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"Fracture Resistance Of Different Endodontic Niti Rotary File Systems: A Narrative Review"

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ABSTRACT
Nickel-Titanium (NiTi) rotary file systems have become a cornerstone in endodontic therapy, significantly enhancing the efficacy of root canal treatments. Despite their benefits, the risk of file fracture remains a notable concern. This narrative review aims to evaluate and compare the fracture resistance of several prominent NiTi rotary file systems, including Trunatomy, ProTaper Gold, 2Shape, HyFlex CM, and HyFlex EDM. By examining the impact of file design, heat treatment, and operational conditions on fracture resistance, this review synthesizes findings from key studies to provide a comprehensive understanding of how different systems perform under various clinical scenarios.
Clinicians can use this information to make informed decisions about file selection based on specific endodontic challenges and canal characteristics. The insights gained from this review are intended to guide best practices in endodontics and reduce the risk of file-related complications during root canal procedures.

Keywords: TruNatomy, ProTaper file system, Hyflex system, 2Shape, Cyclic Fatigue.

INTRODUCTION

Endodontics, the branch of dentistry focused on the diagnosis and treatment of dental pulp and periapical diseases, has seen significant advancements with the introduction of Nickel-Titanium (NiTi) rotary file systems. These systems have transformed root canal therapy by offering enhanced precision, efficiency, and safety compared to traditional hand files. The unique properties of NiTi, such as its superelasticity and shape memory effect, have enabled clinicians to effectively navigate the complex and often curved anatomy of root canals, improving overall treatment outcomes[1].
NiTi rotary files are prized for their flexibility, which allows them to maintain their shape while adapting to the curved paths of root canals. This flexibility, combined with the alloy's resistance to fracture and cyclic fatigue, has made NiTi files the preferred choice in modern endodontic practice. Despite these advantages, the risk of file fracture remains a significant challenge. Fractured files can complicate treatment, leading to additional procedures or potential failure to complete the endodontic therapy effectively[2].
The performance of NiTi rotary files is influenced by several factors, including their design, taper, heat treatment, and operational conditions. Advances in technology have led to the development of various file systems, each designed with specific features to enhance performance and reduce the risk of fracture. Among these, Trunatomy, ProTaper Gold, 2Shape, HyFlex CM, and HyFlex EDM are prominent systems, each incorporating unique design elements and heat treatments to improve durability and functionality[3,4].

- **Trunatomy** files are known for their innovative design and heat treatment, which aim to enhance flexibility and reduce the likelihood of fracture.
- **ProTaper Gold** files utilize a gold heat treatment that provides increased flexibility and resistance to cyclic fatigue compared to earlier versions.
- **2Shape** features a double-helix design and advanced heat treatment, which contribute to its high fracture resistance and effective performance in curved canals.

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• **HyFlex CM** files benefit from CM-Wire technology, offering superior flexibility and resistance to fracture, making them suitable for complex canal anatomies.
• **HyFlex EDM** files are manufactured using Electrical Discharge Machining (EDM), which enhances their mechanical properties and resistance to cyclic fatigue.

Understanding the fracture resistance of these NiTi rotary file systems is crucial for optimizing endodontic treatments and minimizing potential complications. This review aims to provide a detailed comparative analysis of these file systems based on recent studies, highlighting their strengths and limitations. By examining the influence of file design, heat treatment, and operational factors on their performance, this review seeks to offer valuable insights for clinicians to make informed decisions in their endodontic practice[2,5].

In summary, this review will delve into the specific characteristics of Trunatomy, ProTaper Gold, 2Shape, HyFlex CM, and HyFlex EDM systems, evaluating their fracture resistance and practical implications in clinical settings. This comprehensive analysis is intended to guide best practices in endodontics, enhance treatment outcomes, and address the challenges associated with file fracture during root canal procedures.

