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Serbian Dental Journal, vol. 68, N° 2, 2021

REVIEW ARTICLE
PREGLED LITERATURE

DOI: https://doi.org/10.2298/SGS2102086Z
UDC: 616.314-78

How to prevent fracture of NiTi files

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SUMMARY

More certain therapeutic and significantly facilitated solution of everyday endodontic problems are provided by the introduction of NiTi rotary files in endodontic practice and their proper application. However, their widespread use has caused more and more frequent fractures and has become a significant frustrating factor that diminishes their numerous benefits. Torsional stress and cyclic fatigue are the main reasons for the occurrence of a fracture, and the frequency of NiTi file fractures is exactly proportional to the degree of bending of the canal, knowledge of the features of the file, ie. the skill and expertise of the therapist. The most dominant factor for the occurrence of fractures is the dentist who, in addition to manual dexterity, must have a good knowledge of the anatomy of various canal systems and file design in order to make the best choice for each individual case. Properly formed access cavity and knowledge of the working part of NiTi files enable maximum realization of endodontic skills, increased efficiency of intervention and reduced possibility of error during canal instrumentation. The special treatment of NiTi alloy and new solutions related to the design of the working part have significantly increased file flexibility and resistance to cyclic fatigue. Specific design (reduced number of threads, change of conicity, interruption of blade continuity), reduced engagement of file, ie. change of dynamics of movement in the canal (full rotation, reciprocal, eccentric, transaxial), as well as reduced number of processing files, have also significantly influenced the reduction of fracture risks.

The aim of this paper was to analyze the most common reasons for the fracture of NiTi files and emphasize measures and factors that can increase their safe use and reduce complications during canal instrumentation.

Keywords: NiTi files; fractures; file design; motion dynamics

INTRODUCTION

Endodontic treatment has become increasingly safe and effective due to new concepts and methods of "cleaning" and shaping the canal, ie. introduction of new files [1]. More certain therapeutic and significantly facilitated solutions of everyday endodontic problems are provided by the introduction of NiTi rotary files and their proper application [1, 2]. The use of these files, with limited speed and marked flexibility, significantly accelerates canal instrumentation, but unexpected and sudden fractures are still an important frustrating factor that diminishes their numerous benefits [3, 4].

NiTi files have become the standard in endodontic dental treatment over the last two decades and their widespread use has caused more frequent fractures [3, 5, 6]. It has been confirmed that due to rotating, almost all sets of NiTi files are subject to fractures, and that is more common during instrumentation of curved canals [3, 6]. The main reasons for the occurrence of fracture are torsional stress and cyclic fatigue during canal instrumentation [7–10]. Torsional stress occurs due to the friction of the files against the walls of the canal when one part of the file is screwed in the wall, and the other part continues to move, so the fracture occurs due to exceeding the elastic limit [7, 8]. Cyclic fatigue is a consequence of the cumulative effect of bending forces that are repeated in the same place (usually in the area of the curve), so the file is alternately exposed to tensile forces on the outside and compression forces on the inside [9, 10]. It has been confirmed that NiTi files that were previously exposed to torsional stress showed higher resistance to cyclic fatigue, ie that files of smaller diameter are generally more resistant to cyclic fatigue [11, 12].

Clinical studies have shown the frequency of fractures of NiTi rotary files is 0.13–10%, and 0.25–6% for hand files [13–17]. NiTi file fracture most often occurs during endodontic treatment of molars (77–89%) with a higher risk during treatment of the upper (50-55%) compared to the lower molars (25–30%) [13, 15, 16]. In the upper molars, the fracture most often occurs in the mesiobuccal canal (distal curvature of the mesial root), and the lower molars in the mesial canals due to distal and buccal curvature [13].

The frequency of NiTi file fracture is exactly proportional to the curvature of the canal (7% in straight, 35% in slightly curved and 58% in very curved canals), and most often occurs in the apical segment (41–82.7%), then in the middle third (14.8–32%) and least often in the coronal third (2.5-20%) [13, 17].

In a study that examined the frequency of NiTi file fractures in general dental and specialized endodontic surgeries, 88.8% of dentists reported fractures, which were much more common among endodontists who performed multiple interventions and generally treated more severe cases [18].

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The aim of this paper is to assess the most common reasons for the occurrence of NiTi file fractures and emphasize measures and factors that can increase the safety and reduce possible complications during canal instrumentation.

Factors that influence the occurrence of NiTi file fractures

File fractures seriously complicate and compromise endodontic treatment and its prognosis, and therefore require various precautions [13]. Numerous studies have examined factors that can affect the fracture of endodontic files with the main goal of increasing the safety and reducing possible complications during canal instrumentation [3, 6, 9, 10, 11, 14, 17].

