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Review Article

Reciprocating Motion in Endodontics: A Narrative Review

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Abstract

Background and Aim: Various techniques exist for the mechanical preparation of the root canal system using rotary instruments, each with its own unique approach. One notable method is reciprocating motion, which is often recognized for its potential benefits over traditional techniques. This review aims to examine the fundamental characteristics of reciprocating motion in endodontic instruments, highlighting the specific advantages and disadvantages of this approach compared to continuous rotation and other kinematic movements.
Methods: A comprehensive literature search was conducted in PubMed, Scopus, and Google Scholar databases using a structured search strategy for the period from January 2008 to December 2025. The search included keywords related to reciprocating motion, endodontics, root canal preparation, and nickel-titanium instruments. No language restrictions were applied. Studies evaluating the efficacy, safety, and clinical outcomes of reciprocating motion in root canal preparation were included.
Results: The available evidence suggests that reciprocating motion offers several advantages over continuous rotation, including reduced cyclic fatigue, improved centering ability, and decreased risk of instrument fracture, particularly in curved canals. Reciprocating systems have demonstrated efficacy in glide path creation and canal preparation, especially in anatomically challenging cases. However, some studies report comparable outcomes between reciprocating and continuous rotation regarding cleaning efficiency and debris extrusion.
Conclusion: Reciprocating motion represents a viable and effective alternative to continuous rotation for root canal preparation, with particular benefits in complex anatomies. While current evidence supports its clinical use, further long-term studies are needed to establish definitive guidelines for instrument selection and technique optimization.
Key Words: Continuous rotation; endodontics; nickel-titanium instruments; reciprocating motion; root canal preparation

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Introduction

Root canal therapy involves a series of steps, one of which is the mechanical preparation of the root canal system. This procedure causes some widening of the canals, leads to the removal of infected dentin, and facilitates the penetration of disinfectant solutions to the apical terminus (1, 2). With the advent of rotary instruments for mechanical root canal preparation, various movement patterns for file activation were introduced, one of which is reciprocating motion. These systems operate by alternating between clockwise and counterclockwise rotations (1).

Despite the increasing use of reciprocating motion in endodontics and the existence of studies investigating its characteristics, there remains a lack of comprehensive and contextualized knowledge regarding the potential benefits that reciprocating motion can offer for canal preparation. Furthermore, there is a distinct need for a narrative review that encapsulates the evolution of reciprocating technology and integrates diverse findings across multiple studies.
The purpose of this narrative review is to explore the current literature on reciprocating systems in

endodontics, including their performance, advantages, disadvantages, and associated patient outcomes such as postoperative pain.

Shaping Ability and Cutting Efficacy

The shaping and cutting capabilities of root canal preparation instruments are among their most critical features. Instruments with higher efficiency facilitate more effective removal of infected dentin, thereby increasing the speed of the root canal treatment process (2). Enhanced cutting edges and optimized blade design allow the instrument to engage dentin more efficiently, minimizing the formation of the smear layer. This reduction not only improves canal cleanliness but also enhances the penetration of irrigants and sealers, contributing to better disinfection and sealing outcomes (3).

Numerous factors affect this characteristic of instruments. The degree of canal curvature, specialized heat treatments, and the cross-sectional design of the instrument are among the most influential factors affecting this aspect of instrument performance (4). To completely avoid these confounding factors arising from differences among manufactured instruments, a number of studies evaluated the shaping and centering ability of a single file under different kinematic motions, including continuous rotation and reciprocation.

The first article published in this manner was a study conducted by Yared in 2008. This study assessed the use of ProTaper F2 files with reciprocating motion, demonstrating effective instrumentation with minimal risk of transportation and file fracture when using a specific cutting angle (5). According to further studies on Neolix rotary files, canal preparation efficiency could be enhanced by reciprocating motion rather than continuous rotation settings (6).

It should be taken into consideration that many studies conducted on shaping ability and cutting efficacy are in vitro and lack clinical investigation.

Centering Ability and Transportation

An optimal root canal preparation instrument should combine high shaping efficiency with the ability to preserve the original canal anatomy. Maintaining this conformity reduces the risk of canal transportation and deviation from the natural path, thereby preventing unnecessary thinning of the dentinal walls. Such deviations can compromise structural integrity and increase susceptibility to dentinal cracks, root fractures, or canal perforations.

