha, mhm*, etc.) or another question [18].

A medical encounter organized according to one of these classical models is *clinician-centred* and mostly follows the structure of an interview where patients are expected to answer doctors' questions. However, praxis literature has insisted on introducing a more *patient-centred* model that would help doctors reach more precise diagnoses, treat their patients more successfully and achieve better overall results [13]. Nowadays, patient-centredness is recognized as one of the essential constituents of continuous quality improvement (CQI) [19]. Fortin et al. suggested the so-called *biopsychosociological model* that respects patients' needs and promotes changing of some important health and lifestyle habits [20]. This is an 11-phase model – (1) setting the stage for the interview (putting the patient at ease), (2) eliciting the main concern and setting the agenda (deciding what is going to be covered during the interview),

1 Huge cross-disciplinary literature on medical encounters divides into these two categories, praxis literature being concentrated on speakers' intuitions rather than on providing discourse data and discourse literature offering the analysis of talk itself and being frequently oriented towards the balance of power between doctors and patients [13].

(3) asking an open-ended question (in order to let the patient express her/himself), (4) eliciting symptoms, the personal and emotional context, (5) summarizing previous conversation, checking accuracy and preparing the patient for the next step, (6) obtaining a chronological description of the complaint(s), (7) obtaining past medical history, (8) obtaining social history, (9) obtaining family history, (10) physical examination, and (11) terminating the interview. Fortin et. al insist on *integrated interviewing* that promotes using patient-centred skills in the first and the final part of the interview, whereas the central part of the interview is dedicated to physician-centred skills. This is the basic difference between this novel model and the biomedical model, which always favours doctors over patients and give doctors much more space [20].

Having conducted a thorough contrastive research where she compared doctor-patient communication in Serbian and English corpora, Sinadinović came to a conclusion that Serbian doctors still follow the biomedical model, but that there are certain steps which resemble some phases of the biopsychosociological model [21]. This is not surprising if we have in mind that medical encounters in Serbian are much shorter than those in English and they cannot be expected to cover all the recommended steps.

Classical physician-centred medical encounters are similar to interviews with precisely defined roles. In patient-centred interviewing narratives prevail over interviews as patients are allowed to present the problem in their own words and in the way they find most appropriate, while doctors should pay attention to some signals that are usually unobserved in typical doctor-patient communication [1]. Ainsworth-Vaughn believes that telling a story can considerably contribute to a more precise diagnosis [22]. Ainsworth-Vaughn, Davis and Young report that patients usually tell stories in order to bridge the gap between them and their doctor and to fight for their own voice in institutional communication [22, 23, 24]. According to Ainsworth-Vaughn, patients use narratives in order to explain why they have come or who have convinced them to (finally) come as well as to describe their symptoms or details of their lifestyle [22]. On the other hand, when doctors use narratives, they either do it in order to explain the diagnosis and prescribed therapy or to explain how human organism functions in a particular situation and how the prescribed therapy works. Sinadinović showed that narratives in the Serbian corpus were not as numerous as in the English corpus and that there were considerably more narratives told by doctors than those told by patients [21]. The very presence of narratives in medical encounters determines the genre of medical encounter – it possesses elements of both an interview and ordinary conversation. Mishler believes that a medical encounter is more humane when there are narratives in it as they enable patients to present their case in their own way, emotionally and subjectively [18]. This way, the *voice of lifeworld* interferes with the sterile and objective *voice of medicine* [18].

Interruption is an important characteristic of institutional communication in general and doctor-patient interaction in particular. Although both interruptions and overlaps are regularly found in the discourse of medical encounters, interruptions are explored more thoroughly as they are a sign of unequal distribution of power. Beckman and Frankel report that there is an interval of only 18 seconds between doctor's first question and the moment when patient's answer to that question is interrupted [25]. Fairclough offers several reasons for interrupting a patient – by doing this, doctors can direct their patients towards a desired answer and prevent patients from repeating information or sharing irrelevant information [26]. According to Mishler, doctors interrupt their patients in several different ways: (1) by not paying attention to what the patient is saying (*interruption by inattention*), (2) by introducing a new topic and (3) by signalling the patient to stop talking, usually by using a particle *ok* (*active interruption*) [18]. Sinadinović noticed that the doctor interrupted the patient mostly by asking questions and ignoring what the patient was trying to say as it had nothing to do with his agenda [27]. West concluded that doctors interrupted their patients much more frequently than the other way around [28]. Interestingly enough, she discovered that female doctors interrupted patients more rarely than their male colleagues and that patients in comparison with their male colleagues more often interrupted them. Moreover, female doctors were more frequently interrupted by male patients than by female patients [28]. According to Klikovac, patients do interrupt doctors, although not that frequently, and they do it for one of the following reasons: to give a negative answer to the doctor's question, to introduce a new topic, to oppose the doctor's statement or to refuse the doctor's suggestion [29]. Sinadinović discovered that female patients interrupted both male and female doctors more often than male patients, whereas male doctors interrupted patients twice as much as their female doctors [21].

Finally, the choice of lexis doctors use when communicating with patients could be an important obstacle in their relationship. This is the reason why in praxis literature doctors are often advised to avoid technical terms and check if and to what extent their patient has understood them [2]. Doctors tend to use technical terms in order to support knowledge asymmetry and demonstration of power, but very few patients are capable of taking part in such communication. Consequently, patients are confused, and they do not fully understand what is expected of them, so they will possibly fail to adhere to the prescribed therapy or follow doctor's advice. Not all the doctors necessarily use technical terms, but a plethora of research in this field has proved that is frequently the case [27]. Apart from using technical terms, doctors tend to opt for formal lexis and to "translate" patient's words to the language of medicine in order to emphasise their superiority concerning medical knowledge [29]. Sinadinović showed that both oral and written doctor-patient communication in Serbian is characterized by a large number of terms borrowed from English, even when there are adequate Serbian terms [30].

Communication in Dental Medicine

The study of communication is increasingly interdisciplinary and extends across disciplinary boundaries [31]. Thus, the role of communication skills in dentistry has been recognised and investigated as one of key prerequisites for managing and treating patients [32, 33, 34]. Therefore, communication has been incorporated in the curricula of dental schools worldwide [33]. This comes as no surprise taking into account the fact that the Code of Ethics for Dentists in the European Union has stressed the role of communication by describing it as "fundamental to the dentist-patient relationship" [35, 36]. A model that is widely used by dental school to teach communication in health care is the *Calgary-Cambridge* model as it offers step-by-step descriptions of different stages of clinician-patient encounter [33]. However, in recent years an innovative method called *Video Interaction Guidance (VIG)* has proved to be effective in teaching communication in clinical settings [33]. Quinn et al. conducted a study to investigate dentists' perceptions of the video review technique used to foster dentists' communication skills in *complex clinical situations*[2] [33]. Their findings indicate that dentists find this technique beneficial as it helps them become aware of their verbal and non-verbal communication, including the communication strategies they had been applying that turned out to be ineffective [33].

