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SEM analysis of Mtwo instruments after instrumentation of root canals with different curvatures

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SUMMARY

Introduction Deformations and fractures of Ni-Ti instruments during chemomechanical instrumentation of root canals occur due to the action of cyclic and torsional forces. The aim of this research was to analyze the surfaces of the working parts of Mtwo instruments after preparation of root canals with different curvatures using SEM and determine possible changes and deformations after instrumentation.

Materials and methods The study included 3 sets of Mtwo (VDW, Munich, Germany) instruments. Each set was used to instrument 10 canals in three experimental groups (straight, slightly curved, and highly curved canals). Instrumentation was carried out using crown-down technique with the following irrigation solutions, 2% NaOCl (CHLORAXID 2%, Cerkamed, Polska) and Distilled water (Iva, Serbia) in the amount of 5 cm^3. The apical and middle third of the instruments were scanned in two directions using SEM at different magnifications (150-2000X). The SEM images were analyzed using qualitative analysis for the presence of different irregularities according to Eggert et al. Statistical analysis of obtained data was performed using Fisher test at a confidence level of 5% ($\alpha = 0.05$).

Results Most defects (37.3%) were observed in instruments used in highly curved canals, followed by the instruments of the second group (35.6%), and the least defects were (27.1%) observed in the group with straight canals. Higher prevalence of defects was observed in the apical thirds of instruments (54.2%), especially in the experimental group of curved canals where the highest presence was observed (20.3%). The presence of production grooves was observed in all instruments, and the most common types of defects after instrumentation were the appearance of corrosion and changes in the cutting edges. In the group with extremely curved canals fractures were observed in two instruments (10/0.04 and 15/0.05).

Conclusion Root canal curvature significantly affects the occurrence of deformations and fractures of Ni-Ti rotating instruments. The most common types of defects were grooves, corrosion and changes in the blade edges. Mtwo instruments showed deformations in terms of thread changes, microfractures and two complete fractures.

Keywords: Mtwo; Ni-Ti instruments; deformation; curved canals

INTRODUCTION

Rotary instruments are more efficient than manual ones in almost all aspects (speed, simplicity, uniformity and efficiency of instrumentation), but more often they lead to complications in the form of unexpected fractures [1]. There are number of factors influencing the occurrence of defects in Ni-Ti instruments which can be classified into four basic categories: operator related factors (skills, expertise and assessment of therapy protocols), anatomical factors (preparation of the access cavity and root canal anatomy), factors related to instruments (material, design, production process and errors in instrument fabrication) and technical instrumentation factors (instrumentation techniques, instrument reuse, sterilization and irrigation during root canal instrumentation) [2].

During the endodontic procedure, an operator has the most dominant role, who, with good clinical training and adequate manual skills, must make the right choice of instruments and instrumentation techniques, but also recognize the complex morphology of the endodontic space. Complex morphological endodontic systems (double curves, pronounced curvatures of the apical segment, intercanal communications and ramification, apical deltas) significantly complicate biomechanical processing [1, 3]. The degree and level of curvature of the root canal can also significantly affect the occurrence of instrument deformations, especially during instrumentation of the most complex, apical segment [1, 3].

Although the use of nickel-titanium instruments is the standard in the endodontic procedure today, knowledge of the design and their characteristics is basic prerequisite for planning and implementation of the endodontic procedure in each individual case. To prevent deformation and breakage of Ni-Ti instruments, scientists and manufacturers find new design solutions, with different cones, angle inclination, cross section and blade design, different alloy and finished instrument treatments and different ways of activating instruments in root canals [1, 2, 4].

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A lot of different Ni-Ti systems are currently on the market and new ones are appearing every day with numerous innovations and improved features. The Mtwo system (VDW, Munich, Germany) was created by Dr. Malagnino in 2003. Although this system was created two decades ago, due to its specific design and technique of use, it is still widely used and analyzed today [5]. These files are made of conventional alloy (austenitic at room temperature), have a passive tip and a cross section in the shape of the letter S. The instruments have positive inclination angles of the blade from the tip to its handle, without radial curves which provide space for evacuation of dentinal detritus [6]. Two almost vertical blades with aggressive cutting edges require less cutting force compared to instruments with a neutral or negative cutting angle. The greater thread depth from the tip to the handle of these instruments allows for more delicate cutting at the tip and more aggressive in the coronal segment (this design reduces the core diameter and thus increases flexibility) [7].

The specific design and variable length of the sequences along the working part of the Mtwo instruments eliminates the possibility of screwing during continuous rotation and reduces the possibility of apical detritus transportation [5, 8, 9]. The handle of 11mm Mtwo instruments is shorter than other rotary instruments and therefore extremely suitable for work in the molar region.

The aim of this research was to analyze surfaces of the working parts of Mtwo instruments after the preparation of canals with different curvature using SEM and determine their possible changes and deformations after instrumentation.

MATERIAL AND METHOD

The study included 3 sets of Mtwo (VDW, Munich, Germany) instruments. Each set contained four instruments: 10/.04; 15/.05; 20/.06 and with 25/.06. (Figure 1).

Figure 1. Set of Mtwo instruments
Slika 1. Set Mtwo instrumenata
(Figure taken from: https://www.vdw-dental.com/en/products/detail/Mtwo/)
(Slika preuzeta sa: https://www.vdw-dental.com/en/products/detail/Mtwo/)

The study was performed *in vitro* on human premolars, extracted for various reasons after obtaining the consent of the Ethics Committee of the Faculty of Dentistry in Belgrade (No. 36/6). Immediately after extraction, the teeth were stored in 4% sodium hypochlorite solution for two hours, and until the beginning of the preparation in physiological solution with 0.2% thymol in order to prevent the growth of bacteria. The crowns of the teeth were shortened to the level of 2 mm coronally from the enamel-cement junction using a diamond disk. After the access cavity preparation, the initial patency of canals were determined with K-files of size #15 (Dentsply / Maillefer) and the working length was determined for each canal. Xray of the canals with instrument placed inside the canal (#10) and an on-line protractor was taken enabling determination of the curvature degree (Schneider's X-ray technique) [10]. Based on this, the teeth were divided into the three categories:

I group - 10 straight canals - low degree of curvature (less than 10 °),

II group - 10 slightly curved canals - moderate degree of curvature (from 10 ° to 25 °) and

III group - 10 extremely curved canals - with a high degree of curvature (over 25 °).

In order to achieve uniform experimental conditions, each instrument was used in ten canals or until the moment of its fracture (one set was applied in preparation of 10 canals in each experimental group).

Experimental protocol

Preoperative preparation involved cleaning in an ultrasonic tub using a mild disinfectant Orocid Multisept plus ("OCC", Switzerland) for 15 minutes. After additional checking of the obligatory straight line and patency of the canal with K-files of sizes 10 and 15 (MicroMega, France), abundant (5 ml) irrigation with 2% NaOCl solution followed. The canal instrumentation was performed in accordance with the manufacturer's instructions involving the X-Smart Endodontic Rotary Motor (Dentsply, Sirona, Maillefer, Ballaigues Salzburg, Austria) using crown-down technique. Ni-Ti files were regularly cleaned in a sterile sponge to remove dentin residues, and after each rotary instrument, the working length was recapitulated with a hand instrument (#10). After each instrument, 2% NaOCl solution (CHLORAXID 2%, Cerkamed, Polska) and then Distilled water (Iva, Serbia) were used as irrigants in the amount of 5 ml^3, using a plastic syringe and an endodontic irrigation needle with a closed tip and side openings (Side-vented needle, SmearClear, SybronEndo). Ethylenediamine tetra-acetic acid gel, applied to the working part of the instrument, was used as a lubricant (Glyde-Dentsply, Maillefer, Switzerland). During the instrumentation of the canal, each used instrument was carefully inspected with a magnifying glass, in order to detect any changes (possible cracks, fractures, unwinding of threads or other deformations).

