

Cyclic fatigue resistance of trunatomy and xp-endo rise nickel-titanium rotary instruments: An in-vitro study

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Aim: To compare the cyclic fatigue resistance (CFR) of TruNatomy (Dentsply Sirona) and XP-Endo Rise (FKG Dentaire) rotary nickel-titanium (NiTi) instruments under static and dynamic conditions at body temperature.

Materials and methods: Forty new NiTi rotary files were tested: 20 TruNatomy Prime (26/.04) and 20 XP-Endo Rise (25/.04). Tests were performed in artificial stainless-steel canals (60° curvature, 5-mm radius). The canals were submerged in distilled water maintained at $37 \pm 1^\circ\text{C}$ to simulate intracanal temperature. Each instrument was rotated using a torque-controlled motor according to manufacturer recommendations: TruNatomy at 500 rpm, 1.5 Ncm; XP-Endo Rise at 800 rpm, 1 Ncm. Time to fracture (s) was recorded, and the number of cycles to fracture (NCF) was calculated as: $\text{NCF} = (\text{rpm} \times \text{fracture}) / 60$

Fracture fragments were measured under a stereomicroscope, and selected samples examined under scanning electron microscopy (SEM) to confirm fatigue characteristics. Data were analyzed using Student's t-test ($p < 0.05$).

Results: Mean $\pm$ SD NCF values were; XP-Endo Rise: 1423 ± 210 cycles & TruNatomy Prime: 1095 ± 186 cycles. XP-Endo Rise demonstrated significantly higher cyclic fatigue resistance ($p = 0.002$). Fracture occurred at 3.1 ± 0.3 mm from the tip for TruNatomy and 2.9 ± 0.4 mm for XP-Endo Rise. SEM analysis revealed typical ductile fatigue striations and crack initiation zones in both groups, with smoother fracture surfaces in XP-Endo Rise files.

Conclusion: XP-Endo Rise exhibited greater cyclic fatigue resistance than TruNatomy under the tested conditions, likely due to its proprietary MaxWire alloy and design flexibility at body temperature. Both systems, however, showed high CFR suitable for clinical use in curved canals.

Keywords: cyclic fatigue, XP-Endo Rise, TruNatomy, nickel-titanium, rotary instruments, endodontics

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Introduction

Nickel–titanium (NiTi) rotary instruments have revolutionized endodontic practice by significantly enhancing the safety, efficiency, and precision of root canal shaping compared with traditional stainless-steel hand files.¹ Their superelasticity and shape memory allow clinicians to negotiate curved canals with minimal procedural errors such as ledging, transportation, or zipping. These properties stem from the unique metallurgical behavior of NiTi alloys, which can exist in both austenitic and martensitic crystalline phases, enabling controlled flexibility under clinical conditions.²

Despite these advantages, instrument separation due to cyclic fatigue remains a major clinical concern. During canal preparation—especially in curved canals—files undergo repeated cycles of tensile and compressive stress at the point of maximum curvature. Over time, these alternating stresses initiate microcracks that propagate until fracture occurs, often without any visible signs of deformation. Such fractures compromise canal cleanliness and may jeopardize treatment outcomes, particularly when the separated fragment is difficult or impossible to retrieve.³

To address this limitation, manufacturers have invested heavily in thermomechanical processing and innovative heat treatments that modify the microstructure of NiTi alloys, improving their flexibility, fatigue resistance, and control during instrumentation. These modifications alter transformation temperatures, enhance phase stability, and reduce the accumulation of internal stresses during repeated bending. Consequently, several proprietary heat-treated NiTi systems have been introduced, each claiming superior resistance to cyclic and torsional fatigue.⁴

TruNatomy files (Dentsply Sirona) represent one such innovation. Manufactured using a proprietary heat-treated NiTi alloy,