Furthermore, communication represents an integral part of quality health care. There has been a necessity to assess the quality of communication in dental settings. This is carried out by patient satisfaction surveys which role is to measure and monitor patient satisfaction with dental services in primary care institutions, which was first introduced in Serbia in 2010 by distributing a questionnaire that evaluates whether a dentist provides clear explanations of procedures, among other factors contributing to providing quality health care [19]. This is in accordance with the fact that being able to provide proper and comprehensive information is of utter importance in doctor/dentist-patient relationship [35].

Two other studies have emphasised the importance of effective communication in dental practice. One of them was concerned with restorative treatments and understanding patients' expectations related to aesthetics and concluded that any misunderstandings should be prevented by applying effective communication techniques "prior to initiation of irreversible therapy" [37], while the other was concerned with dental anxiety and concluded that being able to discuss dental anxiety with dentist before undergoing dental treatment contributed to alleviating patient anxiety [32].

Yet, the question is – what happens in multilingual settings where linguistic differences may pose a barrier to providing high-quality dental care? This kind of dentist-patient encounter has been described as "exceptionally challenging" [38]. For example, the decision-making process can be significantly affected by linguistic differences, i.e. the fact that a dentist and a patient do not share the same language [35, 38]. Thus, English language has taken on the role of a *lingua franca* of the global health care. Owing to globalisation, medical/dental tourism has been proliferating and English language has become a dominant and an indispensable factor when it comes to communicating with foreign patients and providing quality health care. A study conducted in Australia in order to explore and analyse dentists' perceptions related to providing dental care to patients whose English was limited revealed that on average dentists experienced communication barriers with patients on a weekly or monthly basis as a consequence of patients' inadequate English [38]. Finally, the participants pointed out that it was particularly demanding to provide explanations in the fields of endodontics and periodontics – 28 and 19 per cent, respectively [38].

2 By *complex clinical situations* Quinn et al. refer to dentists attending to patients with intellectual disabilities and communication difficulties [33].

Doctor/Dentist-Patient Communication 2.0

In today's world, telecommunication and technological advances are developing at a very fast rate enveloping in its wake many other areas of life including science and medicine. Telehealth and telemedicine are steadily gaining applicability and seeping into everyday medical practice. Today, with the rise of internet and particularly Web 2.0, there are many different options at hand for a patient to communicate to a doctor or other medical professionals. These include apps, online forums and Q&A types of platforms, private email consultations, video consultations, and even social media. This type of communication via networked computers or other digital devices is called computer-mediated communication (CMC) [39]. CMC is a wider interdisciplinary field that includes psychology, sociology, linguistics, etc. The branch of CMC focused on language and language use which applies the methods of discourse analysis is called computer-mediated discourse (CMD) [40]. CMD covers a variety of genres or as Crystal [41] calls them *internet situations* that include email, chatrooms, discussion groups, MUDs (multi-user dungeons), and many other emerging genres.

One type of these genres includes sites where patients can communicate with doctors/dentists and seek medical advice, support, and online consultation and it falls under the label of computer-mediated medical communication (CMMC) [42]. CMMC in this form is considered asynchronous, where a message is sent and stored somewhere until read, which also makes it more lasting [40, 41]. This type of d-p communication differs from the traditional face-to-face communication in many ways. The patient initiates the communication which is established through messages/emails, turn-taking is typically limited (question and answer) and some questions even stay unanswered. This and the medium considerably influence the communication itself. Namely, textual messages typically cannot convey extra-linguistic information such as intonation, prosody, and other auditory information as well as any type of visual information that could be crucial in a medical consultation. Furthermore, patients typically use pseudonyms, which in turn allows for more disclosure, while at the same time any personal information that could lead to identification is anonymized by page administrators. Other medical information such as tests, findings, and patients' photos are sent directly to the administrators or the corresponding doctor.

The communicative purpose of this online communicative event can vary. Zummo [42] has identified four categories: asking for opinion, asking for a second opinion, explanation or clarification of a term, procedure, etc., therapy, and diagnosis. Doctors, on the other hand, seem to provide a different service than that expected from users. Where possible, they will provide the patient with an answer, but in case of diagnosis they tend to solicit a proper visit, as they cannot make any conclusions without direct evidence [43].

Technological advances are influencing and will continue to influence not only medicine, but also the way medical professionals communicate with patients. The implications of this technological progress also include the way communication is taught to students of medicine and dentistry.

CONCLUSION

Doctor-patient communication is an important cross-sectionally researched subtype of institutional communication that is held essential in the outcomes of medical treatments and patients' general adherence to therapy and doctors' recommendations. There are numerous differences between institutional communication and ordinary conversation with turn-taking organization, word choice and asymmetry being most conspicuous.

Medical encounters have been explored from various aspects, both by linguists (discourse literature) and medical doctors (praxis literature). The classical six-phase biomedical model has been explored and further developed since 1976. In the meantime, experience from practice has shown that a more patient-centred approach is necessary, so a novel biopsychosociological model was suggested in 2012. According to research results, in the context of Serbia, the biomedical model still seems to be more applied.

Doctor-patient communication seems to have elements of both an interview and a narrative. However, researchers report narratives' valuable contribution to more precise diagnoses and strengthening patients' voice in institutional communication. The choice of lexis seems to be one of the main reasons for misunderstandings and poor doctor-patient relationship. Consequently, praxis literature advises doctors to avoid technical terms and too formal lexis when communicating with their patients.

When it comes to dentistry, communication skills are believed to be essential for managing and treating patients. The Calgary-Cambridge model is traditionally used to teach communication, but an innovative model has recently been introduced – *Video Interaction Guidance*, which is found to be effective in teaching communicative strategies. Effective communication in dental practice has been investigated from different perspectives including dentist-patient relationship in primary care institutions (Serbia), dental tourism, understanding patients' expectations concerning restorative treatments, dental anxiety, dentist-patient communication in a multilingual setting (Australia), etc.

Finally, apart from face-to-face communication with a doctor/dentist, there is another option – computer-mediated communication (CMC) that includes apps, online forums, Q&A platforms, private mail and video consultations, etc. Computer-mediated medical communication (CMMC) involves sites where patients communicate with doctors/dentists. CMMC is distinct from typical doctor-patient communication in several ways, limited turn-taking, unanswered questions, and pseudonym use being some of the features.