FACTORS INFLUENCING FRACTURE RESISTANCE

Nickel-Titanium (NiTi) rotary files are widely used in endodontic treatments due to their flexibility and cutting efficiency. However, their propensity to fracture is a significant concern. Understanding the factors that influence the fracture resistance of these systems is essential for optimizing their use and improving clinical outcomes[2,3,5]. The main factors influencing the fracture resistance of NiTi rotary file systems are categorized into material properties, design and geometry, operational factors, and clinical technique[6]. **(TABLE1)**

Table1 . FACTORS INFLUENCING FRACTURE RESISTANCE

Factor	Sub-factors	Explanation
Material Properties	Alloy Composition	Nickel-titanium alloy, heat treatment, controlled memory (CM) wire, electrical discharge machining (EDM)
Design and Geometry	Cross-Sectional Design	Triangular, asymmetrical
	Taper and Core Diameter	Variable taper, slim design
	Tip Design	Active cutting tip, non-cutting tip
Operational Factors	Speed and Torque	Optimal settings, avoidance of excessive force
	Irrigation	Adequate irrigation, debris removal
	Usage Time	Adherence to manufacturer recommendations
Clinical Technique	Operator Skill and Experience	Skill level, gentle handling
	Canal Anatomy	Curved canals, pre-bending capability
	Shaping Technique	Step-down technique, conservative shaping

1. Material Properties

a. Alloy Composition:

• Nickel-Titanium Alloy: The fundamental composition of NiTi alloys provides superelasticity and shape memory, essential for navigating curved root canals. However, the specific ratio and treatment of the alloy can affect its fracture resistance.
• Heat Treatment: Advanced heat treatment processes enhance the flexibility and fatigue resistance of NiTi files. Heat-treated alloys, such as those used in ProTaper Gold and WaveOne Gold, exhibit improved resistance to cyclic fatigue compared to non-treated alloys.

b. Controlled Memory (CM) Wire:

• CM Wire Technology: Files made from CM wire, like HyFlex CM, offer superior flexibility and fatigue resistance. CM wire allows the file to be pre-bent and retain its shape, reducing stress during use.

c. Electrical Discharge Machining (EDM):

• EDM Process: Used in files like HyFlex EDM, the EDM process enhances the material's hardness and resistance to cyclic fatigue, providing a smoother surface that reduces the risk of microcracks.

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2. Design and Geometry

a. Cross-Sectional Design:

- Triangular Cross-Section: Files with a triangular cross-section, such as ProTaper Gold, provide a balance between cutting efficiency and flexibility, reducing torsional stress.
- Asymmetrical Cross-Section: As seen in 2Shape files, asymmetrical designs enhance cutting efficiency while reducing the contact area with canal walls, minimizing torsional stress.

b. Taper and Core Diameter:

- Variable Taper: Variable taper designs, such as those in HyFlex CM and EDM, distribute stress along the file's length, reducing the risk of fracture.
- Slim Design: Systems like TruNatomy feature a slim design with a smaller core diameter, reducing torsional stress and enhancing fracture resistance.

c. Tip Design:

- Active Cutting Tip: Enhances cutting efficiency but may increase stress at the tip, potentially leading to fractures.
- Non-Cutting Tip: Provides a safer, less aggressive approach, reducing stress concentration at the tip.

3. Operational Factors

a. Speed and Torque:

- Optimal Speed and Torque Settings: Using the recommended speed and torque settings for each file system is crucial. Higher speeds and torque can increase cyclic fatigue and torsional stress, leading to fractures.

b. Irrigation:

- Effective Irrigation: Adequate irrigation during use helps to clear debris, reduce frictional heat, and lubricate the canal, reducing the risk of file fracture.

c. Usage Time:

- File Lifespan: Repeated use of NiTi files increases their exposure to cyclic fatigue. Adhering to manufacturer recommendations on the number of uses can prevent fractures.

