UDC: 616.314-089.818.1:615.465 DOI: 10.2298/SGS1001021N

Deformations of the Manual Endodontic Instruments During Root Canal Instrumentation

Jelica Nešković[1], Marija Damjanov[1], Slavoljub Živković[2], Djurica Grga[2], Djuro Koruga[3], Dušan Kojić[3]

[1]School of Dentistry (student of academic specialist studies), University of Belgrade, Belgrade, Serbia
[2]Department of Restorative Dentistry and Endodontics, School of Dentistry, University of Belgrade, Belgrade, Serbia
[3]Department of Automatic Control, Mechanical Engineering, University of Belgrade, Belgrade, Serbia

SUMMARY

Introduction Mechanical instrumentation of the complex root canal system is very demanding procedure which requires use of the various manual and rotary instruments. The aim of this study was to assess the frequency and to verify the possible deformation of the working part of endodontic instruments after their multiple clinical use.

Material and Methods New sets of the manual endodontic instruments (reamers, K-files and Hedstroem) used in routine clinical use (44 instruments) and for root canal instrumentation of extracted teeth (44 instruments) were included in the study. Instrumentation was performed by Step-Back technique and constant irrigation with 0.5% NaOCl solution, 10 ml for each root canal. All the instruments were used 10 times and after use sterilized in a dry sterilizer or autoclave.The working parts of deformed instruments were analyzed using optimagnetic print.

Results The results obtained after clinical use showed deformations of the working part of the reamers in 50%, K-files in 43% and Hedstroem in 66.7% of used instruments. After instrumentation the canal of the extracted teeth, deformations were observed in 87.5% of the reamers, in 50% of the K-files and in 62.5% of Hedstroem files. The difference in frequency of the deformations was not statistically significant. On the instruments used for the preparation the canals of the extracted teeth and sterilized in autoclave, malformations were observed in 86.4%, comparing to the instruments sterilized in a dry sterilizer where malformations of the working part were registered in 59.1% of the cases. That difference was statistically significant (χ^2=5.250; p=0.072).

Conclusion Multiple use of the manual endodontic instruments in clinical conditions leads to increased frequency of malformations of the working part in all types of manual endodontic instruments.

Keywords: manual endodontic instruments; deformation; sterilization

INTRODUCTION

Instrumentation of the root canal system is the most important phase of endodontic procedure and success of the endodontic treatment largely depends on how it is performed. Adequate mechanical instrumentation of the complex root canal space is very often demanding procedure which requires use of various manual and rotary instruments or its combination [1]. Chemomechanical preparation, cleaning and shaping of the root canal system, provides conical form of the canal and ensures safe conditions for high-quality, three-dimensional hermetic obturation [2].

Manual endodontic instruments (reamers, different types of files) are made of high quality steel or nickel-titanium alloy (NiTi) and usually are for multiple uses. All of these canal instruments during the instrumentation or during their clinical use are subject to various forms of stress and thus different deformations. The concentration of stress and potential possibility of deformation or fracture during endodontic instrumentation depends on many factors, primarily on materials they are made of, the canal anatomy, dynamics and frequency of their use, method of preparation and sterilization, the design of the working part of the instrument or application of various chemicals during the instrumentation [2, 3, 4]. All these factors are closely related to the professional qualities of the therapist and mostly depend on his training to use instruments properly with different preparation techniques. However, the main goal is to provide the best possible results after cleaning and shaping the canals and above all safe instrument manipulation in the complex canal system [2].

Although numerous clinical studies confirmed that the manual endodontic instruments of smaller diameter (0.6; 0.8; 0.10; 0.15; 0.20) should be used only once, it is not often respected in clinical practice. Deformations and fractures of instruments in the canal are much more frequent when they are used many times and lead to greater number of complications during endodontic procedure.

The aim of this study was to assess the frequency and to verify possible deformations of the working part of endodontic instruments after their multiple clinical use.

MATERIAL AND METHODS

The research was conducted at the Clinic for Restorative Dentistry and Endodontics, The School of Dentistry in

Address for correspondence: Jelica NEŠKOVIĆ, Miloja Zakića 98, 11000 Belgrade, Serbia; *jelica.neskovic@yahoo.com*

Table 1. Manual endodontic instruments used in the study.
Tabela 1. Ručni endodontski instrumenti korišćeni u studiji.

Instrument Instrument	Number of the instruments used in clinical conditions Broj instrumenata korišćenih u kliničkim uslovima		Number of the instruments used on extracted teeth Broj instrumenata korišćenih na ekstrahovanim zubima	
	Dry sterilizator Suvi sterilizator	Autoclave Autoklav	Dry sterilizator Suvi sterilizator	Autoclave Autoklav
Reamers Proširivači tipa K	8	8	8	8
K-files Turpije tipa K	8	8	8	8
Hedstroem Turpije tipa H	6	6	6	6
Total / Ukupno	44		44	

Belgrade. As a research material, new sets of manual endodontic instruments were used: two sets of reamers (K-reamers KENDO 25 mm; size 0.08, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40); two sets of K-files (K-file KENDO 25 mm; size 0.08, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40); and two sets of Hedstroem (H-file KENDO 25 mm; size of 0.15, 0.20, 0.25, 0.30, 0.35, 0.40). 88 manual endodontic instruments were divided into two groups. 44 instruments from the first group were used in routine clinical practice on the teeth of different morphological groups and different diagnosis, while other 44 instruments were used for canal instrumentation in the extracted human teeth (Table 1).

Both, in clinical and in experimental conditions, each manual endodontic instrument was used for the preparation of ten canals. After preparation the access cavity and content removal from each canal, a set of instruments was used for mechanical instrumentation. Reamers were used with rotational and filing movements, while for the K-files filing movements were used only. Canal instrumentation in both groups was performed by Step-back technique with constant irrigation with 0.5% NaOCl solution in quantities of 10 ml for each root canal. In the group of extracted teeth instrumentation included both simple canal systems (central incisors) and complex canal systems (mesiobuccal and distobuccal canals of the upper first molars).

One set of instruments from each group, after their use, was sterilized in a dry sterilizer (Electronic Sutjeska, Belgrade) at the temperature of 121°C for 6 hours. Also, one set of used instruments was sterilized in autoclave (Vacuclave 24B/30B Melag) at the temperature of 134°C.

Working part of all used instruments was analyzed under the magnifying glass and six times magnification.