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Komunikacija između lekara i pacijenta u medicini i stomatologiji

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KRATAK SADRŽAJ

Komunikacija između doktora i pacijenta jeste vid institucionalne komunikacije čije lingvističke karakteristike mogu u znatnoj meri uticati na zadovoljstvo pacijenata, ali i na ishod lečenja. Medicinski susret ima jasno definisanu strukturu, koja se u poslednje vreme menja iz one koja je usmerena na doktora na onu koja pacijenta stavlja u prvi plan. Stoga je od posebne važnosti da budući doktori medicine i stomatologije poseduju svest o ulozi jezika kada komuniciraju sa svojim pacijentima. Imajući u vidu činjenicu da su i medicina i stomatologija trenutno pod uticajem internacionalizacije, ovaj rad nudi osvrt i na ulogu engleskog jezika. Novi komunikativni modeli i okruženja poput kompjuterski posredovane medicinske komunikacije i video-interakcije takođe su predstavljeni u radu.

Ključne reči: kompjuterski posredovana komunikacija; engleski jezik za medicinske svrhe; institucionalna komunikacija; medicinski susret

UVOD

Komunikacija između lekara i pacijenta kao vid institucionalne komunikacije u prethodnih nekoliko decenija proučavana je u okviru različitih disciplina, poput analize konverzacije, kritičke analize diskursa, sociologije, sociolingvistike, psihologije, antropologije i medicine. Rezultati ovih istraživanja nalaze primenu u medicinskoj praksi kako bi se unapredila interakcija između lekara i pacijenta i kako bi se poboljšali ishodi lečenja. Prethodna istraživanja pokazala su da komunikativni stil lekara značajno utiče na zadovoljstvo pacijenata, kao i na ishod lečenja [1]. Osim toga, čini se da se pacijenti koji uspostave dobru komunikaciju sa svojim lekarima i koji su pravilno informisani o svom stanju brže i uspešnije oporavljaju posle složenih hirurških procedura, kao i da se ređe suočavaju sa depresijom u poređenju sa drugim pacijentima [2]. Proučavanjem interakcije lekara i pacijenta takođe se otkrivaju mogući problemi kada je reč o ovom tipu komunikacije i doprinosi se prevazilaženju tih problema, što dovodi do bolje informisanosti pacijenata, koji mogu tačnije da slede uputstva lekara. Rezultati ovih istraživanja značajni su i za nastavu engleskog jezika za medicinske (akademske) svrhe s obzirom na to da pružaju praktične primere i ukazuju na bitne odlike komunikacije između lekara i pacijenta, što može pomoći budućim doktorima medicine i stomatologije da efikasno komuniciraju sa pacijentima iz inostranstva u doba ekspanzije medicinskog/stomatološkog turizma.

Ovaj rad predstavlja osvrt na komunikaciju između doktora i pacijenta, kao i na karakteristike ovakvog vida institucionalne komunikacije u okviru medicine i stomatologije. Najpre ćemo predstaviti pojam *institucionalne komunikacije* i uporediti ovakav vid komunikacije sa običnom (svakodnevnom) komunikacijom. Odlike medicinskog susreta, kao tipičnog predstavnika institucionalne komunikacije, biće posmatrane sa nekoliko aspekata i predstavljene kroz primere. Najzad, ukazaćemo na značaj komunikacije u stomatologiji i predstaviti najvažnije odlike savremene komunikacije između doktora stomatologije i pacijenta, uključujući kompjuterski posredovanu komunikaciju.

Institucionalna komunikacija

Ovakav oblik komunikacije se uglavnom ostvaruje putem konverzacije između *profesionalaca* (tj. predstavnika institucija) i *laika* (tj. klijenata institucija) u nekoj instituciji kao što je škola, policijska stanica, sudnica ili bolnica, odnosno ambulanta [3]. Takva interakcija: (1) uključuje učesnike sa posebnim ciljevima koji su direktno povezani sa svojim ulogama u okviru neke institucije (npr. lekar–pacijent); (2) podrazumeva postojanje posebnih ograničenja u vezi sa onim što je dozvoljeno ili nije dozvoljeno u datoj komunikaciji; (3) poštuje posebne okvire i procedure koji važe za odgovarajuće institucionalne kontekste [3, 4, 5].

Institucionalna komunikacija razlikuje se od svakodnevne komunikacije u nekoliko aspekata, pri čemu se posebno ističu sistem preuzimanja reči, izbor leksike i asimetrija [3, 6].

Sistem preuzimanja reči u institucionalnoj komunikaciji je prilično sličan sistemu preuzimanja reči u svakodnevnoj komunikaciji, ali u institucionalnoj komunikaciji učesnici mogu biti sankcionisani zbog izgovorenog, npr. ukoliko odgovore kada ne bi trebalo, kada ne odgovore na pitanje kada se to od njih očekuje ili kada govore dok neko drugi govori [6]. Zatim, sistem preuzimanja reči se može značajno razlikovati u zavisnosti od institucije. Predstavnici institucija nekada mogu organizovati sledove tako da postignu određeni cilj kod svojih klijenata. Na primer, kako bi pripremio pacijenta za nepovoljne vesti koje će primiti, lekar može upitati pacijenta za mišljenje o njegovom problemu i tako pripremiti pacijenta za informaciju koja sledi, pri čemu će takođe promeniti način na koji pacijent sagledava problem, što će olakšati pacijentu da obradi i razume nepovoljne vesti [3]. Recimo, pedijatar prvo može upitati roditelje kako oni vide svoje dete i tek onda saopštiti informaciju koju je nameravao, pritom se delimično oslanjajući na utiske samih roditelja [7].

Za razliku od svakodnevne komunikacije, koja je fluidna i podložna varijacijama, institucionalna komunikacija ima jasno određenu strukturalnu organizaciju [3]. Učesnici u institucionalnoj komunikaciji uglavnom biraju formalnije izraze nego što je to slučaj u svakodnevnoj komunikaciji. Takođe se češće opredeljuju za deskriptivne izraze [6], a istraživanjima institucionalne komunikacije uočeno je da predstavnici institucija često biraju prvo lice množine (*mi*) umesto prvog lica jednine *(ja)*, upravo kako bi se predstavili kao predstavnici institucija, a ne kao pojedinci [4]. Institucionalni eufemizmi se takođe često upotrebljavaju kako bi se ublažile moguće problematične situacije [6]. Na primeru engleskog jezika, lekar će često izbegavati reči *pain* (srp. *bol*) i *painful* (srp. *bolno*) i umesto njih upotrebiti neku blažu reč (npr. *sore*) [8].