One operator conducted all instrumentations.

Table 1. Defects and impurities on the working part of Mtwo instruments after instrumentation
Tabela 1. Deformacije i nečistoće na površini radnog dela Mtwo instrumenata posle instrumentacije

Defects and impurities on Mtwo instruments Zatečene deformacije i nečistoće Mtwo instrumenata		I group I grupa		II group II grupa		III group III grupa	
		Apical third % apikalna trećina %	Middle third % srednja trećina %	Apical third % apikalna trećina %	Middle third % srednja trećina %	Apical third % apikalna trećina %	Middle third % srednja trećina %
1.	No Bez vidljivih defekata	0	0	0	0	0	0
2.	Pitting Jamičasta udubljenja	0	0	0	0	0	0
3.	Fretting Žljebovi	100	100	100	100	100	100
4.	Microfractures Mikrofrakture	25	0	0	0	50	0
5.	Complete fractures Kompletne frakture	0	0	0	0	50	0
6.	Metal flash Metalna uglačanost	0	0	0	0	0	0
7.	Metal strips Metalni opiljci	0	0	0	0	0	0
8.	Blunt cutting edge Zatupljene sečivne ivice	25	0	25	0	0	25
9.	Disruption of cutting edges Prekid sečivne ivice	0	0	25	0	0	25
10.	Corrosion Korozija	25	25	50	75	0	25
11.	Debris Debris	0	0	0	0	0	0
12.	Thread change Promena navoja	0	0	25	25	50	25

Table 2. Distribution of defects on Mtwo instruments in different experimental groups
Tabela 2. Distribucija defekata na Mtwo instrumentima u funkciji eksperimentalnih grupa

Experimental group Eksperimentalna grupa	I group I grupa		II group II grupa		III group III grupa	
Working part of instruments Radna površina instrumenta	Apical third % Apikalna trećina %	Middle third % Srednja trećina %	Apical third % Apikalna trećina %	Middle third % Srednja trećina %	Apical third % Apikalna trećina %	Middle third % Srednja trećina %
Deffects % Defekti %	15.2	11.9	18.6	16.9	20.3	16.9
Σ	27.1		35.6		37.3	

After instrumentation, the instruments were cleaned in an ultrasonic bath using a mild disinfectant Orocid Multisept plus ("OCC", Switzerland) for 15 minutes. SEM analysis of used instruments was performed in the laboratory of the Faculty of Mining and Geology, University of Belgrade, at SEM type JEOL JSM-6610LV, Japan. Images were made using a secondary electron detector (SE images - second electron) (150-2000x). The apical and middle thirds of instruments were analyzed from two different directions, and three images were taken for each surface of the instrument. The apical third included the apical 5mm, the middle third - the next 5 mm coronally. After canal preparation, 250 recordings of instruments were examined and the results of the two researchers were reconciled by Cohen Kappa analysis.

Qualitative analysis of the presence of various irregularities was applied as per Kristina Egert at al.: Grade 1 – No visible defect, Grade 2 – pitting, Grade 3 – grooves (Fretting), Grade 4 – microfractures, Grade 5 – complete fractures (Complete fracture), Grade 6 – metal flash, Grade 7 – metal strips, Grade 8 – Blunt cutting edge, Grade 9 – Disruption of cutting edge, Grade 10 – Corrosion, Grade 11 – presence of debris [11]. A qualitative analysis was performed, but without quantifying the obtained results.

Statistical analysis of the obtained data was performed using Fisher test at a confidence level of 5% ($\alpha = 0.05$).

RESULTS

The results of SEM analysis of Mtwo instruments after instrumentation of canals with different curvatures are presented in Tables 1, 2, 3 and Figures 2–7.

The results of the study indicated that, following instrumentation there was no instrument without deformation. The analysis of the images showed the presence of defects in the form of grooves on all instruments created as a result of instrumentation process (Table 1). Most defects (37.3%) were observed on instruments used for instrumenting extremely curved canals, followed by instruments of the second group (35.6%), and the least defects were observed in the group of straight canals (27.1%). 2). Higher

Table 3. Deformations on the surface of the working part of Mtwo instruments after instrumentation
Tabela 3. Deformacije na površini radnog dela Mtwo instrumenata posle instrumentacije

	I group I grupa		II group II grupa		III group III grupa	
Instrument Instrument	**Apical third apikalna trećina**	**Middle third srednja trećina**	**Apical third apikalna trećina**	**Middle third srednja trećina**	**Apical third apikalna trećina**	**Middle third srednja trećina**
10-0.04	Blunt cutting edge Zatuplena sečivna ivica Corossion Korozija	Corossion Korozija	Disruption of cutting edges Prekid sečivne ivice Corossion Korozija Thread change Promene navoja	Corossion Korozija	Microfractur Mikrofrakture Complete fractures Kompletne frakture Thread change Promene navoja	
15-0.05					Microfracture Mikrofraktura Complete fractures Kompletne frakture	Blunt cutting edge Zatupljena sečivna ivica Corossion Korozija Thread change Promene navoja
20-0.06				Corossion Korozija Thread change Promene navoja		
25-0.06	Microfractur Mikrofraktura		Blunt cutting edge Zatupljena sečivna ivica Corossion Korozija	Corossion Korozija	Thread change Promene navoja	Disruption of cutting edges Prekid sečivne ivice

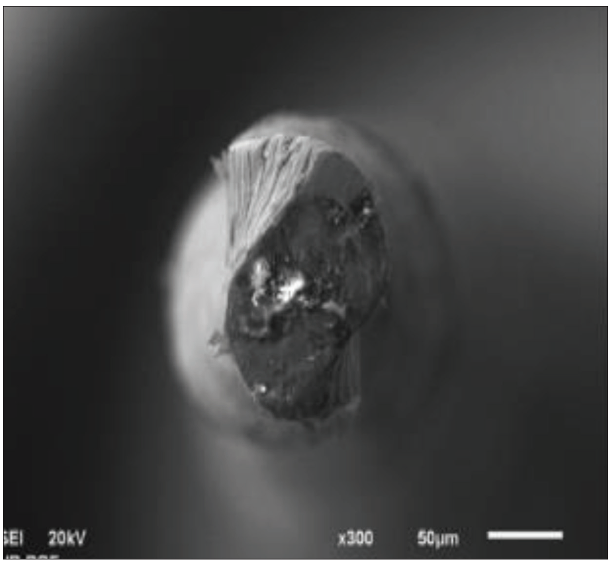

Figure 2. SE image of Mtwo 10/.04 instrument with complete fracture (fractographic image at magnification ×300) which shows the difference in the appearance of the fracture surface in the central and peripheral area.
Slika 2. SE snimak MTwo 10/0,04 instrumenta sa kompletnom frakturom (fraktografski snimak na uvećanju ×300), na kojoj se uočava razlika u izgledu frakturne površine centralne i površinske zone frakturne površine.

prevalence of defects was observed in the apical surface of instruments (54.2%), especially in the third experimental group (20.3%) (Table 2).