For manual endodontic instruments (size 0.08, 0.15 and 0.20) with visible deformations of the working part, cross-sections were made at the distances of 3.9, 4.0 and 4.2 mm from the tip of the instrument, for further analysis. The instruments were initially placed in a mold with autopolymerized acrylic and then cut in sections 1 mm thick using the device IsoMet 4000 (Buehler) and the blade IsoCut 7. The velocity of the blade (thick 0.7 mm) placed perpendicular to the axis of the instrument was 6mm/min at 4000 rpm. New (unused) instruments of the same diameter, prepared identically, served as controls.

Cross-sections of the working parts of deformed instruments were analyzed using optimagnetic image (optimagnetic fingerprint) to register any changes in the structure of the material. This method is based on the interaction between light and matter and relationships of electrical and magnetic forces in covalent and intermolecular contacts in the matter. Reflected polarized light has the electric component of interaction between light and matter, the difference in response to stimulation with white light (electromagnetic wave) and reflected polarized light (electric wave) gives magnetic properties of matter (optimagnetic print) [5].

Digital recordings in RGB system color (R – red, G – green and B – blue) were used for analysis. According to them, pixels were selected in the red and blue canal for white diffuse light (W) and reflected polarized light (P). The algorithm used in data analysis was based on the color chart called "Maxwell's triangle" and the operation of spectral convolution according to the relation of (RB) and (WP). Short label emphasizes that in the spectral convolution algorithm, for the optimagnetic print calculation, the difference in spectra of red and blue channel of white and polarized light is used. Thus, the method and algorithm for getting unique spectral fingerprint is based on the convolution RGB channel diagram made on the basis of digital recordings obtained from the interaction of light and matter at the individual and multiple wavelengths [5].

RESULTS

Deformations of the working part of the reamers after clinical use are found in 50%, of K-files in 43% and Hedstroem in 66.7% of used instruments. However, there was statistically significant difference in frequency of the deformations between used endodontic instruments (Table 2). On endodontic instruments sterilized in a dry sterilizer deformations were registered in 63.6% while on instruments sterilized in the autoclave in 40%. Statistically significant difference in the frequency of deformations regarding the method of sterilization was not observed (Table 3).

Deformations of the working part of the instruments after the canal preparation in extracted teeth were observed in 87.5% of reamers, in 50% of K-files and 62.5% of Hedstroem files. Statistically significant differences in the frequency of deformations on the instruments were not found (χ^2=5.250; p=0.072; Table 4). On instruments sterilized in a dry sterilizer, deformation was

Table 2. Deformations of the working part of the endodontic instruments used in clinical conditions.
Tabela 2. Deformacije radnog dela endodontskih instrumenata korišćenih u kliničkim uslovima.

Instrument Instrument	Deformation Deformacija		Total Ukupno
	No / Ne	Yes / Da	
Reamers Proširivači tipa K	8 (50.0%)	8 (50.0%)	16 (100.0%)
K-files Turpije tipa K	9 (56.3%)	7 (43.8%)	16 (100.0%)
Hedstroem Turpije tipa H	4 (33.3%)	8 (66.7%)	12 (100.0%)
Total Ukupno	21 (47.7%)	23 (52.3%)	44 (100.0%)

Table 3. Deformations of the working part of the endodontic instruments used in clinical conditions depending on the sterilization type.
Tabela 3. Deformacije radnog dela endodontskih instrumenata korišćenih u kliničkim uslovima u zavisnosti od načina sterilizacije.

Sterilization type Način sterilizacije	Deformation Deformacija		Total Ukupno
	No / Ne	Yes / Da	
Dry sterilization Suva sterilizacija	8 (36.4%)	14 (63.6%)	22 (100.0%)
Autoclave Autoklav	13 (59.1%)	9 (40.9%)	22 (100.0%)
Total Ukupno	21 (47.7%)	23 (52.3%)	44 (100.0%)

Table 4. Deformations of the working part of the endodontic instruments used on extracted teeth.
Tabela 4. Deformacije radnog dela endodontskih instrumenta korišćenih kod ekstrahovanih zuba.

Instrument Instrument	Deformation Deformacija		Total Ukupno
	No / Ne	Yes / Da	
Reamers Proširivači tipa K	2 (12.5%)	14 (87.5%)	16 (100.0%)
K-files Turpije tipa K	8 (50.0%)	8 (50.0%)	16 (100.0%)
Hedstroem Turpije tipa H	6 (37.5%)	10 (62.5%)	16 (100.0%)
Total Ukupno	16 (33.3%)	32 (66.7%)	48 (100.0%)

Table 5. Deformations of the working part of the endodontic instruments used on extracted teeth depending on sterilization type.
Tabela 5. Deformacije radnog dela endodontskih instrumenta korišćenih kod ekstrahovanih zuba u zavisnosti od načina sterilizacije.

Sterilization type Način sterilizacije	Deformation Deformacija		Total Ukupno
	No / Ne	Yes / Da	
Dry sterilization Suva sterilizacija	9 (40.9%)	13 (59.1%)	22 (100.0%)
Autoclave Autoklav	3 (13.6%)	19 (86.4%)	22 (100.0%)
Total Ukupno	12 (27.3%)	32 (72.7%)	44 (100.0%)

Table 6. Deformations of the working part of the endodontic instruments during endodontic treatment.
Tabela 6. Deformacije radnog dela endodontskih instrumenata pri rutinskoj kliničkoj instrumentaciji kanala korena zuba.

Instrument Instrument	Number Broj	Deformation type Vrsta deformacije							
		Curvature Zakrivljenost		Thread loss Gubitak navoja		Curvature and thread loss Zakrivljenost i gubitak navoja		Fracture Lomljenje	
		Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav
Reamers Proširivači tipa K	16		1 (0.30)	3 (0.10; .15; 0.25)	2 (0.08; .15)	1 (0.08)	1 (0.10)	-	-
K-files Turpije tipa K	16	1 (0.15)	1 (0.10)	2 (0.20; .30)	-	2 (0.08; 0.10)	1 (0.10)	-	-
Hedstroem Turpije tipa H	12	2 (0.25; .35)	1 (0.30)	1 (0.30)	1 (0.20)	1 (0.20)	1 (0.15)	1 (0.15)	-
Total Ukupno	44	3	3	6	3	4	3	1	-
Total number of instruments with deformations Ukupan broj instrumenata sa deformacijama	23								

Table 7. Deformations of the working part of the endodntic instruments during endodontic treatment on extracted tooth.
Tabela 7. Deformacije radnog dela endodontskih instrumenata pri preparaciji kanala korena ekstrahovanog zuba.