Key factors influencing the risk of canal transportation during instrumentation include the angle of file insertion, the initial curvature of the canal, and the metallurgical properties and heat treatment of the instrument (7). Each of these factors plays a crucial role in determining the instrument's ability to maintain centrality and anatomical integrity throughout the preparation process.

Micro-computed tomography-based investigations have consistently demonstrated that reciprocating and continuous rotary systems exhibit comparable canal transportation and centering ability in curved root canals. In mandibular molar mesial roots with single curvature, WaveOne Gold, R-Motion (FKG Dentaire, La-Cheaux-de Fonds, Switzerland), and Reciproc Blue (VDW, Munchen, Germany) showed no statistically significant differences in canal transportation or centering ratio at 3, 5, and 7 mm from the apex (8).

Comparative evaluations between reciprocating and rotary systems have reported variable findings depending on canal morphology. In curved mesiobuccal canals of mandibular molars assessed by CBCT, TruNatomy (Dentsply Sirona, Ballaigues, Switzerland) demonstrated significantly lower canal transportation than Reciproc Blue (VDW, Munchen, Germany) and EDMax (Neolix SAS, Évron, France) , while centering ability showed limited differences, restricted to the buccolingual dimension at specific apical levels (9). Conversely, micro-CT studies in oval or long-oval canals frequently reported no significant differences in transportation or centering ability between reciprocating and rotary systems, despite differences in prepared surface area and volume (10).

An ex vivo retreatment study of extracted maxillary molars demonstrated that during retreatment of MB1 and MB2 canals, Reciproc Blue (VDW, Munchen, Germany), WaveOne Gold, and a continuous rotation system (ProDesign Logic) demonstrated minimal apical transportation and canal centralization, irrespective of kinematics (10). Notably, a significant reduction in dentin thickness below 0.5 mm in the danger zone of MB2 canals was consistently observed after retreatment, independent of the instrumentation system or motion used (10).

Instrument metallurgy and geometric design exert a substantial influence on shaping outcomes. Heat-treated alloys, including Blue-Wire, Gold-Wire, and CM wire, were associated with increased flexibility and improved canal centralization. However, larger apical sizes and greater tapers (e.g., 25/.08 and 40/.06) were associated with increased canal transportation, particularly in curved canals. Regressive and variable taper designs were associated with conservative coronal dentin removal and proper centering of root canal preparation (8).

In a comparative study evaluating the centering ability of different kinematic motions, WaveOne Gold instruments demonstrated significantly more centered root canal preparations and reduced canal transportation compared with rotary ProTaper Next and adaptive Twisted Files (11). This outcome contrasts with earlier reports that associated reciprocating WaveOne systems with increased transportation (12, 13). The authors attribute this discrepancy to differences in instrument design and metallurgy: previous investigations assessed the original WaveOne instruments, which were manufactured from conventional NiTi alloy and lacked the thermomechanical treatment applied to WaveOne Gold. The proprietary heat treatment of the Gold alloy enhances flexibility, elasticity, and resistance to cyclic stress, thereby improving the instrument's ability to conform to canal curvature and maintain centering during preparation. Consequently, the superior performance of WaveOne Gold appears to derive primarily from its advanced metallurgical properties rather than reciprocating motion alone (11). This distinction highlights the critical influence of alloy composition and design modifications on clinical outcomes and cautions against direct comparisons of the impact of different kinematics on canal transportation during root canal preparation without accounting for differences in NiTi alloy processing.

Overall, studies have demonstrated that reciprocating and continuous rotation systems produce similar centering abilities and limited canal transportation when evaluated under standardized conditions. Discrepancies among studies were primarily related to differences in imaging modality (micro-CT vs. CBCT), canal morphology, curvature severity, and apical preparation size. CBCT-based assessments tended to underestimate subtle canal deviations compared with micro-CT, contributing to variability in reported outcomes.

In summary, the reviewed evidence indicates that canal anatomy and instrument design parameters exert a greater influence on canal transportation and centering ability than kinematic motion alone.

Microbial Reduction

The ultimate goal of root canal preparation is to achieve maximal microbial load reduction within the canal system. This is accomplished through the mechanical removal of biofilm and infected dentin, in conjunction with the application of antimicrobial irrigants. The more effectively an instrument can remove dentin in a safe manner, the greater the extent of microbial reduction. Accordingly, the cutting efficiency of the instrument plays a critical role in the success of endodontic disinfection.

