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Original Research Article

Assessment of fracture behaviour in heat-treated NiTi rotary endodontic files following multiple uses: An in-vitro study

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Abstract

Aim and Objectives: Evaluate the fracture behaviour and warning signs (e.g., deformation) of two heat-treated nickel–titanium rotary files—EdgeEndo and TorqueEndo—during repeated simulated clinical use, and determine whether fracture risk differs between them.
Introduction: Nickel-titanium (NiTi) rotary endodontic files have revolutionized root canal therapy due to their superior flexibility and shape memory. However, despite advancements in heat treatment technologies that enhance their mechanical properties, these instruments remain susceptible to fracture, especially after repeated clinical use. Understanding the fracture behaviour of heat-treated NiTi files is essential for improving their safety and durability. This in-vitro study aims to assess how multiple uses influence the fracture resistance and failure modes of these instruments under simulated clinical conditions.
Materials and Methods: This in-vitro pilot study used 16 extracted maxillary first premolars with ~5° curvature (n = 8 per file type). Each file was used up to 16 times or until fracture, following crown-down preparation, standard irrigation, and sterilization protocol. Files were inspected at 10× magnification after each use for permanent deformation or micro cracks. Fisher's Exact Test was applied for statistical analysis due to the small sample size ($\alpha = 0.05$).
Results: Edge End**o:** 5 fractures; 4 preceded by bending, Torque Endo**:** 6 fractures; all preceded by deformation. No significant difference in fracture frequency was found ($p = 0.64$). Warning signs typically appeared after approximately six uses.
Conclusion: Both file systems displayed visible warning signs—primarily bending—prior to fracture. No conclusive difference in fracture risk was observed, although this pilot study is limited by size, canal allocation bias, and its in-vitro setup. These findings support further large-scale, randomized studies with microstructural documentation.

Keywords: Cyclic fatigue resistance, File separation, Heat treatment, Microstructural analysis

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1. Introduction

Nickel–titanium (Ni–Ti) rotary instruments have enabled more efficient root canal shaping due to their flexibility and fatigue resistance.[1] Heat-treated variants (e.g., M-Wire, gold heat treatments) offer further performance improvements. Yet, instrument fracture remains a clinical challenge, often occurring without forewarning.[2] Early identification of warning signs such as bending, unwinding, or micro crack formation—can enhance patient safety.[3] This study examines these indicators in two heat-treated file systems (EdgeEndo and TorqueEndo) during repeated use in curved canals. It also explores whether anatomical differences (buccal vs. palatal) affect fracture behaviour.

2. Materials and Methods

2.1. Study design

A controlled in-vitro pilot study aimed at evaluating fracture warning signs in two Ni–Ti file systems under simulated clinical conditions.

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2.2. Sample size and rationale

A total of 16 files (8 per group) were selected for feasibility. No pre-study power analysis was conducted; statistical comparisons used Fisher's Exact Test due to low sample size.

2.3. Specimen selection

Sixteen freshly extracted human maxillary first premolars with ~5° curvature were selected (confirmed by Schneider's method). Teeth with root fractures, resorption, or calcification were excluded. Samples were stored in 0.1% thymol solution to maintain integrity.

2.4. Canal assignment

Group A – EdgeEndo**:** palatal canal

Group B – TorqueEndo**:** buccal canal

This non-randomized allocation introduces anatomical differences that may influence fatigue testing and are acknowledged as a limitation.

2.5. Instrumentation protocol

1. Glide path established with #15 K-file.
2. Working length determined radio graphically (1mm short of the apex).
3. Crown-down technique using each file up to working length at manufacturer-specified speed/torque.
4. Irrigation: 2 ml of 2.5% NaOCl per use.
5. Sterilization: Autoclaved at 121 °C/15 psi/15 min between uses.

2.6. Evaluation and failure criteria

Files inspected under 10× stereomicroscope. Permanent deformation (bending, unwinding) or fractures were recorded. Files were discarded after fracture or 16 uses.

2.7. Statistical analysis

Frequencies and percentages calculated for each failure type. Fisher's Exact Test used given low event counts ($\alpha = 0.05$).

3. Results

3.1. Clinical relevance to study

Pre-fracture warning signs: The bent/twisted flutes and micro cracks you observed after the 6th use in Edge Endo and Torque Endo files are consistent with early-stage failure mechanisms seen in SEM. These signs are typically followed by either torsional or fatigue-induced fractures.

Fracture morphology: Post-microscopic images of fractured flutes would likely reveal ductile dimples and striations, confirming the type of mechanical failure either cyclic fatigue (curved canals) or torsional overload (stressed, bound files in tight canals). Deformation was typically noted around the 6th use in both groups. Fracture frequency did not differ significantly ($p = 0.64$). (**Table 1**)

Table 1: Defect incidence (n = 8 per group)

Defect Type	Edge endo	Torque endo	P-value (Fisher's)
No deformation	1 (12.5%)	3 (37.5%)	—
Bending/deformation	4 (50%)	4 (50%)	—
Fracture	5 (62.5%)	6 (75%)	0.64
No deformation	1 (12.5%)	3 (37.5%)	—

