REVIEW ARTICLE

J Korean Dent Sci. 2022;15(2):112-120
https://doi.org/10.5856/JKDS.2022.15.2.112
pISSN 2005-4742 • eISSN 2713-7651

Selection of Nickel-Titanium Files according to the Clinical Procedure and Factors of File Fracture: A Narrative Review

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In this article, the contemporary root canal treatment procedure using nickel-titanium (NiTi) instruments was reviewed to understand the correlations between the properties of files and safety of the clinical usage. Literatures were reviewed according to the process of clinical procedure of the root canal preparation, mainly for shaping during orifice flaring, glide-path preparation, and main canal instrumentation. Considering the reasons for NiTi file fracture, clinically implacable issues and ideas were discussed to reduce the fracture risk and increase clinical efficiency of the NiTi file systems. Various kinds of NiTi file systems have their own characteristics and properties given from their geometries and heat treatments and so on. Proper selection and careful usage of the NiTi file systems may reduce the risk of file fracture and increase the efficiency of NiTi file systems. Understanding of the clinical implications from the mechanical properties and characteristics of the engine driven NiTi instruments may decrease the risk of NiTi file fractures and increase the success rate in root canal treatment.

Key Words: Coronal flaring; Dental instruments; Endodontics; Fatigue; Fractures; Root canal therapy

Introduction

Now the history of the commercially branded nickel-titanium (NiTi) files is over 30 years after the first manufacturing in 1988 using the NiTi alloy[1].

It is well known and agreed with that the NiTi files have much better performance than stainless-steel (SS) files in terms of shaping efficiency and effectiveness with fewer canal aberrations[2,3]. However, the fracture during usage sometimes makes a clinically challenging situation due to the difficulty of file retrieval and may decrease the success rate and cause a poor prognosis of the endodontically treated tooth[4,5].

There are two main modes of file fractures inside

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Received for publication November 28, 2022; Returned after revision December 7, 2022; Accepted for publication December 13, 2022

of the root canal. One is the cyclic fatigue fracture caused by repetitive stresses composed of compressive stress and tensile stress during rotation. Another one is torsional fracture which usually occurs when the file tip binds in the canal while the engine rotates the file shaft continuously[4]. Clinically, cyclic fatigue fracture seems to be more prevalent in curved root canals, while torsional fracture may happen even in a straight canal[4,6].

Although there are numerous articles published, the *in-vitro* and/or *ex-vivo* tests may have lower clinical relevance and the experimental conditions do not represent the 3-dimensional canal shape or conditions which related the stress generations during instrumentations.

Nevertheless, the clinical implications from the published studies and literatures still would help the proper file selections considering the clinical simulation conditions and application for better efficiency and effectiveness of root canal preparation[7-10]. According to the process of root canal shaping, the correlation between the mechanical properties and fracture resistances of the NiTi files based on the literatures are discussed (Fig. 1).

Files for Orifice Flaring

The purpose of orifice flaring is not only enlargement of the canal entrance but also gaining a straight-line access to middle and apical root canal lumen for better performance during root canal shaping procedure and consequently cleaning and obturation efficiency[11-13].

To get a straight-line access, the triangular (in 2-dimensional radiographs) dentin shelf area should be removed. Without this process, the rotary NiTI file may have higher stresses and higher risk of fatigue fracture. According to Pedullà et al.[11,13], an inclined insertion into the canals decreases the cyclic fatigue resistance of the NiTi instruments at all radii of curvatures tested. The synergistic effect of a small radius of curvature and access angulation of heat-treated instruments decreases their fatigue resistance[13]. Nonetheless, the martensite dominant Reciproc® Blue files (VDW, München, Germany) exhibited higher cyclic fatigue resistance than the original Reciproc® (VDW) when the access to the canal was straight or with a limited inclination[11].