Asimetrija je jedna od osnovnih odlika institucionalne komunikacije i, prema Heritidžu, vidljiva je na nekoliko različitih nivoa: (1) učešće; (2) interakcijski i institucionalni *knowhow*;

(3) epistemološka opreznost i asimetrija po pitanju znanja; (4) asimetrija po pitanju prava na pristup znanju [6]. Kada je reč o asimetriji po pitanju učešća u interakciji, ona se može prikazati kroz činjenicu da predstavnici institucija uglavnom preuzimaju inicijativu tokom konverzacije, u čemu se oslikava i njihova moć u odnosu na klijenta. Ipak, istraživanje koje su sprovele Sinadinović i Polovina pokazalo je da su lekari često prihvatali inicijativu pacijenta, što je u suprotnosti sa prethodnim istraživanjima [9]. Institucionalni *knowhow* ukazuje na različite stavove koje učesnici imaju po pitanju problema zbog kojeg je klijent i došao u instituciju; odnosno, ono što je od izrazito velikog značaja za klijenta može biti samo još jedan rutinski slučaj za predstavnika institucije. Asimetrija u pogledu znanja ogleda se u dva različita oblika: a) predstavnik institucije može biti oprezan prilikom iskazivanja svog mišljenja o nečemu ili može otvoreno pokazivati superiornost, što je čest slučaj u interakciji između lekara i pacijenta, gde lekari ističu svoje znanje u određenoj oblasti. Nasuprot tome, pacijenti mogu propustiti priliku da postave važna pitanja upravo zbog nedostatka znanja u domenu određene oblasti, a iz istog razloga mogu pogrešno protumačiti lekarevu agendu [6, 10]. Naposletku, pravo na pristup znanju ogleda se u činjenici da klijenti institucija nemaju prava na isto znanje koje poseduje predstavnik institucije zahvaljujući svojoj poziciji, obrazovanju i profesiji. U interakciji između lekara i pacijenta, ovo bi značilo da pacijent svom lekaru ne bi trebalo da otkriva da se o svom problemu prethodno informisao putem interneta ili nekog drugog izvora. Pored toga, primećeno je da lekari koji odvode svoju decu kod pedijatara pokušavaju da se ponašaju kao roditelji koji ne znaju ništa u takvim situacijama, a ne kao doktori, pritom ne ističući svoje znanje kako ne bi uvredili kolegu [6, 11].

Medicinski susret

Medicinski susret se smatra tipičnim predstavnikom institucionalne komunikacije kao „strogo organizovan događaj" koji je gotovo potpuno ritualizovan [12, 13]. Autori u okviru literature koja se bavi *diskursom*, ali i literature koja se bavi *medicinskom praksom*[1] saglasni su da postoji nekoliko faza medicinskog susreta, ali ne postoji jasan konsenzus kada je u pitanju broj ovih faza, kao i njihov sadržaj. Birn i Long su bili prvi lingvisti koji su ispitivali model poznat kao *biomedicinski model*, a koji se sastojao od šest faza: (1) uspostavljanje veze između lekara i pacijenta; (2) definisanje razloga za pacijentov dolazak; (3) usmeni i/ili fizički pregled pacijenta; (4) razmatranje stanja pacijenta uz pomoć pacijenta, ukoliko je to neophodno; (5) razmatranje daljeg lečenja ili ispitivanja; (6) završetak konverzacije, pri čemu je mahom lekar onaj koji okončava razgovor [14]. Heritidž i Mejnard su uvažili ovih šest faza, ali su ih dopunili stavom da prva faza medicinskog susreta treba da bude opuštajuća i srdačna, kao i da u petoj fazi stanje pacijenta ne treba da razmatra samo lekar, već da i pacijent treba da bude uključen, pri čemu će se uvažavati njegovo mišljenje o narednim koracima koje je potrebno preduzeti [15]. Gotovo identične modele srećemo kod Hita (Heath), kao i kod Gila i Robertsa (Gill & Roberts) [16, 17], dok Mišler insistira na modelu koji čine tri dela: (1) lekarovo pitanje; (2) pacijentov odgovor; (3) procena pacijentovog odgovora od strane lekara (npr. *a-ha*, *mhm*, itd.) ili naredno pitanje [18].

Medicinski susret organizovan prema jednom od ovih klasičnih modela predstavlja susret koji je usmeren na lekara i uglavnom prati strukturu intervjua u kome se od pacijenata očekuje da odgovara na pitanja lekara. Međutim, u literaturi koja se bavi medicinskom praksom već neko vreme se insistira na modelu koji je u većoj meri usmeren na pacijenta i koji bi pomogao lekarima da uspostave što preciznije dijagnoze, pruže što bolju negu pacijentima i ostvare što bolje rezultate u svakom smislu. Danas se usmerenost na pacijenta prepoznaje kao jedan od osnovnih elemenata kontinuiranog unapređenja kvaliteta zdravstvene zaštite [19]. Tako su Fortin i autori predložili tzv. *biopsihosociološki model*, koji podrazumeva poštovanje potreba pacijenata i usmeren je ka promovisanju promena po pitanju važnih navika u vezi sa zdravljem i stilom života [20]. Ovaj model se sastoji od ukupno jedanaest faza: (1) stvaranje atmosfere u kojoj će se razgovor odvijati (tako da se pacijent oseća lagodno); (2) saznanja o pacijentovom problemu i pravljenje plana za razgovor, odnosno agende (odluka o tome koje teme će biti obrađene razgovorom); (3) postavljanje pitanja otvorenog tipa (kako bi se pacijentu omogućilo da sam iskaže svoj problem); (4) saznanja o simptomima, ličnom i emocionalnom kontekstu; (5) sumiranje prethodne konverzacije, proveravanje tačnosti podataka i priprema pacijenta za naredni korak; (6) prikupljanje hronološkog opisa tegobe, odnosno tegoba; (7) pribavljanje anamneze; (8) prikupljanje informacija o društvenoj istoriji; (9) prikupljanje informacija o porodičnoj istoriji; (10) fizički pregled pacijenta; (11) završetak intervjua. Fortin i autori insistiraju na *integrisanom intervjuisanju* koje se zasniva na primenjivanju veština kojima pacijent preuzima centralnu ulogu u prvom i završnom delu intervjua, dok je središnji deo posvećen veštinama kojima se lekar stavlja u prvi plan. Ovo predstavlja osnovnu razliku između ovog novog modela i biomedicinskog modela, kojim se uvek ističe uloga lekara, kome se daje i mnogo više prostora u konverzaciji [20].