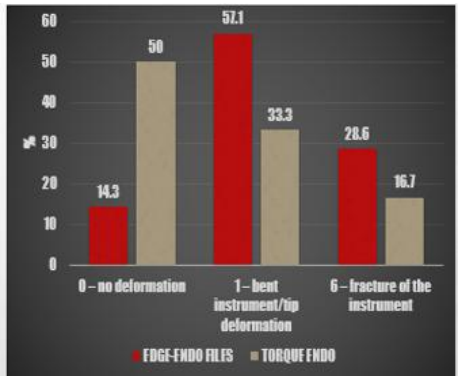

Figure 1: Bar diagram of incidence of fracture of two files

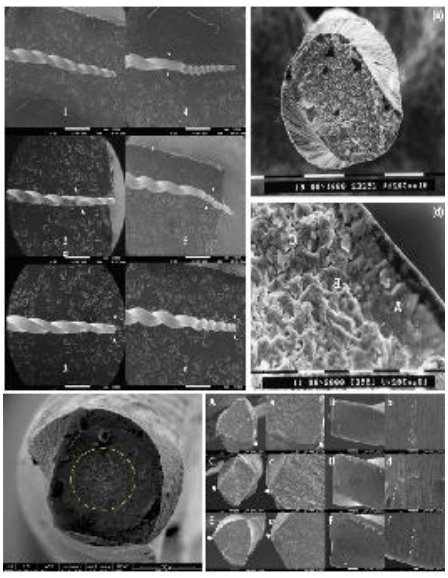

Figure 2: SEM images of various types of defects noticed

4. Discussion

Warning Signs: Bending and permanent deformation preceded fractures, aligning with prior research.

Brand Comparison: No significant difference in fracture occurrence; small sample delivers low power.

Anatomical Bias: Using different canal types possibly affected fatigue—should be randomized in future studies.

Material Properties: EdgeEndo's heat-treated, electropolished surface might resist fatigue differently than TorqueEndo.

Sterilization Effects: Multiple autoclave cycles may reduce fatigue resistance.

Clinical Simulation Limitations: The static in-vitro setting lacks physiological factors like periodontal ligament compliance.

Visual Documentation: No micrographs included; future work should incorporate image-based evidence.

Statistical Considerations: Fisher's test more suitable for small samples; future studies should include formal sample size planning.

Nickel-Titanium (NiTi) rotary instruments have brought significant advancements in root canal preparation due to their low modulus of elasticity, which allows them to navigate curved canals with continuous rotation. Despite these advantages, instrument separation continues to pose a clinical challenge. This in vitro study aimed to assess the progression of damage leading up to fracture in heat-treated NiTi rotary files. Files were examined under a stereomicroscope (10×) after each use to detect early signs of damage. Only instruments without manufacturing defects were included to eliminate confounding factors.

Although the stated aim focused on fracture, the results primarily discuss intermediate signs such as bending and deformation. These observations are still relevant as precursors to breakage and may provide early clinical warning signs, but disconnect between aim and measured outcomes should be addressed in future designs.

5. Defect Types and Frequency

Minor defects such as bending, stretching of the flutes, and dented cutting edges were classified based on a standardized scoring system. Severe defects included reverse twisting, length alteration, and fracture.[4] The most frequent defect observed was tip deformation, especially after the sixth use (**Table 1**)—an indicator of accumulating stress before separation-which is depicted in the bar diagram (**Figure 1**).

However, there is a discrepancy between the data presented and conclusions drawn. The abstract claims Edge Endo showed more defects, yet the results table shows higher rates of "no deformation" in Torque Endo, suggesting better performance. This contradiction needs resolution—either through clearer data reporting or reinterpretation of findings.[5,6]

6. Metallurgical and Clinical Context

The performance differences may be attributable to metallurgical processing. Heat treatment alters the phase transition behaviour of NiTi alloys, enhancing fatigue resistance. Edge Endo's superior performance in some aspects could be due to its cryogenic tempering and smoother electro polished surface, which are known to delay crack propagation. Nonetheless, repeated autoclaving and canal curvature significantly influence instrument fatigue, as supported by prior studies.[7,8]

In conclusion, while this study highlights signs of file fatigue that precede fracture, several design limitation including small sample size, statistical inconsistency, and anatomical bias—limit the generalizability of the findings. Future studies should incorporate larger, randomized samples, blind evaluations, and uniform canal assignment. Incorporating SEM images (**Figure 2**) or high-resolution stereo micrographs will further support structural observations. Clinicians should remain vigilant for early signs of file deformation and adjust instrument use accordingly to reduce the risk of unexpected separation.[9,10]

7. Recommendations for Future Research

Conduct larger, randomized trials with pre-planned sample sizes. Randomize canal assignment to eliminate anatomical biases. Include microstructural imaging (e.g., SEM) to document deformation stages. Implement blinded assessment to mitigate evaluator bias. Use dynamic fatigue simulations for more realistic testing. Evaluate sterilization cycles and their impact on file life.

8. Conclusion

EdgeEndo and TorqueEndo files show detectable warning signs especially bending before fracture. No significant difference in fracture susceptibility was found in this pilot. Given canal allocation bias and in-vitro constraints, results are preliminary. Clinically, inspecting files after ~6 uses is recommended to reduce fracture risk. Ongoing research with improved methodology is warranted.

9. Conflict of Interest

None.

10. Source of Funding

None.

11. Ethical approval

This study was approved by institute ethical approval committee with ref. no. IEC/IRB No. KMCTDC/IEC/2023/02. All specimens anonymised; no human or patient identifiers involved.

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