Another file system One Flare (Micro-Mega, Besançon, France), which is a dedicated system for canal orifice flaring, was introduced with heat-treated NiTi

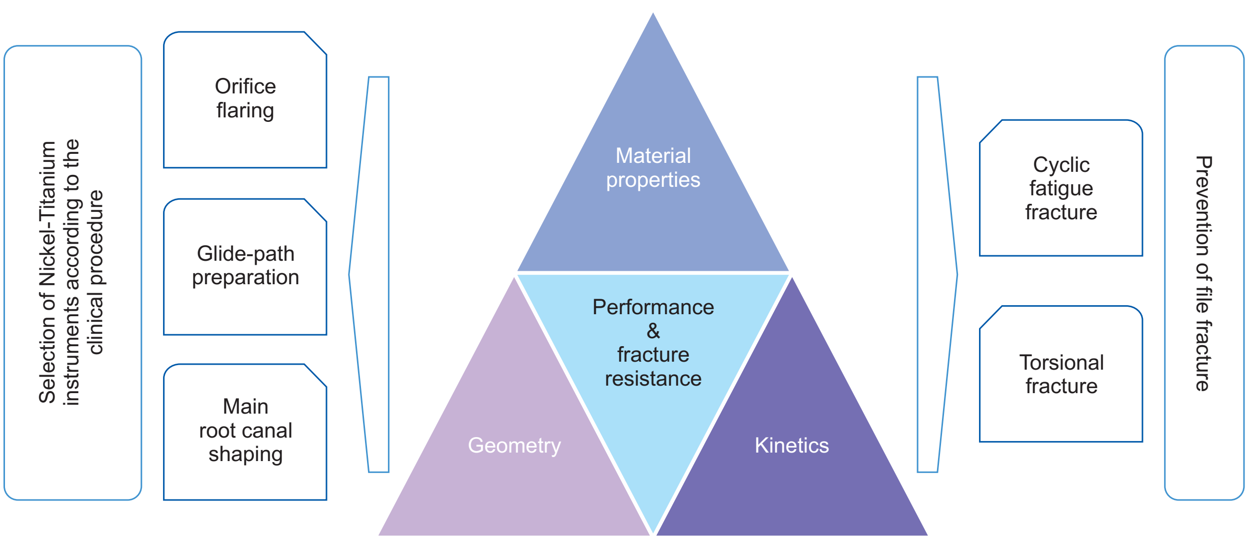

Fig. 1. Schematic contents of the review according to the clinical procedures of root canal shaping and factors of file fracture.

alloy, T-wire called by the manufacturer. Ataya et al.[12] reported the heat-treatment to T-wire increased the cyclic fatigue resistance of the flaring files without reduction of torsional strength. These properties made it possible that the heat-treated orifice flaring instruments would be used for gutta-percha removal during endodontic retreatment in a clinic setting.

Files for Glide-path Preparation

Glide-path establishment is another important process as an initial step before the main root canal shaping. Glide-path preparation is also a crucial step to minimize the NiTi file fracture. It was suggested to make a sufficient lumen with a smooth canal wall which may permit the super-loose fitting for the #10 K-file[14-16]. Some clinicians try to get the glide-path using a bigger sized #15 or #20 SS K-files. However, due to the stiffness of the SS files, it could result in a ledge formation or other types of canal aberrations[5,16]. Many kinds of NiTi files for glide-path preparation have been launched in the market and clinicians may choose one for better efficiency.

Among the engine driven rotary NiTi glide-path instrument system, PathFile system (Dentsply Sirona, Ballaigues, Switzerland) was introduced with 3 different sizes, #13, #16 and #19. They have 2% tapered shafts and thus are more flexible than other bigger tapered file systems despite being made of conventional NiTi alloy. While they have higher flexibility from the thin 2% taper, which might result in lower torsional resistance, they have as much torsional resistance as the 3% tapered glide-path file systems from their square cross-section[17,18]. On the other hand, the G file system (Micro-Mega) showed comparable torsional resistance although they might have lower torsional resistance due to the triangular cross-section[17-19]. Sung et al.[17] reported that the 3% taper of G file system was an optimal selection for file manufacturing along with triangular cross-section. Meanwhile, the G file system, which has an asymmetrical cross-section, has a snake movement or swaggering motion when it rotates, and these movements may give a greater chance to find a way to go apically.

For the development of One G file system (Micro-Mega) which is the first single file glide-path preparation system, the optimal pitch and heat treatment were studied[19-21]. Kwak et al.[20] reported that the torsional strength of the experimental (prototype) file was reduced by heat treatment and increased by the short pitch length. Al Raeesi et al.[21] also reported a shorter pitch distance increased cyclic fatigue resistance and torsional strength of the One G glide-path instruments. Thus, a non-heat-treated file with a shorter pitch length would be favorable as a rotary glide-path instrument.

In the meanwhile, the buckling resistance and/or stiffness is also an important property for the thin instrument like in glide-path files[22]. When the glide-path preparation instruments moved in the dynamic / rotation motion as in clinical situations, the buckling resistance of the heat-treated NiTi glide-path instruments was higher than in the static condition. Therefore, the heat-treated instruments may have better buckling resistance than the conventional NiTi instrument in clinical situations[22,23].

