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# A single-file endodontic treatment – A promising endodontic concept

## Endodontsko lečenje jednim instrumentom – perspektivni endodontski koncept

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### Introduction

Effective cleaning of the tooth canal system and adequate canal shaping are the basic preconditions and key requirements for the success of endodontic treatment [1]. Chemomechanical canal treatment implies complete debridement of the internal endodontic space (pulp tissue remains, bacteria), i.e. the canal formation in the form of an elongated cone and the maximum preservation of its original morphology [1–3]. Research has confirmed that proper instrumentation with adequate irrigation and medication cannot completely eliminate, but only reduce bacteria from the canal and its inaccessible parts [1, 3, 4]. A special issue in cleaning is the apical third, both due to anatomical specifics and due to inadequate diameter of the apical preparation, which further complicates the debridement of this part of the canal [5–7].

Canal preparation can be realized by manual and machine rotary files made of stainless steel and files made of nickel titanium (NiTi) alloy. The introduction of NiTi alloy into the manufacturing of endodontic files is one of the greatest evolutionary advances in endodontic dental treatment, and their application is a major step and an important standard in the chemomechanical procedure [2, 7]. Primarily due to good mechanical features (biocompatibility, low modulus of elasticity, corrosion resistance) and the feature of "smart materials" to be able to return to their original shape after deformation, rotary NiTi files opened a new perspective in canal preparation [7, 8]. They preserve the original canal morphology, reduce the possibility of transportation, significantly speed up the instrumentation and make it quite efficient and safe thanks to the outstanding flexibility [8–11]. However, despite numerous advantages, fractures of NiTi files during their clinical application are still a major issue and a significant frustration for many dentists [12, 13].

The aim of this paper was to present a new and promising concept of a single-file treatment, and to show the development and strategies of single NiTi files and the possibility of their application in different clinical situations.

### The development of NiTi rotary files

Today, modern endodontic treatment cannot be imagined without the techniques of machine instrumentation and the use of NiTi files [2, 7, 9]. Endodontists currently have more than 160 different NiTi systems at their disposal that use full rotation, reciprocal movements, and eccentric or transaxial movements during canal treatment. NiTi files can differ in the specific design of the working part, conicity, cross section and length of the working part, specific tip, tilt angle of the cutting edge, special thermal preparation of the alloy, etc. [7, 9].

Although NiTi alloy was first used in orthodontics, its use in endodontics is certainly one of the most significant steps towards a more successful canal treatment [14, 15]. The main features of NiTi alloy (56% Ni, 44% Ti) are superplasticity and shape memory effect, which allow the file to return to its original shape after relief (or heating). It has been confirmed that a wire made of this alloy can deform 7–8%, or 40 times more than a stainless steel wire [14–16].

Direct and strong bonds between electrons, which after elastic or pseudoelastic deformation enable the return to the original shape, are responsible for the high flexibility of the alloy. Stress-induced thermoelastic transformation (stress, temperature) implies a martensitic transformation into the austenitic phase, where the elasticity of the alloy increases and the file returns to its original shape after the cessation of stress [7, 14, 16, 17].

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The first NiTi rotary file was introduced by John Mc Spaden in 1992 (conicity 02), and only two years later the NiTi ProFile system (conicity 04 and 06) with a specific design of the working part was introduced into endodontic practice. In the mid-1990s, the Light Speed system was introduced with a file that had a long flexible axis and a short working part (0.25–2 mm), which was used to process the canal apical segment [2, 7, 9].

New design concepts of NiTi files have shifted the focus of the dental industry towards increasing cutting efficiency and reducing possible complications (especially fracture) during canal preparation. This includes a specific design of the working part that provides efficient cutting and elimination of dentin, with a significant reduction of contacts between the file and the walls, and thus stress during the canal preparation [7, 17–19].

The first generation of 1993 NiTi files included sets of fixed conicity files along the entire length of the working part (04, 06), where it was necessary to use all the files in the set for efficient cleaning and shaping [2, 20].

The second generation of NiTi files (appeared in 2001) had active cutting edges and variable conicity on the working part of the file (progressive multiconicity), which significantly limited their cutting effect and reduced the possibility of screwing [2, 17, 19, 20].

