Sem analysis of working surface in new manual endodontic instruments

Milica Jovanović-Medojević¹, Martina Pelemiš², Jelena Nešković¹, Marijana Popović-Bajić¹, Đorđe Stratimirović³, Slavoljub Živković¹

¹University of Belgrade, School of Dental Medicine, Department for Restorative Dentistry and Endodontics, Belgrade, Serbia; ²Private Dental Practice AdenT, Belgrade, Serbia; ³University of Belgrade, School of Dental Medicine, Department of Basic Sciences, Belgrade, Serbia

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].

Address for correspondence: Milica JOVANOVIĆ-MEDOJEVIĆ, Rankeova 4, Belgrade; medojevic.milica@gmail.com
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 the working surface.
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 HF instruments (56% apical and middle third) (Tables 3, 4, 5, Figure 3). 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 noticed on all 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 | Second group | Third group |
|-------|-------------|--------------|-------------|
|       | PRVA GRUPA  | Druga GRUPA  | treća GRUPA |
|       | Apikal trećina | Srednja trećina | Apikal trećina | Srednja trećina | Apikal trećina | Srednja trećina |
| 15    | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi |
|       | Metal flash Metalne uglačane površine | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | | |
|       | Disruption Prekid | Debris | Debris | Debris | Debris | Debris |
| 20    | 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 strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci |
|       | Corrosion Korozija | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris |
| 25    | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi |
|       | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci strips | Metal strip Metalni opiljci strips | Metal strip Metalni opiljci | Metal strip Metalni opiljci |
|       | Corrosion Korozija | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris |
| 30    | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi |
|       | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci |
|       | Corrosion Korozija | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris |
| 35    | 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 strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci |
|       | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris |
| 40    | Pitting Jamičasta udubljenja | | | | | |
|       | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi | Fretting Žlebovi |
|       | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci | Metal strip Metalni opiljci |
|       | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris | Debris Debris |
Table 5. Presence of defects and dirt on working surface of tested HF instruments

|   | First group PRVA GRUPA | Second group Druga GRUPA | Third group treća GRUPA |
|---|------------------------|---------------------------|--------------------------|
| io | Apical third | Middle third | Apical third | Middle third | Apical third | Middle third |
|   | Apikalna trećina | Srednja trećina | Apikalna trećina | Srednja trećina | Apikalna trećina | Srednja trećina |
| 15 | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Pitting |
|   | Metal strips | Metalni opiljci | Metal strips | Metalni opiljci | Metal strips | Metalni opiljci | Metal strips | Metalni opiljci |
|   | Debris | Debris | Debris | Debris | Debris | Debris | Debris | Debris |
| 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 | Debris | Debris | Debris | Debris | Debris | Debris | Debris |
| 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 opiljici | Metal strips | Metalni opiljici |
|   | Debris | Debris | Debris | Debris | Debris | Debris | Debris | Debris |
| 30 | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi |
|   | Metal strips | Metalni opiljci | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici |
|   | Debris | Debris | Debris | Debris | Debris | Debris | Debris | Debris |
| 35 | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi |
|   | Metal strips | Metalni opiljci | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici |
|   | Debris | Debris | Debris | Debris | Debris | Debris | Debris | Debris |
| 40 | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi | Fretting | Žlebovi |
|   | Metal strips | Metalni opiljci | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici | Metal strips | Metalni opiljici |
|   | Debris | Debris | Debris | Debris |

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×
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...
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 Hedstrom 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 composi-
tion 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, 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.

ACKNOWLEDGMENT

The experimental part of this study was conducted in the SEM-EDS laboratory of the Faculty of Mining and Geology, University of Belgrade, and on this occasion I thank the laboratory team led by Prof. Suzana Eric PhD, Kristina Sarić PhD, and Vladica Cvetković PhD.