Instrument Instrument	Number Broj	Deformation type Vrsta deformacije							
		Curvature Zakrivljenost		Thread loss Gubitak navoja		Curvature and thread loss Zakrivljenost i gubitak navoja		Fracture Lomljenje	
		Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav	Dry steril. Suva steril.	Autoclave Autoklav
Reamers Proširivači tipa K	16	3 (0.08; 0.30; 0.40)	3 (0.30; 0.35; 0.40)	2 (0.15; 0.35)	2 (0.08; 0.10)	1 (0.20)	2 (0.20; 0.15)	1 (0.25)	-
K-files Turpije tipa K	16		2 (0.10; 0.25)		3 (0.08; 0.15; 0.40)	1 (0.08)	2 (0.20; 0.30)	-	-
Hedstroem Turpije tipa H	12	2 (0.25; 0.35)		3 (0.15; 0.20; 0.40)	1 (0.30)	-	4 (0.15; 0.20; 0.25; 0.40)	-	-
Total Ukupno	44	5	5	5	6	2	8	1	-
Total number of instruments with deformations Ukupan broj instrumenata sa deformacijama	32								

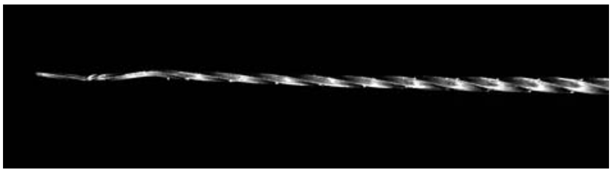


Figure 1. Deformation in a term of thread loss (reamer 0.10) in the apical third of the working part after clinical use and sterilization in dry sterilizer.
Slika 1. Deformacija instrumenta u vidu gubitka navoja (proširivač tipa K, 0,10) u apikalnoj trećini radnog dela nakon korišćenja u kliničkim uslovima i sterilizacije u suvom sterilizatoru.

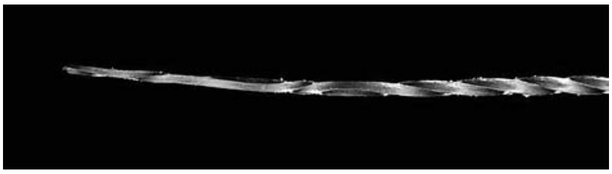


Figure 2. Deformation in a term of thread loss (reamer 0.20) in the apical and middle third of the working part after use on extracted teeth and sterilization in autoclave.
Slika 2. Deformacija instrumenta u vidu gubitka navoja (proširivač tipa K, 0,20) u apikalnoj i srednjoj trećini radnog dela nakon instrumentacije kanala kod ekstrahovanih zuba i sterilizacije u autoklavu.

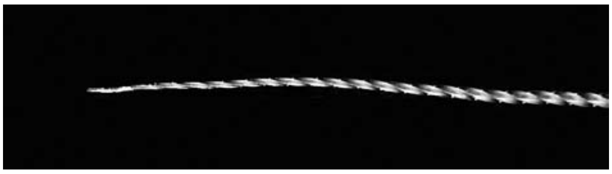


Figure 3. Deformation in a term of thread loss (K-file 0.08) in the apical third of the working part after clinical use and sterilization in dry sterilizer.
Slika 3. Deformacija instrumenta u vidu gubitka navoja (turpija tipa K, 0,8) u apikalnoj trećini radnog dela nakon korišćenja u kliničkim uslovima i sterilizacije u suvom sterilizatoru.

Figure 4. Deformation in a term of thread loss (K-file, 0.20) in the apical third of the working part after use on extracted teeth and sterilization in autoclave.
Slika 4. Deformacija instrumenta u vidu gubitka navoja (turpija tipa K, 0,20) u apikalnoj trećini radnog dela nakon instrumentacije kanala kod ekstrahovanih zuba i sterilizacije u autoklavu.

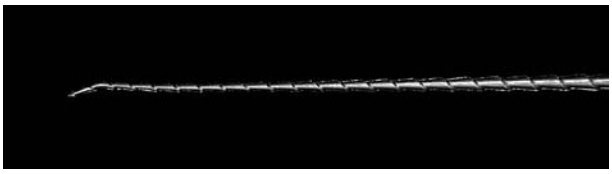


Figure 5. Deformation in a term of curvature (Hedstroem, 0.15) in the apical third of the working part after clinical use and sterilization in autoclave.
Slika 5. Deformacija instrumenta u vidu zakrivljenja (turpija tipa H, 0,15) u apikalnoj trećini radnog dela nakon korišćenja u kliničkim uslovima i sterilizacije u autoklavu.

observed in 59.1% while after sterilization in autoclave deformation of the working part was observed in 86.4%. This difference was statistically significant (χ^2=4.125; p=0.042; Table 5).

On reamers which were sterilized in a dry sterilizer after a routine clinical application, deformations in the form of curvature and loss of thread were registered in one instrument, while the loss of thread was observed in three reamers in the apical third of the working part of the instrument (Table 6, Figure 1). Reamers sterilized in autoclave after clinical application showed curvature in one instrument, the curvature and loss of thread also in one, while the loss of thread was registered in two instruments (Table 6).

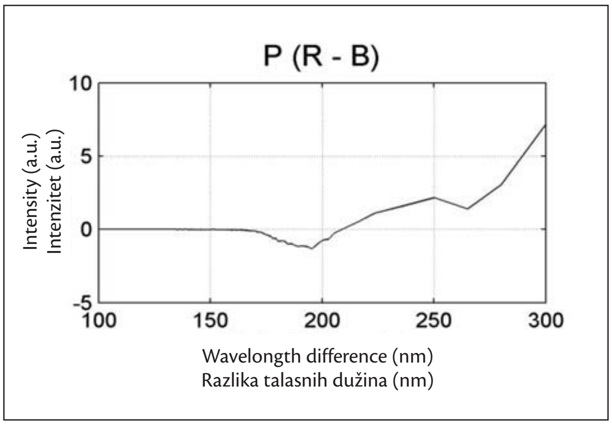
After instrumentation of the canals in extracted teeth and sterilization in a dry sterilizer, curvature was recorded in three reamers, loss of thread in two instruments, and the curvature and loss of thread on one. Fracture was observed in apical third of one reamer (Table 7). In reamers sterilized in autoclave curvature was observed in the three instruments, the loss of thread in two (Figure 2), while the curvature and loss of thread were registered in two instruments (Table 7).