Since 2007 (the third generation), dental technology has been focused on the production of NiTi alloy files with improved features (special thermal treatment), which has significantly increased flexibility and resistance to cyclic fatigue, i.e. reduced the possibility of fracture [2, 16, 20].

The fourth generation of NiTi files appeared on the market in 2011 and included a change in the dynamics of movement in the canal. In addition to reciprocal movements, this concept included only one file for complete canal cleaning and shaping [2, 3, 9, 18, 20].

The fifth generation (2015) has been designed so that the center of gravity and the center of rotation of NiTi files are not in the same axis, which significantly reduces the contact between the file and the canal walls, and increases the flexibility and efficiency of cutting dentin [2, 7, 10, 12].

A research has confirmed that the efficiency and safety of files can be increased by applying new NiTi alloys with superior mechanical features, i.e. improvements in the process of their production [7, 10, 12, 20]. The mechanical features of NiTi alloy (superelasticity, memory effect) can be improved by changing the chemical composition [8], finishing surface treatment of the alloy during manufacturing [7, 17] or electrochemical treatment (electropolishing) [17, 21, 22].

The introduction of new alloys into the file manufacturing (Nitinol 508; Ni 55.8%, Ti 44.2%) and their exposure to thermal treatment (alternating heating and cooling) confirmed their superior mechanical features, i.e. greater flexibility and increased resistance to cyclic fatigue [18, 20, 23–25]. In order to improve fracture resistance, dental technology today uses methods of implantation of an alloy with argon, boron or nitrogen ions, coating of files with a layer of nitrite, plasma immersion and electropolishing, or deep cryogenic treatment [7–18, 21, 22, 26–28].

**A single-file endodontic treatment**

Continuous development of endodontics includes numerous ideas, techniques and strategies for more efficient canal preparation, but clinical reality confirms that it is still difficult to completely and predictably clean and shape the canal system [1, 2, 7, 9]. Cleaning efficiency is particularly limited in the apical part of the canal [9, 29, 30].

Single-file canal preparation is a completely new concept that has fundamentally changed a lot in endodontics (conceptually, procedurally and economically) [2, 9, 31, 32]. Single-file canal instrumentation (regardless of diameter, length and bending degree) is a strategy based on the concept of "less is more". This significantly shortens the duration of an endodontic intervention (3–4 times), eliminates the possibility of cross-contamination (occurs in sets with multiple files) and significantly saves time and financial costs for both the patient and the endodontist [2, 9, 31–34]. Facilitated and simplified intervention, in addition to time, significantly reduces the fatigue of the file and thus "minimizes" the possibility of its fracture [2, 7, 9, 31, 32].

The concept of a single-file treatment includes different systems that use full (continuous) rotation, reciprocal movements, or a combination of full rotation and reciprocal movements. In recent years, systems with eccentric (asymmetric) or transaxial (longitudinal) movement of files have been introduced in order to reduce cyclic fatigue and increase the cutting efficiency of files [2, 7, 28, 35]. Some newer NiTi systems combine full rotation and reciprocal movements (Genius system, Ultradent, USA) using an endomotor (Elements) where there is an automatic switch from rotary to reciprocal movement (90° clockwise and 30° counterclockwise) if the resistance increases during the file rotation in the canal [7, 31–33].

Systems with eccentric (asymmetric) movement are recommended for canals with irregular morphology because they enable contact between the file and hard-to-reach parts of the canal. These movements are used by the systems such as Pro Taper Next, XP Endo Shaper and TruShape [7, 31].

Transaxial file movement is represented by a new self-adjusting file (SAF). In fact, it is a specially designed hollow and flexible file (which adapts to the shape of the canal in three dimensions) and is connected to a continuous irrigation source via a special silicone tube [8, 33, 34].

*Single files with reciprocal movements*

The curvature of the canal is an important issue of preparation, but also a cause for frustration and fear of dentists that this morphological specificity does not lead to fracture of the file. Deformations and frequent fractures of NiTi files, as a consequence of torsional stress and cyclic fatigue, influenced the introduction of new preparation concepts based primarily on changes in movement dynamics and reduction of the number of files for chemomechanical processing of canals [2, 31–37].