TruNatomy instruments feature a slim 0.8 mm shaft and regressive taper design, allowing for conservative canal enlargement while maintaining adequate strength. The system is intended to preserve pericervical dentin and minimize excessive dentin removal, consistent with the philosophy of minimally invasive endodontics. TruNatomy's off-centered parallelogram cross-section provides an efficient cutting action while reducing the screwing-in effect, resulting in smoother canal preparation and enhanced control.^{4,5}

XP-Endo Rise (FKG Dentaire), on the other hand, is a newer single-file system designed to simplify canal shaping while providing exceptional flexibility. It is fabricated from **MaxWire** alloy, a proprietary NiTi formulation characterized by a unique phase transformation at body temperature. At room temperature, the alloy remains in its martensitic phase, which is relatively soft and easily pre-bent. Upon heating to approximately 37 °C—the physiological intracanal temperature—it transforms into the austenitic phase, gaining shape memory and enhanced flexibility. This phase-dependent behavior allows XP-Endo Rise to adapt dynamically to the canal anatomy, reducing stress concentration and improving fatigue life.⁶

Cyclic fatigue resistance (CFR) is widely recognized as a critical indicator of the mechanical durability of NiTi rotary instruments. The test quantifies the number of stress cycles an instrument can endure before fracturing under controlled conditions that simulate the curvature of root canals. By evaluating CFR at body temperature, researchers can better approximate the performance of instruments in real clinical scenarios, since temperature affects the phase transformation and thus the flexibility of thermally treated alloys.⁷

In recent years, several investigations have highlighted that heat-treated

instruments demonstrate different fatigue behaviors depending on their alloy composition, manufacturing method, and operational parameters such as rotational speed and torque. Systems like XP-Endo Rise, with temperature-sensitive alloys, may perform differently at 37 °C compared to room temperature.⁸ Therefore, standardized in-vitro studies are necessary to quantify these differences objectively and determine their implications for clinical safety and efficiency.

The TruNatomy and XP-Endo Rise systems also differ in cross-sectional geometry, taper design, and kinematic motion—all of which influence their mechanical performance. The slender profile of TruNatomy facilitates conservative canal enlargement but may increase localized stress at points of curvature. Conversely, the triangular cross-section and adaptive alloy of XP-Endo Rise distribute stress more evenly, theoretically enhancing fatigue resistance.⁴⁻⁷ Understanding these geometric and metallurgical distinctions is essential for clinicians selecting instruments based on anatomical complexity and procedural goals.

Moreover, advances in manufacturing precision, surface finishing, and alloy heat treatment have collectively contributed to extending the fatigue life of NiTi instruments.⁵ Yet, despite these improvements, the unpredictability of instrument separation continues to challenge clinicians. Therefore, identifying which system offers superior cyclic fatigue resistance under clinically simulated conditions can provide meaningful guidance for safe and effective endodontic practice.

Several studies have compared earlier XP-Endo instruments such as the XP-Endo Shaper and XP-Endo Finisher with other rotary systems, reporting favorable flexibility and fatigue resistance. However, limited data exist specifically comparing XP-Endo Rise with other modern heat-treated systems like

TruNatomy. Given that both systems are marketed as next-generation instruments optimized for conservative preparation, a direct comparison under standardized testing conditions is both clinically relevant and scientifically valuable.^{7, 8} This study aims to compare their cyclic fatigue resistance under standardized conditions at body temperatures.

Materials and Methods

Sample size calculation

Using cyclic fatigue as the primary outcome, power analysis was used to calculate the total sample size. With a power of 80%, the effect size (w) of 0.46 was calculated at the alpha (α) level of 0.05 (5%) and beta (β) level of 0.20 (20%). The minimum estimated sample size was 40 samples. This analysis was made using the findings of an earlier study.⁴ Thus, there were 20 samples in each group, for a total sample size of 40. To calculate the sample size, G*Power Version 3.1.9.2 was used.

Selection of samples

- Total samples: 60 rotary instruments (30 TN, 30 XPR).
- Size & taper: TruNatomy Prime (26/.04) and XP-Endo Rise (25/.04).
- All instruments inspected under 20x magnification for defects or distortions before testing.