Defects were observed on the thinnest (10/.04) and most conical instrument (25/.06) in all three experimental groups. For the instrument 15/.05, changes were recorded only in the third group and for instrument 20/.06 only in the second group (Table 3). The most common type of defect after instrumentation was corrosion. It was observed on one instrument in the first group (10/.04) (apical and middle third); two instruments in the second group (10/.04 and 25/.60) (apical and middle third) and one instrument in the middle third (20/.06); while in the third group the defect was registered in the middle third of one instrument (15/.05) (Table 3). Along with corrosion, dullness, rupture of the cutting edges, the appearance of microfractures was also observed. Blunted blade edge was observed in the apical third of the thinnest (10/.04) instrument in the first group (the same instrument which showed corrosion), in the apical third (25/.06) of the instrument in the second group and in the middle third of the instrument (25/.06) of the third group. The interrupted cutting edge was noted in the apical third of the smallest instrument (10/.04) in the second group and in the middle third of one instrument (25/.06) in the third group. Microfracture was observed in the apical third of the instrument (15/.05) in the first group and in the apical third of two instruments in the third group, (10/.04 and 15/.05). Complete fractures were recorded on the same instruments in the third group (10/.04 and 15/.05). The fracture of instrument 10/.04 occurred after nine uses (length of the fractured fragment 1.5 mm) and after the eighth use of instrument 15/.05 (fragment of 0.8 mm) (Table 3, Figure 2, 3).

Fractographic micrographs (Figure 3) under 1500× and 2000× magnifications showed the central zones of the fracture surface with microscopic holes (which is an indicator of torsional changes) and clear traces of circular abrasion on its outer parts. Another defect was the appearance of a thread change and twisting (present only after preparation of curved (25% apical and middle third) and extremely curved canals (50% apical and 25% middle third) (Table 1). This change was observed in the second experimental group on two instruments (in the apical third of the instrument (10/.04) and in the middle third of the instrument (20/.06)), and on three instruments in the third group, (in the apical third of the instruments

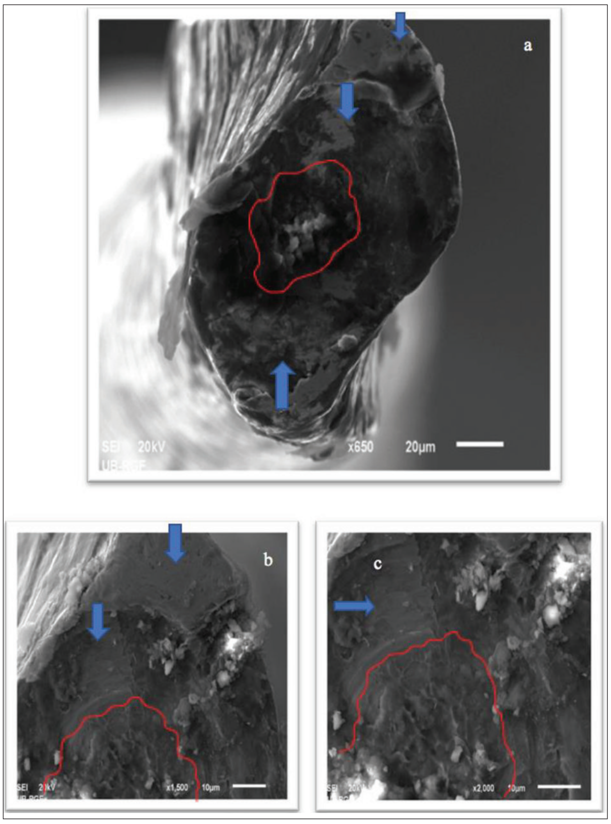

Figure 3. SE images of Mtwo 10/.04 instrument with complete fracture:
a) fracture surface (×650) on which central zones with microscopic holes (marked with a red field) and circular traces of abrasion on the outer parts of the fracture surface (marked with blue arrows) are clearly visible; b) detail from Figure 3a at higher magnification (×1500) and c) detail from Figure 3a at higher magnification (×2000)
Slika 3. SE snimci MTwo 10/0,04 instrumenta sa kompletnom frakturom:
a) frakturna površina (×650) na kojoj se jasno uočavaju centralne zone sa mikroskopskim rupicama (označene crvenim poljem) i kružni tragovi abrazije na spoljašnjim delovima frakturne površine (označene plavim strelicama);
b) detalj sa slike 3a na većem uvećanju (×1500) i c) detalj sa slike 3a na većem uvećanju (×2000)

10/.04 and 20/.06) and in the middle third of one instrument (15/.05) (Figure 4, 5, 6).

SEM images (Figure 4) showed longitudinal image of a fractured Mtwo instrument (15/.05), thread changes (thread straightening and unwinding) with an abundance of microfractures on the surface of the fractured instrument, especially in the immediate vicinity of the fracture. The same finding was observed on the fracture surface of the Mtwo 15/.05 instrument (Figure 7). The occurrence of thread change deformation in bent and exteremly bent canals shows a statistically significant difference in relation to the group with straight canals ($p < 0,05$).

DISCUSSION

The experimental protocol applied in this paper was developed in accordance with the previously used models for testing changes on Ni-Ti rotating instruments. This research represents an *in vitro* study on extracted teeth

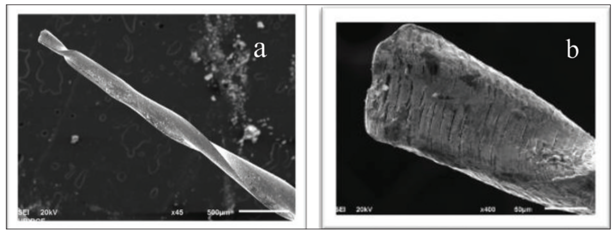

Figure 4. SE recordings of Mtwo instrument 15/.05 (longitudinal recording):
a) ×45 magnification showing thread changes (thread straightening and unwinding) and complete apical segment fracture;
b) longitudinal SE image of the apical fracture (×400) on which a multitude of microfractures were observed on the surface of the fractured instrument.
Slika 4. SE snimci MTwo instrumenta 15/0,05 (uzdužni snimak):
a) uvećanje ×45 na kome se uočavaju promene navoja (ispravljanje i odmotavanje navoja) i kompletna fraktura apikalnog segmenta;
b) uzdužni SE snimak apikalne frakture (×400) na kom se primećuje mnoštvo mikrofraktura na površini zalomljenog instrumenta.