4. Clinical Technique

a. Operator Skill and Experience:

- Skill Level: The clinician's skill and familiarity with the specific file system can significantly impact fracture resistance. Experienced operators are more adept at minimizing stress on the files.
- Gentle Handling: Avoiding excessive force and using gentle, controlled motions can reduce the risk of fractures.

b. Canal Anatomy:

- Curved Canals: Navigating severely curved or complex canals increases the stress on NiTi files. Choosing files with higher flexibility and fatigue resistance, such as those made from CM wire, can mitigate this risk.
- Pre-Bending Capability: The ability to pre-bend files, as seen in HyFlex CM, aids in better navigation of curved canals, reducing fracture risk.

c. Shaping Technique:

- Step-Down Technique: Using a step-down technique, where the canal is progressively enlarged with a sequence of files, can distribute stress and reduce the risk of fractures.
- Conservative Shaping: Techniques that preserve more dentin, such as those used with TruNatomy files, reduce stress on the files during instrumentation.

TRUNATOMY

TruNatomy files shape the canal into a continuously tapering design while preserving crucial tooth structure. This new system simplifies the process for dentists, ensuring safety and enhanced mechanical qualities. The design aspects of TruNatomy instruments have been highlighted to showcase their practical applicability and advantages[6,7].

Metallurgy and Design Features[6-9]

Unlike traditional rotating files with a 1.1 mm diameter, TruNatomy is crafted from a smaller wire blank of 0.8 mm diameter, enhancing its flexibility. Post-manufacturing heat treatment further boosts the superelastic characteristics of the files. Though the files may appear misshapen when removed from the canal, they adapt to the canal anatomy upon insertion. Additionally, the shorter handle of 9.5 mm aids in straight canal entry.

The TruNatomy system comprises a Glider and preparation tools, featuring the greatest taper at the apical areas, which reduces coronally to maintain uniformity. The system includes three shape files, an orifice modifier, and a glider. Operating at 500 rpm with a torque setting of 1.5 Ncm, these files, especially the Orifice Modifier, have unique features:

- Active Cutting Flutes: 7.5 mm flutes on a 16 mm shank.
- Triangular Cross-Section: Modified for better cutting efficiency.
- ISO Tip Size: 20 with a fixed 0.08 taper.

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These characteristics make the TruNatomy system more advantageous compared to other contemporary file systems, including:

- Coronal Maximum Flute Diameter: 0.8 mm, smaller than the SX instrument's 1.2 mm.
- Closer Cutting Flutes: Spaced at 7 mm, compared to 14.5 mm in other systems.
- Shorter Handle: 9.5 mm, compared to the SX instrument's 11 mm handle.

The TruNatomy Glider is available in lengths of 21, 25, and 31 mm, with a parallelogram-centered cross-section, 14 mm of active cutting flutes, an ISO 17 tip size, and an average taper of 0.02. Its regressive variable taper ensures the shank ends with a maximum flute diameter of 0.8 mm.

For optimal root canal shaping, the system includes three different tip-size instruments for preparation. The Prime instrument, with a red stopper, is applicable in nearly all cases, providing a versatile and efficient solution for endodontic treatment.

PROTAPER GOLD

The ProTaper Gold (PTG) NiTi rotary file system, developed by Dentsply Sirona, is a modern advancement in endodontic instruments designed to improve the efficiency and safety of root canal treatments. Building upon the success of the ProTaper Universal (PTU) system, ProTaper Gold incorporates innovative features that enhance performance, flexibility, and fracture resistance, making it a trusted choice among dental professionals worldwide[7,8,11].

Key Features of ProTaper Gold

1. **Advanced Metallurgy:**
   - PTG files are made from a unique heat-treated nickel-titanium alloy that enhances flexibility and cyclic fatigue resistance.
   - This proprietary heat treatment allows the files to maintain their shape and performance during challenging procedures, particularly in curved canals.