Reciprocating preparation systems, through their characteristic push–pull motion, have demonstrated a notable ability to disrupt bacterial biofilms. This mechanical disruption facilitates more effective penetration of irrigating solutions, thereby enhancing the overall efficacy of canal debridement and microbial elimination (14). According to the results of a systematic review of in vitro studies, both reciprocating and continuous rotary systems are equally effective in diminishing microbial populations in infected root canals; yet neither method ensures complete disinfection (14). Therefore, the use of an appropriate chemical protocol for disinfecting the root canal system is crucial (14).

Debris Extrusion

To date, there is no consensus regarding the impact of instrumentation kinematics on apical extrusion of debris. While some systematic reviews and recent articles found no significant difference between rotary and reciprocating motion (15, 16), older investigations found a significant difference and concluded that reciprocating motion induces greater extrusion of debris compared to sequential rotary and single-file continuous rotation instruments (17, 18).

In a more recent study, a more significant variable than instrumentation kinematics has been discussed: the level of instrumentation relative to the apical foramen (16). It was stated that if instrumentation extends beyond the limit of the root canal, more debris extrusion occurs. Additionally, a laboratory study indicated that using a larger tip size with a single reciprocating instrument resulted in less debris being extruded from the root canal (19). It could be suggested that a more crown-down approach before reaching the full working length could reduce the microbial load and dentinal chips at the apical third of the root canal and eventually result in less debris extrusion.

There is ongoing disagreement regarding the extent of apical debris extrusion during endodontic retreatment. While one study reported reduced extrusion with reciprocating systems (20), another found that multi-file rotary systems were associated with lower debris extrusion (21). In the same study, it was also demonstrated that the time required for removal of root canal filling materials was significantly shorter when using reciprocating systems compared to both multi-file rotary and manual techniques (21).

However, findings from systematic and umbrella reviews investigating this issue have concluded that reciprocating systems result in greater apical debris extrusion (22, 23). This conclusion, however, appears to be potentially inaccurate, as it may not adequately account for methodological inconsistencies and confounding variables across the included studies, such as the number of instruments used and the actual results obtained from the studies.

Postoperative Pain

The clinical significance of apical debris extrusion lies in its impact on post-treatment pain. While some research found that reciprocating instrumentation led to a higher incidence of postoperative pain (24), others showed the opposite (25, 26). A recent systematic review of clinical trials on postoperative pain associated with non-surgical root canal treatments revealed that the kinematics of file motion does not influence the level of postoperative pain (27).

Several factors contribute to pain after root canal treatment, including the number of treatment visits, pulp condition, and periapical status (22). Therefore, it is essential to focus on variables that have proven effective in managing pain, such as avoiding over-instrumentation and overfilling, along with ensuring complete chemo-mechanical preparation of the root canal system (28).

Fatigue and Instrument Fracture

Instrument separation within the root canal can significantly affect the outcome of endodontic treatment (29). Accordingly, considerable efforts have been directed toward improving the metallurgical properties of preparation instruments and optimizing their kinematic design to minimize the risk of file fracture.

The reciprocating motion employed in engine-driven systems simulates the balanced force technique traditionally used with manual instruments. This motion not only facilitates the preservation of the canal's original anatomy—thereby reducing the risk of transportation and deviation—but also contributes to a lower incidence of instrument fracture. Specifically, the counterclockwise disengaging movement reduces the file's engagement with canal walls, thereby decreasing torsional stress and enhancing safety during instrumentation. The main advantage of using instruments in reciprocating motion is their higher fatigue resistance, reducing file fracture in narrow and severely curved canals. Numerous studies have demonstrated the superiority of this method compared to continuous rotation single files and sequenced rotary files (30-32).

In a recent study, a single-file system was utilized under two kinematic protocols—continuous rotation and reciprocation—to assess its cyclic and torsional fatigue resistance. The results demonstrated that reciprocating motion significantly enhanced the instrument's resistance to mechanical fatigue (33).