In K-files sterilized in a dry sterilizer after routine clinical use, deformations in the form of a curvature were found in one instrument. Loss of thread is registered in two instruments and the curvature and loss of thread also in two (Table 6, Figure 3) In K-files sterilized in the autoclave after the clinical use, the curvature was recorded in one and the curvature and loss of thread also in one (Table 6). K-files used on extracted teeth and sterilized in a dry sterilizer had deformations in the form of curvature and loss of thread in one instrument while in group of instruments sterilized in autoclave curvature was registered in two instruments. Curvature and loss of thread were observed also in two instruments. Loss of threads is observed in three files (Figure 4, Table 7).

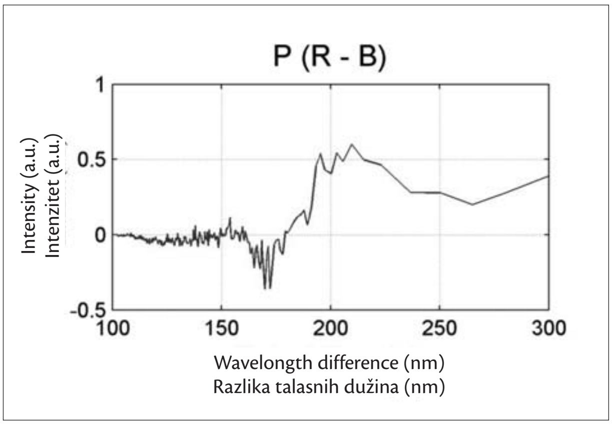
Deformations in the form of the curvature of the Hedstroem files sterilized in a dry sterilizer after clinical use were observed in two instruments (Figure 5). Loss of thread was registered in one and the curvature and loss of thread also in one. Fracture was also observed in only one instrument (Table 6). In files sterilized in autoclave, curvature was recorded in one and the loss of thread also in one. The same was for curvature and loss of thread (Table 6).

Hedstroem files, used for canal instrumentation in extracted teeth and sterilized in a dry sterilizer had deformations in the form of curvature in two and loss of thread in three instruments (Table 7). In Hedstroem files sterilized in the autoclave curvature and loss of thread were observed in four and the loss of thread in one file only (Table 7).

Cross-section analysis of new unused manual instrument (the reamer; 0.15) and deformed part of the instrument (the reamer; 0.15) by optomagnetic print showed that there is a difference in the structure of the material between these instruments (Graphs 1 and 2). The analysis also showed that changes in used instruments were especially presented in the area of deformation.



Graph 1. Diagram of the cross section of unused reamer (0.15).
Grafikon 1. Dijagram poprečnog preseka nekorišćenog proširivača (0,15).



Graph 2. Diagram of the cross section of the deformation of used reamer (0.15).
Grafikon 2. Dijagram poprečnog preseka korišćenog proširivača (0,15) na mestu deformacije.

DISCUSSION

The outcome of endodontic treatment mostly depends on the quality and safe mechanical instrumentation of root canals. Although the design of the endodontic instruments (especially rotary) was considerably improved and instrumentation techniques have become safer and more efficient, deformations and fractures of instruments during endodontic procedures are still a significant problem [6, 7].

Endodontic instruments are exposed to numerous stresses during clinical use in the complex root canal system [6, 8]. Specifically, during root canal instrumentation various clinical factors can incorporate during cleaning and shaping of the root canal and they are hard to control. These are the morphology of the root canal system and initial diameter of the canal (curvature, length and width), the selection and design of the endodontic instruments, preparation technique, irrigation and experience of the therapist [2, 4]. Therefore, canal instruments are exposed to various forms of stress during clinical use and the concentration of stress and potential possibility for deformation (curvature, loss of thread, fracture) mainly depend on the complexity of the canal system, the dynamics of use in the canal (rotation, filing) how many times were used, sterilization type and above all, experience of the therapist. After multiple use, instruments become less effective and vulnerable to fractures when used in the complex canal system [9, 10].

In this study manual endodontic instruments were used in routine clinical practice in patients with different teeth diagnosis and different canal systems. Canal instrumentation in extracted teeth included teeth with complex canal system (upper molars with narrow and curved buccal canals) and frontal teeth with a simple canal system, to ensure similar conditions to clinical conditions [2]. To obtain similar instrumentation conditions, all instruments were used 10 times and canal preparations in clinical and experimental conditions were done by one practitioner. The experience of the therapist as well as his sense of the work is important factors in assessing possible damage of the endodontic instruments during their use [6].

Deformations of the working part of reamers were slightly more presented in the root canal preparation of extracted teeth. This could be explained by the fact that some of extracted teeth had narrowed and curved canals, while in the routine clinical practice, the choice of teeth for endodontic treatment depended only on the current pathology of the patients in the clinic. This could explain also increased resistance of the larger reamers during instrumentation of the narrow canal compared to the instruments of smaller dimensions [8]. The greatest number of deformities in the form of curvature and loss of thread and one fracture of small size reamer confirmed the fact that these instruments should be used only once [8, 11]. The excessive rotation in curved and narrowed canal leads to torsion stress, because while the handle of the instrument rotates, the tip of the instruments in curved and narrowed canal is squeezed and hard to rotate. When this stress overcomes the limits of material fatigue fracture or fractures of the instrument occur(s) [8, 12, 13, 14]. It has been confirmed that manual endodontic instruments show excellent plastic deformation before fracture occurs [8, 12].

Design of the K-files allows only filing movements in the canal and therefore the deformation of these instruments were fairly consistent in routine clinical use and during root canal instrumentation in extracted teeth [11, 13]. Deformations in the form of the curvature are the result of the narrow canal, cross-sectional design and inertia that occurs during the canal preparation [7]. When the tip of the instrument is forced through the small lumen of the canal, it causes large torsion stress and deformation of the working part even if rotation is low [7, 8]. Mathematical analysis showed that the concentration of stress occurs at the edges of the instrument, not on the cutting edge, which disrupts the efficiency of dentine cutting during the canal instrumentation [6].

Deformations of the working part of the instrument were significantly present after sterilization in autoclave. This could be explained by increased temperature during sterilization but also the fact that these instruments are used repeatedly in a complex canal system, where the working part was often stressed during the instrumentation [10, 11]. Increase in diameter of manual instrument contributes to the increasing resistance to deformation and reducing the resistance to material fatigue [6, 13]. This is especially important after multiple use of instruments. Right preparation technique would be to use larger diameter files first, then the smaller (crown-down). That way, one provides less friction when shaping narrow canal [2, 7, 12].