Different factors that can be classified into four categories, affect the occurrence of NiTi file fractures: a) factors related to the therapist (skill and expertise); b) anatomical factors (access cavity and canal anatomy); c) factors related to the file (material, design, production process) and d) technical factors of instrumentation (dynamics of file movement, irrigation, reuse, sterilization) [19–22].

In order to eliminate the risk of possible fractures and deformations of NiTi rotary files during canal preparation, dental technology has developed several new strategies in creating and designing their working part (conicity, cross section, working part design), special thermomechanical procedures in alloy preparation, ie different kinetics of file movement in the canal [1, 9, 20, 21, 22].

A dentist is certainly the most important and most dominant factor influencing the appearance of defects and fractures, ie. his knowledge, expertise and clinical training. In addition to manual skills and knowledge of instrumentation techniques, the practitioner must have a good knowledge of the anatomy of different canal systems (number, arrangement, angle and diameter of canal curvature, additional canals), or file design, to make the best choice for each case [3, 16, 18]. Good planning and detailed analysis of the course of endodontic treatment are necessary for success, but also for prevention of possible fractures [16, 17].

The first and certainly the most important step in preventing fractures is the proper formation of the access cavity and adequate opening of the canals. This provides good visualization of endodontic space, facilitates the control of bending and preparation of the complex apical segment of the canal [3, 15, 16, 23]. Properly formed access cavity is the first step in preventing fracture, because it enables easier movement of the files in the canal, significantly minimizes the stress of bending and twisting, and prevents possible fractures when it comes to patients with limited mouth openings. Canal entrance processing (Gates-Gliden) and checking the patency with hand files significantly facilitate rectilinear access to the canals and reduce the cyclic fatigue of the file during movement in the canal [3, 15, 16].

Apical preparation is a special problem due to inaccessibility and inadequate diameter, reduced effect of irrigation solution and frequent existence of apical curvature that makes it difficult to reach the file to the apical narrowing. Therefore, the blade efficiency of the file and the solvent effect of irrigation are reduced in this part of the canal, and the possibility of retention of debris is increased, as well as the frequent formation of "blockage" that can cause fracture of the file [24, 25].

DESIGN OF NITI FILES

Knowledge and understanding of the design of NiTi files enables the practitioner to maximize endodontic skills, increased efficiency and reduced possibility of error during canal instrumentation [3, 26]. Cyclic fatigue and torsional stress are the most common causes of the damage and fractures during canal instrumentation and are a function of the material and design of the working part, i.e the dynamics of movement [7, 8, 9, 26]. The resistance of files to cyclic fatigue depends on numerous factors, primarily on the metallurgical features of the alloy and production process, file design (cross-sectional design, length, conicity, blade thread depth), preparation technique, irrigation, rotation speed, number of used files and of course canal curvature and dentist training [4, 8, 26, 27].

The first NiTi rotary file was introduced in 1992 (standard conicity of 2%) and was made of conventional NiTi wire (56% Ni, 44% Ti) with a "shape memory" effect (after unloading, it returns to its original shape), and with extremely biocompatible properties and corrosion resistance [1, 4, 8, 16].

A large number of different NiTi sets have been presented during the last decades (more than 160), with the basic goal of increasing their clinical efficiency and safety with innovative file design, new production processes and special treatments of NiTi alloy, ie affecting resistance to torsional loads, cyclic fatigue and flexibility [1, 8, 20]. High flexibility and shape memory are based on the fact that atoms in the alloy exist in two conformational forms (martensite and austenite), which significantly depend on the ambient temperature and stress (tension) during the movement of the files. The elasticity of the alloy increases with the change of phase, ie martensitic transformation into austenitic (in the martensitic phase the file bends with a slight force), and returns to its original shape after the cessation of stress [4, 9, 20, 26].

Files with an austenitic phase are used for instrumenting straight canals, and NiTi files with a higher share of the martensitic phase show greater flexibility and resistance to cyclic fatigue and are used for instrumenting highly bent canals [28]. An important step in improving physical and mechanical properties of NiTi files is the introduction of new design solutions and production technologies of alloys related to thermal and electrochemical treatment of the working part, as well as the procedure of ion implantation and protection of alloy with various nano coatings [1, 3, 20, 28, 29].

Electrochemical surface treatment of NiTi alloys was a key factor for increasing blade efficiency and increased resistance to cyclic fatigue [29], and the introduction of new heat-treated alloys (M-wire, CM-wire, Max-wire) significantly increased flexibility and resistance to torsional stresses [4, 9, 30, 31]. The alloy is alternately and under controlled conditions heated and cooled by heat treatment, in order to provide its specific properties related to increased flexibility and greater resistance to cyclic fatigue [9, 28].