Based on findings from previous research, it can be inferred that Adaptive Torque Reverse (ATR) motion may represent one of the safest approaches to root canal preparation (Figure 1). This motion is specifically designed for file systems that cut in the clockwise direction, with the file predominantly rotating in that direction. The system operates under a low torque limit (typically 1.5 N·cm or lower). When the file encounters resistance and reaches the preset torque limit, it transitions into a reciprocating motion. This shift not only reduces torsional stress on the instrument but also allows continued progression toward the working length—unlike conventional full-reverse systems, which often interrupt the apical advancement of rotary instruments. By combining enhanced safety with procedural efficiency, ATR motion maximizes both the speed and reliability of canal preparation, offering a promising advancement in endodontic instrumentation (34).

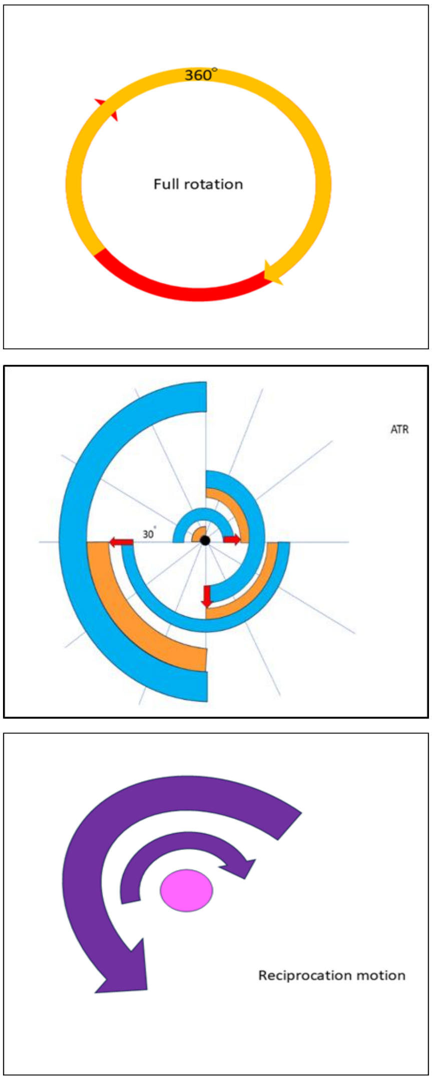

Figure 1. Schematic representation of the various kinematic approaches employed in root canal instrumentation. ATR: Adaptive torque reverse

Induction of Dentinal Defects

Dentinal microcracks could lead to vertical root fractures and negatively affect tooth longevity. The incidence of dentinal defects in rotary and reciprocating file systems has been compared in several studies, and reports indicate that both rotary and reciprocating systems tend to form more dentinal defects than hand files (35). However, the difference between these two systems (rotary and reciprocating) is often not statistically significant (35, 36). An in vivo study has indicated that modern reciprocating file systems such as Reciproc Blue (VDW, Munchen, Germany) are generally safe and do not propagate microcracks (37). Files like TruNatomy (Dentsply Sirona, Ballaigues, Switzerland) and ONE RECI (MicroMega, Besancon, France) have demonstrated similar capability in maintaining dentin integrity (36).

Glide Path Preparation

Creating a glide path can improve file navigation, shaping efficiency, and lower the risk of procedural errors, particularly in curved canals; hence, it is essential for greater safety during root canal preparation. According to studies, reciprocating motion accompanied by heat-treated glide path files shows higher fatigue resistance and shorter preparation times in comparison with conventional instruments (38).

Recent studies have evaluated the cutting and shaping capabilities of reciprocating glide path file systems in comparison to continuous rotation instruments. The findings consistently demonstrate the superior performance of reciprocating systems in terms of both cutting efficiency and shaping ability (38). Studies also report no significant difference in glide path creation time between systems such as WaveOne Gold Glider (Dentsply Maillefer, Ballaigues, Switzerland) and ProGlider (Dentsply Maillefer, Ballaigues, Switzerland). Glide path techniques do not affect dentinal microcracks, but they can reduce root canal transportation and enhance cutting ability (38, 39).

Laboratory data show that reciprocating glide path instruments (WaveOne Gold Glider, R-Pilot) are at least as efficient as rotary systems in reaching working length and tend to provide equal or better centering when compared with constant rotation, while ATR can partially bridge the gap between continuous rotation and reciprocation (40, 41).

Clinical trials indicate that engine-driven glide path preparation, whether reciprocating or rotary, reduces postoperative pain compared with manual glide path instrumentation or no glide path, while reciprocating versus rotary kinematics per se do not show consistent differences in patient-reported pain outcomes (42, 43).

