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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

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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	

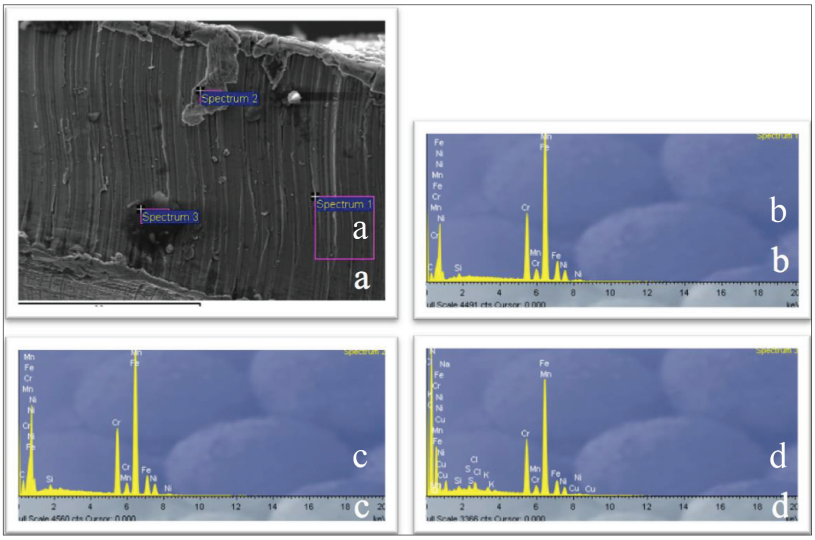


Figure 1. EDS analysis of KF instruments (ISO 20): a) SE image with marked points which were analyzed (Spectrum 1–3); b) Diagram of EDS analysis Spectrum 1; c) Diagram of EDS analysis Spectrum 2; d) Diagram of EDS analysis Spectrum 3
Slika 1. EDS analiza instrumenta KF (ISO 20): a) SE snimak sa obeleženim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

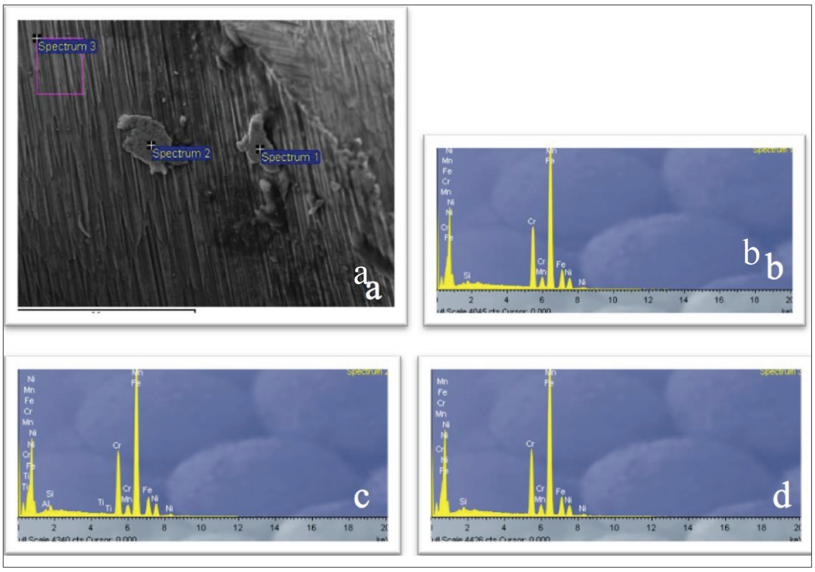


Figure 2. EDS analysis of HF instrument (ISO 25): a) SE image with marked points which were analyzed (Spectrum 1–3); b) Diagram of EDS analysis Spectrum 1; c) Diagram of EDS analysis Spectrum 2; d) Diagram of EDS analysis Spectrum 3