Deformations of the working part of Hedstroem files were also fairly consistent in routine clinical use and during instrumentation of the root canal in extracted teeth but in a slightly larger number than the K-files. The curvature of the manual endodontic instruments was slightly expressed near to the tip of the instrument also in the larger diameter instruments. This could be explained by presented stress during instrumentation in curved and narrowed canals. Excessive stress did not cross the border of material fatigue and fracture of the instrument was not presented (except in one case) because this file was used carefully and without rotation in the canal [13]. During the cutting of the dentine and filing movements (up-down),stress was smaller than the mechanical properties of materials of which the instrument was built, and the anatomy of the canal did not have influenced on deformations [8, 15].

CONCLUSION

Multiple use of the manual endodontic instruments in clinical conditions and during the canal instrumentation in extracted teeth led to malformations of the working part in the form of curvature and loss of thread in all types of used instruments. Higher degree of deformations was shown on instruments sterilized in the autoclave after their use.

REFERENCES

1. Hülsmann M, Schäfer E. Problems in Endodontics: Etiology, Diagnosis and Treatment. Hanover Park, IL: Quintessence Pub Co; 2009.
2. Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of toot canals: shaping goals, techniques and means. Endod Topics. 2005; 10:30-76.
3. Hilt BR, Cunningham CJ, Shen C, Richards N. Torsional properties of stainless-steel and NiTi files after multiple autoclav sterilization. J Endodont. 2000; 26:76-80.
4. Zuolo M, Walton RE. Instruments deterioration with usage: Nickel-titanium versus stainless steel. Quintessence Int. 1997; 28:397-402.
5. Koruga B, Tomić A. Method and algorithm for analyisis of light-matter interaction based on spectral convolution. Us Pat App. 2008; 61/061-852.
6. Shen Y, Haapasalo M, Cheung GS, 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; 35:129-32.
7. Shen Y, Cheung GS, Peng B, Haapasalo M. Defects in nickel-titanium instrumentis after clinical use. Part 2: Fractografic analysis of fractured surface in a Cohort study. J Endod. 2009; 35:133-6.
8. Cheung GS, Bian Z, Shen Y, Peng B, Darvell BW. Comparison of defects in Pro Taper hand-operated and engine-driven instruments after clinical use. Int Endodont J. 2007; 40:169-78.
9. Papasbos P, Messer HH. Rotary NiTi instrument fracture and its consequences. J Endod. 2006; 32:1031-43.
10. Schäfer E. Effect of sterilization on the cutting eficiency of PVD-coated NiTi endodontic instruments. Int Endod J. 2002; 35:867-72.
11. Schäfer E, Schultz-Bongert U, Tulus G. Comparison of hand stainless steel and nickel titanium rotary instrumentation: a clinical study. J Endod. 2004; 30:432-5.
12. Sonntag D, Delchen S, Stachniss V. Root-canal shaping with manual and rotary NiTi files pedformed by students. Int Endod J. 2003; 36:715-23.
13. Kazemi RB, Stenman E, Spangberg IS. A comparison of stainless steel and NiTi H type instruments of identical design: torsion and bending tesis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009; 90:500-6.
14. Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. J Endod. 2005; 31:845-50.
15. Valois CRA, Silva LP, Azevedo RB. Atomic force microscopy study of stainless-steel and nickel-titanium files. J Endod. 2005; 31:882-5.

Received: 20/01/2010 • Accepted: 28/01/2010

Deformacije ručnih endodontskih instrumenata tokom instrumentacije kanala korena zuba

Jelica Nešković[1], Marija Damjanov[1], Slavoljub Živković[2], Đurica Grga[2], Đuro Koruga[3], Dušan Kojić[3]

[1]Stomatološki fakultet (student akademskih specijalističkih studija), Univerzitet u Beogradu, Beograd, Srbija
[2]Klinika za bolesti zuba, Stomatološki fakultet, Univerzitet u Beogradu, Beograd, Srbija
[3]Katedra za automatsko upravljanje, Mašinski fakultet, Univerzitet u Beogradu, Beograd, Srbija

KRATAK SADRŽAJ

Uvod Mehanička instrumentacija složenog kanalskog sistema zuba je vrlo težak i komplikovan zahvat i zahteva primenu različitih ručnih i mašinskih rotirajućih instrumenata. Cilj rada je bio da se utvrdi učestalost deformacija radnog dela ručnih endodontskih instrumenata posle njihove višekratne kliničke primene.

Materijal i metode rada U istraživanju su korišćeni setovi novih ručnih endodontskih instrumenata (proširivači tipa K, turpije tipa K, turpije tipa H) koji su korišćeni u rutinskoj kliničkoj primeni (44 instrumenta) i za instrumentaciju kanala ekstrahovanih zuba (44 instrumenta). Kod svih kanala instrumentacija je urađena tzv. *step-back* tehnikom uz stalnu irigaciju rastvorom NaOCl od 0,5% u količini od 10 ml za svaki kanal. Svi instrumenti su korišćeni deset puta i nakon primene sterilisani u suvom sterilizatoru, odnosno autoklavu. Preseci deformisanih radnih delova instrumenata su analizirani metodom optimagnetnog otiska.

Rezultati Rezultati istraživanja su nakon kliničke primene ukazali na deformacije radnog dela proširivača tipa K kod 50%, turpija tipa K kod 43% i turpija tipa H kod 66,7% korišćenih instrumenata. Nakon instrumentacije kanala ekstrahovanih zuba deformacije kod proširivača su uočene u 87,5%, kod turpija tipa K u 50%, a kod turpija tipa H u 62,5% slučajeva. Razlika u učestalosti deformacija nije bila statistički značajna. Kod instrumenata korišćenih za preparaciju kanala ekstrahovanih zuba i sterilisanih u autoklavu deformacija radnog dela je uočena kod 86,4% njih, a kod sterilisanih u suvom sterilizatoru kod 59,1% instrumenata. Ova razlika je bila statistički značajna (χ^2=5,250; p=0,072).

Zaključak Višekratna primena ručnih endodontskih instrumenata u kliničkim uslovima dovodi do povećane učestalosti deformacija radnog dela svih tipova ovih instrumenata.