It can be concluded that reciprocating kinematics for glide path preparation can be considered superior overall to simple continuous rotary and manual kinematics, primarily because they provide greater cyclic fatigue resistance, favorable centering behavior, and low clinical fracture rates, while maintaining at least equivalent shaping efficiency and postoperative pain outcomes (42-44). However, the superiority of reciprocation is not absolute: optimized rotary kinematics (ATR) and advanced rotary designs (such as TruNatomy (Dentsply Sirona, Ballaigues, Switzerland) and One G) can match or surpass reciprocating systems in specific parameters like torsional resistance, screw-in force reduction, or 24-hour pain in selected clinical scenarios, highlighting that instrument design and motor algorithms are crucial modifiers of kinematic effects (39, 43).

Therefore, reciprocating glide path kinematics should be preferred when mechanical safety in curved canals is prioritized, with high cyclic fatigue resistance and low fracture risk, while modern rotary systems remain valid alternatives in experienced hands, particularly when combined with advanced rotation modes and careful case selection.

Time of Preparation

Preparation time is a factor of high importance in endodontic procedure efficiency, especially in retreatment and pediatric cases. Both rotary and reciprocating systems are significantly faster than manual methods such as stainless-steel K-files. Studies report that single-file reciprocating and rotary techniques take comparable time in most cases, but sequential continuous rotary systems (e.g., ProTaper Universal) are generally slower than reciprocating systems (e.g., WaveOne Gold) (45). Additionally, undergraduate students were able to achieve faster results using reciprocating and rotary file systems in simulated blocks (46). Furthermore, coronal preflaring has been reported to enhance efficiency by decreasing the number of pecking motions required to reach working length with reciprocation (47). These results collectively support that reciprocating systems are time-saving, especially in challenging cases and educational settings.

In a recent study, the success rate and retrieval time of fractured ProTaper Universal and WaveOne Gold files were compared. Although no significant difference was observed in the success rate of file retrieval between the two systems, the time required to remove the WaveOne Gold file was significantly shorter than that for the continuous rotation instrument (48).

Due to the superior fatigue resistance of reciprocating systems and their lower risk of instrument fracture—particularly in severely curved canals—it is possible to safely reach the working length with fewer pecking motions. In contrast, continuous rotation systems typically require multiple short-range pecking movements to achieve the same level of safety during canal preparation.

Root Canal Filling Removal

A key factor for successful non-surgical retreatment is effective removal of root canal filling material. While no instrumentation system is capable of complete filling material removal, reciprocating systems have demonstrated favorable performance in removing canal filling material, with comparable or superior efficacy to manual or rotary techniques (49). Apical extrusion of filling materials is common with both rotary and reciprocating systems; however, no significant differences were observed in the amount of extruded debris (49). Another study highlighted enhancement of removal efficiency following the combination of reciprocating instruments with ultrasonic irrigation, especially in cases where calcium silicate-based sealers are used (50). However, the procedure's success also relies on the type of obturating material and canal anatomy. Rotary systems like ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) may provide slightly faster removal, but they are more likely to induce dentinal defects due to their greater stiffness and rotational stress (51). In conclusion, reciprocating systems offer a promising balance between removal efficacy and maintaining dentinal integrity, which makes them a suitable option for retreatment procedures.

Clinical Outcome

Reciprocating systems have demonstrated promising clinical outcomes, with studies showing comparable or superior results to instrumentation with rotary files. High success rates over years, efficacy, and simplified handling of these file systems have been reported in some studies (52, 53).

In a randomized multicenter clinical trial by Machado et al., 240 necrotic teeth were assigned to single-visit root canal treatment, utilizing two kinematics (rotary and reciprocating) and two apical enlargement approaches (with and without intentional foraminal enlargement). Postoperative pain was then measured. Across groups, statistically significant differences appeared only with tooth type, periradicular status, and sealer extrusion, while the rotary without intentional foraminal enlargement combination showed lower pain—but only at 24 hours—indicating a short-term advantage for that condition rather than a generalized kinematic effect (54).

In this article, methodological imbalances likely influenced pain outcomes: the reciprocating without intentional foraminal enlargement group had many more mandibular first molars, periradicular diagnoses differed between groups, and overfilling rates varied markedly—all factors plausibly linked to pain. Notably, the group with the lowest pain (rotary without intentional foraminal enlargement) also had the lowest sealer extrusion (5%), whereas other groups—especially those with intentional foraminal enlargement—had far more overfilling, and prior evidence associates zinc-oxide–eugenol sealer extrusion with higher postoperative pain.