Knowledge of the design features of the working part of the NiTI file is one of the most important prerequisites for efficient preparation, but also a significantly lower possibility of fracture [1, 3, 26]. Resistance to cyclic fatigue mostly depends on the size of cross section, conicity, length of the working part, depth of the cutting edges, surface imperfection of the file, rotation speed, etc. [15, 17, 26, 31]. It has been observed that thinner and more flexible files are more resistant to cyclic fatigue and more sensitive to torsional loads, while thicker ones are more sensitive to cyclic fatigue, but can withstand higher torque [17, 26]. Since increased conicity is often the reason for fracture, dental technology has offered shorter files with progressive multiconicity, which significantly reduces the engagement (contact) of the file with the walls, and thus stress and the possibility of screwing, with more efficient cutting and removal of detritus from the canal [7, 8].

The specific cross-section of the file (U, S shape), ie. number and depth of blades are also factors that lead to screwing and possible fractures, so files with shallow blade edges and constant cross section shape are more resistant to fractures [3, 26]. Surface imperfections of the new NiTi files and higher speed also affect the appearance of fractures. Deformations and fractures of the file are four times more frequent at higher speeds (over 350 rpm) compared to lower speeds (160 rpm), as well as at higher torsional load (3N/cm^2) compared to 1N/cm^2 [3, 11, 12].

Reduced engagement of the NiTi file in the canal can be solved by shortening the working part, reducing the number of threads, changing the conicity, interrupting the continuity of the blade, using files in correct order and changing the dynamics of movement [3, 14, 26]. Since the torque is directly proportional to the surface of engaged file in the canal, smaller torque requires higher number of revolutions and sharper blade needs less threads [3, 12, 26, 27).

Dynamics of movement of NiTi files in the canal

Frequent fractures of NiTi files in the canal influenced the introduction of new concepts of instrumentation primarily based on the change of movement dynamics, ie. reduction of the number of files for canal treatment [1, 10, 16]. Initially, only full rotation was used to start the NiTi file, and the instrumentation was most often realized with several file sets (initially with 5-6, and later with 3), while in recent years endodontics with single file has become more common, which significantly reduces the risk of fracture [2, 6, 8]. The fear of screwing (and thus fracture) in systems with full rotation influenced the introduction of systems with reciprocal movements that significantly increases the resistance to cyclic fatigue and prolongs life of files. Files with reciprocal movements are mainly represented by a single file that significantly reduces the instrumentation time, but also the stress during canal instrumentation [1, 25, 27].

Research confirms that the system with reciprocal movements is currently the most popular, because it allows greater flexibility and increased file resistance to cyclic fatigue, ie. efficient cleaning and shaping with reduced postoperative sensitivity [1, 13, 32, 33]. Reciprocal movements are based on movements of balanced forces, where rotation counterclockwise (cutting direction) and a much shorter movement in a clockwise direction significantly reduce both torsional stress and cyclic fatigue, and thus the possible screwing of the file [1, 26, 34, 35, 36]. The benefits of these files are shorter processing time, reduced possibility of cross-contamination and reduction of fear of fracture, because only one instrument is used [16, 32, 33, 34].

A system that uses a combination of full rotation and reciprocal movements (Genius system, Ultradent, USA) has been introduced in recent years, with instrumentation performed reciprocally and final instrumentation with full rotation files, which significantly increases resistance to torsional fractures [1, 34].

Some NiTi systems that use individual files rotate eccentrically (asymmetrically) in the canal and thus provide efficient canal cleaning with irregular morphology [1, 35]. Representative of these files is XP ENDO Shaper, a new generation of NiTi files, made of a special alloy (Max-wire), with a unique design of the working part (snake shape), which provides exceptional flexibility and increased resistance to cyclic fatigue. The specific design of the file also enables higher rotation speed (800 rpm), more efficient irrigation and more efficient removal of detritus from inaccessible parts of the canal [1, 35, 36].

The Self Adjusting File (SAF) has a completely different design and movement kinetics than existing NiTi systems. This NiTi file is hollow, mesh and flexible, and during transaxial movement (vibration) it enables more efficient and always fresh irrigation, that is continuously delivered to the canal via a silicone tube. This file has high resistance to fracture, adapts three-dimensionally and cleans the canal system very efficiently [1, 3, 7, 37].