REFERENCES

1. Peters OA, Peters CI, Basrani B. Cleaning and shaping the root canal system. In: Hargreaves MH, Berman LH, Cohen S, editors. Pathways of the pulp. St Louis, MO: Elsevier; 2015. p. 209–79.
2. Bartols A, Bormann C, Werner L, Schienle M, Walther W, Dörfer CE. A retrospective assessment of different endodontic treatment protocols. PeerJ. 2020;8:e8495. [DOI: 10.7717/peerj.8495] [PMID: 32030328]
3. Gavini G, Santos MD, Caldeira CL, Machado MEI, Freire LG, Iglescas EF, et al. Nickel-titanium instruments in endodontics: A concise review of the state of the art. Braz Oral Res. 2018;32(2Suppl 1):e67. [DOI: 10.1590/1807-3107/orbr.2018.vol32.00067] [PMID: 30365608]
4. Lopes HP, Elias CN, Siqueira JF Jr, Soares RG, Souza LC, Oliveira JC, et al. Mechanical behavior of pathfinding endodontic instruments. J Endod. 2012;38(10):1417–21. [DOI: 10.1016/j.joen.2012.05.005] [PMID: 22980191]
5. Bakshi D, Hedge V. Comparison of surface characteristics of apical third of rotary niti files manufactured from different phases of NiTi before and after use: An SEM analysis. DJAS. 2016;4(1):18–22. [DOI: 10.1055/s-0038-1672040]
6. Sattapan B, Palamara J, Messer H. Torque during canal instrumentation using rotary nickel-titanium files. J Endod. 2000;26(3):156–60. [DOI: 10.1097/00004770-200003000-00008] [PMID: 11199710]
7. Ankrun M, Hartwell GR, Truitt JE. K3 Endo, ProTaper, and Profile file systems: breakage and distortion in severely curved roots of molars. J Endod. 2004;30(4):230–2. [DOI: 10.1097/00004770-200404000-00013] [PMID: 15085054]
8. Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. J Endod. 2005;31(12):845–50. [DOI: 10.1097/01.dod.0000164127.62864.7c] [PMID: 16306815]
9. Iqbal MK, Kohli MR, Kim JS. A retrospective clinical study of incidence of root canal instrument separation in an endodontics graduate program: a Penndent study. J Endod. 2006;32(11):1048–52. [DOI: 10.1016/j.joen.2006.03.001] [PMID: 17055904]
10. Wu J, Lei G, Yan M, Yu Y, Yu J, Zhang G. Instrument separation analysis of multi-used ProTaper Universal rotary system during root canal therapy. J Endod. 2011;37(6):758–63. [DOI: 10.1016/j.joen.2011.02.021] [PMID: 21787484]
11. Bergenholtz G, Lekholm U, Milthom R, Heden G, Odejsko B, Engström B. Retreatment of Endodontic fillings. Scand J Dent Res. 1979;87(3):217–24. [DOI: 10.1111/j.1600-6022.1979.tb00675.x] [PMID: 293884]
12. Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. J Endod. 2006;32(11):1031–43. [DOI: 10.1016/j.joen.2006.06.008] [PMID: 17055902]
13. Cheung GS. Instrument fracture: mechanisms, removal of fragments, and clinical outcomes. Endod Topics. 2009;16:1–26. [DOI: 10.1111/j.1610-1566.2009.00239.x]
14. McGuigan MB, Louca C, Duncan HF. Clinical decision-making after endodontic instrument fracture. Br Dent J. 2013;214(8):395–400. [DOI: 10.1038/sj.bdj.2013.379] [PMID: 23619858]
15. Cohen S, Hargreaves K. Pathways of the Pulp. 10th ed. Elsevier; 2011.
16. Popović J, Gašić J, Radičević G. The Investigation of Ultrasound經營 Methods on Contaminated Endodontic Files. J Health Res. 2017;4(3):194–7. [DOI: 10.4103/cjhr.cjhr_12_17]
17. Thompson SA. An overview of nickel-titanium alloys used in dentistry. Int Endod J. 2003;34(4):297–310. [DOI: 10.1046/j.1365-2591.2000.00339.x] [PMID: 11307203]
18. Bourke personalised C, Lambrianidis T. Factors Affecting Intracanal Instrument Fracture. In: Lambrianidis T. (eds). Management of Fractured Endodontic Instruments. Springer, Charn, 2018. p. 31–60.
19. Egger C, Peters O, Babakov F. Wear of Nickel-Titanium Light-speed Instruments Evaluated by Scanning Electron Microscopy. J Endod. 1999;25(7):494–7. [DOI: 10.1016/S0165-2399(99)00289-1] [PMID: 10687515]
20. Patel D, Bashetty K, Srinexa A, Archania S, Saviitha B, Vijay R. Scanning electron microscopic evaluation of the influence of manual and mechanical glide path on the surface of nickel-titanium rotary instruments in moderately curved root canals. An in-vivo study. J Conserv Dent. 2016;19(6):549–54. [DOI: 10.4103/0972-0707.194035] [PMID: 27994317]
21. Mustafa M. Knowledge, attitude and practice of general dentists towards sterilization of endodontic files. A cross – sectional study. Indian J Sci Tech. 2016;9(11):[DOI: 10.17485/jetc/2016/v9i11/81086]
22. Enabulele JE, Omo JO. Dental assistants’ knowledge, attitude, and practice of endodontic sterilization - A cross-sectional study. Saudi Endod J. 2018;8(2):106–10. [DOI: 10.1097/01.don.0000164127.62864.7c] [PMID: 16306815]
23. Yenni M, Bandi S, Avula SSJ, Margana PGJS, Pranitha Kakarla P, Amrutavalli A. Comparative Evaluation of Four Different Sterilization Methods on Contaminated Endodontic Files. J Health Res. 2017;4(3):194–7. [DOI: 10.4103/ahrwahr_12_17]
24. Popović J, Gašić J, Zivkovic S, Petrović A, Radičević G. Evaluation of biological debris on endodontic instruments after cleaning and sterilization procedures. Int Endod J. 2010;43(4):336–41. [DOI: 10.1111/j.1365-2591.2010.00686.x] [PMID: 20487454]
25. Lopes HP, Elias CN, Siqueira Junior JF. Defects from the manufacturing process of K-type files. Rev Paul Odontol. 2002;244–7
26. Chianello G, Specian VL, Hardt L, Raldi D, Marques JL, Habitante S. Surface Finishing of Unused Rotary Endodontic Instruments: A SEM Study. Braz Dent J. 2008;19(2):109–13. [DOI: 10.1590/s0103-64402008000200004]