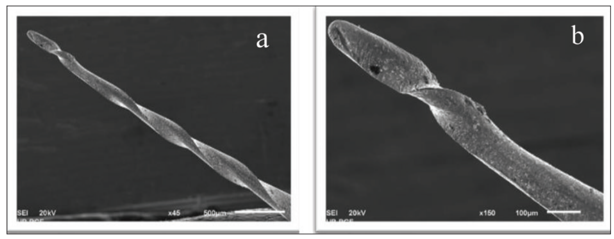

Figure 5. SE images: a) Mtwo instrument (10/.04 of the second group at magnification ×45) on which changes in the thread (unscrewing, straightening) are observed; b) the apical segment of the Mtwo instrument (10/.04 of the second group at magnification ×150) on which changes in the thread (unscrewing, straightening) are observed;
Slika 5. SE snimci: a) MTwo instrumenta (10/0,04 druge grupe na uvećanju ×45) na kome se uočavaju promene navoja (odvijanje, ispravljanje); b) apikalnog segmenta MTwo instrumenta (10/0,04 druge grupe na uvećanju ×150) na kome se uočavaju promene navoja (odvijanje, ispravljanje);

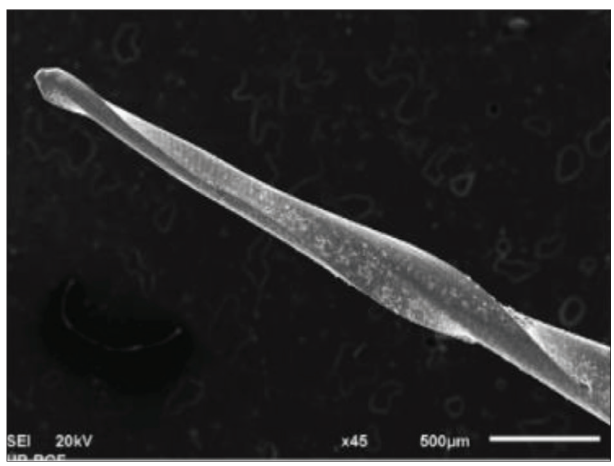

Figure 6. SE image of the apcal segment of the Mtwo instrument (20/.06 of the third group at magnification ×45) on which the straightening of the thread is observed
Slika 6. SE snimak apikalnog segmenta MTwo instrumenta (20/0,06 treće grupe na uvećanju ×45) na kome se uočava ispravljanje navoja

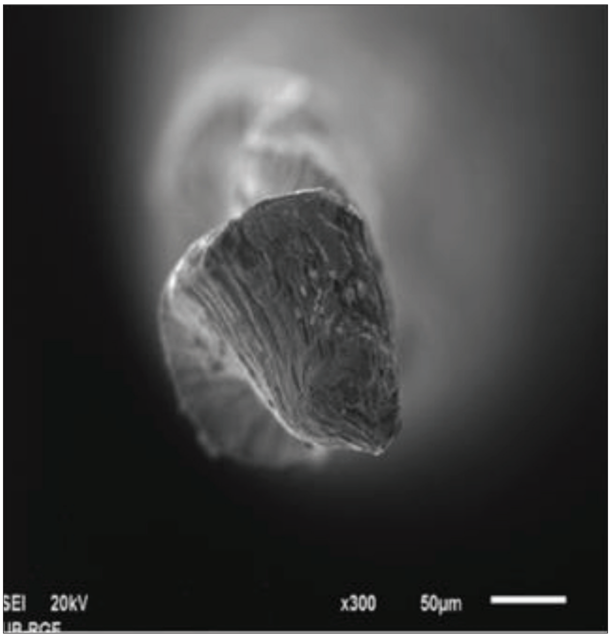

Figure 7. SE image of the fracture surface of the Mtwo instrument 15/.05 at magnification ×300, which shows a multitude of microfractures
Slika 7. SE snimak frakturne površine MTwo instrumenta 15/0,05 na uvećanju ×300, na kojoj se uočava mnoštvo mikrofraktura

which was conducted in laboratory conditions, in order to provide conditions close to the clinical situation.

The results of this study confirmed the views that the most frequent occurrence of defects is in the apical segment of the instrument, especially after the instrumentation of complicated endodontic systems [7, 8, 9, 12, 13, 14]. It is stated in the literature that deformations and fractures of instruments most often occur in complex molar systems (more often than in the anterior and premolar teeth) [7, 9, 14]. The most common occurrence of fractures was observed in the mesiobuccal canals of the molars of the upper and lower jaw, due to their complex curvature [12]. Mesial roots of the lower molars are curved not only distally, but very often mesiobuccal canal is additionally curved lingually and mesiolingual buccally. Analyzing the incidence of fracture of Ni-Ti instruments in different groups of Di Fiore teeth, the refractive rate in anterior teeth was 0.28%, premolar 1.56% and molar 2.74% [15].

Mtwo is the only system that has instruments of small dimensions (10/.04 and 15/.05) and all instruments in the set are used for instrumentation up to full working length [16]. The specific size and design of the instrument 10/.04 is used to establish the initial passability and formation of the instrumentation path (glide path) [16]. Blunted cutting edge and blade edge breakage, corrosion, thread changes, microfractures and complete fractures of the instrument 10/.04, indicate vulnerability of the Mtwo instrument of the smallest dimensions during instrumentation of exteremly curved canals. The results of this study are in agreement with the results of studies where the thinnest instruments showed most fractures and most deformations [17–19]. It has been confirmed that the shape and size of the cross section of instruments can affect their fatigue resistance, where thinner instruments are more resistant to cyclic fatigue and more sensitive to torsional loads, while thicker instruments can withstand higher torque and are more sensitive to cyclic fatigue [17]. In the study of Inan and Ganulol, authors observed a refraction in the apical third (fragments of 1 mm and less) in smaller instruments (10/.04 and 15/.05) [14]. Due to the small size and localization of fractured instrument tips (in isthmus or apical delta), clinicians are often unaware of their occurrence [18]. With the Mtwo system, all instruments are used for instrumentation up to full working length, so the stress is much higher on thinner and less conical instruments. Therefore, Shen at al. in their study suggested a single use of thinner instruments, in order to avoid deformations and fractures [19].

Ni-Ti instrument fracture is the most complex error during rotary instrumentation. Unlike stainless steel instruments that are visibly deformed before fracture (bending, unwinding of threads), rotating NiTi instruments very often break without warning and visible signs of deformation [1, 2]. Fracture of rotary NiTi instruments can occur as a result of torsional stress, cyclic fatigue, or a combination of these two factors. When passing through curved canal, rotary instrument is exposed to the action of tensile (tension) forces on the outer side of the curve, and on the inner side to the action of compressive forces. These forces alternately act on the rotating instrument during instrumentation, which often leads to breakage [2]. It has been observed that duration of use and increase in torque significantly reduce the resistance of the instrument to cyclic fatigue [4].

Fractures due to torsional stress occur when there is a large contact area between the instrument and dentinal wall and if the apical pressure is too strong during instrumentation [1, 2]. Accumulation of torsional stress of the instrument and exceeding the elastic limit of Ni-Ti alloy leads to its plastic deformation and fracture [1, 2]. Zones of microscopic holes are most often observed on the fractured surface, which indicate a torsion change without concentric signs characteristic of fractures caused by cyclic fatigue [20]. Torsional changes are characterized by unwinding, straightening and twisting of the thread and fractures are directly dependent on the anatomy of the canal, the characteristics of Ni-Ti alloy, instrument design, applied speed, and experience and skill of therapist [18]. Reduction of torsional load and possible screwing of instruments in the canal is achieved by mandatory use of endomotors with torque control. In full rotation systems, due to repeated torsional stresses of instruments, this is the most common cause of deformations and fractures [21].

Two fractures of Mtwo instruments in the third experimental group confirmed torsional stress as the cause. On the SEM images of the cross section of the fractured instrument (10/.04), the central zones with microscopic holes that indicate torsional changes are clearly visible. In the study of Inan and Gonulol, longitudinal micrographs of the same instrument showed thread changes (straightening and unwinding of the thread) with numerous microfractures on the surface of the fractured instrument [14]. The same finding was observed on the fracture surface Mtwo (15/.05) of the instrument where the fracture site coincides with the position of maximum bending where the instruments of the smallest dimensions and the smallest cone (10/.04, 15/.05), ie, the greatest flexibility showed less resistance on torsional loads, which is in accordance with the results of this study [14].