Posle temeljne kontrastivne analize kojom je obuhvatila komunikaciju lekara i pacijenta u srpskom i engleskom korpusu, Sinadinović je došla do zaključka da se lekari u Srbiji još uvek drže biomedicinskog modela, ali da postoje određeni koraci koji su slični nekim fazama u okviru biopsihosociološkog modela [21]. Ovaj podatak ne iznenađuje, imajući u vidu da su medicinski susreti koji se odvijaju na srpskom jeziku mnogo kraći nego oni koji se odvijaju na engleskom jeziku, te se ne može očekivati da će biti uključeni sve predloženi koraci.

Klasični medicinski susreti u okviru kojih se lekar ističe u prvi plan slični su intervjuima sa precizno utvrđenim ulogama. U komunikaciji koja je usmerena na pacijenta pripovedanje preovladava u odnosu na intervjue, jer je pacijentima dozvoljeno da predstave svoj problem sopstvenim rečima i na način koji oni smatraju odgovarajućim, dok lekari treba da obrate pažnju na neke signale koji uglavnom ne budu primećeni u tipičnoj komunikaciji između doktora i pacijenta [1]. Ejnsvort-Von (Ainsworth-Vaughn) smatra da prepričavanje može u značajnoj meri doprineti preciznijoj dijagnozi [22]. Dejvis (Davis), Jang (Young) i Ejnsvort-Von ističu da se pacijenti uglavnom koriste prepričavanjem kako bi premostili jaz između sebe i lekara i kako bi se izborili za sopstveni glas u institucionalnoj komunikaciji [22, 23, 24]. Prema Ejnsvort-Von, pacijenti koriste pripovedanje kako bi obrazložili razlog dolaska ili objasnili ko ih je (konačno) naterao da posete svog lekara, ali i da bi objasnili simptome ili detalje u vezi sa svojim načinom života

1 Obimna krosdisciplinarna literatura koja se tiče medicinskog susreta može se svrstati u dve kategorije: a) literatura o medicinskoj praksi koja je usredsređena na intuicije govornika pre nego na pružanje podataka o diskursu; b) literatura o diskursu koja se bavi analizom same komunikacije i često je usmerena ka odnosu moći između doktora i pacijenata [13].

[22]. S druge strane, kada se lekari koriste pripovedanjem, oni to čine kako bi obrazložili dijagnozu ili prepisanu terapiju ili kako bi objasnili kako ljudski organizam funkcioniše u određenoj situaciji, kao i kako prepisana terapija deluje. Sinadinović je ustanovila da pripovedanje u srpskom korpusu nije tako zastupljeno kao u engleskom korpusu, kao i da su pripovedanja od strane lekara češća od pripovedanja pacijenata [21]. Samo prisustvo pripovedanja u medicinskim susretima određuje žanr medicinskog susreta, koji poseduje elemente intervjua i svakodnevne komunikacije. Mišler (Mishler) smatra da upravo pripovedanje čini medicinski susret humanijim, jer to omogućava pacijentima da iznesu sopstveni slučaj na svoj način, emocionalno i subjektivno [18]. Na ovaj način, „glas svakodnevnog života“ utiče na sterilan i objektivan „glas medicine“ [18].

Prekidanje sagovornika je važna odlika institucionalne komunikacije, uopšteno govoreći, a posebno je to slučaj kada je reč o komunikaciji između doktora i pacijenta. Iako i prekidi i preklapanja predstavljaju učestale pojave u diskursu medicinskih susreta, prekidanje sagovornika se podrobnije ispituje, jer ono predstavlja indikator nejednake distribucije moći. Bekman i Frenkl (Beckman & Frankel) ustanovili su da postoji interval od svega 18 sekundi između prvog pitanja postavljenog od strane lekara i trenutka kada se pacijentov odgovor na to pitanje prekida [25]. Ferklaf (Fairclough) navodi nekoliko obrazloženja za prekidanje pacijenta od strane lekara – na ovaj način doktori mogu da navedu pacijenta na željeni odgovor i izbegnu ponavljanje odgovora ili nepotrebne informacije [26]. Prema Mišleru, lekari prekidaju svoje pacijente na nekoliko načina: (1) ne obraćajući pažnju na ono što pacijent govori; (2) uvodeći novu temu; i (3) dajući znak pacijentu da prestane da govori (*aktivno prekidanje*) [18]. Sinadinović je uočila da doktori uglavnom prekidaju pacijenta tako što postavljaju pitanja ili ignorišu ono što pacijent pokušava da kaže, jer nema nikakve veze sa lekarovom agendom [27]. Vest je zaključila da doktori prekidaju pacijente znatno češće nego što pacijenti prekidaju lekare [28]. Posebno je zanimljivo saznanje da lekarke znatno ređe prekidaju pacijente nego lekari, kao i da pacijenti češće prekidaju lekarke nego lekare [28]. Prema Klikovac, pacijenti prekidaju lekare, mada ne tako često, a to čine kako bi odrično odgovorili na pitanje lekara, uveli novu temu, suprotstavili se tvrdnji ili odbili predlog lekara [29]. Sinadinović je u svom istraživanju primetila da pacijenti ženskog pola češće prekidaju lekare i muškog i ženskog pola nego pacijenti muškog pola, dok lekari muškog pola dvostruko više prekidaju pacijente nego što je to čine lekari ženskog pola [21].

Najzad, izbor leksike kojom se koriste doktori prilikom komunikacije sa pacijentima može predstavljati prepreku u uspostavljanju dobrog odnosa između lekara i pacijenta. Upravo je ovo razlog zbog kojeg se u literaturi o medicinskoj praksi često sreće preporuka da treba izbegavati stručne izraze, kao i da treba proveriti u kojoj meri ih je pacijent razumeo [2]. Doktori upotrebljavaju stručne izraze kako bi istakli asimetriju u znanju i nadmoć, ali vrlo mali broj pacijenata može da učestvuje u takvoj komunikaciji. Iz toga proističe da se pacijenti osećaju zbunjeno i ne razumeju potpuno šta se od njih očekuje, što može dovesti do toga da se neće pridržavati prepisane terapije ili poslušati savete svog lekara. Ne koriste nužno svi doktori stručne termine, ali mnoštvo istraživanja je pokazalo da je to česta pojava [27]. Osim upotrebe stručnih izraza, doktori se često opredeljuju za formalniju leksiku i „prevode“ reči pacijenata na jezik medicine kako bi naglasili superiornost u smislu medicinskog znanja koje poseduju [29]. Sinadinović je ustanovila da kako usmena tako i pisana komunikacija između lekara i pacijenta na srpskom jeziku obiluje izrazima koji su pozajmljeni iz engleskog jezika, čak i u slučajevima kada postoji adekvatan izraz na srpskom jeziku [30].