Glide-path preparation using NiTi rotary files has better clinical efficiency than the manual SS file. Especially, creating the glide-path using NiTi rotary files produced less debris extrusion than using manual SS files[14]. Ha et al.[14] reported the progressive taper design of ProGlider (Dentsply Sirona), the center-off cross-section of One G, and the alternative-pitch design of ScoutRace (FKG Dentaire, La Chaux-de-Fonds, Switzerland) may have increased efficiencies for debris removal with minimal extrusion during glide-path preparation.

Meanwhile, for the effective establishment of glide-path, Ha et al.[24] reported that the repetitive insertion of a glide-path preparation file up to 10 times at working length created an adequate lumen for subsequent apical shaping without apical transportation at D0 level. Abu-Tahun et al.[25] also reported that repetitive insertions of glide-path establishment files at the working length reduced stress generation during the shaping using NiTi instruments.

However, Kwak et al.[26] evaluated the effect of glide-path preparation and coronal preflaring on torque generation during canal preparation using rotary NiTi files. They reported that the summed torque was reduced by glide-path preparation and coronal preflaring, whereas the maximum torque was not reduced by the glide-path preparation. It will be advantageous to create a glide-path together with coronal preflaring to reduce the stress and reactive forces to the NiTi file and root dentin during root canal preparation.

The establishment of a larger glide-path before NiTi rotary instrumentation appeared to be appropriate for safely shaping the canal[27]. Ha and Park[27] recommended to establish a #20 glide-path with a NiTi file before using a ProTaper NiTi rotary instrument (Dentsply Sirona) system safely. Therefore, a glide-path of sufficient size ensures less torsional stress, thereby increasing the lifespan of the rotary instrument used for canal preparation.

Files for Main Root Canal Shaping

Once canal orifice flared and glide-path were properly gained, clinicians may select any kind of NiTi file systems for instrumentation of the remaining main part of root canals. Of course, NiTi files are much more efficient and better than the SS files[2-4]. Nonetheless, all the file systems have a potential risk of fracture during intracanal usage[4,5,8-10], manufacturers have tried to improve the mechanical properties or fracture resistance of NiTi instruments by developing specific cross-sectional designs, surface treatment and producing different thermomechanically treated NiTi alloys[28,29].

In terms of surface treatment, Kim et al.[30] reported that the instruments with abundant machining grooves seemed to have a higher risk of fatigue fracture. Especially the TF file (Kerr Endodontics, Gilbert, AZ, USA) manufactured in a twisted technique with R-phase NiTi alloy showed high fatigue fracture resistance. They reported the specific surface characteristics of TF resulted in irregular microcracks near the fracture area and it decreased the speed of crack propagation[30]. The heat-treated K3XF (Kerr Endodontics) instruments that used R-phase heat treatment technology also showed improved cyclic fatigue resistance without decline of torsional strength[31]. In this study, interestingly, K3XF showed numerous micropores with various diameters on the side aspect of the file flute. These micropores seem to limit crack propagation, probably acting as a stopper and/or distributor. On the side surface of K3XF near the torsional fracture area, the micropores were compressed and deformed elliptically, and thus these may absorb the stresses and increase torsional resistance[31].

CM-wire instruments showed higher flexibility and cyclic fatigue resistance than M-wire and conventional NiTi instruments[32]. Furthermore, in this study, Hyflex EDM (Coltène/Whaledent, Burgess Hill, UK) instruments, which are manufactured by using electro discharge machining (EDM), showed a higher fatigue resistance[32]. The electrical sparks cause typical crater-like surface changes during the EDM process[33]. This EDM manufacturing method does not produce machining grooves that are common by conventional manufacturing method, and this special surface treatment may increase fracture resistance.

Clinically, cyclic fatigue seems to be more prevalent in curved root canals, whereas torsional failure might happen even in a straight canal[4-8]. However, both failure modes probably occur simultaneously in clinical situations. Most studies of fracture simulation of NiTi files have been performed separately for cyclic fatigue or torsional failure test[6-8], but fracture simulation has been rarely studied to correlate these 2 modes of fracture. Kim et al.[9] reported that approximately 75% cyclic fatigue may reduce torsional resistance. Cheung et al.[10] reported that the torsional preloads within the super-elastic limit of the material may increase the cyclic fatigue resistance of NiTi rotary instruments. Oh et al.[34] reported that torsional preloading within the ultimate values could enhance the torsional strength of NiTi instruments and the total energy until fracture was maintained constantly, regardless of the alloy type. From these three studies[9,10,34], collectively, the cyclic fatigue (re-use after sterilization) should be carefully controlled much more than the torsional stress because in a clinic setting, clinicians can control or limit the torsional stress by using the dedicated endodontic motors in which the maximum torque can be limited with auto-reverse function.