In vitro studies have confirmed that prolonged clinical use of NiTi files reduces their resistance to cyclic fatigue, and therefore a single application is recommended [9, 10]. Sterilization of new or used files also reduces the resistance to cyclic fatigue and affects the occurrence of corrosion due to changes in the surface layer of titanium oxide [16, 20, 38]. The use of different lubrication gels, ie irrigation solution (NaOCl) can also have corrosive effects of NiTi alloy. It has been confirmed that NaOCl in concentration of 1% affects torsional and cyclic resistance after a cumulative exposure of 2.5 h, while longer-term exposure (18 h) also shows clear signs of corrosion [16, 38, 39]. The problem caused by immersion of files in NaOCl solution is related to metallurgical features and the occurrence of galvanic currents (handle and working part are made of two different metals) can accelerate corrosion and reduce fracture resistance [40, 41, 42].

CONCLUSION

File fracture during canal instrumentation is a serious iatrogenic complication that compromises endodontic treatment and largely depends on the therapist. Exceptional skills and expertise are required, as fractures are more common in less experienced practitioner. Preclinical training on extracted molars is mandatory and necessary in order to provide routine and experience with NiTi files, before using them in clinical conditions. The therapist also must be well acquainted with the canal anatomy of the teeth, the number and shape of the canals, the position of the curve and must plan the whole endodontic intervention well. In addition, therapist must clearly and precisely form the access cavity and clearly shape the entrances to the root canals.

The clinician must know the design of NiTi files and material they are made of (type of alloy), and choose files with working parts that will ensure reduced engagement of the file during canal instrumentation. Also, lower speed and less torque should be used during canal instrumentation and proposed protocol must be followed. The patency of the canal should be checked with hand instruments and it is obligatory to use lubricants and abundant irrigation with solutions during canal instrumentation.

The therapist must know the dynamics of the file movement and choose a preparation technique that prevents a possible fracture. Reciprocal movements are currently the most efficient, because they significantly reduce stress and the possibility of screwing during canal instrumentation due to the specific dynamics of movement in the canal. Numerous studies have confirmed that the frequency of file fractures is extremely low in clinicians who are well aware of possible fractures.

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Received: 25.03.2021 • Accepted: 27.05.2021

Kako sprečiti frakturu NiTi instrumenata

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KRATAK SADRŽAJ

Uvođenjem NiTi rotirajućih instrumenata u endodontsku praksu i njihovom pravilnom primenom obezbeđena su izvesnija terapijska rešenja i znatno je olakšano rešavanje svakodnevnih endodontskih problema. Međutim, njihova široka primena uzrokovala je sve učestalije frakture i postala značajan frustrirajući faktor koji umanjuje njihove brojne benefite. Torziono naprezanje i ciklični zamor su glavni razlozi za nastanak frakture, a učestalost loma NiTi turpija je upravo srazmerna stepenu povijenosti kanala, poznavanju karakteristika instrumenta, odnosno veštini i stručnosti terapeuta. Najdominantniji faktor za nastanak fraktura je stomatolog, koji osim manuelne spretnosti mora dobro poznavati anatomiju različitih kanalskih sistema i dizajn turpije kako bi napravio najbolji izbor za svaki pojedinačni slučaj. Pravilno formiran pristupni kavitet i poznavanje radnog dela NiTi instrumenata omogućavaju maksimalnu realizaciju endodontske veštine, povećanu efikasnost intervencije i smanjenu mogućnost greške tokom obrade kanala. Poseban tretman NiTi legure i nova rešenja vezana za dizajn radnog dela značajno su povećali fleksibilnost turpije i otpornost na ciklični zamor. Specifičan dizajn (smanjen broj navoja, promena koničnosti, prekid kontinuiteta sečiva) i smanjena angažovanost instrumenta, odnosno promena dinamike kretanja u kanalu (puna rotacija, recipročna, ekcentrična, transaksijalna) i smanjenje broja turpija za obradu, uticali su i na značajno smanjenje rizika od preloma.

Cilj ovog rada je bio da ukaže na najčešće razloge za pojavu fraktura NiTi turpija i apostrofira mere i faktore koji mogu povećati sigurnost instrumentacije i smanjiti moguće komplikacije tokom obrade kanala.

Ključne reči: NiTi turpije; frakture; dizajn turpije; dinamika kretanja

UVOD

Zahvaljujući novim konceptima i metodama „čišćenja“ i oblikovanja kanala, odnosno novim instrumentima, endodontska terapija je postala sve sigurnija i efikasnija [1]. Uvođenjem NiTi rotirajućih instrumenata i njihovom pravilnom primenom obezbeđena su izvesnija terapijska rešenja i značajno je olakšano rešavanje svakodnevnih endodontskih problema [1, 2]. Primena ovih instrumenata sa ograničenim brojem obrtaja i izrazitom fleksibilnošću značajno ubrzava preparaciju kanala, ali su neočekivane i iznenadne frakture još uvek važan frustrirajući faktor koji anulira njihove brojne koristi [3, 4].