Komunikacija u stomatologiji

Proučavanje komunikacije je postalo krajnje interdisciplinarno i prevazilazi granice među naučnim oblastima [31]. Stoga je značaj komunikacijskih veština prepoznat i analiziran kao jedan od ključnih preduslova za rad sa pacijentima [32, 33, 34]. Ovo je razlog zbog kojeg se komunikacija nalazi u kurikulumima stomatoloških fakulteta širom sveta [33], posebno ako se uzme u obzir činjenica da Etički kodeks stomatologa u Evropskoj uniji ističe ulogu komunikacije opisujući je kao „presudnu za odnos između stomatologa i pacijenta“ [35, 36]. Model koji se na stomatološkim fakultetima često primenjuje za nastavu komunikacije u zdravstvu jeste *Calgary-Cambridge,* koji sadrži detaljne opise različitih faza medicinskog susreta [33]. Međutim, poslednjih godina se uvodi inovativan model koji podrazumeva video-interakciju – *Video Interaction Guidance* i koji se pokazao kao vrlo efikasan kada je u pitanju nastava komunikacije u kliničkom okruženju [33]. Kvin i autori su sproveli istraživanje kako bi ispitali utiske stomatologa o ovoj tehnici, koja podrazumeva pregledanje video-materijala koji sadrži snimke konverzacije stomatologa i pacijenta, sa ciljem da se unaprede veštine komunikacije stomatologa u *složenim kliničkim sittuacijama*[2] [33]. Njihovi rezultati pokazuju da stomatolozi smatraju ovu tehniku korisnom, jer im ona pomaže da steknu svest o svojoj verbalnoj i neverbalnoj komunikaciji, uključujući strategije koje su primenjivali, a koje nisu efikasne [33].

Komunikacija predstavlja sastavni deo kvalitetne zdravstvene zaštite. Stoga, postoji potreba za procenom kvaliteta komunikacije u stomatološkoj praksi. Ovo je jedan od aspekata koji se ocenjuje u okviru anketa koje su u Srbiji prvi put uvedene 2010. godine, a kojima se ispituje zadovoljstvo pacijenata stomatološkim uslugama u institucijama primarne zdravstvene zaštite, a jedna od stavki tiče se pružanje jasnih instrukcija [19]. Ovo je u skladu sa stavom da je pružanje odgovarajućih i podrobnih informacija od izrazitog značaja za odnos između lekara/stomatologa i pacijenta [35].

Treba navesti još dva istraživanja koja su ukazala na značaj komunikacije u stomatološkoj praksi. Jedno od njih tiče se restaurativnih procedura i toga koliko je važno razumeti očekivanja pacijenta koja se tiču estetike. Zaključak ovog istraživanja bio je da treba predupprediti nesporazume primenom efikasnih strategija u komunikaciji „pre započinjanja tretmana koji se ne može opovrgnuti“ [37]. U fokusu drugog istraživanja jeste anksioznost koju pacijenti mogu osećati zbog odlaska stomatologu, a zaključak je bio da mogućnost da se o ovom problemu razgovara pre samog tretmana značajno ublažava taj osećaj kod pacijenta [32].

Međutim, postavlja se pitanje šta se dešava u multilingvalnoj sredini, gde jezičke razlike mogu predstavljati prepreku kada je reč o pružanju kvalitetne stomatološke usluge. Ovakav susret smatra se vrlo zahtevnim [38]. Na primer, jezičke razlike, tj. činjenica da stomatolog i pacijent ne govore istim jezikom, mogu u velikoj meri uticati na donošenje odluka [35, 38]. Tako je usled

2 Pod *složenim kliničkim situacijama* podrazumevaju se situacije u kojima se stomatolog bavi pacijentima sa intelektualnim smetnjama koji imaju poteškoće u komunikaciji [3].

globalizacije i porasta medicinskog i stomatološkog turizma engleski jezik preuzeo ulogu *zajedničkog jezika*, odnosno *lingua franca* i postao dominantan, nezaobilazan faktor u komunikaciji sa pacijentima iz inostranstva. Istraživanje sprovedeno u Australiji koje je za cilj imalo da ispita utiske stomatologa o pružanju stomatološke zdravstvene zaštite pacijentima sa ograničenim znanjem egleskog jezika pokazalo je da se stomatolozi u proseku jednom nedeljno ili jednom mesečno susreću sa problemima u komunikaciji zbog neadekvatnog znanja engleskog jezika koje poseduju njihovi pacijenti [38]. Učesnici u istraživanju su takođe istakli da im je posebno teško da pruže objašnjenja u domenu endodoncije (28%) i parodontologije (19%) [38].

Komunikacija između lekara/stomatologa i pacijenta

U današnjem svetu, telekomunikacije i tehnologija se brzo razvijaju i utiču na druge oblasti života uključujući nauku i medicinu. Telezdravstvo i telemedicina postepeno prodiru u svakodnevnu medicinsku praksu i sve više se upotrebljavaju. Danas, razvitkom interneta, a posebno svetske mreže, tj. Web 2.0, sve je više mogućnosti na raspolaganju pacijentima koji žele da stupe u kontakt sa lekarom i drugim medicinskim osobljem. Opcije koje su na raspolaganju uključuju različite aplikacije, onlajn forume i platforme Q&A (pitanje–odgovor), privatne konsultacije putem mejla, video-konsultacije, pa čak i društvene mreže. Ovakva vrsta komunikacije putem umreženih računara i drugih digitalnih uređaja naziva se komunikacijom uz posredstvo računara (KPR) [39]. KPR je šira interdisciplinarna oblast koja uključuje različite discipline, kao što su psihologija, sociologija, lingvistika itd. Podoblast KPR koja se usredsređuje na jezik i upotrebu jezika i koja koristi metodologiju analize diskursa naziva se diskursom uz posredstvo računara [40]. Diskurs uz posredstvo računara podrazumeva različite vrste žanrova ili, kako ih Kristal [41] naziva, *internet situacije* koje obuhvataju elektronsku poštu, ćaskaonice, diskusione grupe, virtualne igraonice i mnoge druge žanrove koji su u nastajanju.