27. Shen Y, Haapasalo M, Cheung CS, Peng B. Defects in nickel-titanium instruments after clinical use. Part 1: Relationship between observed imperfections and factors leading to such defects in a cohort study. J Endod. 2009;35(1):129–32. [DOI: 10.1016/j.joen.2008.10.014] [PMID: 19084142]

28. Schäfer E, Tepel J. Relationship Between Design Features of Endodontic Instruments and Their Properties. Part 3. Resistance to Bending and Fracture. J Endod. 2001;27(4):299–303. [PMID: 11485273]

29. Van Eldik DA, Zilm PS, Rogers AH, Marin PD. A SEM evaluation of debris removal from endodontic files after cleaning and steam sterilization procedures. Aust Dent J. 2004;49(3):128–35. [DOI: 10.1111/j.1834-7819.2004.tb00610.x] [PMID: 15497356]

30. Bonetti-Filho I, Esberard R, Leonardo RT, Del Rio CE. Microscopic evaluation of three endodontic files pre and post instrumentation. J Endod. 1998;24(7):461–3. [DOI: 10.1016/s0099-2399(98)80046-0] [PMID: 9693570]

31. Roth TM, Whitney SI, Walker SG, Friedman S. Microbial Contamination of Endodontic Files Received from the Manufacturer. J Endod. 2006;32(7):649–51. [DOI: 10.1016/j.joen.2005.09.006] [PMID: 16793473]

32. Nagaratna PJ, Shashikiran ND, Subbareddy VV. In vitro comparison of NiTi rotary instruments and stainless steel hand instruments in root canal preparations of primary and permanent molar. J Indian Soc Pedod Prev Dent. 2006;24(4):186–91. [DOI: 10.4103/0970-4388.28075] [PMID: 17183182]
SEM analiza površine radnog dela novih ručnih endodontskih instrumenata

Milica Jovanović-Medojević¹, Martina Pelemiš², Jelena Nešković¹, Marijana Popović-Bajić¹, Đorđe Stratimirović³, Slavoljub Živković¹

¹Univerzitet u Beogradu, Stomatološki fakultet, Katedra za bolesti zuba i endodonciju, Beograd, Srbija; ²Privatna stomatološka ordinacija AdenT, Beograd, Srbija; ³Univerzitet u Beogradu, Stomatološki fakultet, Katedra za bazične stomatološke nauke, Beograd, Srbija

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 metoda

U istraživanju su korišćena tri seta novih ručnih instrumenata: K-File (KF), (18 instrumenata) (Dentsply Maillefer, Switzerland) i Hedstrom 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 Fishegovog 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. Debris je uočen na svim KF (100% apikalno i sredinom) i HF (56% apikalno i 56% u sredini trećini). Prisustvo udubljenja zabeleženo je kod HF (33% apikalno i 39% u sredini trećini) i HF (11% apikalno i 6% u sredini trećini). Korozija radne površine, pojava uglučene površine i prekid sečivine isprave su uočeni samo u grupi HF.