Tokom poslednje dve decenije NiTi turpije su postale standard u endodontskom lečenju zuba, pa je i njihova široka primena uzrokovala sve učestalije frakture [3, 5, 6]. Potvrđeno je da su zbog ušrafljivanja skoro svi setovi NiTi instrumenata podložni frakturama, pri čemu je ovaj problem znatno češći tokom obrade povijenih kanala [3, 6]. Glavni razlozi za pojavu frakture su torzioni stres i ciklični zamor tokom instrumentacije kanala [7–10]. Torziono naprezanje nastaje usled trenja instrumenata o zidove kanala kada u predelu krivine dođe do ušravljivanja dela instrumenta a drugi nastavlja sa kretanjem, pa usled prekoračenja granice elastičnosti dolazi do frakture [7, 8]. Ciklični zamor je posledica kumulativnog efekta sila savijanja koje se ponavljaju na istom mestu (najčešće u predelu krivine), pa je instrument tokom rotacije naizmenično izložen silama zatezanja na spoljašnjoj strani, odnosno silama kompresije na unutrašnjoj strani [9, 10]. Potvrđeno je da NiTi instrumenti koji su prethodno izloženi torzionom stresu pokazuju veću otpornost na ciklični zamor, odnosno da su instrumenti manjeg dijametra uglavnom otporniji na ciklični zamor [11, 12].

Kliničke studije pokazuju da je učestalost fraktura NiTi rotirajućih instrumenata 0,13–10%, a kod ručnih instrumenata 0,25–6% [13–17]. Do frakture NiTi turpija najčešće dolazi tokom endodontskog tretmana molara (77–89%) [13, 15, 16], pri čemu je veći rizik tokom terapije gornjih (50–55%) u odnosu na donje molare (25–30%) [13]. Kod gornjih molara fraktura se najčešće dešava u bukomezijalnom kanalu (distalna krivina mezijalnog korena), a kod donjih u mezijalnim kanalima usled distalne i bukalne povijenosti [13].

Učestalost loma NiTi turpija je upravo proporcionalna povijenosti kanala (7% kod pravih, 35% kod blago povijenih i 58% u jako povijenim kanalima), a najčešće se dešava u apeksnom segmentu (41–82,7%), potom u srednjoj trećini (14,8–32%), a najređe u kruničnoj trećini (2,5–20%) [13, 17].

U studiji koja je proveravala učestalost loma NiTi instrumenata u opštim stomatološkim i specijalizovanim endodontskim ordinacijama 88,8% stomatologa je prijavilo frakture, pri čemu su one bile mnogo češće među endodontistima koji realizuju više intervencija i uglavnom tretiraju teže slučajeve [18].

Cilj ovog rada je bio da ukaže na najčešće razloge za pojavu fraktura NiTi turpija i apostrofira mere i faktore koji mogu povećati sigurnost instrumentacije i smanjiti moguće komplikacije tokom obrade kanala.

FAKTORI KOJI UTIČU NA POJAVU FRAKTURA NITI TURPIJA

Frakture instrumenata ozbiljno komplikuju i kompromituju endodontski tretman i njegovu prognozu i zbog toga obavezuju na konstantan oprez preduzimanjem brojnih mera predostrožnosti [13]. Brojne studije su istraživale faktore koji mogu uticati na lom endodontskih turpija sa osnovnim ciljem da se poveća sigurnost instrumentacije i smanje moguće komplikacije tokom obrade kanala [3, 6, 9, 10, 11, 14, 17].

Na pojavu fraktura NiTi turpija utiču brojni faktori, koji se mogu klasifikovati u četiri kategorije: a) faktori vezani za terapeuta (veština i stručnost); b) anatomski faktori (pristupni kavitet i anatomija kanala); c) faktori vezani za instrument (materijal, dizajn, proizvodni proces) i d) tehnički faktori instrumentacije (dinamika kretanja instrumenata, irigacija, ponovna upotreba, sterilizacija).

Da bi se eliminisao rizik od mogućih fraktura i deformacija NiTi rotirajućih instrumenata tokom preparacije kanala, dentalna tehnologija je razvila nekoliko novih strategija u kreiranju i dizajniranju njihovog radnog dela (koničnost, poprečni presek, dizajn radnog dela), posebne termomehaničke procedure u pripremi legure, odnosno različitu kinetiku kretanja instrumenta u kanalu [19–22].