Fractographic findings and SEM fracture images of Mtwo instruments are consistent with the results of the study done by Cheung et al. [20]. The torsional type of fracture is more common in narrow, curved, and complicated apical portions of the canal (where there is high probability of instrument screwing) [20].

The results of the Tzanetakis study show that the prevalence of refracted Ni-Ti instruments in the apical third (52.5%) was significantly higher compared to the middle (27.5%) and coronary (12.5%) third of the canal [22]. Ungerechts et al. also indicated that 39.5% of fractured Ni-Ti instruments were registered in mesobucal canals of the molars and that 76.5% of these fragments were located apically [23].

The occurrence of defects on the largest and most conical instrument in all three experimental groups (25/.06) is also confirmed in the literature [24, 25]. Tripi et al. SEM study analyzed the occurrence of defects, wear and fatigue, after instrumentation with Mtwo instruments and indicated more frequent occurrence of deformations in instruments of larger dimensions, which according to Ullman and Peters, are less flexible and less resistant to cyclic fatigue [24, 25]. In a study comparing the Mtwo and ProTaper Next systems, it was also observed that the resistance to cyclic fatigue is lower in instruments with larger diameter [26]. Schafer et al. in a study on blade efficiency reported significantly shorter time of canal instrumentation with Mtwo instruments and without the appearance of a fracture during instrumentation [12, 13].

The study by Canga et al. (2020) also indicated high efficiency of the Mtwo system in cleaning and shaping curved canals, without the appearance of fracture (after processing four canals in endo blocks) [8]. This finding is consistent with the results of this study where fractures were registered after the ninth and tenth application in extremely curved canals. The results of the study by Vadhana et al. also indicated higher resistance to cyclic fatigue of M-Two instruments compared to all other tested Ni-Ti instruments [27].

Following the design characteristics and specifics of the use of Mtwo instruments, Malagnino pointed out that increasing the speed inevitably leads to deformations and fractures of the instruments. The lower rotation speed does not reduce the efficiency of this system but allows maximum control and complete safety [8, 9].

Although the Mtwo system was created 18 years ago, due to its specific design and characteristic size, there are new possibilities of its application, ie the way of activation and starting in the canal (by changing the depth of progress and reducing the rotation speed) [28, 29].

CONCLUSION

The curvature of the root canal significantly affects the occurrence of deformations and fractures of Ni-Ti rotating instruments. Fractographic examination of fracture surfaces showed signs of torsional fracture, and Mtwo instruments showed deformations in the form of thread changes and microfractures. The appearance of these changes warns clinicians of the possibility of a fracture and the obligation to exclude instruments from further use.

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Analiza defekata MTwo instrumenata posle obrade kanala različite povijenosti (SEM)

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KRATAK SADRŽAJ

Uvod Deformacije i fraktura Ni-Ti instrumenata tokom hemomehaničke obrade kanala nastaju usled dejstva cikličnih i torzionih sila. Cilj ovog istraživanja je bio da se primenom SEM-a analiziraju površine radnog dela MTwo instrumenata nakon preparacije kanala različite povijenosti i utvrdi eventualno postojanje promena i deformacija nakon instrumentacije.

Materijali i metode U istraživanje su uključena tri seta MTwo (VDW, Munich, Germany) instrumenata. Svaki set je korišćen za obradu 10 kanala u tri eksperimentalne grupe (pravi, blago povijeni i izrazito povijeni kanali). Instrumentacija je realizovana krunično-apeksnom tehnikom, a kao iriganси su primenjeni u količini od po 5 cm³, 2% rastvor NaOCl (CHLORAXID 2%, Cerkamed, Poljska) i destilovana voda (Iva, Srbija). SE snimci apikalne i srednje trećine instrumenata iz dva različita pravca, snimani pomoću SEM-a, na različitim uvećanjima (150–2000×) analizirani su kvalitativnom analizom prisustva različitih nepravilnosti po Edžeru i sar. Statistička analiza dobijenih podataka urađena je primenom Fišerovog testa na nivou pouzdanosti od 5% ($\alpha = 0{,}05$).

Rezultati Najviše defekata (37,3%) uočeno je na instrumentima koji su upotrebljeni za obradu izrazito povijenih kanala, zatim na instrumentima druge grupe (35,6%), a najmanje defekata je bilo (27,1%) u grupi sa pravim kanalima. Veća zastupljenost defekata se uočava na apikalnoj trećini instrumenata (54,2%), posebno u trećoj eksperimentalnoj grupi, gde je uočeno najveće prisustvo – 20,3%. Uočeno je prisustvo proizvodnih žlebova na svim instrumentima, a najučestaliji tipovi defekta nakon instrumentacije su bili pojava korozije i promene sečivnih ivica. Uočene su frakture na dva instrumenta (10/0,04 i 15/0,05) u grupi sa izuzetno povijenim kanalima.

Zaključak Na osnovu rezultata ove studije može se zaključiti da povijenost korenskog kanala znatno utiče na pojavu deformacija i prelom Ni-Ti rotirajućih instrumenata. Najučestaliji tipovi defekata su bili žlebovi, korozija i promene sečivnih ivica. MTwo instrumenti su pokazali deformacije u vidi promene navoja, mikrofraktura i dve kompletne frakture.

Ključne reči: MTwo; Ni-Ti instrumenti; deformacije; povijeni kanali

UVOD

Rotirajući instrumenti su u odnosu na ručne efikasniji u gotovo svim aspektima (brzina, jednostavnost, ujednačenost i efikasnost instrumentacije), ali mnogo češće dovode do komplikacija u vidu neočekivanih fraktura [1]. Brojni su faktori koji utiču na pojavu defekata Ni-Ti instrumenata, koji se mogu klasifikovati u četiri osnovne kategorije: faktori vezani za operatere (veština, stručnost i procena terapeuta), anatomski faktori (preparacija pristupnog kaviteta i anatomija korenskog kanala), faktori vezani za instrumente (materijal, dizajn, proizvodni proces i greške pri izradi instrumenata) i tehnički faktori instrumentacije (tehnike instrumentacije, ponovna upotreba instrumenata, sterilizacija i irigacija tokom obrade kanala korena) [2].

Tokom izvođenja endodontskog zahvata najdominantniju ulogu ima operater, koji uz dobru kliničku obuku i adekvatnu manuelnu veštinu mora napraviti pravi izbor instrumenata i tehnika obrade, ali i prepoznati kompleksnu morfologiju endodontskog prostora.

Kompleksni morfološki endodontski sistemi (duple krivine, izrazite povijenosti apikalnog segmenta, interkanalne komunikacije i ramifikacije, apikalne delte) značajno otežavaju biomehaničku obradu [1, 3]. Stepen i nivo povijenosti kanala korena zuba takođe mogu značajno uticati na pojavu deformacija instrumenata, posebno tokom instrumentacije najkompleksnijeg, apikalnog segmenta [1, 3].