Ključne reči: ručni endodontski instrumenti; deformacije; sterilizacija

UVOD

Instrumentacija kanala korena zuba je najvažnija faza endodontske procedure i od njene pravilne realizacije uglavnom zavisi i uspeh endodontskog lečenja. Adekvatna mehanička obrada složenog kanalskog prostora je često vrlo teška i komplikovana i zahteva primenu različitih ručnih i mašinskih rotirajućih instrumenata, odnosno njihovu kombinaciju [1]. Hemomehaničkom pripremom, čišćenjem i oblikovanjem kanalskog sistema neophodno je obezbediti konični oblik kanala i osigurati bezbedne uslove za kvalitetnu trodimenzionalnu hermetičku opturaciju tako pripremljenog kanala korena zuba [2].

Endodontski instrumenti za ručnu upotrebu (proširivači, različite vrste turpija) izrađeni su od visokokvalitetnog čelika ili nikl-titanijumske legure (NiTi) i obično se koriste višekratno. Svi oni su tokom instrumentacije kanala, odnosno tokom kliničke upotrebe podložni različitim vidovima pritiska, a time i različitim deformacijama. Koncentracija pritiska i mogućnost njihove deformacije ili lomljenja tokom njihovog rukovanja zavisi od raznih faktora: materijala od kojeg su izrađeni, anatomskih osobina kanala, dinamike i učestalosti njihove primene u kanalu, načina pripreme i sterilizacije, dizajna radnog dela samog instrumenta i primene različitih hemijskih sredstava tokom instrumentacije [2, 3, 4]. Svi ovi faktori su blisko povezani sa stručnim kvalitetima terapeuta i najviše zavise od njegove obučenosti da pravilno koristi instrumente tokom realizacije različitih tehnika preparacije kanala. Ipak, osnovni cilj je obezbeđivanje najboljeg efekta čišćenja i oblikovanja kanala, a nada sve bezbednosti tokom manipulacije u komplikovanom kanalskom sistemu [2].

Iako mnoge kliničke studije potvrđuju da ručne endodontske instrumente manjeg prečnika (0,6; 0,8; 0,10; 0,15; 0,20) treba koristiti samo jednokratno, to se u kliničkoj praksi vrlo često ne poštuje. Naime, deformacije i lomljenje instrumenata u kanalu su mnogo češći kod njihove višekratne upotrebe, pa su zbog toga ove komplikacije tokom izvođenja endodontskog postupka česte i značajne.

Cilj rada je bio da se proveri učestalost mogućih deformacija radnog dela ručnih endodontskih instrumenata posle njihove višekratne rutinske kliničke primene u preparaciji kanala korena zuba.

MATERIJAL I METODE RADA

Istraživanje je urađeno na Klinici za bolesti zuba Stomatološkog fakulteta Univerziteta u Beogradu. Kao materijal korišćeni su setovi novih ručnih endodontskih instrumenata: dva seta proširivača tipa K (*KENDO K-reamers* 25 mm, veličine 0,08; 0,10; 0,15; 0,20; 0,25; 0,30; 0,35; 0,40), dva seta turpija tipa K (*KENDO K-file* 25 mm, veličine 0,08; 0,10; 0,15; 0,20; 0,25; 0,30; 0,35; 0,40) i dva seta turpija tipa H – Hedstrom (*KENDO H-file* 25 mm, veličine 0,15; 0,20; 0,25; 0,30; 0,35;0,40). Korišćeno je ukupno 88 ručnih kanalskih instrumenata svrstanih u dve grupe. Prvu grupu su činila 44 instrumenta koja su korišćena u rutinskom kliničkom radu kod endodontskih zahvata na zubima različitih morfoloških grupa i različitih dijagnoza, a drugu takođe 44 instrumenta korišćena za instrumentaciju kanala ekstrahovanih zuba (Tabela 1).

Kako u kliničkim, tako i u eksperimentalnim uslovima svi ručni endodontski instrumenti su upotrebljeni za preparaciju deset kanala. Nakon formiranja pristupnog kaviteta i uklanjanja sadržaja iz kanala, svaki set instrumenata je korišćen za mehaničku instrumentaciju kanala korena zuba. Proširivači su korišćeni pokretima rotacije i turpijanja, a turpije isključivo longitudinalnim pokretima turpijanja. Instrumentacija kanala u obe grupe realizovana je tzv. *step-back* tehnikom uz stalnu irigaciju rastvorom NaOCl od 0,5% u količini od 10 ml za svaki kanal korena. U grupi ekstrahovanih zuba instrumentacija je obuhvatila jednostavne kanalske sisteme (centralni sekutići) i instrumentaciju složenih kanala (bukomezijalni i bukodistalni kanali gornjih prvih molara).

Po jedan set korišćenih endodontskih instrumenata iz svake grupe je nakon primene sterilisan u suvom sterilizatoru (*Electronic Sutjeska, Beograd*) na temperaturi od 121°C tokom šest sati, a drugi u autoklavu (*Vacuclave 24B/30B Melag*) na temperaturi od 134°C.

Radni deo svih upotrebljenih ručnih endodontskih instrumenata je analiziran lupom pri uvećanju od šest puta.

Kod ručnih endodontskih instrumenata sa vidljivim deformacijama radnog dela veličine 0,08, 0,15 i 0,20 napravljeni su preseci na udaljenosti od 3,9, 4,0 i 4,2 mm od vrha instrumenta zbog pripreme za dalju analizu. Instrumenti su najpre uloženi u kalup s autopolimerizujućim akrilatom, a potom su aparatom *IsoMet 4000* (*Buehler*) i sečivom *IsoCut 7* napravljeni preseci debljine 1 mm. Sečivo debljine 0,7 mm upravno na osovinu instrumenta zalivenog u akrilatni kalup kretalo se brzinom od 6 mm u minuti pri 4.000 obrtaja u minuti. Kao kontrola poslužili su preseci novih nekorišćenih endodontskih instrumenata istog prečnika, koji su pripremljeni na istovetan način.

Preseci deformisanih radnih delova instrumenata su analizirani metodom optomagnetnog otiska (engl. *optomagnetic fingerprint*), kako bi se ustanovile promene u strukturi materijala deformisanog ručnog instrumenta. Ova metoda je zasnovana na interakciji između svetlosti i materije i odnosa električnih i magnetnih sila u kovalentnim i međumolekularnim vezama u materiji. Kako odbijena polarizovana svetlost sadrži električnu komponentu interakcije između svetlosti i materije, razlika u odzivima na stimulaciju belim svetlom (elektromagnetni talas) i odbijene polarizovane svetlosti (električni talas) daje magnetna svojstva materije (optomagnetni otisak) [5].