Najvažniji i najdominantniji faktor koji utiče na pojavu defekata i fraktura je sigurno stomatolog, odnosno njegovo znanje, stručnost i klinička obučenost. Osim manuelnih veština i poznavanja tehnika instrumentacije, praktičar mora dobro poznavati anatomiju različitih kanalskih sistema (broj, raspored, ugao i prečnik povijenosti kanala, dodatnih kanala), odnosno dizajn turpije kako bi napravio najbolji izbor za svaki pojedinačni slučaj [3, 16, 18]. Dobro planiranje i detaljna analiza toka endodontske intervencije pre njenog otpočinjanja su takođe neophodni za uspeh, ali i za sprečavanje eventualnih fraktura [16, 17].

Prvi i sigurno najznačajniji korak u sprečavanju fraktura je pravilno formiranje pristupnog kaviteta i adekvatna obrada ulaza u kanale. Time se obezbeđuje dobra vizuelizacija endodontskog prostora, olakšava kontrola povijenosti i preparacija kompleksnog apeksnog segmenta kanala [3, 15, 16, 23]. Pravilno formiran pristupni kavitet je prvi korak u sprečavanju frakture jer omogućava olakšano kretanje instrumenta u kanalu, značajno minimalizuje stres na savijanje i uvijanje i sprečava eventualne frakture kod pacijenata sa ograničenim otvaranjem usta. Obrada ulaza u kanale (Gates-Gliden) i provera prohodnosti ručnim instrumentima značajno olakšavaju pravolinijski pristup kanalima i smanjuju ciklični zamor instrumenta tokom kretanja u kanalu [3, 15, 16].

Apeksna preparacija je poseban problem zbog nepristupačnosti i neadekvatnog dijametra, umanjenog efekta rastvora za irigaciju i, skoro uvek, postojanja apikalne povijenosti koja otežava dosezanje turpije do apikalnog suženja. Zbog toga je u ovom delu kanala smanjena sečivna efikasnost instrumenta i rastvarački efekat irigansa, a povećana mogućnost zadržavanja debrisa i često formiranje „blokade“, koja može uzrokovati frakturu instrumenta [24, 25].

DIZAJN NITI INSTRUMENATA

Poznavanje i razumevanje dizajna NiTi instrumenata omogućavaju praktičaru maksimalnu realizaciju endodontske veštine, povećanu efikasnost i smanjenu mogućnost greške tokom obrade kanala [3, 26]. Ciklični zamor i torzioni napon su najčešći uzroci oštećenja i fraktura tokom instrumentacije kanala i u funkciji su materijala i dizajna radnog dela, odnosno dinamike kretanja [7, 8, 9, 26]. Otpornost instrumenata na ciklični zamor zavisi od brojnih faktora, a pre svega od metalurških karakteristika legure i proizvodnog procesa, dizajna instrumenta (dizajn poprečnog preseka, dužina, koničnost, dubina sečivnih navoja), tehnika preparacije, irigacije, brzine rotacije, broja korišćenih instrumenata i, naravno, povijenosti kanala i obučenosti stomatologa [4, 8, 26, 27].

Prvi NiTi rotacioni instrument je predstavljen 1992. g. (standardna koničnost 2%) i bio je izrađen od konvencionalne NiTi žice (56% Ni, 44% Ti) sa efektom „pamćenja oblika“ (posle rasterećenja se vraća u prvobitni oblik), sa izrazitim biokompatibilnim osobinama i otpornošću na koroziju [1, 4, 8, 16].

Tokom poslednjih decenija predstavljen je veliki broj različitih setova NiTi (više od 160) sa osnovnim ciljem da se inovativnim dizajnom turpije, novim proizvodnim procesima i posebnim tretmanima NiTi legure poveća njihova klinička efikasnost i sigurnost, odnosno utiče na otpornost na torziona opterećenja, ciklični zamor i fleksibilnost [1, 8, 20]. Visoka fleksibilnost i pamćenje oblika baziraju se na činjenici da atomi u leguri postoje u dva konformaciona oblika (martenzit i austenit), koji značajno zavise od temperature okoline i stresa (napetosti) tokom kretanja instrumenata. Promenom faze, odnosno martenzitnom transformacijom u austenitnu, povećava se elastičnost legure (u martenzitnoj fazi instrument se povija uz neznatnu silu), a po prestanku stresa ponovo se vraća u originalni oblik [4, 9, 20, 26].

Instrumenti sa austenitnom fazom se koriste u obradi pravih, a NiTi instrumenti sa većim udelom martenzitne faze pokazuju veću fleksibilnost i otpornost na ciklični zamor i koriste se za obradu izrazito povijenih kanala [28]. Važan iskorak u poboljšanju fizičkih i mehaničkih svojstava NiTi turpija je uvođenje novih dizajnerskih rešenja i proizvodnih tehnologija legure vezanih za termičku i elektrohemijsku obradu radnog dela, kao i postupak jonske implantacije i zaštite legure različitim nanopremazima [1, 3, 20, 28, 29].