Jedna vrsta ovih žanrova su i stranice na kojima pacijenti mogu da komuniciraju sa lekarima/stomatolozima u svrhu traženja medicinskog saveta, podrške i onlajn konsultacija i one potpadaju pod naziv medicinska komunikacija uz posredstvo računara [42]. Medicinska komunikacija uz posredstvo računara u ovom obliku smatra se asinhronom komunikacijom, u kojoj se poslata poruka negde pohranjuje do trenutka čitanja, što je čini i trajnijom [40, 41]. Ova vrsta komunikacije između lekara/stomatologa i pacijenta razlikuje se od tradicionalnog susreta na mnogo načina. Pacijent započinje komunikaciju koja se uspostavlja putem poruka/imejla, preuzimanje reda govorenja je uglavnom ograničeno (pitanje–odgovor), a neka pitanja čak ostaju neodgovorena. Navedeno kao i sam medijum značajno utiču na samu komunikaciju. Naime, tekstualne poruke obično ne mogu da prenesu ekstralingvističke informacije kao što su intonacija, prozodija i druge zvučne informacije, pa ni bilo koju vrstu vizuelne informacije, koje mogu biti od suštinske važnosti u medicinskom susretu. Pored toga, pacijenti uglavnom koriste pseudonime, koji ih podstiču da budu otvoreniji u pružanju informacija lekarima. Istovremeno, administratori stranice anonimiziraju svaki lični podatak koji može dovesti do identifikacije pacijenta. Druge medicinske informacije u formi testova, rezultata i slika pacijenata šalju se direktno administratorima ili lekaru/stomatologu sa kojim pacijenti razgovaraju.

Komunikativna namena ovakvog onlajn komunikativnog događaja varira. Zumo [42] je identifikovala četiri kategorije: traženje mišljenja, traženje drugog mišljenja, objašnjenje medicinskog termina, procedure itd, traženje terapije i traženje dijagnoze. S druge strane, lekari/stomatolozi izgleda pružaju drugačiju vrstu usluge od one koju pacijenti očekuju. Kada je to moguće, odgovoriće na pitanje, ali kada je u pitanju dijagnoza, imaju tendenciju da preporuče posetu lekaru/stomatologu, jer bez konkretnih uvida u stanje pacijenta ne mogu da donose nikakve zaključke [43].

Napredak tehnologije utiče i uticaće na medicinu, kao i na način na koji medicinsko osoblje komunicira sa pacijentima. Implikacije ovakvog napretka podrazumevaju i način na koji se komunikacija podučava studentima medicine i stomatologije.

ZAKLJUČAK

Komunikacija između lekara i pacijenta predstavlja vid institucionalne komunikacije koja se smatra ključnom za ishod lečenja i utiče na to u kojoj će se meri pacijenti pridržavati prepisane terapije. Ujedno je ovo oblast koja je u fokusu krosdisciplinarnih istraživanja. Brojne su razlike između institucionalne i svakodnevne komunikacije, pri čemu se posebno izdvajaju sistem preuzimanja reči, izbor leksike i asimetrija.

Medicinski susret analiziran je sa različitih aspekata, kako od strane lingvista (literatura koja se bavi diskursom), tako i od strane doktora (literatura koja se bavi medicinskom praksom). Klasični biomedicinski model koji se sastoji od šest faza ispitivan je i usavršavan od 1976. godine. U međuvremenu se, na osnovu iskustva iz prakse, pojavila potreba za pristupom koji pacijenta stavlja u prvi plan, tako da je 2012. godine predložen biopsihosociološki model. Prema rezultatima istraživanja, čini se da je u Srbiji još uvek zastupljeniji biomedicinski model.

Komunikacija između doktora i pacijenta sadrži elemente intervjuisanja i pripovedanja. Međutim, istraživanja pokazuju da pripovedanje značajno doprinosi preciznijoj dijagnozi i glasu pacijenta u institucionalnoj komunikaciji. Deluje da je odabir leksike jedan od glavnih uzroka zbog kojih dolazi do nesporazuma i loše veze između doktora i pacijenta.

Kada je reč o stomatologiji, komunikacijske veštine se smatraju ključnim za rad sa pacijentima. Model *Calgary-Cambridge* se tradicionalno primenjuje sa ciljem učenja komunikacije, ali je nedavno uveden inovativni model pod nazivom *Video Interaction Guidance*, koji se pokazao efikasnim. Efikasna komunikacija u stomatološkoj praksi proučava se sa različitih aspekata, uključujući interakciju stomatologa i pacijenta (Srbija), stomatološki turizam, očekivanja pacijenata kada su u pitanju restorativne procedure, anksioznost pacijenata, komunikacija između stomatologa i pacijenta u multilingvalnom okruženju (Australija) itd.

Najzad, osim komunikacije sa lekarom ili stomatologom koja se odvija licem u lice, postoji još jedna mogućnost – kompjuterski posredovana komunikacija koja podrazumeva aplikacije, onlajn forume, platforme predviđene za pitanja i odgovore, privatnu elektronsku poštu, video-konsultacije i sl. Kompjuterski posredovana medicinska komunikacija podrazumeva internet stranice gde pacijenti mogu komunicirati sa lekarima ili stomatolozima. Između ostalog, kompjuterski posredovana medicinska komunikacija razlikuje se od tipične komunikacije između doktora i pacijenta zbog ograničenog sistema preuzimanja reči, neodgovorenih pitanja i upotrebe pseudonima.

Da li ste pažljivo čitali radove?

1. Laseri u stomatologiji mogu se koristiti za:
   a) zarastanje koštanog tkiva
   b) terapiju zubne pulpe
   c) očuvanje vitaliteta pulpe

2. Kod dijabetesa melitusa je:
   a) smanjen protok pljuvačke
   b) povećan protok pljuvačke
   c) nepromenjen protok pljuvačke

3. SEM analizom su proveravani radni delovi:
   a) ručnih endodontskih instrumenata
   b) mašinskih endodontskih instrumenata
   c) i ručnih i mašinskih endodontskih instrumenata

4. Kod endodontskih silera je ispitivana:
   a) tvrdoća
   b) fluidnost
   c) antibakterijski potencijal

5. Prvi prototip lasera je napravljen:
   a) 1950. godine
   b) 1960. godine
   c) 1970. godine

6. Na radnom delu ručnih endodontskih instrumenata je proveravano:
   a) postojanje proizvodnih efekata
   b) prisustvo debrisa
   c) postojanje fraktura

7. Fluidnost endodontskih silera je proveravana:
   a) kod dva silera
   b) kod tri silera
   c) kod četiri silera

8. Studija o protoku pljuvačke je obuhvatila:
   a) 50 pacijenata
   b) 90 pacijenata
   c) 120 pacijenata

9. Prvi prototip lasera napravio je:
   a) Albert Ajnštajn
   b) Goldman
   c) Majman

10. SEM anlizom su proveravana:
    a) po dva seta ručnih endodontskih instrumenata
    b) po tri seta ručnih endodontskih instrumenata
    c) po četiri seta ručnih endodontskih instrumenata

11. Fluidnost endodontskih silera je proveravana pri opterećenju od:
    a) 0,5 kg
    b) 1 kg
    c) 2 kg

12. Grupa sa kontrolisanim dijabetesom je obuhvatila:
    a) 30 pacijenata
    b) 40 pacijenata
    c) 50 pacijenata

13. Prva primena lasera na oralnim tkivima opisana je od strane:
    a) Goldmana
    b) Sterna i Sognesa
    c) Majersa

14. Grupa sa loše kontrolisanim dijabetesom je obuhvatila:
    a) 20 pacijenata
    b) 30 pacijenata
    c) 40 pacijenata