U analizi su korišćeni digitalni snimci u sistemu boja RGB (*Red* – crvena; *Green* – zelena; *Blue* – plava) na osnovu kojih su odabrani pikseli u crvenom i plavom kanalu za belu difuznu svetlost (*W*) i odbijenu polarizovanu svetlost (*P*). Algoritam korišćen u analizi podataka je zasnovan na dijagramu boja nazvanom „Maksvelov trougao" i operaciji spektralne konvolucije prema odnosu (R-B)&(W-P). Skraćena oznaka ističe da se u algoritmu spektralne konvolucije za proračun optomagnetnog otiska koristi razlika spektara crvenog (R) i plavog (B) kanala bele svetlosti (W) i polarizovane svetlosti (P). Tako su metoda i algoritam za dobijanje jedinstvenog spektralnog otiska zasnovani na konvolucionom dijagramu RGB kanala dobijenom na osnovu digitalnih snimaka koji daju interakciju svetlosti i materije na pojedinačnim i višestrukim talasnim dužinama [5].

REZULTATI

Deformacije radnog dela nakon kliničke primene uočene su kod proširivača u 50%, kod turpija tipa K u 43%, a kod turpija tipa H u 66,7% korišćenih instrumenata. Utvrđena je statistički značajna razlika u učestalosti deformacija između korišćenih endodontskih instrumenata (Tabela 2). Kod endodontskih instrumenata sterilisanih u suvom sterilizatoru deformacije su otkrivene u 63,6% slučajeva, a kod instrumenata sterilisanih u autoklavu u 40%. Ova razlika u učestalosti deformacija u zavisnosti od načina sterilizacije, međutim, nije bila statistički značajna (Tabela 3).

Deformacije radnog dela instrumenta nakon preparacije kanala ekstrahovanih zuba uočene su u 87,5% proširivača, 50% turpija tipa K i 62,5% turpija tipa H. Statistički značajne razlike u učestalosti deformacija instrumenata nije bilo (χ^2=5,250; p=0,072; Tabela 4). Kod 59,1% instrumenata sterilisanih u suvom sterilizatoru uočena je deformacija radnog dela, dok je nakon sterilizacije u autoklavu ova deformacija ustanovljena kod 86,4% korišćenih instrumenata. Ova razlika je bila statistički značajna (χ^2=4,125; p=0,042; Tabela 5).

Kod proširivača tipa K koji su nakon rutinske kliničke primene sterilisani u suvom sterilizatoru deformacije u vidu zakrivljenosti i gubitka navoja su zabeležene kod jednog instrumenta, dok je gubitak navoja uočen kod tri proširivača u apikalnoj trećini radnog dela instrumenta (Tabela 6, Slika 1). Kod proširivača tipa K koji su sterilisani u autoklavu zakrivljenost je uočena kod jednog instrumenta, kao i zakrivljenost i gubitak navoja, dok je gubitak navoja zabeležen kod dva korišćena instrumenta (Tabela 6).

Pri instrumentaciji kanala ekstrahovanih zuba i sterilizaciji u suvom sterilizatoru zakrivljenost je zabeležena kod tri proširivača, gubitak navoja je uočen kod dva instrumenata, a zakrivljenost i gubitak navoja kod jednog. Lomljenje je uočeno u apikalnoj trećini jednog proširivača (Tabela 7). Kod proširivača sterilisanih u autoklavu zakrivljenost je uočena kod tri instrumenta, gubitak navoja kod dva (Slika 2), dok su zakrivljenost i gubitak navoja zabeleženi kod dva instrumenta (Tabela 7).

Kod turpija tipa K koje su nakon rutinske kliničke upotrebe sterilisane u suvom sterilizatoru uočene su promene u vidu zakrivljenosti kod jednog instrumenta, gubitak navoja je zabeležen kod dva instrumenta, kao i zakrivljenost i gubitak navoja (Tabela 6, Slika 3). Na turpijama tipa K koje su sterilisane u autoklavu zakrivljenost je zabeležena kod jednog instrumenta, kao i zakrivljenost i gubitak navoja (Tabela 6). Turpije tipa K korišćene na ekstrahovanim zubima i sterilisane u suvom sterilizatoru imale su deformacije u vidu zakrivljenosti i gubitka navoja kod jednog instrumenta, dok je u grupi sterilisanih u autoklavu zakrivljenost registrovana kod dva, kao i zakrivljenost i gubitak navoja. Gubitak navoja je uočen kod tri turpije (Slika 4, Tabela 7).

Deformacije u vidu zakrivljenosti kod turpija tipa H sterilisanih u suvom sterilizatoru su nakon kliničke upotrebe uočene kod dva instrumenta (Slika 5), gubitak navoja je zabeležen kod jednog, kao i zakrivljenost i gubitak navoja. Lomljenje je takođe uočeno kod samo jednog instrumenta (Tabela 6). Kod turpija sterilisanih u autoklavu zakrivljenost je zabeležena kod jednog, kao i gubitak navoja, odnosno zakrivljenost i gubitak navoja (Tabela 6).

Turpije tipa H korišćene za instrumentaciju kanala ekstrahovanih zuba sterilisane u suvom sterilizatoru imale su deformacije u vidu zakrivljenosti kod dva, a gubitak navoja kod tri instrumenta (Tabela 7). Kod turpija tipa H sterilisanih u autoklavu zakrivljenost i gubitak navoja je uočena kod četiri, a gubitak navoja kod samo jedne turpije (Tabela 7).

Analiza preseka nekorišćenog ručnog instrumenta (proširivač tipa K; 0,15) i preseka deformisanog dela instrumenta (proširivač tipa K; 0,15) optomagnetnim otiskom otkrila je razliku u strukturi materijala ovih instrumenata (Grafikoni 1 i 2). Analiza je takođe pokazala da su promene kod korišćenih instrumenata naročito izražene na mestu deformacije.

DISKUSIJA

Ishod endodontskog lečenja zuba u najvećoj meri zavisi od kvalitetne i sigurne mehaničke instrumentacije kanala korena zuba. Iako je poslednjih godina značajno poboljšan dizajn endodontskih instrumenata (pogotovo mašinskih rotirajućih), a tehnike instrumentacije postale sigurnije i efikasnije, deformacije i lomljenje ovih instrumenata tokom izvođenja endodontskog postupka i dalje su značajan problem [6, 7].