Iako primena nikl-titanijumskih instrumenata danas predstavlja standard u endodontskoj proceduri, poznavanje dizajna i njihovih osnovnih karakteristika je osnovni preduslov za planiranje i realizaciju endodontskog postupka u svakom pojedinačnom slučaju. Da bi se sprečila deformacija i lom Ni-Ti instrumenata, naučnici i proizvođači pronalaze nova dizajnerska rešenja, sa različitim konusima, nagibom uglova, poprečnim presekom i dizajnom sečiva, različitim tretmanima legure i gotovih instrumenata, odnosno različitim načinom aktivacije instrumenata u korenskim kanalima [1, 2, 4].

Puno različitih Ni-Ti sistema je trenutno na tržištu a svakim danom se pojavljuju novi sa brojnim inovacijama i unapređenim karakteristikama. MTwo sistem (VDW, Munich, Germany) stvorio je dr Malagnino 2003. godine. Iako je ovaj sistem nastao pre dve decenije, zbog svog specifičnog dizajna i tehnike upotrebe i danas se široko koristi i analizira [5]. Ove turpije su nastale od konvencionalne legure (austenitne na sobnoj temperaturi), imaju pasivan vrh i poprečni presek u obliku slova s. Instrumenti imaju pozitivne nagibne uglove sečiva od vrha do njegove drške, bez radijalnih krivina koji obezbeđuju prostor za evekuaciju dentinskog detritusa [6]. Dva skoro vertikalna sečiva sa agresivnim sečivnim ivicama zahtevaju manju silu sečenja u odnosu na instrumente sa neutralnim ili negativnim sečivnim uglom. Veća dubina navoja od vrha prema dršci ovih instrumenata omogućava delikatnije sečenje na vrhu i agresivnije u kruničnom segmentu (ovaj dizajn smanjuje prečnik jezgra i tako povećava fleksibilnost) [7].

Specifičan dizajn i promenljiva dužina sekvenci duž radnog dela MTwo instrumenata eliminiše mogućnost ušrafljivanja tokom kontinuirane rotacije i smanjuje mogućnost apikalne transportacije detritusa [5, 8, 9]. Drška od 11 mm Mtwo instrumenata je kraća od drugih mašinskih instrumenata i zbog toga izuzetno pogodna za rad u molaroj regiji.

Cilj ovog istraživanja je bio da se primenom SEM-a analiziraju površine radnog dela MTwo instrumenata nakon preparacije kanala različite povijenosti i utvrdi eventualno postojanje promena i deformacija nakon instrumentacije.

MATERIJAL I METODA

U istraživanje su uključena tri seta MTwo (VDW, Munich, Germany) instrumenata. Svaki set je sadržavao četiri instrumenata: 10/0,04; 15/0,05; 20/0,06 i sa 25/0,06 (Slika 1).

Studija je izvedena je u *in vitro* uslovima na humanim premolarima, ekstrahovanim iz različitih razloga nakon dobijene saglasnosti Etičkog odbora Stomatološkog fakulteta u Beogradu (br. 36/6). Odmah po ekstrakciji zubi su dva sata čuvani u 4% rastvoru natrijum-hipohlorita, a do početka preparacije u fiziološkom rastvoru sa 0,2% timola da bi se sprečio rast bakterija. Dijamantskim diskom krunica zuba je skraćivana na nivo 2 mm koronarno od gleđno-cementne granice. Nakon formiranja pristupnog kaviteta, inicijalna prohodnost kanala je utvrđena K-turpijama veličina #15 (Dentsply/Maillefer) i utvrđena radna dužina za svaki kanal. Radiografijom kanala sa instrumentima (#10) i pomoću onlajn uglomera određen je njegov stepen povijenosti (Šnajderovom rendgenografskom tehnikom) [10]. Na osnovu toga, zubi su podeljeni u tri kategorije:

a) 10 pravih kanala – nizak stepen povijenosti (manje od 10°),
b) 10 blago povijenih kanala – umereni stepen povijenosti (od 10° do 25°) i
c) 10 jako povijenih kanala – sa velikim stepenom povijenosti (preko 25°).

Da bi se postigli ujednačeni eksperimentalni uslovi, svaki instrument je upotrebljen u deset kanala ili do trenutka njegove frakture (po jedan set je primenjen za obradu 10 kanala u svakoj eksperimentalnoj grupi).

Eksperimentalni protokol

Preoperativna priprema je podrazumevala čišćenje u ultrazvučnoj kadici uz korišćenje blagog dezinficijensa Orocid Multisept plus („OCC“, Switzerland) u trajanju od 15 minuta.

Nakon dodatne provere obaveznog pravolinijskog pravca i prohodnosti kanala K-turpijama veličine 10 i 15 (MicroMega, France), usledila je obilna (5 ml) irigacija 2% rastvorom NaOCl. Instrumentacija kanala je realizovana u skladu sa uputstvima proizvođača krunično-apeksnom tehnikom i primenom X-Smart Endodontic Rotary Motora (Dentsply, Sirona, Maillefer, Ballaigues Salzburg, Austria). Ni-Ti turpije su redovno čišćene u sterilnom sunđeru da bi se uklonili ostaci dentina, a posle svakog mašinskog instrumenta izvršena je rekapitulacija radne dužine ručnim instrumentom #10. Kao irigans, posle svakog instrumenta, u količini od po 5 cm³, korišćeni su 2% rastvor NaOCl (CHLORAXID 2%, Cerkamed, Poljska) i potom destilovana voda (Iva, Srbija). Irigansi su aplikovani pomoću plastičnog šprica i endodontske igle za irigaciju sa zatvorenim vrhom i bočnim otvorima (Side-vented needle, SmearClear, SybronEndo). Kao lubrikant tokom preparacije korišćen je gel etilendiamin tetra-acetatne kiseline (Glyde-Dentsply, Maillefer, Switzerland), aplikovan na radni deo instrumenata. Tokom obrade kanala, svaki upotrebljeni instrument je pažljivo pregledan pomoću lupe, radi detekcije bilo kakve promene (eventualnih pukotina, lomova, odvrtanja navoja ili drugih deformacija).

Preparaciju je realizovao jedan operater.

Nakon instrumentacije instrumenti su očišćeni u ultrazvučnoj kadici uz primenu blagog dezinficijensa Orocid Multisept plus („OCC“, Switzerland) u trajanju od 15 minuta.

SEM analiza upotrebljenih instrumenata je izvršena u laboratoriji Rudarsko-geološkog fakulteta, Univerziteta u Beogradu, na SEM-u tipa JEOL JSM-6610LV, Japan. Izrađeni su snimci pomoću detektora za sekundarne elektrone (SE snimci – second electron) (150–2000×). Analizirane su apeksna i srednja trećina instrumenta iz dva različita pravca, a za svaku površinu instrumenta su napravljena po tri snimka. Apeksna trećina je obuhvatala apikalnih 5 mm, a srednja narednih 5 mm radnog dela rotirajućih Ni-Ti instrumenata.

Pregledano je 250 snimaka instrumenata nakon preparacije kanala, a usaglašavanje rezultata dva istraživača izvršeno je analizom Cohen Kappa.

Primenjena je kvalitativna analiza prisustva različitih nepravilnosti po Kristini Egert i saradnicima: Ocena 1 – bez vidljivog defekta, Ocena 2 – jamičasta udubljenja, Ocena 3 – žlebovi, Ocena 4 – mikrofrakture, Ocena 5 – potpune frakture, Ocena 6 – metalna uglačanost, Ocena 7 – metalni opiljci, Ocena 8 – tupe sečivne ivice, Ocena 9 – prekid sečivne ivice, Ocena 10 – korozija, Ocena 11 – prisustvo debrija [11]. Urađena je kvalitativna analiza, ali bez kvantifikovanja dobijenih rezultata.

