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SHORT COMMUNICATION:

CONTEMPORARY NITI ROTARY INSTRUMENTATION AND THE INTEGRITY OF ROOT DENTIN: DOES CUTTING-EDGE SHAPING CREATE FUTURE FRACTURES? — A NARRATIVE REVIEW

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ABSTRACT

Nickel-titanium (NiTi) rotary instruments have transformed endodontics by enabling efficient, predictable root canal shaping. However, concerns persist about their impact on dentin integrity, particularly microcrack formation and long-term fracture risks. This narrative review evaluates evidence on contemporary NiTi systems—including thermally treated alloys and reciprocating files—and their effects on dentin structural integrity. While advanced designs reduce torsional stress, in vitro studies report conflicting outcomes on microcrack induction. Clinicians must balance shaping efficiency with preservation of dentin strength. Further in vivo studies are needed to correlate laboratory findings with clinical outcomes.

Keywords: Nickel-titanium, rotary instrumentation, dentin microcracks, root fracture, endodontics.

INTRODUCTION

Root canal preparation is a critical step in endodontic treatment, aiming to eliminate infected tissue while preserving dentin structure. The introduction of nickel-titanium (NiTi) rotary instruments in the 1990s marked a paradigm shift from stainless steel files, offering superior flexibility and resistance to torsional fracture [1]. Contemporary NiTi systems now incorporate thermally treated alloys (e.g., CM Wire, Gold

Wire) and adaptive motions (reciprocation, continuous rotation), promising enhanced safety and efficiency [2].

Despite these advancements, studies suggest that rotary instrumentation may induce microcracks in root dentin, potentially predisposing teeth to vertical root fractures (VRFs) [3].

This review examines:

- The evolution of NiTi systems and their biomechanical impact on dentin.
- Evidence linking instrumentation techniques to dentinal defects.
- Strategies to minimize structural compromise during shaping.

Evolution of NiTi Rotary Systems:

First- and Second-Generation Files

Early NiTi instruments (e.g., ProFile, LightSpeed) improved upon stainless steel files but had limitations in cyclic fatigue resistance and taper variability [4]. Second-generation systems like ProTaper Universal introduced progressive tapers, reducing canal transportation but increasing torsional stress [5].

Third-Generation Innovations:

Modern systems leverage metallurgical advancements:

Thermally treated alloys (e.g., HyFlex CM, EdgeSequel): Exhibit controlled memory and enhanced flexibility, reducing apical stress [6].

Reciprocating motion files (e.g., WaveOne Gold, Reciproc): Single-file systems that minimize cyclic fatigue via reverse cutting motions [7].

Offset design instruments (e.g., TRUShape): Asymmetric tapers preserve pericervical dentin [8].

Mechanisms of Dentin Damage During Instrumentation:

Microcrack Formation:

Rotary files generate frictional heat and shear stress, leading to microcracks, particularly in the apical third.[9] Adorno et al demonstrated that crack propagation correlates with file kinematics (rotation vs. reciprocation) and taper size [10].

Dentin Removal and Structural Weakening:

Excessive taper preparation (e.g., >6%) reduces radicular dentin thickness by up to 30%, compromising fracture resistance [11]. Bier et al [12] found that ProTaper F2 instruments caused deeper cracks than Mtwo files due to aggressive taper design.

Cyclic Fatigue and Torsional Stress

File fracture and dentin defects are linked to:

High RPM (>300): Increases screw-in forces [13].

Insufficient irrigation: Leads to dentin dehydration and brittleness [14].

Evidence on NiTi Systems and Dentin Integrity:

Studies Reporting Microcrack Induction

Liu et al compared hand files with rotary systems (ProTaper, K3) and found a 2.5× higher crack incidence with rotary use [15].

Bürklein et al [16] reported that reciprocating files (WaveOne) caused fewer cracks than continuous rotation systems (ProTaper).

Studies Refuting Significant Damage:

Versiani et al observed no difference in fracture resistance between teeth instrumented with Reciproc and hand files [17].