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

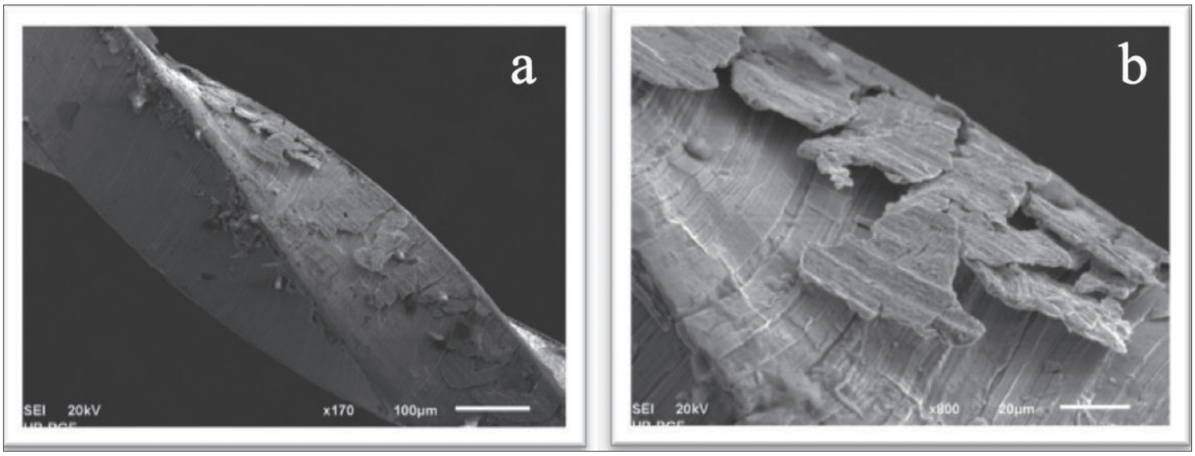
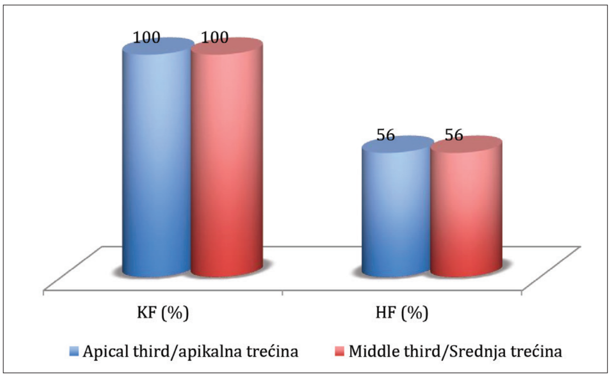
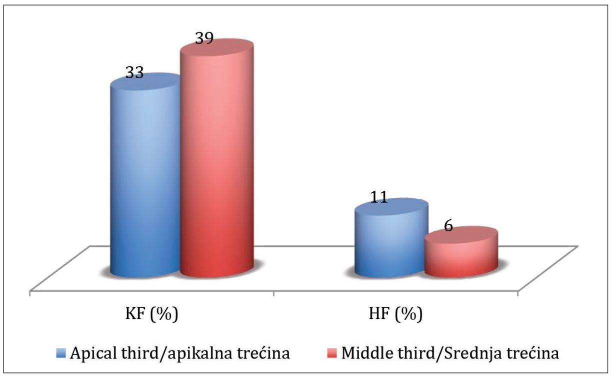


Figure 3. SEM analysis of working surface (middle third) of KF instruments with metal strips and fretting: a) magnification 170×, b) magnification 800×
Slika 3. SEM analiza radnog dela (srednja trećina) instrumenta KF sa metalnim opiljcima i žljebovima: a) uvećanje 170×, b) uvećanje 800×



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

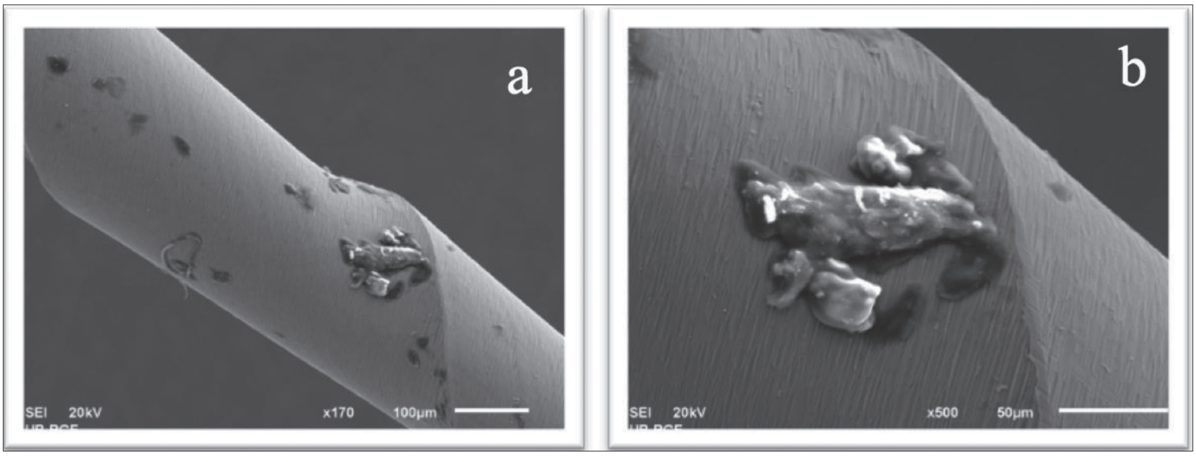


Figure 4. SEM of middle third of KF 20 instrument with debris: a) magnification 170×, b) magnification 500×
Slika 4. SEM srednje trećine instrumenta HF 20 sa debrisom: a) uvećanje 170×, b) uvećanje 500×