Zaključak

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

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

UVOD

Hemomehanička obrada kanala se najčešće realizuje ručnim endodontskim instrumentima (od nserdućeg čelika ili Ni-Ti legure) v mašinskim Ni-Ti rotirajućim endodontskim instrumentima uz adekvatnu i obilnu irrigaciju kanalskog sistema [1]. Iako su Ni-Ti rotirajući instrumenti postali deo svakodnevnog cvijeta i njegovu vulnerabilnost na frakturu. Defekti na površini deluju samo u grupi KF.

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 uglučene površine i prekid sečivine isprave su uočeni samo u grupi HF.

Zaključak

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

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

Većina novih endodontskih instrumenata nije sterilna i na njihovoj površini se mogu naći različiti metalni ostaci, nečistoće, organskog i neorganog porekla. Proces proizvodnje endodontskih instrumenata od nserdućeg čelika može dovesti do prisustva sitnih opiljaka – metal koji se u manjoj ili većoj meri zadržava na površinama radnog dela endodontskih instrumenata [16].

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

Endodontski instrumenti od nserdućeg čelika se uglavnom izrađuju postupkom uvrtanja različitih profila žica po uzdužnoj osnovi, formirajući sečiva od vertikalnih ivica žice [17]. Pri- sustvo nepravilnosti na površini instrumenta može povećati njegovu vulernabilnost na frakturu. Defekti na površini deluju kao tačke koncentracije napona i izazivaju inicijaciju i širenje pukotina, sa velikom mogućnošću pojava 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 Hedstrom 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 apeksa i srednja trećina instrumenata iz dva različita pravca i sva strana instrumenata je analizirana sa po tri snimka.

Analiza prisustva različitih nepravilnosti i grešaka tokom procesa izrade je obuhvatila kriterije koje je predložila Eggert sa saradnicima [19]: ocena 1 – bez vidljivih defekta; ocena 2 – jamčiasta 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 kvantitativna analiza ali bez kvantifikovanja dobijenih rezultata. Semikvantitativnom, EDXS analizom utvrđen je hemijski sastav zatečene nečistoće.

Analizom SEM mikrofotografija utvrđeno je postojanje kontaminacija na površini novih instrumenata, a naknadnom EDXS analizom je utvrđen njen hemijski sastav. Na taj način je utvrđena površina instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata.

EDXS analiza instrumenta KF (ISO 20) (Slika 1, Tabela 1) za spektar jedan je utvrđena na čistom delu površine instrumenata, dok je analiza instrumenata dva i tri instrumenata na kontaminiranoj površini. Najzastupljeniji element je ultrarapidni element na instrumenata (13,45 mas%) i u manjoj meri hrom, mangan i nikl u različitim masnim koncentracijama. EDXS analiza za drugi i treći spektar je uvećana na kontaminiranoj površini. Najzastupljeniji element je na instrumenatima sa jednim spektrom je hrom sa maksimalnom zastupljenošću od 71,12 mas% i minimalnom od 69,53 mas%. Osnovni sastav instrumenata je sastavljen od aluminija i silicijuma.

Metodu izrade instrumenta postojalo je minimalno od 69,53 mas%. Prisutni su i aluminijum, silicijum i niklon. Mangan i nikl su prisutni u različitim masnim koncentracijama. EDXS analiza za drugi i treći spektar je uvećana na kontaminiranoj površini. Najzastupljeniji element je na instrumenatima sa jednim spektrom je hrom sa maksimalnom zastupljenošću od 71,12 mas% i minimalnom od 69,53 mas%. Osnovni sastav instrumenata je sastavljen od aluminija i silicijuma.

Prisustvo defekata na radnom delu instrumenata postojalo je minimalno od 69,53 mas%. Osnovni sastav instrumenata je sastavljen od aluminija i silicijuma.

Diskusija

Uspeh endodontske terapije zavisi pre svega od pravilne instrumentacije, odnosno od biomehaničkih obrade i od gubitak hermetičkog optuživljanja kanala korena. Endodontski instrumenti svojom dizajnom, metalurškim karakteristikama, izgledom svojoj površini. Na novim ručnim instrumentima nije uočeno uglačanje površine, a u novim instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata.

Poređenje rezultata utvrđeno je na apikala i srednjoj trećini instrumenata (17% i 11% apikalna i 11% srednja trećina) (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.

DISKUSIJA

Uspeh endodontske terapije zavisi pre svega od pravilne instrumentacije, odnosno od biomehaničkih obrade i od gubitak hermetičkog optuživljanja kanala korena. Endodontski instrumenti svojom dizajnom, metalurškim karakteristikama, izgledom svojoj površini. Na novim ručnim instrumentima nije uočeno uglačanje površine, a u novim instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata.