2. **Innovative Design and Geometry:**
   - ProTaper Gold files feature a convex triangular cross-section, which enhances cutting efficiency and reduces the risk of binding during use.
   - The files are designed with a continuously changing helical angle, improving their ability to remove debris and facilitating smoother canal shaping.

3. **Variable Taper:**
   - The PTG system includes a variable taper design that helps reduce stress concentrations during operation. This design allows for a gradual increase in taper from the tip to the coronal portion of the file, ensuring optimal performance and safety.

4. **Shorter Handle:**
   - PTG files come with a shorter handle (11 mm), which improves maneuverability and allows for better control during canal preparation.

5. **Presterilized and Single Use:**
   - PTG files are available presterilized and intended for single use, ensuring sterility and eliminating the risk of cross-contamination.

File Series

The ProTaper Gold system consists of a series of shaping and finishing files, each designed for specific functions:

- **Shaping Files (S1, S2):** Used for initial canal shaping, these files help establish the desired canal configuration.
- **Finishing Files (F1, F2, F3):** These files are used for final shaping and refinement of the canal, ensuring a smooth and clean preparation[9].

2SHAPE

The 2Shape NiTi rotary file system, developed by Micro-Mega, is a contemporary endodontic instrument designed to enhance the efficiency and safety of root canal procedures. This system features a simplified sequence and innovative design aimed at improving flexibility, cutting efficiency, and fracture resistance (**TABLE 2)**.

Table 2 . The 2Shape NiTi rotary file system

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Feature	Description
Simplified Two-File System	TS1 (initial shaping, 25/.04 taper), TS2 (final shaping, 25/.06 taper)
Advanced Metallurgy	Heat-treated NiTi alloy for flexibility and fatigue resistance
Unique Design and Geometry	Asymmetrical cross-section for improved cutting efficiency and reduced torsional stress
Variable Pitch	Reduces screwing effect and ensures smooth progression
Enhanced Safety Features	Non-cutting tip, recommended speed and torque settings

Feature & Description

1. Simplified Two-File System:

a. The 2Shape system employs a simplified approach with only two files, TS1 and TS2, which are used for shaping the root canal.
b. TS1: Used for initial shaping, it features a 25/.04 taper.
c. TS2: Used for final shaping, it has a 25/.06 taper.

2. Advanced Metallurgy:

a. The files are made from a heat-treated NiTi alloy, which enhances flexibility and resistance to cyclic fatigue.
b. The proprietary heat treatment process helps the files withstand the stresses encountered during canal preparation.

3. Unique Design and Geometry:

a. The 2Shape files have an asymmetrical cross-section that improves cutting efficiency and reduces torsional stress.
b. This design allows for better debris removal and reduces the risk of instrument separation.

4. Variable Pitch:

a. The files feature a variable pitch design, which helps in reducing the screwing effect and ensures smooth progression along the canal.

5. Enhanced Safety Features:

a. The tip of the 2Shape files is designed to be non-cutting, which reduces the risk of ledging and perforation.
b. The files are designed to be used at a recommended speed and torque to minimize the risk of fracture[9].

HYFLEX CM

The HyFlex CM (Controlled Memory) NiTi rotary file system, developed by Coltene, is a cutting-edge tool in endodontics designed to improve root canal treatment efficiency and safety. This system features innovative design and metallurgy that enhance flexibility, resistance to cyclic fatigue, and adaptability to various canal anatomies, making it a popular choice among dental practitioners **(TABLE 3)** [7,9,10].

TABLE 3 Features of HyFlex CM

Feature	Description
Controlled Memory Technology	Retains original shape after significant stress, minimizing fracture risk in curved canals.
Advanced Metallurgy	Proprietary NiTi alloy provides exceptional flexibility and fatigue resistance.
Variable Taper Design	Reduces stress during use, enhancing canal shaping ability without compromising integrity.
Asymmetrical Cross-Section	Enhances cutting efficiency and reduces binding and debris accumulation.
Ease of Use	User-friendly design allows for easy handling and manipulation.