A complementary educational cohort compared a hybrid rotary technique (hand + rotary) with full reciprocation (WaveOne Gold; Dentsply Maillefer, Ballaigues, Switzerland) across 368 student cases, tracking procedural errors and outcomes (55). Overall procedural errors were more frequent with reciprocation, driven by significantly more over-instrumentation in the WaveOne Gold group. However, the occurrence of ledges, transportation, and file separation was not different. Importantly, when survival was analyzed with appropriate time-to-event methods, there was no significant difference in tooth survival between hybrid rotary and reciprocation, and baseline periapical index, not kinematics, was the dominant predictor of worse survival. These findings indicate that, in novice hands, reciprocation may increase certain technical errors (notably over-instrumentation) without measurably worsening survival when cases are followed over time.

Reciprocation may be associated with more over-instrumentation among students, yet this did not translate into worse survival, suggesting operator training and apical control are more pivotal than motion. Accordingly, it can be concluded that neither kinematic outperforms the other in long-term clinical outcomes, and clinicians should prioritize apical limit control and minimization of root filling material extrusion.

Overall, root canal preparation with reciprocating files offers predictable and efficient outcomes in various clinical settings such as primary root canal treatments and non-surgical retreatments (52, 53).

Conclusion

Based on this narrative review, reciprocating motion systems demonstrate comparable performance to continuous rotary systems in several clinical domains, including shaping efficiency, preservation of the original canal anatomy, incidence of postoperative pain, and overall clinical outcomes. In addition to these similarities, reciprocating systems offer notable advantages in terms of ease of use, enhanced resistance to instrument fracture, and reduced preparation time. However, results regarding their performance in terms of debris extrusion and postoperative pain remain inconsistent.

Given these benefits, the use of reciprocating instruments may offer advantages for glide path creation and canal preparation in anatomically complex cases—such as severely curved or calcified canals—where procedural safety, efficiency, and canal integrity are of paramount importance. However, clinical decisions must be individualized based on the dentist's expertise and specific case factors.

Clearly, more well-designed clinical trials are needed to obtain more accurate results regarding the performance of reciprocating systems, as the current evidence is mixed and there is considerable methodological variability across studies.

Declarations

Ethical Considerations

This article is a narrative review and does not contain any studies with human participants or animals performed by any of the authors. Therefore, ethical approval and informed consent were not required.

Availability of Data and Materials

The data supporting this narrative review are available from the cited references. Further inquiries can be directed to the corresponding author.

Competing Interest
The authors declare that they have no conflict of interest related to this study.
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Authors' Contributions

Yasmin Karbalaei Kamran (YKK) contributed to the conception and design of the review, literature search and acquisition of data, analysis and interpretation of the literature, and drafting of the manuscript. **Faranak Noori (FN) c**ontributed to the conception and design of the review, literature search and data extraction, critical revision of the manuscript for important intellectual content, and final approval of the version to be published. Served as the corresponding author and supervised all aspects of the work. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Declaration of Generative Artificial Intelligence (AI) Utilization

During the preparation of this work, the authors used ChatGPT-4 for the purpose of improving language, grammar, punctuation, and overall readability of the manuscript. The AI tool was used solely for language editing and proofreading assistance. After using this tool, the authors carefully reviewed and edited the content as needed and take full responsibility for the final content of the published article.