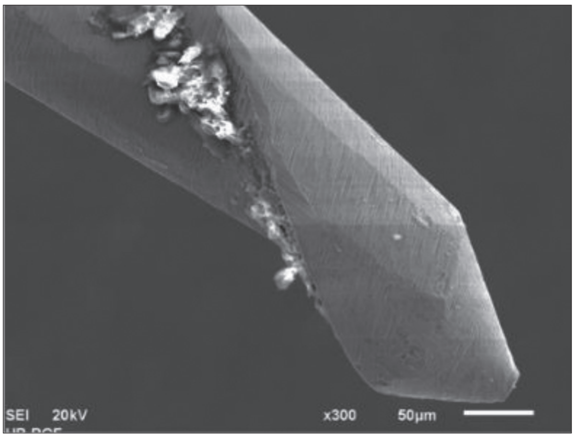


Figure 5. SEM of apical third of KF 25 instrument with debris (magnification 300×)
Slika 5. SEM apikalne trećine instrumenta KF 25 sa debrisom (uvećanje 300×)

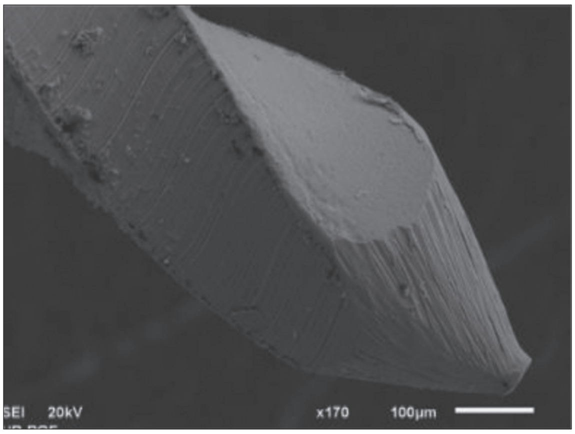


Figure 6. SEM of apical third of HF 35 instrument with pitting
Slika 6. SEM apikalne trećine instrumenta HF 35 sa jamičastim udubljenjima

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

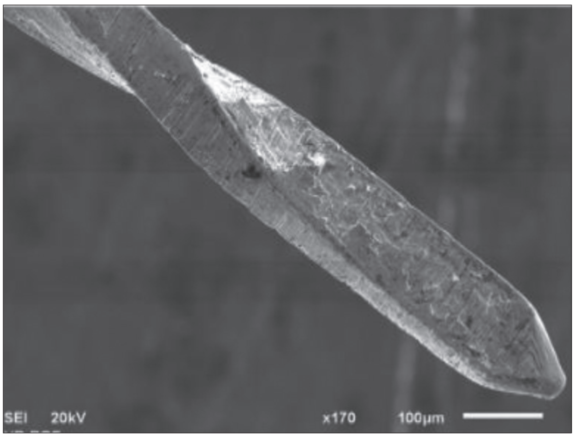


Figure 7. SEM of apical third in KF15 instrument with metal flash and disruption of cutting edge
Slika 7. SEM apikalne trećine instrumenta KF15 sa metalnom uglačanošću i prekidom sečivne ivice

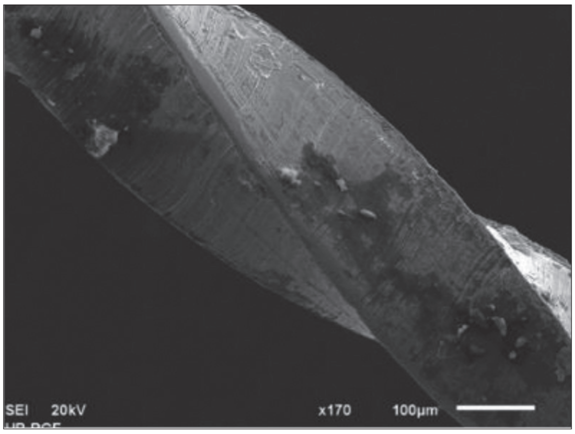


Figure 8. SEM of middle third of KF 25 instrument with corrosion
Slika 8. SEM srednje trećine instrumenta KF 25 na kom se uočava korozija

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.