Key Features of HyFlex CM

1. Controlled Memory Technology:

• The standout feature of HyFlex CM files is their Controlled Memory technology, which allows the files to retain their original shape even after being subjected to significant stress.
• This characteristic enables the files to efficiently navigate curved canals while minimizing the risk of fracture.

2. Advanced Metallurgy:

• HyFlex CM files are made from a proprietary NiTi alloy that provides exceptional flexibility and fatigue resistance.

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• The unique heat treatment process enhances the mechanical properties of the files, allowing them to withstand the rigors of canal preparation.

3. Variable Taper Design:
• The files feature a variable taper design that helps reduce stress during use, enhancing their ability to shape canals without compromising their integrity.
• This design allows for a gradual increase in taper from the tip to the coronal portion of the file, ensuring efficient cutting and debris removal.

4. Asymmetrical Cross-Section:
• The HyFlex CM files have an asymmetrical cross-section that enhances cutting efficiency while reducing the risk of binding and debris accumulation during use.

5. Ease of Use:
• The user-friendly design of the HyFlex CM files allows for easy handling and manipulation during canal preparation, providing clinicians with improved control and confidence.

File Series
The HyFlex CM system consists of several instruments, each designed for specific functions within the endodontic treatment process[10,11]:
• Shaping Files (HX 10, HX 20, HX 25): Used for initial canal shaping, these files establish the desired canal configuration.
• Finishing Files (HX 30, HX 35): These files refine and smooth the canal preparation, ensuring optimal cleaning and shaping outcomes[12,13].

HYFLEX EDM
The HyFlex EDM (Electrical Discharge Machining) NiTi rotary file system, developed by Coltene, represents a cutting-edge approach in endodontic instrumentation. This system utilizes advanced manufacturing techniques to produce files with unique characteristics that enhance flexibility, cutting efficiency, and durability. HyFlex EDM files are designed to improve the efficacy of root canal treatments while ensuring safety and ease of use for dental practitioners[14,15,16].

Key Features of HyFlex EDM
1. Electrical Discharge Machining Technology:
• The unique manufacturing process of HyFlex EDM files involves electrical discharge machining, which produces highly precise and uniform file geometries.
• This technique enhances the files' surface quality and reduces defects, resulting in improved performance during canal preparation.

2. Enhanced Flexibility:
• HyFlex EDM files are known for their exceptional flexibility, allowing them to navigate complex canal anatomies without risk of fracture or separation.
• The files can adapt to the canal shape, minimizing the chances of canal transportation and preserving the natural tooth structure.

3. Optimized Cutting Efficiency:
• The files feature a special cross-section that enhances cutting efficiency and promotes effective debris removal during use.
• Their design helps to reduce the risk of clogging and binding, facilitating smooth and effective canal shaping.

4. Variable Taper Design:
• HyFlex EDM files utilize a variable taper design that allows for efficient shaping of the canal while minimizing stress concentration during use.
• This design provides a gradual increase in taper from the tip to the coronal portion of the file, ensuring optimal performance.

5. Improved Durability:

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• The advanced manufacturing process contributes to the durability of HyFlex EDM files, allowing them to withstand the mechanical stresses encountered during root canal treatments.

File Series

The HyFlex EDM system consists of various instruments, each designed for specific tasks in the endodontic procedure:

• Shaping Files: Designed for initial canal shaping, these files create the desired canal configuration while providing flexibility and cutting efficiency.

• Finishing Files: These files refine and smooth the canal preparation, ensuring optimal cleaning and shaping outcomes[16].

CONCLUSION

The fracture resistance of NiTi rotary file systems is influenced by a complex interplay of material properties, design features, operational factors, and clinical techniques. Advances in alloy composition, heat treatment, and manufacturing processes have significantly enhanced the durability and performance of these files. Clinicians must carefully consider these factors when selecting and using NiTi rotary files to minimize the risk of fracture and ensure effective and safe endodontic treatment.

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