Artificial Canal Design

A custom-made stainless-steel block was fabricated with simulated root canals:

- 60° curvature and 5 mm radius (based on Schneider's method).⁸
 - Canal inner diameter: 1.5 mm.
 - The curvature located 5 mm from the tip to simulate mid-root curvature.
 - Continuous lubrication with synthetic oil to minimize friction and heat generation.⁹
- Testing Procedure:

Each file was mounted on its respective handpiece; TruNatomy driven by Endo motor (X-Smart IQ) at 500 rpm, torque 1.5 Ncm, and XP-Endo Rise driven at 800 rpm, torque 1 Ncm, as per manufacturer's instructions. 10

The files were introduced into the artificial canal until the tip reached the curvature. Rotation was maintained until fracture occurred. The time to fracture (in seconds) was recorded using a digital chronometer. Each test was repeated under identical conditions at room temperature ($23 \pm 1^\circ\text{C}$).

Measurement of Fragment Length
After fracture, the separated fragment length was measured with a digital caliper to confirm consistent positioning of the instrument inside the canal.

Statistical analysis

All data was collected, tabulated and statistically analyzed. By examining the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests, numerical data were checked for normality. Parametric (normal) distribution was seen in the data. Independent t-test used to compare mean time to fracture and fragment length between groups.

The significance level was set at $P \leq 0.05$. IBM® SPSS® Statistics Version 20 was used for statistical analysis.

Results

Results have shown that XP-Endo Rise had the highest cyclic fatigue resistance mean value. There was a statistically significant difference ($P\text{-value} = 0.002$) (Table 1, Figure 1).

Table 1: Cyclic Fatigue Resistance and Fracture Characteristics.

Parameter	TruNatomy	XP-Endo Rise	P-value
Mean NCF (cycles)	1095±186	1423±210	0.002*
Mean time to fracture (s)	131±22	107±16	
Fracture Length	3.1±0.3	2.9±0.4	

* Significant at $P \leq 0.05$, Different superscripts are statistically significantly different

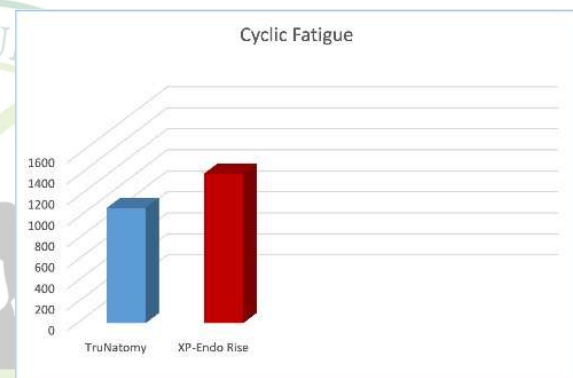


Figure 1: Cyclic Fatigue Resistance and Fracture characteristics of TruNatomy and XP-Endo Rise.

SEM observation

Both groups showed ductile fracture features with fatigue striations radiating from the crack initiation area. XP-Endo Rise samples revealed more homogeneous surfaces and fewer microvoids, indicating higher resistance to cyclic deformation (Figure 2 & 3).

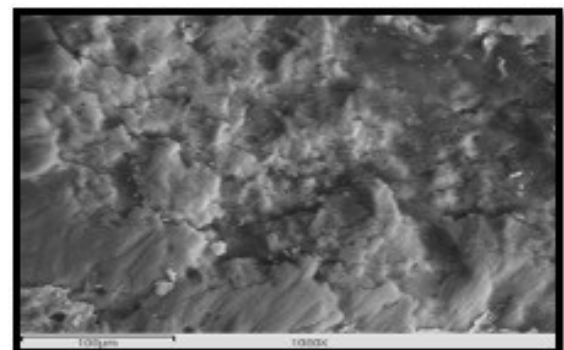


Figure 2: Scanning electron micrograph of the Fracture Surface of XP-Endo Rise (1000X)