Pedullà et al [18] demonstrated that thermally treated files (HyFlex CM) produced fewer defects than conventional NiTi.

Factors Influencing Dentin Preservation

1. Instrumentation Technique:

Crown-down approach: Reduces apical stress by pre-flaring coronal dentin [19].

Single-file systems: Minimize repetitive dentin contact (e.g., XP-endo Shaper) [20].

2. Alloy Properties:

CM Wire: Lower elastic modulus reduces stress transmission [21].

Gold-treated files: Enhance fatigue resistance (e.g., Gold Wire by Dentsply) [22].

3. Operational Parameters:

Optimal torque (1–2 Ncm) and RPM (250–300) limit crack initiation [23].

Pecking motion (3–5 mm amplitude) prevents screw-in effects [24].

4. Irrigation and Lubrication:

Copious irrigant delivery together with chelating gel or liquid lubricants during rotary root canal preparation helps keep dentine hydrated and significantly reduces torque and apically directed forces on NiTi instruments, thereby decreasing the mechanical stresses at the file–dentin interface that are implicated in dentinal microcrack formation and root dentin defects [25].

Clinical Implications and Future Directions:

While in vitro data suggest that advanced NiTi systems reduce dentinal damage, clinical evidence remains sparse.

Recommendations include:

Selecting minimally invasive systems: TRUShape or HyFlex EDM for curved canals [26]. Adopting hybrid techniques: Combine rotary and hand files in fragile roots [27].

Long-term monitoring:

VRFs may manifest years post-treatment; CBCT follow-ups are advised [28]. Emerging technologies like AI-guided shaping and 3D-printed customized files could further optimize dentin preservation [29].

CONCLUSION

Contemporary NiTi systems offer unparalleled efficiency but require careful technique to avoid dentinal damage. Thermally treated and reciprocating files show promise in minimizing microcracks, though clinicians must tailor instrumentation to root anatomy. Future research should prioritize in vivo studies correlating laboratory findings with clinical fracture rates.

REFERENCES

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod. 1988;14(7):346-51.
2. Gavini G, Santos MD, Caldeira CL, Machado MEL, Freire LG, Iglecias EF, Peters OA, Candeiro GTM. Nickel-titanium instruments in endodontics: A concise review of the state of the art. Braz Oral Res. 2018;32(suppl 1):e67.
3. Adorno CG, Yoshioka T, Suda H. Crack initiation on the apical root surface caused by three different nickel-titanium rotary files at different working lengths. J Endod. 2011;37(4):522-5.
4. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod. 2004;30(8):559-67.
5. Ruddle CJ. The ProTaper technique. Endod Topics. 2005;10:187-90.
6. Alapati SB, Brantley WA, Svec TA, Powers JM, Nusstein JM, Daehn GS. SEM observations of nickel-titanium rotary endodontic instruments that fractured during clinical use. J Endod. 2005;31(1):40.
7. De-Deus G, Silva EJ, Vieira VT, Belladonna FG, Elias CN, Plotino G, Grande NM. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files. J Endod. 2017;43(3):462-6.
8. Lopes HP, Vieira MV, Elias CN, Gonçalves LS, Siqueira JF Jr, Moreira EJ, Vieira VT, Souza LC. Influence of the geometry of curved artificial canals on the fracture of rotary nickel-titanium instruments subjected to cyclic fatigue. J Endod. 2020;46(8):1102.
9. Liu R, Hou BX, Wesselink PR, Wu MK, Shemesh H. The incidence of root microcracks caused by 3 different single-file systems versus the ProTaper system. J Endod. 2013;39(8):1054-6.
10. Bürklein S, Tsotsis P, Schäfer E. Incidence of dentinal defects after root canal preparation: Reciprocating versus rotary instrumentation. J Endod. 2013;39(4):501.
11. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod.2009;35(2):236-8.
12. De-Deus G, Belladonna FG, Souza EM, Silva EJ, Neves Ade A, Alves H, Lopes RT, Versiani MA. Micro-computed tomographic assessment on the effect of ProTaper Next and Twisted File Adaptive systems on dentinal cracks. J Endod. 2015;41(7):1116.
13. Pedullà E, Corsentino G, Ambu E, Rovai F, Campedelli F, Rapisarda S, La Rosa GR, Rapisarda E, Grandini S. Influence of continuous rotation or reciprocation of Optimum Torque Reverse motion on cyclic fatigue resistance of nickel-titanium instruments. Int Endod J. 2017;50(8):762-8.
14. Zuolo ML, De-Deus G, Belladonna FG, Silva EJ, Lopes RT, Souza EM, Versiani MA, Zaia AA. Micro-CT evaluation of dentinal microcracks after root canal preparation with TRUShape and Self-Adjusting File systems. J Endod. 2017;43(4):619-22.
15. Elnaghy AM, Elsaka SE. Evaluation of root canal transportation, centering ratio, and remaining dentin thickness associated with ProTaper Next instruments with and without glide path. J Endod. 2017;43(3):450-4.
16. Silva EJNL, Giraldes JFN, de Lima CO, Vieira VTL, Elias CN, Antunes HS. Influence of heat treatment on torsional resistance and surface roughness of nickel-titanium instruments. Int Endod J. 2019;52(11):1645-51.
17. Ha JH, Kim SK, Cohenca N, Kim HC. Effect of R-phase heat treatment on torsional