Statistička analiza dobijenih podataka urađena je primenom Fišerovog testa na nivou pouzdanosti od 5% ($\alpha = 0{,}05$).

REZULTATI

Rezulatati SEM analize MTwo instrumenata nakon instrumentacije kanala različite povijenosti predstavljeni su u tabelama 1, 2, 3 i slikama 2–7.

Rezulati studije ukazuju da nakon instrumentacije nije postojao nijedan instrument bez deformacije. Analizom snimaka uočava se prisustvo defekata u vidu žlebova na svim instrumentima, koji su nastali kao rezulatat proizvodnog procesa (Tabela 1).

Najviše defekata (37,3%) uočeno je na instrumentima koji su upotrebljeni za obradu izrazito povijenih kanala, zatim na instrumentima druge grupe (35,6%), a najmanje defekata je uočeno u grupi pravih kanala (27,1%) (Tabela 2). Veća zastupljenost defekata je uočena na apikalnoj površini instrumenata (54,2%), posebno u trećoj eksperimentalnoj grupi (20,3%) (Tabela 2).

Defekti su uočeni na najtanjem (10/0,04) i najkoničijem instrumentu (25/0,06) u sve tri eksperimentalne grupe. Kod instrumenta 15/0,05 promene su zabeležene samo u trećoj, a kod instrumenta 20/0,06 samo u drugoj grupi (Tabela 3).

Najučestaliji tip defekta nakon instrumentacije je bila pojava korozije. Uočena je u jednom instrumentu prve grupe (10/0,04) (apikalna i srednja trećina); na dva instrumenta druge grupe (10/0,04 i 25/0,60) (apikalni i srednji deo) i jednom instrumentu u srednjoj trećini (20/0,06), dok je u trećoj grupi defekt registrovan u srednjoj trećini kod jednog instrumenta (15/0,05) (Tabela 3). Uz koroziju, uočena je zatupljenost, prekid sečivnih ivica i pojava mikrofraktura. Zatupljena sečivna ivica je uočena na apikalnoj trećini najtanjeg (10/0,04) instrumenta prve grupe (isti instrument na kome je primećena i korozija), apikalnoj trećini (25/0,06) instrumenta druge grupe i srednjoj trećini instrumenta (25/0,06) treće grupe.

Prekid sečivne ivice je notiran na apikalnoj trećini najmanjeg instrumenta (10/0,04) druge grupe i srednjoj trećini instrumenta (25/0,06) treće grupe. Mikrofraktura je primećena u apikalnoj trećini instrumenta (15/0,05) prve grupe, u apikalnoj trećini kod dva instrumenta treće grupe (10/0,04 i 15/0,05). Na istim instrumentima treće grupe (10/0,04 i 15/0,05) zabeležena je i KOMPLETNA FRAKTURA. Na instrumentu 10/0,04 fraktura je nastala posle devet korišćenja (dužina zalomljenog fragmenta 1,5 mm), a na instrumentu 15/0,05 nakon osme upotrebe (fragment od 0,8 mm) (Tabela 3, slike 2, 3).

Analizirajući fraktografsku mikrofotografiju (Slika 3), na uvećanjima ×1500 i ×2000 uočavaju se centralne zone frakturne površine sa mikroskopskim rupicama (koje su pokazatelj torzionih promena) i jasni tragovi kružne abrazije na njenim spoljašnjim delovima.

Defekt koji je uočen a nije predstavljen u kriterijumima je pojava promene navoja tj. njihovog odvijanja i uvrtanja (zastupljen samo posle preparacije povijenih (25% apikalna i srednja trećina) i jako povijenih kanala (50% apikalna i 25% srednja trećina) (Tabela 1). Ova promena je uočena u drugoj eksperimentalnoj grupi na dva instrumenta (na apikalnoj trećini instrumenta (10/0,04) i srednjoj trećini instrumenta (20/0,06)), i u trećoj grupi na tri instrumenta (na apikalnoj trećini instrumenata 10/0,04 i 20/0,06) i srednjoj trećini jednog instrumenta (15/0,05) (slike 4, 5, 6).

Analizirajući SE snimke (Slika 4) koji pokazuju uzdužni snimak frakturiranog MTwo instrumenta (15/0,05), takođe se uočavaju promene navoja (ispravljanje i odmotavanje navoja) sa obiljem mikrofraktura na površini zalomljenog instrumenta, posebno u neposrednoj blizini frakture.

Isti nalaz je uočen i na frakturnoj površini Mtwo 15/0,05 instrumenta (Slika 7). Pojava deformacije promene navoja u povijenim i izrazito povijenim kanalima pokazuje statistički značajnu razliku u odnosu na grupu sa pravim kanalima ($p < 0,05$).

DISKUSIJA

Eksperimentalni protokol primenjen u ovom radu razvijen je u skladu sa prethodno korišćenim modelima za ispitivanje promena na Ni-Ti rotirajućim instrumentima. Istraživanje je sprovedeno u laboratorijskim uslovima, kao *in vitro* studija na ekstrahovanim zubima kako bi se obezbedili uslovi bliski kliničkoj situaciji.

Rezultati ove studije potvrđuju stavove o najučestalijoj pojavi defekata u apikalnom segmentu instrumenta, posebno nakon instrumentacije komplikovanih endodontskih sistema [7, 8, 9, 12, 13, 14]. U literaturi se navodi da deformacije i frakture na instrumentima najčešće nastaju u kompleksnim molarnim sistemima (češće nego u frontalnoj i premolarnoj regiji) [7, 9, 14]. Najčešća pojava fraktura je uočena u meziobukalnim kanalima molara gornje i donje vilice, zbog njihove kompleksne povijenosti [12]. Mezijalni korenovi donjih molara su povijeni ne samo prema distalno već je vrlo često meziobukalni kanal dodatno povijen lingvalno, a meziolingvalni bukalno. Analizirajući incidencu frakture Ni-Ti instrumenata u različitim grupama zuba, Di Fiore iznosi stopu zalamanja kod prednjih zuba 0,28%, premolara 1,56% i molara 2,74% [15].

MTwo je jedini sistem koji ima instrumente malih dimenzija (10/0,04 i 15/0,05) i svi instrumenti u setu se koriste za instrumentaciju do pune radne dužine [16]. Specifična veličina i dizajn instrumenta 10/0,04 koristi se za uspostavljanje inicijalne prohodnosti i formiranje instrumentacione putanje [16]. Zatupljena sečivna ivica i prekid sečivne ivice, korozija, promene navoja, mikrofrakture i kompletne frakture na instrumentu 10/0,04 ukazuju na vulerabilnost MTwo instrumenta najmanjih dimenzija tokom preparacije jako povijenih kanalnih sistema. Rezultati ove studije su u saglasnosti sa rezultatima istraživanja gde su najtanji instrumenti pokazali najviše fraktura i najviše deformacija [17, 18, 19]. Potvrđeno je da oblik i veličina poprečnog preseka instrumenata mogu uticati na njihovu otpornost na zamor, pri čemu su tanji instrumenti otporniji na ciklični zamor i osetljiviji na torziona opterećenja, a deblji instrumenti mogu izdržati veći obrtni moment i osetljiviji su na ciklični zamor [17]. Inan i Ganulol su u svojoj studiji otkrili da kod većine manjih instrumenata (10/0,04 i 15/0,05) dolazi do zalamanja u apikalnoj trećini (fragmenta 1 mm i manje) [14]. Zbog malih dimenzija i lokalizacije frakturiranih vrhova instrumenata (u istmusima ili apikalnoj delti) kliničari često nisu ni svesni njihove pojave [18]. Kod MTwo sistema svi instrumenti se koriste za instrumentaciju do pune radne dužine, pa je zato i stres mnogo veći na tanjim i instrumentima manje koničnosti. Zbog toga su Shen i saradnici u svojoj studiji sugerisali jednokratnu upotrebu tanjih instrumenata, kako bi se izbegle deformacije i frakture [19].