Endodontski instrumenti su tokom kliničke upotrebe izloženi brojnim pritiscima u komplikovanom kanalskom sistemu zuba [6, 8]. Naime, tokom instrumentacije kanala korena zuba inkorporiraju se različiti klinički faktori koje je tokom čišćenja i oblikovanja kanala korena teško kontrolisati. To su, pre svega, morfološke osobenosti kanalskog sistema zuba i inicijalni prečnik kanala (zakrivljenost, dužina, širina), izbor i dizajn endodontskih instrumenata, tehnike preparacije i irigacije kanala korena zuba i, naravno, iskustvo terapeuta [2, 4]. Kanalski instrumenti su zato izloženi različitim vidovima pritiska tokom kliničke primene, a koncentracija pritiska i mogućnost deformacije (zakrivljenost, gubitak navoja, lomljenje) uglavnom zavise od komplikovanosti kanalskog sistema, dinamike primene u kanalu (rotacija, turpijanje), učestalosti korišćenja, načina sterilizacije i praktičnog iskustva terapeuta. Zbog toga su ovi instrumenti manje efikasni tokom instrumentacije i podložniji lomljenju pri korišćenju u komplikovanom kanalskom sistemu [9, 10].

U ovom istraživanju ručni endodontski instrumenti su korišćeni u rutinskoj kliničkoj praksi kod pacijenata s različitom patologijom zuba i različitim kanalskim sistemima. Instrumentacija kanala kod ekstrahovanih zuba obuhvatila je zube sa složenijim kanalskim sistemom (gornji molari sa suženim i zakrivljenim bukalnim kanalima), odnosno prednje zube s jednostavnijim kanalskim sistemom, kako bi se obezbedili uslovi slični kliničkim [2]. Da bi uslovi instrumentacije bili što ujednačeniji, svi instrumenti su korišćeni po deset putna, a preparaciju kanala i u kliničkim i u eksperimentalnim uslovima obavio je jedan praktičar. Iskustvo terapeuta je veoma važan faktor u proceni mogućih oštećenja endodontskih instrumenata tokom rada, kao i njegov osećaj pri radu [6].

Deformacije radnog dela proširivača tipa K bile su nešto češće pri preparaciji kanala korena ekstrahovanih zuba. Ovo bi se moglo objasniti činjenicom da je kod ekstrahovanih zuba bilo više kanalskih sistema sa suženim i zakrivljenim kanalima nego što je to bilo u rutinskoj kliničkoj praksi, gde je izbor zuba za endodontsko lečenje zavisio od trenutne patologije zuba pacijenta koji se javio na Kliniku. Ovim bi se mogla objasniti i povećana otpornost proširivača većih dimenzija tokom instrumentacije suženih kanala u odnosu na instrumente manjeg prečnika [8]. Najveći broj deformacija u vidu zakrivljenja i gubitka navoja i jedno lomljenje kod proširivača manjih dimenzija samo potvrđuje činjenicu da ove instrumente treba koristiti samo jedanput [8, 11]. Naime, preterana rotacija u zakrivljenom i suženom kanalu dovodi do torzionog stresa, jer dok se drška ručnog instrumenta rotira, vrh instrumenta u zakrivljenom i suženom kanalu je stisnut i teško se okreće. Kada ovaj pritisak prevaziđe granice zamora materijala, dolazi do lomljenja instrumenta [8, 12, 13, 14]. Potvrđeno je inače da ručni endodontski instrumenti pokazuju izuzetnu plastičnu deformaciju pre nego što dođe do preloma [8, 12].

Dizajn turpija tipa K omogućava samo pokrete turpijanja u kanalu i zbog toga su deformacije ovih instrumenata bile prilično ujednačene i u rutinskoj kliničkoj primeni i pri instrumentaciji kanala korena ekstrahovanih zuba [11, 13]. Deformacije u vidu zakrivljenja instrumenta posledica su suženog prečnika kanala, dizajna poprečnog preseka i inercije koja se javlja tokom pripreme kanala [7]. Kada se vrh instrumenta forsira kroz mali lumen kanala, dolazi do velikog torzionog stresa i deformacije radnog dela i pri najmanjoj rotaciji [7, 8]. Matematička analiza je pokazala da do koncentracije pritiska dolazi na delu instrumenta uz ivicu, a ne na samoj sečivnoj ivici, čime se i remeti efikasnost sečenja dentina pri instrumentaciji kanala [6].

Deformacije radnog dela instrumenta su bile značajno veće nakon sterilizacije u autoklavu. Ovo bi se moglo objasniti povećanom temperaturom tokom sterilizacije, ali i činjenicom da su ovi instrumenti korišćeni nekoliko puta u komplikovanom kanalskom sistemu, gde je radni deo bio češće pod pritiskom tokom instrumentacije kanala [10, 11]. Povećanje promera ručnog instrumenta doprinosi povećanju otpornosti na deformaciju, ali i smanjuje otpornost na zamor materijala [6, 13]. Ovo je naročito važno nakon povećanog broja korišćenja instrumenata u kanalu. Izborom prave tehnike preparacije, gde se prvo koriste turpije većeg prečnika pa onda manjeg (*crown-down*), omogućava se manje trenje prilikom oblikovanja kanala instrumentima malog prečnika [2, 7, 12].

Deformacije radnog dela turpije tipa H takođe su bile prilično ujednačene i pri rutinskoj kliničkoj primeni i pri instrumentaciji kanala korena ekstrahovanih zuba, ali u nešto većem broju nego kod turpija tipa K. Zakrivljenost ovih ručnih endodontskih instrumenata je bila nešto izraženija pri vrhu instrumenta, kao i kod instrumenta većeg prečnika. Ovo bi se moglo objasniti izraženim pritiskom tokom instrumentacije u suženim i zakrivljenim kanalima. Preterani pritisak nije prešao granice zamora materijala i nije izazvao lomljenje instrumenta (osim u jednom slučaju), jer je ova turpija korišćena pažljivo i bez rotacije u kanalu [13]. Naime, sečenjem dentina i pokretima turpijanja (gore-dole) pritisak je bio manji od mehaničkih odlika materijala od kojih je instrument izrađen, a anatomske osobenosti kanala nisu dodatno uticale na deformacije [8, 15].

ZAKLJUČAK

Posle višekratne primene endodontskih instrumenata u kliničkim uslovima i pri instrumentaciji kanala ekstrahovanih zuba došlo je do izraženih deformacija radnog dela u vidu zakrivljenosti i gubitka navoja kod svih tipova korišćenih instrumenata. Veći stepen deformacija je utvrđen kod instrumenata koji su nakon korišćenja sterilisani u autoklavu.