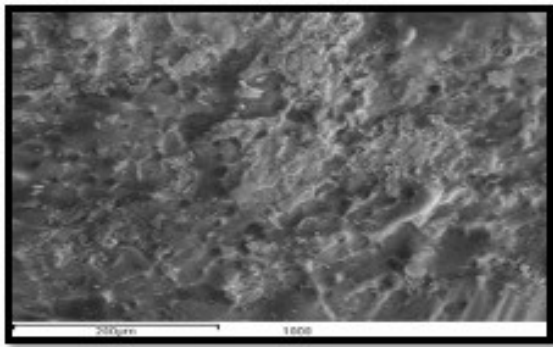


Figure 3: Scanning electron micrograph of the Fracture Surface of TruNatomy (1000X)

Discussion

The present study aimed to compare the cyclic fatigue resistance of two recently developed NiTi rotary systems—TruNatomy and XP-Endo Rise, which were both designed to preserve canal anatomy and reduce the risk of procedural errors.¹¹ The rationale behind this comparison lies in the increasing clinical emphasis on minimally invasive endodontics and the need for instruments that can maintain flexibility while resisting fatigue failure during canal preparation, especially in highly curved canals.²

Cyclic fatigue fracture remains a major concern in clinical endodontics because it can occur unpredictably, even without visible signs of deformation. Thus, identifying which system exhibits superior fatigue resistance helps clinicians choose safer and more durable instruments. By comparing these systems under standardized conditions, this research provides valuable data to bridge the gap between manufacturer claims and real-world mechanical performance.²

The experimental design of this study was intended to minimize confounding variables and replicate, as closely as possible, the clinical stresses experienced by instruments in curved canals.

Both groups used comparable tip sizes and tapers (TN 26/.04 vs. XPR 25/.04). This was done to ensure that any difference

in fatigue resistance was primarily due to metallurgical and geometric factors rather than size or taper variations, which are known to influence cyclic fatigue behavior.¹²

The standardized stainless-steel canal (60° curvature, 5 mm radius) represents a severe but clinically relevant challenge for rotary files. Using a fixed curvature and radius ensured that each file experienced the same level of cyclic stress. Although stainless-steel canals cannot fully reproduce the elasticity of dentin, they provide excellent reproducibility and control over experimental conditions essential for mechanical comparisons.⁸

Each instrument was operated according to manufacturer recommendations—TruNatomy at 500 rpm, 1.5 Ncm torque; XP-Endo Rise at 800 rpm, 1 Ncm torque. This was necessary to reflect realistic clinical use. It is noteworthy that although XPR operates at higher speeds, it still exhibited greater resistance to cyclic fatigue. This finding underscores that speed alone does not dictate failure behavior; rather, the alloy composition and phase transformation play more decisive roles.¹³

The tests were conducted at room temperature (23°C), which might not fully represent intraoral conditions (~35°C). Some studies have shown that heat-treated NiTi files exhibit reduced fatigue resistance at body temperature due to phase transformation behavior. Nevertheless, testing at room temperature offers consistent control and facilitates comparison with previous literature.¹⁴

Continuous lubrication was applied to reduce heat buildup and surface friction between the file and the canal walls, as excessive friction could lead to premature failure unrelated to true cyclic fatigue. The consistency of fragment lengths between both groups also confirmed that the files were inserted to equal depths and exposed to identical bending stresses.^{9, 15}

The findings revealed that XP-Endo Rise exhibited significantly higher cyclic fatigue resistance than TruNatomy (mean 623.9 s vs. 415.3 s; $p < 0.001$). This result aligns with the mechanical properties expected from their respective manufacturing processes and geometrical designs.⁴

The superior performance of XP-Endo Rise can be attributed to its MaxWire alloy, which undergoes a martensitic–austenitic transformation depending on temperature and stress. This phase transformation allows the instrument to adapt dynamically to canal anatomy and reduce stress accumulation at the point of maximum curvature.^{13, 16}

TruNatomy, although also heat-treated, is produced from a Controlled Memory (CM) NiTi alloy that offers flexibility but less phase adaptability.⁷ This metallurgical distinction likely explains the longer fatigue life of XPR observed in the present study.