Fraktura Ni-Ti instrumenta je najkompleksnija greška tokom mašinske instrumentacije. Za razliku od instrumenata od nerđajućeg čelika koji se vidno deformišu pre frakture (savijanje, odmotavanje navoja), rotirajući NiTi instrumenti se vrlo često lome bez upozorenja i vidljivih znakova deformacije [1, 2]. Fraktura mašinskih NiTi instrumenata može nastati kao rezultat torzionog naprezanja, cikličnog zamora, ili kombinacijom ova dva faktora. Pri prolasku kroz povijeni kanal, mašinski instrument je izložen dejstvu zateznih (tenzionih) sila na spoljašnjoj strani krivine, a na unutrašnjoj strani dejstvu kompresivnih sila. Ove sile tokom uvlačenja i izvlačenja naizmenično deluju na rotirajući instrument, što često dovodi do loma [2]. Uočeno je da dužina upotrebe i povećanje obrtnog momenta značajno redukuju otpornost instrumenta na ciklični zamor [4].

Frakture usled torzionog naprezanja nastaju kada postoji velika kontaktna površina između instrumenta i dentinskog zida i ukoliko je apikalni pritisak prejak tokom instrumentacije [1, 2]. Akumulacijom torzionog stresa instrumenta i prekoračenjem granice elastičnosti Ni-Ti legure dolazi do njegove plastične deformacije i preloma [1, 2]. Na frakturnoj površini najčešće se uočavaju zone mikroskopskih rupica koje ukazuju na torzionu promenu i bez koncentričnih znakova karakterističnih za frakture nastale usled cikličnog zamora [20]. Torzione promene odlikuje odmotavanje, ispravljanje i uvijanje navoja, a frakture su u direktnoj zavisnosti od anatomije kanala, karakteristika Ni-Ti legure, dizajna instrumenata, primenjene brzine, odnosno iskustva i spretnosti terapeuta [18].

Smanjenje torzionog opterećenja i mogućeg ušrafljivanja instrumenata u kanalu se postiže obaveznom upotrebom endomotora sa kontrolom torka. U sistemima pune rotacije, usled ponavljanih torzionih naprezanja instrumenata, ovo je najčešći uzrok deformacija i pojave fraktura [21].

Dve frakture MTwo instrumenata u trećoj eksperimentalnoj grupi potvrđuju torzioni stres kao uzrok. Na SE snimcima poprečnog preseka zalomljenog instrumenta (10/0,04) jasno se uočavaju centralne zone sa mikroskopskim rupicama koje ukazuju na torzione promene. Inan i Gonulol u studiji na uzdužnim mikrofotografijama istog instrumenta uočavaju promene navoja (ispravljanje i odmotavanje navoja) sa brojnim mikrofrakturama na površini zalomljenog instrumenta [14]. Isti nalaz je uočen na frakturnoj površini Mtwo (15/0,05) instrumenta, gde se mesto preloma poklapa sa položajem maksimalne povijenosti gde su instrumenti najmanjih dimenzija i najmanjeg konusa (10/0,04, 15/0,05), odnosno najveće fleksibilnosti, pokazali manju otpornost na torziona opterećenja, što je u saglasnosti sa rezultatima ove studije [14].

Fraktografski nalazi i SE snimci preloma Mtwo instrumenata su u skladu sa rezultatima studije koju su sproveli Cheung i saradnici (Cheung et al., 2007). Torzioni tip frakture je češći u uskim, povijenim i komplikovanim apikalnim delovima kanala (gde postoji velika verovatnoća ušrafljivanja instrumenta) [20].

Tzanetakis u svojoj studiji pokazuje da je prevalencija zalomljenih Ni-Ti instrumenata u apikalnoj trećini (52,5%) bila značajno veća u poređenju sa srednjom (27,5%) i koronarnom (12,5%) trećinom kanala. [22]. Ungerechts sa saradnicima takođe ukazuje da je 39,5% prelomljenih Ni-Ti instrumenata registrovano u mezobukalnim kanalima molara i da je 76,5% ovih fragmenata locirano apikalno [23].

Pojava defekata na najvećem i najkoničnijem instrumentu u sve tri eksperimentalne grupe (25/0,06) takođe ima potvrdu u literaturnim navodima [24, 25]. Tripi je SEM analizom analizirao pojavu defekata, habanja i zamora nakon instrumentacije MTwo instrumentima i ukazao na češću pojavu deformacija kod instrumenata većih dimenzija, koji su prema nalazima Ulmana i Petersa manje fleksibilni i manje otporni na ciklični zamor [24, 25]. U studiji koja je poredila MTwo i ProTaper Next sistem takođe je uočeno da je otpornost na ciklični zamor manja kod instrumenata sa većim dijametrom [26].

Schafer i sar. su u studiji o sečivnoj efikasnosti ukazali na značajno kraće vreme preparacije kanala MTwo instrumentima i bez pojave frakture tokom instrumentacije [12, 13].

Cang i sar. (2020) takođe su ukazali na visoku efikasnost MTwo sistema u čišćenju i oblikovanju povijenih kanala, bez pojave frakture (nakon obrade četiri kanala u endoblokovima) [8]. Ovaj nalaz je u saglasnosti sa rezultatima ove studije, gde su frakture registrovane posle devete i desete primene kod izuzetno povijenih kanala. Vadhan i sar. u svojoj studiji takođe ukazuju na veću otpornost na ciklični zamor MTwo instrumenata u odnosu na sve ostale ispitivane Ni-Ti instrumente [27].

Prateći karakteristike dizajna i specifičnosti upotrebe MTwo instrumenata, Malagnino je istakao da povećanje brzine neminovno dovodi do deformacija i fraktura instrumenata. Manja brzina rotacije ne umanjuje efikasnost ovog Sistema, ali omogućava maksimalnu kontrolu i potpunu sigurnost [8, 9].

Iako je MTwo sistem nastao pre 18 godina, zahvaljujući specifičnom dizajnu i karakterističnoj veličini, postoje nove mogućnosti njegove primene odnosno načina aktivacije i pokretanja u kanalu (promenom dubine napredovanja i smanjenjem brzine rotacije) [28, 29].

ZAKLJUČAK

Povijenost korenskog kanala značajno utiče na pojavu deformacija i preloma Ni-Ti rotirajućih instrumenata. Fraktografskim ispitivanjem frakturnih površina uočeni su znaci torzionog preloma, a MTwo instrumenti su pokazali deformacije u vidi promene navoja i mikrofraktura. Pojava ovih promena upozorava kliničare na mogućnost frakture i obavezu isključivanja instrumenata za dalju upotrebu.