15. SEM-om je proveravano ukupno:
    a) 12 instrumenata
    b) 15 instrumenata
    c) 18 instrumenata

16. Ispitivanje fluidnosti Endometazona N je uključivalo:
    a) samo jedan odnos prah–tečnost
    b) tri odnosa prah–tečnost
    c) pet odnosa prah–tečnost

17. Primena lasera u stomatologiji prvi put je publikovana:
    a) 1975. godine
    b) 1985. godine
    c) 1987. godine

18. Najveće vrednosti stimulisane pljuvačke su uočene kod:
a) zdravih ispitanika
b) bolesnika sa kontrolisanim dijabetesom
c) bolesnika sa loše kontrolisanim dijabetesom

19. SEM analiza ručnih instrumenata je posmatrana:
a) na uvećanju 100×
b) na uvećanju 150×
c) na uvećanju 170×

20. Opterećenje silera je urađeno preko:
a) papira
b) folije
c) staklene pločice

21. Primena lasera u mekotkivnoj hirurgiji uključuje:
a) lasere Nd:YAG
b) rubinske lasere
c) CO_2 lasere

22. Protok nestimulisane i stimulisane pljuvačke je bio:
a) u pozitivnoj korelaciji sa KEP-om
b) u negativnoj korelaciji sa KEP-om
c) u identičnoj korelaciji sa parodontalnim parametrima

23. Hemijski sastav prisutnih nečistoća na radnom delu ručnih instrumenata je proveravan:
a) SEM analizom
b) EDXS analizom
c) kalorimetrijski

24. Opterećenje silera kod kontrolne grupe je iznosilo:
a) > 20 mm
b) < 20 mm
c) > 40 mm

25. Laseri se mogu podeliti u:
a) četiri osnovne kategorije
b) tri osnovne kategorije
c) dve osnovne kategorije

26. Protok nestimulisane i stimulisane pljuvačke je bio:
a) u negativnoj korelaciji sa parodontalnim parametrima
b) u pozitivnoj korelaciji sa parodontalnim parametrima
c) u identičnoj korelaciji sa parodontalnim parametrima

27. Rezultati SEM analize ručnih instrumenata su pokazali da:
a) svi instrumenti imaju po neki defekt
b) polovina instrumenata ima po neki defekt
c) trećina instrumenata ima po neki defekt

28. Fluidnost svih testiranih silera je iznosila:
a) 20,7–27,8 mm
b) 29,6–30,0 mm
c) 30–39 mm

29. Kontinualni tip lasera proizvodi:
a) neprekidni laserski zrak sa stabilnom izlaznom snagom
b) neprekidni laserski zrak sa nestabilnom izlaznom snagom
c) neprekidni laserski zrak sa pulsnim modulom

30. Smanjen protok pljuvačke kod obolelih od dijabetesa tipa 2:
a) značajno utiče na stanje oralnog zdravlja
b) neznačajno utiče na stanje oralnog zdravlja
c) utiče zavisno od godina bolesnika

31. Najučestaliji tip defekata kod analiziranih ručnih instrumenata je bio:
a) udubljenje
b) debris
c) prisustvo metalnih opiljaka

32. Fluidnost kod endometazona je iznosila:
a) 20,7–27,8 mm
b) 29,6–30 mm
c) 30–39 mm

33. Pulsni laseri produkuju pulseve između:
a) 0,5 i 200 ns
b) 0,5 i 300 ns
c) 0,5 i 500 ns

34. Prisustvo debrisa kod KF instrumenta uočeno je kod:
a) 50% instrumenata
b) 70% instrumenata
c) 100% instrumenata

35. Fluidnost silera ROTH 801 je iznosila:
a) 20,7–27,8 mm
b) 29,6–30 mm
c) 30–39 mm

36. Ultrabrzi laseri produkuju pulseve između:
a) 5 FS (femtosekundi)-100ps
b) 5 FS (femtosekundi)-200ps
c) 5 FS (femtosekundi)-300ps

37. Prisustvo udubljenja je kod HF instrumenata uočeno u:
a) 11% apikalno i 5% srednja
b) 11% apikalno i 6% srednja
c) 11% apikalno i 8% srednja

38. Fluidnost kod silera Tubliseal je iznosila:
a) 20,7–27,8 mm
b) 29,6–30 mm
c) 30–39 mm

39. Laseri u stomatologiji koriste svetlo od:
a) 100–400 nm
b) 400–700 nm
c) 100–700 nm

40. Korozija radne površine ručnih instrumenata je uočena:
    a) samo u KF
    b) samo u HF
    c) i u KF i u HF

41. Ređe zamešan endometazon je pokazao:
    a) znatno veću fluidnost od standardno zamešanog
    b) znatno manju fluidnost od standardno zamešanog
    c) identičnu fluidnost kao i standardno zamešan

42. Laseri se u stomatologiji mogu koristiti za dijagnozu karijesa?
    a) Da
    b) Ne
    c) Zavisi od dubine karijesa

43. Učestalost prisustva kandide kod obolelih od dijabetesa tipa 2 je bila izrazita:
    a) kod bolesnika sa očuvanim zubima
    b) kod bolesnika sa fiksnim nadoknadama
    c) kod bolesnika sa mobilnim nadoknadama

44. Prekid sečivne ivice je uočen:
    a) samo kod KF
    b) samo kod HF
    c) i kod KF i kod HF

45. Najveću fluidnost kod testiranih silera je pokazao:
    a) endometazon
    b) ROTH 801
    c) TUBLI Seal

46. Na interakciju sa laserskim zrakom utiču optička svojstva tkiva?
    a) Da
    b) Ne
    c) Zavisi od veličine oštećenja tkiva

47. Kod obolelih od dijabetesa tipa 2 između protoka pljuvačke i kandidijaze je uočena:
    a) pozitivna korelacija
    b) negativna korelacija
    c) identična korelacija

48. Gušći sileri pokazuju:
    a) manju fluidnost
    b) veću fluidnost
    c) identičnu fluidnost kao i ređe zamešani

49. Prisustvo debrisa je kod HF uočeno u:
    a) 56% apikalno i 56% srednja
    b) 56% apikalno i 11% srednja
    c) 11% apikalno i 56% srednja

50. Fluidnost silera je u korelaciji sa:
    a) oblikom i širinom kanala
    b) tehnikom mešanja
    c) tehnikom opturacije

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