resistance and cyclic fatigue fracture. J Endod. 2013;39(3):389-93.

18. Plotino G, Grande NM, Testarelli L, Gambarini G. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. Int Endod J. 2012;45(7):614-8.
19. Arias A, Perez-Higueras JJ, de la Macorra JC. Differences in cyclic fatigue resistance between ProTaper Next and ProTaper Universal instruments at different levels. J Endod. 2014;40(9):1477-81.
20. Hieawy A, Haapasalo M, Zhou H, Wang ZJ, Shen Y. Phase transformation behavior and resistance to bending and cyclic fatigue of ProTaper Gold and ProTaper Universal instruments. J Endod. 2015;41(7):1134-8.
21. Pirani C, Iacono F, Generali L, Sassatelli P, Nucci C, Lusvarghi L, Gandolfi MG, Prati C. HyFlex EDM: superficial features, metallurgical analysis and fatigue resistance of innovative electro discharge machined NiTi rotary instruments. Int Endod J. 2016;49(5):483-93.
22. Uygun AD, Kol E, Topcu MK, Seckin F, Ersoy I, Tanriver M. Variations in cyclic fatigue resistance among ProTaper Gold, ProTaper Next and ProTaper Universal instruments at different levels. Int Endod J. 2016;49(5):494-9.
23. Jamleh A, Komabayashi T, Ebihara A, Nassar M, Watanabe S, Yoshioka T, Miyara K, Suda H. Root surface strain during canal shaping and its influence on apical microcrack development: a preliminary investigation. Int Endod J. 2015;48(12):1103-11.
24. Ozyurek T, Yılmaz K, Uslu G. Shaping ability of Reciproc, WaveOne GOLD, and HyFlex EDM single-file systems in simulated S-shaped canals. J Endod. 2017;43(5):805-9.
25. Peters OA, Boessler C, Zehnder M. Effect of liquid and paste-type lubricants on torque values during simulated rotary root canal instrumentation. Int Endod J. 2005 Apr;38(4):223-9.
26. Topcuoglu HS, Topcuoglu G. Cyclic fatigue resistance of Reciproc Blue and Reciproc files in an S-shaped canal. J Endod. 2017;43(10):1679-82.
27. Kiefner P, Ban M, De-Deus G. Is the reciprocating movement per se able to improve the cyclic fatigue resistance of instruments? Int Endod J2014;47(5):430-6.
28. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971;32(2):271-5.
29. Zanza A, Seracchiani M, Reda R, Miccoli G, Testarelli L, Di Nardo D. Metallurgical tests in endodontics: a narrative review. Bioengineering 2022; 9 (1): 30.