Elektrohemijska obrada površine NiTi legure bila je ključni faktor za povećanje sečivne efikasnosti i povećane otpornosti na ciklični zamor [29], a uvođenje novih termički tretiranih legura (M-wire, CM-wire, Max-wire) značajno je povećalo fleksibilnost i otpornost na torziona naprezanja [4, 9, 30, 31]. Termičkim tretmanom se legura naizmenično i pod kontrolisanim uslovima zagreva i hladi kako bi se obezbedila njena specifična svojstva vezana za povećanu fleksibilnost i veću otpornost na ciklični zamor [9, 28].

Poznavanje karakteristika dizajna radnog dela NiTI instrumenta je jedan od najvažnijih preduslova za efikasnu preparaciju ali i značajno manju mogućnost za pojavu frakture [1, 3, 26]. Otpornost na ciklični zamor najviše zavisi od veličine poprečnog preseka, koničnosti, dužine radnog dela, dubine sečivnih ivica, površinske nesavršenosti instrumenta, brzine rotacije i dr. [15, 17, 26, 31]. Uočeno je da su tanji i fleksibilniji instrumenti otporniji na ciklični zamor i osetljiviji na torziona opterećenja, dok su deblji osetljiviji na ciklični zamor, ali mogu izdržati veći obrtni moment (tork) [17, 26]. S obzirom na to da je povećana koničnost često razlog za pojavu loma, dentalna tehnologija je ponudila kraće turpije progresivne multikoničnosti, čime se značajno smanjuje angažovanost (kontakt) instrumenta sa zidovima, a time i stres i mogućnost ušrafljivanja, uz efikasnije sečenje i uklanjanje detritusa iz kanala [7, 8].

Specifičan poprečni presek turpije (oblik slova U, S), odnosno broj i dubina sečiva, takođe su faktori koji dovode do ušrafljivanja i mogućih fraktura, pa su zato instrumenti sa plićim sečivnim ivicama i konstantnim oblikom poprečnog preseka otporniji na prelome [3, 26]. Površinske nesavršenosti novih NiTi turpija i veća brzina takođe utiču na pojavu fraktura. Deformacije i lom instrumenta su četiri puta češći pri većim brzinama (preko 350 o/min.) u odnosu na manje brzine (160 o/min.), kao i pri većem torzionom opterećenju (3 N/cm^2) u odnosu na 1 N/cm^2 [3, 11, 12].

Smanjena angažovanost NiTi turpije u kanalu može se rešiti skraćenjem radnog dela, smanjenjem broja navoja, promenom koničnosti, prekidom kontinuiteta sečiva, pravilnim redosledom korišćenja i promenom dinamike kretanja [3, 14, 26]. S obzirom na to da je tork direktno proporcionalan površini angažovanog instrumenta u kanalu, manji tork zahteva i veći broj obrtaja, a oštrija sečiva manje navoja [3, 12, 26, 27].

DINAMIKA KRETANJA NITI INSTRUMENATA U KANALU

Česte frakture NiTi instrumenta u kanalu uticale su na uvođenje novih koncepata preparacije koji se baziraju pre svega na promeni dinamika kretanja, odnosno smanjenju broja instrumenata za obradu kanala [1, 10, 16]. Za pokretanje NiTi turpija je u početku korišćena samo puna rotacija, a preparacija je najčešće realizovana setovima sa više instrumenata (u početku sa 5-6, a kasnije sa 3), dok je poslednjih godina sve zastupljenija endodoncija jednom turpijom, čime se značajnije smanjuje i rizik od preloma [2, 6, 8]. Strah od ušrafljivanja (a time i loma) kod sistema sa punom rotacijom uticao je na uvođenje sistema sa recipročnim pokretima, čime se značajno povećava otpornost na ciklični zamor i produžava životni vek turpija. Dodatna prednost je što su turpije sa recipročnim pokretima uglavnom predstavljene jednom turpijom koja značajno smanjuje vreme preparacije ali i stres tokom obrade kanala [1, 25, 27].

Istraživanja potvrđuju da je sistem sa recipročnim pokretima trenutno najpopularniji jer omogućava veću fleksibilnost i povećanu otpornost instrumenata na ciklični zamor, odnosno efikasno čišćenje i oblikovanje uz smanjenu postoperativnu osetljivost [1, 13, 32, 33]. Recipročni pokreti se baziraju na pokretima balansiranih sila, gde rotacija u smeru suprotnom kretanju kazaljke na satu (sekući smer) i mnogo kraći pokret u smeru kazaljke izrazito smanjuju i torzioni stres i ciklični zamor, a time i moguće ušrafljivanje turpije [1, 26, 34, 35, 36]. Benefiti ovih turpija uključuju i kraće vreme obrade, smanjenu mogućnost unakrsne kontaminacije i redukovanje straha od loma jer se koristi samo jedan instrument [16, 32, 33, 34].