The file preparation technique with reciprocal movements is mainly represented by a single NiTi file. Reciprocal

movements in the canal are based on the technique of balanced forces and involve the rotation of the files counterclockwise (cutting direction) and a much shorter movement in a clockwise direction (file relaxation). These movements reduce the contact surface with the canal wall, and thus torsional stress and cyclic fatigue, which significantly prolongs the life of the file [35, 36, 38–40].

For the first time, a study by Yared [41] reports on the application of the Pro Taper F2 NiTi file (intended for full rotation) in the technique with reciprocal movements. The study has shown a significant reduction in cyclic fatigue (compared to full rotation) and a number of benefits related to shorter processing times, reduction of possible cross-contamination and alleviation of fear of possible deformations and fractures because only one file is used [27, 33, 41].

Several systems that use single disposable files and special motors for reciprocal movements have been introduced on the dental market since 2008. NiTi files are mainly made of special NiTi alloy with special thermal treatment (increased flexibility and resistance to cyclic fatigue), specific working part and cross section (S-shape) and progressive conicity (Wave One, Wave One Gold-Dentsply, Sirona, Ballaigues, Switzerland; Reciproc, Reciproc Blue-Vdw, Munich, Germany; Unicone- Medin, Nove Mesto, Chech Republic; Pro Design R- Eazy Equipamentos Odontologicos, Belo Horizonte, Brazil; X1 Blue File-Mk Life, Porto Alegre, Brazil) [27, 33, 35, 38, 42, 43].

Reciprocating file movements counterclockwise provides apical movement and cutting of the dentin, and a movement in a clockwise direction relaxes or reduces torsional stress and prevents "clamping" in the canal [35, 38, 43]. The preparation technique with reciprocal movements, in addition to speed and safety, allows that 80% of canals with moderate bending can be processed without prior check of passability by hand files [2, 7, 35, 39]. Fracture of NiTi files most often occurs in bent canals due to torsional stress or cyclic fatigue when a part of the file is "blocked" in the canal (curve), and the other continues to move. Cyclic fatigue fracture occurs due to the cumulative effect of bending forces at the place of maximum bending (curve) [7, 10, 18, 27, 35]. Torsional fatigue is significantly lower in reciprocal movements because the file alternately shifts from the active cutting movement to the non-cutting movement, which increases the resistance to cyclic fatigue and prolongs the clinical life of the file [31].

The results of numerous studies show that reciprocal movements of the file in the canal lead to less cyclic fatigue and significantly rarer fractures [7, 18, 31, 34, 35, 39, 42].

A study by De-Deus et al. [44] has indicated greater resistance to cyclic fatigue of the Pro Taper F2 file using the technique of reciprocal turns (630 cycles) compared to full rotation (160 cycles) and confirmed that higher speed increases the possibility of fracture. Gambarini et al. [45] and Castelló-Escrivá et al. [46] have also confirmed that reciprocal movements extend the life of the NiTi file and indicated that greater resistance is affected by the speed and cutting angles [45], i.e. the type of NiTi alloy and the diameter of the canal curvature. A study by Neelakantan et al. [47] has tested the cyclic fatigue resistance of single files in double-bent "S" canals and found that files with reciprocal movements (Reciproc) showed significantly higher resistance compared to files with full rotation (One Shape).

The advantages of files with reciprocal movements have been confirmed in a research related to canal cleaning and shaping, cutting efficiency and retreatment [7, 9, 31, 32, 35, 36, 43].

Compared to those with full rotation, files with reciprocal movements showed higher resistance to cyclic fatigue, better cutting efficiency, shorter preparation time and slightly higher accumulation of debris in the canal [48]. In an *in vitro* study by Yilmaz et al. [49] (with an intracanal temperature of 35°C), the full-rotation file (Hy Flex Edm) has shown greater resistance to cyclic fatigue compared to files with reciprocal movements (Wave One, Reciproc Blue). Azim et al. [50] have compared several systems with single files and different dynamics of movement and pointed to high resistance to cyclic fatigue of XP Endo Shaper. In a study by Alcade et al. [38], it has been confirmed that the cyclic fatigue of the file with reciprocal movements is also affected by the type of NiTi alloy the file is made of.