Poređenje rezultata utvrđeno je na apikala i srednjoj trećini instrumenata (17% i 11% apikalna i 11% srednja trećina) (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.

Uspeh endodontske terapije zavisi pre svega od pravilne instrumentacije, odnosno od biomehaničkih obrade i od gubitak hermetičkog optuživljanja kanala korena. Endodontski instrumenti svojom dizajnom, metalurškim karakteristikama, izgledom svojoj površini. Na novim ručnim instrumentima nije uočeno uglačanje površine, a u novim instrumenata i proveri eventualno postojanje proizvodnih nečistoća ili defekata.

Poređenje rezultata utvrđeno je na apikala i srednjoj trećini instrumenata (17% i 11% apikalna i 11% srednja trećina) (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.
Ostaci maziva (korišćenog tokom proizvodnje), epitelnih ćelija, ispitivanja kvaliteta njihove završne obrade i uslova pakovanja. Pripreme [25]. SEM analiza je na ovaj način imala mogućnost sredno po otvaranju fabričkog pakovanja, bez ikakve prethodne instrumenata, u ovoj studiji su instrumenti analizirani nepokrenim, jer aceton u ultrazvuku korišćen za dobijanje čistih i suvih instrumenata. Za razliku od studije Lopesa i saradnika (2002), u srednjoj potvrđuje komplikovanost izrade čistih endodontskih u stopostotnom procentu i HF u procentu od 56% (apikalno i novim instrumentima [30]. Bonetti Filho i saradnici su takođe mogu se objasniti specifičnim tehnološkim procesom izrade, jer je primećena na malom procentu (KF, HF), i redukovati reparacija tkiva [29]. Ovakav nalaz je u saglasnosti gruppama u stopostotnom procentu, potvrđuje komplikovanost pažljivu manipulaciju [28]. Značaj pojave ovog tipa defekta na površini instrumenata [28]. Značaj ovih elemenata u poboljšavanju osobina instrumenata. Ovakav sastav legure obezbeđuje dobre mehaničke osobine uz značaj ovih 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 novih instrumenata od nerđajućeg čelika. Konvencionalna izrada novih ručnih endodontskih instrumenata uokviru produkcije i neadekvatnog pakovanja i kompromitirava 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, Peenbacilluspecies i tri gljičnica soja) [31].

Problemom tokom proizvodnog procesa mogu nastati i zbog kvaliteta same žice od koje se izrađuju, jer čestice oksida i karića mogu ostati inkorporisane u leguri tokom proizvodnje, stvarajući kritične zone koje mogu biti nukleaciona mesta za pojavu mikrošupljina [32]. Pod dejstvom korozivnih faktora (irigacionih rastvora, dezinfekcije i sterilizacije) i pod dejstvom tornih i cikličnih opterećenja tokom instrumentacije može doći do korozijske 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.

Vela 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 novih instrumenata od nerđajućeg čelika. Konvencionalna izrada novih ručnih endodontskih instrumenata uokviru produkcije i neadekvatnog pakovanja i kompromitirava 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, Peenbacilluspecies i tri gljičnica soja) [31].

Problemom tokom proizvodnog procesa mogu nastati i zbog kvaliteta same žice od koje se izrađuju, jer čestice oksida i karića mogu ostati inkorporisane u leguri tokom proizvodnje, stvarajući kritične zone koje mogu biti nukleaciona mesta za pojavu mikrošupljina [32]. Pod dejstvom korozivnih faktora (irigacionih rastvora, dezinfekcije i sterilizacije) i pod dejstvom tornih i cikličnih opterećenja tokom instrumentacije može doći do korozijske 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.

Vela 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 novih instrumenata od nerđajućeg čelika. Konvencionalna izrada novih ručnih endodontskih instrumenata uokviru produkcije i neadekvatnog pakovanja i kompromitirava 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, Peenbacilluspecies i tri gljičnica soja) [31].

Problemom tokom proizvodnog procesa mogu nastati i zbog kvaliteta same žice od koje se izrađuju, jer čestice oksida i karića mogu ostati inkorporisane u leguri tokom proizvodnje, stvarajući kritične zone koje mogu biti nukleaciona mesta za pojavu mikrošupljina [32]. Pod dejstvom korozivnih faktora (irigacionih rastvora, dezinfekcije i sterilizacije) i pod dejstvom tornih i cikličnih opterećenja tokom instrumentacije može doći do korozijske 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.