Poslednjih godina predstavljen je sistem koji koristi kombinaciju pune rotacije i recipročne pokrete (Genius sistem, Ultradent, USA), gde se instrumentacija obavlja recipročnim a finalna obrada turpijama sa punom rotacijom, čime se značajno povećava otpornost na torzione frakture [1, 34].

Pojedini NiTi sistemi koji koriste pojedinačne turpije u kanalu se rotiraju ekscentrično (asimetrično) i na taj način obezbeđuju efikasno čišćenje i kanala sa nepravilnom morfologijom [1, 35]. Predstavnik ovih turpija je XP ENDO Shaper, nova generacija NiTi instrumenata izrađena od posebne legure (Max-wire) sa jedinstvenim dizajnom radnog dela (zmijolik oblik) koji obezbeđuje izuzetnu fleksibilnost i povećanu otpornost na ciklični zamor. Specifičan dizajn turpije omogućava i veću brzinu rotacije (800 o/min.), efikasniju irigaciju i efikasnije uklanjanje detritusa iz nepristupačnih delova kanala [1, 35, 36].

Potpuno drugačiji dizajn i kinetiku kretanja od postojećih NiTi sistema ima samopodešavajuća turpija (SAF – Self Adjusting File). Ova NiTi turpija je šuplja, mrežasta i fleksibilna i tokom transaksijalnog kretanja (vibracije) omogućava efikasniju irigaciju uz uvek svež irigans koji se preko silikonske cevčice kontinuirano doprema u kanal. Ova turpija poseduje visoku otpornost na frakturu, trodimenzionalno se adaptira i vrlo efikasno čisti kanalni sistem [1, 3, 7, 37].

In vitro istraživanja su potvrdila da produžena klinička primena NiTi instrumenata smanjuje njihovu otpornost na ciklični zamor, pa se zbog toga preporučuje jednokratna primena [9, 10]. Sterilizacija novih ili korišćenih turpija takođe smanjuje otpornost na ciklični zamor i utiče na pojavu korozije usled promena na površinskom sloju titanijum-oksida [16, 20, 38]. Primena različitih gelova za lubrikaciju, odnosno rastvora za irigaciju (NaOCl), takođe može uticati na korozivne efekte NiTi legure. Potvrđeno je da koncentracija NaOCl od 1% utiče na torzionu i cikličnu otpornost nakon kumulativne izloženosti od 2,5 h, dok dugotrajnija izloženost (18 h) pokazuje i jasne znake korozije [16, 38, 39]. Problem koji nastaje potapanjem instrumenata u rastvor NaOCl vezan je metalurške karakteristike i pojavu galvanskih struja (drška i radni deo su od dva različita metala) koje mogu ubrzati koroziju i time smanjiti otpornost na frakturu [40, 41, 42].

ZAKLJUČAK

Fraktura instrumenta tokom preparacije je ozbiljna jatrogena komplikacija koja kompromituje endodontski tretman i u najvećoj meri zavisi od terapeuta. Praktičar mora posedovati izuzetnu veštinu i stručnost jer su frakture mnogo češće kod neiskusnih. Obavezan je i neophodan predklinički trening na ekstrahovanim molarima kako bi se obezbedili rutina i iskustvo sa NiTi turpijama, pa tek onda primena u kliničkim uslovima. Terapeut mora dobro poznavati kanalnu anatomiju zuba, broj i oblik kanala, položaj krivine i dobro isplanirati endodontsku intervenciju. Osim toga, mora jasno i precizno formirati pristupni kavitet i jasno predstaviti ulaze u kanale korena.

Kliničar mora poznavati dizajn NiTi instrumenata i materijal od koga je izrađen (vrsta legure) i izabrati turpije sa radnim delom koji će obezbediti smanjenu angažovanost instrumenta tokom preparacije kanala. Treba koristiti manje brzine i manji tork tokom obrade kanala i pridržavati se predloženog protokola. Prohodnost kanala treba proveriti ručnim instrumentima i obavezno koristiti lubrikante i obilnu irigaciju rastvorima tokom preparacije kanala.

Terapeut mora poznavati dinamiku kretanja instrumenta i odabrati tehniku preparacije koja prevenira moguću frakturu. Recipročni pokreti su trenutno najefikasniji jer zbog specifične dinamike kretanja u kanalu značajno smanjuju stres i mogućnost ušrafljivanja tokom instrumentacije kanala.

Brojne studije su potvrdile da je kod kliničara koji su svesni mogućih fraktura učestalost preloma turpije izuzetno niska.