Meanwhile, clinicians may choose the file with different file shaft lengths from 21 mm to 31 mm in markets. Isik et al.[35] reported that the instrument with a longer shaft may have higher maximum torsional strength or toughness than that with a shorter shaft. It was concluded again by Gambarini et al.[36] as the longer the instrument the higher the torsional resistance is and concluded that the shaft length should be considered as an important factor about torsional resistance.

Most NiTi file systems are used in the rotation mode with various speed limitations. In terms of rotation speed of the NiTi instruments, Ha et al.[37] reported that the torsional resistances of the rotary files were not affected by the rotational speed. Kitchens et al.[38] also reported that the number of rotation cycles to fracture, which means the cyclic fatigue resistance, was not related to the speed at which the files were operated.

Beside the rotation motion, other kinetics were also tried and applied to NiTi file systems for better clinical performance and fracture resistance as well. After the reciprocating motion suggested by Yared[39] using only one file of ProTaper F2, many kinds of reciprocating systems were introduced. Kim et al.[40] compared the initial two brands of reciprocating file systems, Reciproc and WaveOne (Dentsply Sirona), with conventional ProTaper file systems, and these reciprocating systems had higher fracture resistances in both of the cyclic and torsional modes. You et al.[41] reported the reciprocating motion might be an attractive alternative method to prevent procedural errors during root canal shaping. Through a systematic review, Ahn et al.[42] reported that instruments with reciprocating motion seemed to have better resistance to cyclic fatigue with less canal transportation tendency than the instruments with continuous rotating motion.

However, the reciprocating mode had been reported that it has some more vibration than the conventional rotation motion and patients may feel discomfort, especially in periodontally involved teeth with increased mobility[43]. However, most of the concerns about the reciprocating kinetics were proved that it is comparable to rotary motion and minimal risk of apical dentin crack formation and debris extrusion[42].

Beside the reciprocating mode, adaptive mode, and Optimum Torque Reverse (OTR) motion were also introduced for a better shaping performance of the NiTi files and fracture resistances. Kwak et al.[44] reported that the adaptive motion may reduce torque generation without increasing preparation time and NiTi files with a smaller cross-sectional area using adaptive movement would be helpful to reduce the potential risk of root dentin damage. Pedullà et al.[45] reported that the adaptive motion could improve the qualities of root canal shaping rather than the use of conventional NiTi instruments and/or continuous rotation in the coronal and middle thirds of the root canals, but not in the apical one. These findings suggest the use of adaptive motion with conventional NiTi files to improve centering ability without affecting other preparation qualities of root canals[45]. The reduction of torsional stress through adaptive motion may enhance the durability of instruments and reduce the potential risk of dentinal cracks[46]. Therefore, the use of adaptive motion would be useful to reduce the torsional stress of instrument and root dentin. OTR motion reduced both torque and screw-in force during the crown-down preparation phase of the crown-down technique and during the apical preparation phase of the single-length technique[47]. Pedullà et al.[48] reported that OTR motion significantly improved cyclic fatigue resistance of all instruments tested compared with continuous rotation motion. Kyaw et al.[49] also reported that continuous rotation and OTR motion performed similarly in shaping the canals.

As reviewed above, the torque generation during root canal shaping may be affected by not only anatomic features, such as the degree of calcification and curvature angle of the root canal, but also by the features of the NiTi file, such as the cross-sectional design, heat treatment, and the type of movement[30,50]. To reduce overall stresses for the root dentin as well as the instrument, again, the proper selection of the file systems and usage are highly important to reduce the risk of file fracture and to increase the effectiveness of the shaping procedures as well[51].

Conclusion

Based on the reviewed contents about the mechanical properties of NiTi files and fracture resistances, clinicians may use proper NiTi file systems considering their clinical implications. Clinicians may select the file systems for a dedicated usage during the root canal instrumentation such as orifice flaring, glide-path preparation, and main root canal shaping.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgement

This work was supported by a 2-year Research Grant from Pusan National University, Busan, South Korea.

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