Al Sudani et al. [51] have examined the effect of cutting angle on the efficiency of reciprocal NiTi files and pointed out that Wave One removes the least dentin, that files with a larger cone have a weaker cutting effect and poorer centering, that all files lead to transportation, and that files with a cutting angle of less than 30° have greater resistance to cyclic fatigue.

Files with a smaller cone are more efficient in shaping the "S" canal [52], and reciprocal files (Reciproc, Wave One) are less efficient in preserving the curve [53]. Saber et al. [54] confirmed that files with reciprocal movements better keep the curve, and files with full rotation provide faster instrumentation. A study by Elashiri et al. [55] has confirmed the effective canal shaping with full-rotation files, as well as with files with reciprocal movements, with slightly better centering and greater apical extrusion in both.

The results of the research of files with reciprocal movements showed that complete cleaning of the canal is an unachievable goal and that it mostly depends on: the design of the working part, the design of the tip, alloy and its thermal treatment or movement dynamics during the preparation [2, 7, 35, 36, 56–59].

The spectral segment of the canal is a special issue in cleaning [7, 56, 59–62]. Data on canal transportation (formation of a new path deviating from the original morphology) and extrusion (transfer of cut dentin, bacteria) during the preparation generally indicate similar findings of reciprocal and full-rotation files [7, 35, 63, 64]. In addition to efficient cutting, better centering is also an important benefit of reciprocal files because the file follows the path of less resistance and can be used without creating patency with hand files [35, 41]. Studies by Dhingra et al. [63] and Zan et al. [64] have shown that reciprocal movements show better centering, fewer dentin fissures and less transportation , or less extrusion of bacteria into periapical structures.

A meta-analysis of the influence of single reciprocal and two sets of rotary files have confirmed that all files lead

to apical extrusion and that the inflammatory response in the periapex does not depend on the number but on the design and kinematics of file movement [65]. In the preparation of bent canals, single NiTi files with full rotation and reciprocal are equally safe and efficient because they do not change the curvature and do not lead to the canal transportation [66, 67].

When preparing the mesiobuccal canal of the first upper molar, full-rotation files provide better centering and less transportation than files with reciprocal movements [68]. The research has also confirmed that files with reciprocal movements provide shorter treatment times and less debris compared to multi-file and full-rotation sets [69].

Several studies have confirmed the efficacy of files with reciprocal movements in the retreatment of inadequate endodontic healing and confirmed the possibility of their use in gutta-percha removal in both straight and curved canals [70–72]. Although data on the clinical use of single files with reciprocal movements are very scarce, available studies confirm their efficiency in biomechanical preparation, which lasts shorter [73], by reducing postoperative pain after endodontic intervention [73, 74], efficient apical preparation and reducing the number of bacteria [75, 76], i.e. efficient canal obturation with single gutta-percha point after the preparation with a single file [77].

A recent research has confirmed that the use of NiTi files with reciprocal movements is a safe and simple concept of canal preparation [78, 79]. In a retrospective clinical study, postgraduate students have prepared 2,056 canals without problems and with a small percentage of file fractures [78], and in another study files with reciprocal movements were a very safe and acceptable method for practical endodontic education [79].

*Single files with full rotation*

The use of NiTi files with full rotation is standard in endodontics despite frequent fractures due to possible screwing in the canal [2, 7, 9, 31, 35]. The fear of possible breakage is further increased in sets with more files, so dental technology has tried new concepts of preparation with a smaller number of files in a set (three) or with only one file [7, 9, 31–33].