XP-Endo Rise has a slim, triangular cross-section that minimizes metal mass and allows better stress distribution along the file. In contrast, TruNatomy's off-centered parallelogram cross-section, while designed to reduce screwing-in effects and dentin removal, may localize stress at certain points during cyclic rotation, increasing the likelihood of fracture under repeated loading.¹¹

Although higher rotational speeds theoretically increase the number of stress cycles per unit time and could lead to faster failure, XP-Endo Rise's superior alloy flexibility compensates for this, leading to a paradoxical improvement in overall fatigue life. This finding supports previous studies that suggest alloy properties are more critical than rotational speed in determining fatigue resistance.^{7, 13}

The non-significant difference in fragment lengths between the two groups indicates that both instruments fractured at a

consistent curvature point within the artificial canal. This supports the validity of the test model and confirms that variations in fracture time reflect material performance rather than inconsistencies in canal positioning.

The increased cyclic fatigue resistance of XP-Endo Rise suggests a lower risk of file separation in curved canals, which may enhance clinical safety and efficiency. However, TruNatomy's conservative shaping philosophy and minimal dentin removal could still make it advantageous in narrow canals where canal preservation outweighs speed or fatigue resistance. Therefore, the choice between systems may depend on the clinical scenario rather than mechanical strength alone.^{14, 19-21}

Despite its controlled setup, this in-vitro study cannot fully replicate the complex conditions within the root canal system, such as torsional loads, temperature fluctuations, and variable canal anatomy. Future research should employ dynamic cyclic fatigue tests at body temperature, possibly using micro-CT analysis to correlate design parameters with fatigue patterns. Additionally, combining cyclic fatigue testing with torsional resistance evaluation could offer a more comprehensive understanding of instrument performance.

In summary, the results confirm the study's aim by demonstrating that the metallurgical composition, cross-sectional geometry, and manufacturing design have significant influence on cyclic fatigue resistance. The XP-Endo Rise system, with its adaptive alloy and streamlined design, provides enhanced durability compared to TruNatomy. These insights are valuable for clinicians seeking to balance efficiency, safety, and canal preservation during root canal preparation.

Conclusion

The geometrical design features and mode of manufacturing of nickel-titanium rotary files directly affect their

cyclic fatigue resistance. XP-Endo Rise files showed superior resistance compared to TruNatomy, this could be due to its MaxWire alloy and triangular cross-section. Both systems are suitable for curved canals, with XP-Endo Rise offering enhanced durability.

Ethics approval

The study protocol was reviewed and approved by the Ethical Committee of October 6 University, Faculty of Dentistry, under approval number [RECO6U/37-2024].

Competing interests

The authors declare that they have no competing interests.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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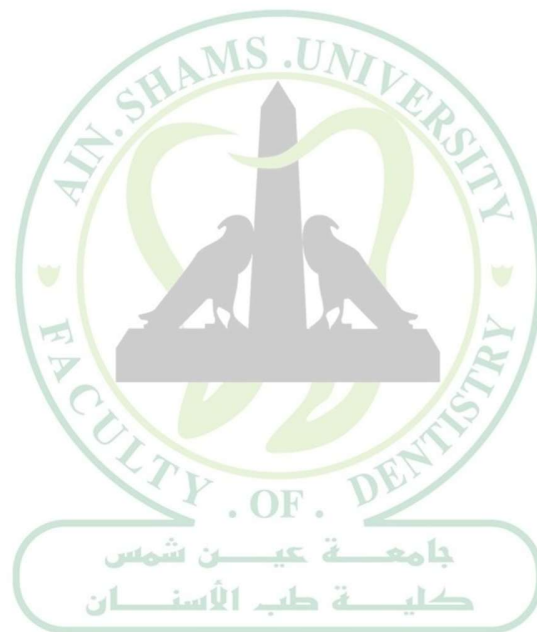
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