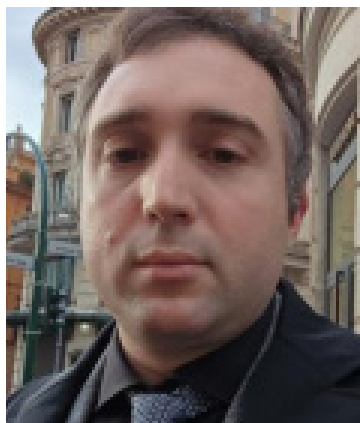

Editorial



Present and future of nickel-titanium in endodontics

In recent decades, novel materials and techniques have been proposed to enhance the quality and outcomes of endodontic procedures. Among these innovations, nickel-titanium (NiTi) alloys have transformed endodontic instrumentation by combining superelasticity, shape-memory behavior, and biocompatibility, which together enable safer shaping of curved canals and shorter procedures compared with stainless-steel files (3,8,11). Yet important limitations persist: instrument separation driven by cyclic fatigue or torsional overload, variability of performance in real clinical conditions, and the perennial need to balance cutting efficiency, safety, and durability (5,9).

Much of the most substantial progress concerns the refinement of alloy processing, cross-sectional geometry, mass distribution, and kinematics. Experimental and clinical research—spanning imaging, canal morphology, and in vivo torque/temperature monitoring—has been pivotal for understanding how instruments actually perform and fail under realistic loads, thereby informing

safer and more effective designs (1–11).

Current evidence converges on several points.

- Thermal treatment (e.g., proprietary heat-treatments that modulate phase transformation temperatures) increases flexibility, extends fatigue life, and reduces brittleness; modern lines may even vary heat-treatment across files in the same sequence (11).
- Cross-sectional design and reduced metal mass strongly influence flexural fatigue, torsional resistance, and failure modes; unconventional, reduced-core or coreless designs (e.g., scrubbing concepts) open alternative shaping strategies but may trade off cutting dynamics or debris evacuation (3).
- Clinical use alters mechanical properties, so understanding how repeated usage and sterilization affect fatigue is essential for both safety and cost-effectiveness (1). Finally, operating parameters—speed, torque, and motion kinematics—critically shape outcomes and should be reported and controlled with rigor to allow meaningful comparisons across studies and devices (5,6).

Future Directions: Challenges & Promising Trends

Based on the current evidence, some of the future directions and requirements include:

1. Optimizing geometric designs for both fatigue resistance and cutting efficiency is essential. Innovative designs and reduced metal mass (including the absence of a core) may enhance fatigue life; however, they might adversely impact cutting performance, debris removal, or torsional strength. Future designs must therefore carefully balance these considerations. Additionally, a more precise assessment of cutting efficiency and debris removal will be required (3,4).
2. Enhanced thermal and metallurgical control, coupled with a better understanding of phase transformations (austenite/martensite), heat treatments, and potentially new alloying or processing methods (such as cryogenic or innovative surface treatments), will persist in advancing fatigue life, strength, flexibility, and safety (11).
3. Functionalized surfaces and coatings in nanoengineering have garnered significant attention. To date, most research has focused on geometry, design, and torque/fatigue. However, the broader field also encompasses surface functionalization, including coatings and modifications aimed at reducing friction, wear, and microcracks. These represent promising areas for future development (8).
4. Improved in vitro–in vivo correlation and the introduction of new metrics, such as the torque range, provide more clinically relevant parameters than static torsional failure. The integration of in vivo measurements—including torque, temperature, and usage cycles—with in vitro testing will facilitate the development and evaluation of instruments under more realistic stress conditions (5,6,9).
5. Instrumentation, kinematics, and motion—reciprocation, adaptive motions, and novel motion protocols—may enhance fatigue resistance or ensure safer operation. The development of new motors and classification systems contributes by providing clearer comparative data (5).
6. Single-file systems raise concerns regarding cost and reusability. As these systems gain popularity, it becomes essential to evaluate how reuse and sterilization procedures impact their strength, ensuring safety and cost-effectiveness (1,3).
7. Regulatory Standards and Testing Protocols

There remains variability in the measurement of fatigue, torsional stress, torsion under bending, and related factors. Numerous publications emphasize the importance of standardizing test canals, artificial curvature, temperature control,

and failure endpoints. Achieving future consensus on testing protocols will facilitate more effective comparisons across studies and assist manufacturers in aligning with reproducible safety standards (9,11).

Conclusion

In summary, Nickel-Titanium continues to be the primary material for contemporary endodontic canal shaping, owing to its flexibility, strength, and ability to mitigate procedural risks. Recent scholarly contributions have substantially enhanced the understanding of how design elements (such as geometry and cross-section), usage conditions (including new versus used instruments), operational parameters (such as torque and motion), and thermal treatments collectively influence performance and safety. Advancements in areas such as surface functionalization, innovative kinematic techniques, and the development of more realistic testing metrics are anticipated to further elevate the reliability, durability, and clinical safety of NiTi instruments.

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