It has also been confirmed that NiTi files make it difficult to reach all parts of the canal (30–50% of the wall surface remains intact), so using only one file significantly reduces the efficiency of chemomechanical procedures and makes it difficult to clean inaccessible parts (isthmus, ramification, additional canals, diverticula) [1–4, 7, 32]. Cleaning and shaping canals with a single file in full rotation significantly speeds up instrumentation, but also reduces the risk of fracture (one file instead of a set) [2, 9, 31, 32, 35]. Systems with single files, made of special NiTi alloy with special thermal treatment, have increased flexibility and resistance to cyclic fatigue and provided efficient cleaning and shaping of very complex canal systems (narrow, bent) with shorter processing time [31, 32, 35, 56, 57, 80–83]. Single files with full rotation are a completely new generation of files made of Max Wire alloy with a unique geometry of the working part (asymmetric cross section) and often with a shifted center of rotation that allows “wavy” movement and more efficient cutting with reduced possibility of screwing [9, 31, 32, 37]. The combination of flexibility and fracture resistance ensures efficient preparation of bent canals while preserving the original anatomy, with a reduced risk of transportation and perforation [32, 84–86].

Since 2011, dental technology has introduced a number of single files that use full rotation for canal preparation: Hy Flex EDM (Coltene, Whaledent, Alstatten, Switzerland),One File EDM (Coltene, Whaledent, Alstatten, Switzerland), Neoniti (Neolix, Sas, Chatres-La-Foret), One Shape (Micro Mega, Besancon, France), One Curve (Micro Mega, Besancon, France), F 360 (Komet, Brasseler, Lemgo, Germany), T File (India), Edge File (Edge Endo, Albuquerque, Nm), F6 Sky Taper (Komet, Milan, Italia), Pro Taper Next (Dentsply, Maillefer, Ballaigues, Switzerland), Revo S (Micromega).

The analysis of the functionality and efficiency of single files with full rotation has shown that in bent canals, the file in the area of curvature is exposed to repeated and alternating cycles of flexion and compression, which usually leads to fracture. It has been confirmed that NiTi rotary files can withstand several hundred of these cycles, but can break suddenly after a short rotation in the canal [32, 35, 87].

The data from the available literature confirm that the cyclic fatigue of the full rotation file is influenced by numerous factors, primarily: the angle and diameter of the canal curvature, file size and conicity, kinematics of movement, rotation speed, sterilization effects, or skills and experience of the endodontist [87–92].

In a study by Topçuoğlu et al. [87] on the resistance to cyclic fatigue of single files with full rotation, the One Curve (C Wire alloy) and Edge File (Fire-Wire alloy) systems have shown higher resistance than Hy Flex (CM alloy) in double-bent “S” canals and at different temperatures (20°C, 35°C).

The resistance of files with previously heat-treated alloy (Hy Flex EDM, Vortex Blue, Pro Taper Gold, One Curve) to cyclic fatigue has been tested in a similar study and it has confirmed that Hy Flex EDM files have the highest resistance to cyclic fatigue, followed by One Curve, and that the Pro Taper Gold and Vortex Blue files are less resistant [10, 93].

The influence of temperature [94, 95], thermal treatment and design on the cyclic fatigue of three generations of single files with full rotation indicated superior features of the One Curve system compared to One Shape New Generation at all tested temperatures [96]. In a study by La Rosa et al. [95], it has been shown that single files with full rotation have a decrease in resistance to cyclic fatigue at body temperature (35°C) while lower irrigation temperature (20°C) has no effect.

The examination of the efficacy of the preparation in the first lower molars showed that there were no significant differences in the occurrence of canal transportation between different rotational systems in the apical and middle third of the canal. The file with full rotation (Neoniti) led to transportation in the coronal third due to the pronounced conicity of this file of 8% [96].

The studies on the clinical application of single files with full rotation, although there have not been many, have indicated a significant simplification of instrumentation protocols, reduced risk of cross-contamination, increased exposure to high torsional stress and cyclic fatigue, and the need for mandatory file rejection after the treatment [97, 98].

The enviable clinical performance of the F6 Sky Taper file with full rotation has been confirmed in the effective endodontic therapy of the upper first and second molars. Biomechanical instrumentation is realized with the 6% conicity file, which preserves the original curvature of the canal even at very pronounced curves [99].

*Single files with eccentric rotational motion*

Some NiTi files rotate asymmetrically and eccentrically in the canal, which enables more efficient cleaning and shaping of canal systems with irregular morphology, because the file can reach inaccessible parts of the canal [7, 32].

XP Endo Shaper is a unique file of the new generation of NiTi files with a "snake-like" shape and unique working part geometry, which, thanks to its exceptional flexibility, contracts and expands during rotation and thus effectively adapts to canal system irregularities. It is made of the special Max Wire alloy (FKG) which provides greater flexibility and increased resistance to cyclic fatigue, and thus more efficient cleaning with a significantly accelerated canal processing procedure. Increased speed and "snake-like" shape provide increased "turbulence" of the irrigation solution, which keeps the dentinal debris in a liquid state and removes it more efficiently from the canal walls [7, 32, 100–103].

A research has confirmed that, after the preparation of the canal with XP Endo Shaper, less smear layer remains on the walls, primarily due to adequate dimensions of the apical preparation (30.04) and better effects of irrigation solution [100, 101]. There was no difference in cleaning efficiency of oval canals using the Tru Shape, Xp Endo Shaper and SAF files [100], while XPS showed exceptional resistance to cyclic fatigue [102, 103].

Compared to Reciproc Blue and HY Flex Edm files, this single file (XPS) caused significantly less apical extrusion of dentinal debris [103].

*Single files with transaxial movement*

In order to find a file that could meet all the requirements of optimal canal preparation, dental technology provided practitioners with a self-adjusting NiTi file with a completely different design and kinematics of movement in the canal.

The self-adjusting file (SAF) is hollow and flexible, and it adapts to the shape of the canal in three dimensions, while it moves transaxially during chemomechanical processing. This unusual file design allows both continuous and highly efficient canal irrigation because the hollow file is connected to a source for continuous irrigation via a silicone tube. Vibration and movement of the file during instrumentation lead to "turbulence" and additional activation of the solution, which significantly increases its solvent effect and the cleaning efficiency of the canal system [31, 104, 105]. SAF has high fracture resistance, preserves the original canal morphology and provides fast and efficient cleaning of all parts of the canal (4 minutes), thanks to continuous irrigation and always fresh solution [105].

A scanning electron microscope (SEM) analysis of the canal cleaning efficiency has shown that SAF, in combination with continuous irrigation, provides efficient cleaning in the apical zone of the canal [104]. The fact that the therapist has the ability to simultaneously and alternately use irrigants (NaOCl, EDTA) and choose the strength of the solution, gives this NiTi file high performance in cleaning even very complex (highly bent) canal systems [105].

## Conclusion

Great progress in endodontic treatment has been made with the introduction of NiTi rotary files. The special treatment of NiTi alloy and the specific design of the working part provide exceptional flexibility and efficiency of the files in different canal systems, but the frustrations of practitioners due to possible fractures are still present.

Canal preparation with a single file is a promising concept where a single file is used for complete cleaning and shaping of the canal. This significantly shortens the instrumentation (3–4 times), reduces file fatigue and possible cross-contamination, saves time for the patient and the therapist, and reduces the risk of fracture (only single file is used, not a set of files).

The concept of canal therapy with a single file includes files with full rotation, reciprocal movements, a combination of rotational and reciprocal, i.e. eccentric rotational and transaxial movements.

Files with reciprocal movements enable fast, simple, safe and less stressful instrumentation of most canals, with a significantly lower risk of fracture.

Full rotation of single files is a good choice for fast and safe canal treatment with respect to clinical protocol and with the use of a traditional endodontic motor.

Files with eccentric rotational movement achieve fast and efficient instrumentation, good adaptation of the file to canal irregularities, and provide greater resistance to cyclic fatigue by balanced contact with the walls.

Transaxial movement of the self-adjusting file, with always fresh and continuous irrigation, ensures fast and efficient cleaning of all parts of the canal system.

There is still no file that fully meets all the requirements of optimal canal preparation, regardless of the fact that canal therapy with a single file is more cost-effective and lasts shorter. Additional studies and strategies for improving new materials and techniques are needed, in order to ensure the efficiency and safety of endodontic files during canal treatment.

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