References

1. Chaniotis A, Ordinola-Zapata R. Present status and future directions: management of curved and calcified root canals. Int Endod J. 2022;55(Suppl 2):656-84.
2. Nayak A, Jain PK, Kankar PK, Jain N. On comprehensive analysis of root canal shaping ability of three endodontic files of different kinematics. Proc Inst Mech Eng H. 2021; 235(8):947-57.
3. Jeon IS, Spångberg LS, Yoon TC, Kazemi RB, Kum KY. Smear layer production by 3 rotary reamers with different cutting blade designs in straight root canals: a scanning electron microscopic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003;96(5):601-7.
4. Vasconcelos R, Arias A, Peters OA. Lateral and axial cutting efficiency of instruments manufactured with conventional nickel-titanium and novel gold metallurgy. Int Endod J. 2018;51(5):577-83.
5. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. Int Endod J. 2008; 41(4):339-44.
6. Aminsobhani M, Avval AR, Hamidzadeh F. Evaluation of curved canal transportation using the neoniti rotary system with reciprocal motion: a comparative study. Int J Dent. 2021;2021:4877619.
7. Ebihara A, Yahata Y, Miyara K, Nakano K, Hayashi Y, Suda H. Heat treatment of nickel-titanium rotary endodontic instruments: effects on bending properties and shaping abilities. Int Endod J. 2011;44(9):843-9.
8. Matos TC, Khoury RD, Santos CHSD, Barbosa AF, Lopes RT, Silva EJNL, et al. Shaping efficiency of heat-treated reciprocating systems in mandibular molars: a micro-CT analysis. Eur J Dent. 2025; 19(1): 257-64.
9. Zargar N, Zandi B, Safi Y, Mehrabani M. Apical transportation and centering ability of Trunatomy, Edmax, and Reciproc Blue in curved mesiobuccal canals of mandibular molars. Iran Endod J. 2025;20(1):29-36.
10. Santos-Junior AO, Fontenele RC, Tavares KIMC, Torres FFE, Pinto JC, Rosim PLB, et al. Effectiveness and safety of three NiTi systems in endodontic retreatment of MB1 and MB2 root canals: a micro-CT and CBCT combined analysis. Clin Oral Investig. 2025;29(4):198.
11. Eliasz W, Kubiak K, Poncyljusz W, Surdacka A. Root canal transportation after root canal preparation with ProTaper Next, WaveOne Gold, and twisted files. J Clin Med. 2020;9(11):3661.
12. Liu W, Wu B. Root canal surface strain and canal center transportation induced by 3 different nickel-titanium rotary instrument systems. J Endod. 2016;42(2):299-303.
13. Zhao D, Shen Y, Peng B, Haapasalo M. Root canal preparation of mandibular molars with 3 nickel-titanium rotary instruments: a micro-computed tomographic study. J Endod. 2014;40(11):1860-4.
14. Eren SK, Uzunoğlu-Özyürek E, Karahan S. Influence of reciprocating and rotary instrumentation on microbial reduction: a systematic review and meta-analysis of in vitro studies. Restor Dent Endod. 2021;46(2):e20.
15. Zhang C, Liu J, Liu L. The influence of ProTaper and WaveOne on apically extruded debris: a systematic review and meta-analysis. J Conserv Dent. 2018;21(5):474-80.
16. Goulart TS, Prado MM, Tieppo GC, Fischer BV, Schuldt DPV, Coelho BS, et al. Do instrument kinematics and the

apical preparation limit influence canal disinfection and bacterial extrusion? Odontology. 2025;113(2):571-80.
17. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod. 2012;38(6):850-2.
18. Saberi AE, Ebrahimipour S, Saberi M. Apical debris extrusion with conventional rotary and reciprocating instruments. Iran Endod J. 2020;15(1):38-43.
19. Cuellar MRC, Pereira TC, de Vasconcelos L, Pedrinha VF, Vivan RR, Duarte MAH, et al. Reducing apical bacterial extrusion: the impact of Reciproc file size and irrigation technique. Iran Endod J. 2024;19(3):176-82.
20. Silva EJNL, Sá L, Belladonna FG, Neves AA, Accorsi-Mendonça T, Vieira VT, et al. Reciprocating versus rotary systems for root filling removal: assessment of the apically extruded material. J Endod. 2014;40(12):2077-80.
21. Lu Y, Wang R, Zhang L, Li H, Zheng Q, Zhou X, et al. Apically extruded debris and irrigant with two NiTi systems and hand files when removing root fillings: a laboratory study. Int Endod J. 2013;46(12):1125-30.
22. Immich F, de Araújo LP, da Gama RR, da Rosa WLO, Piva E, Rossi-Fedele G. Fifteen years of engine-driven nickel-titanium reciprocating instruments, what do we know so far? An umbrella review. Aust Endod J. 2024; 50(2):409-63.
23. Caviedes-Bucheli J, Rios-Osorio N, de Pineres-Milazzo CG, Jiménez-Peña M, Portigliatti R, Gaviño-Orduña JF, et al. Effectiveness, efficiency, and apical extrusion of 2 rotaries and 2 reciprocating systems in removing filling material during endodontic retreatment: a systematic review. J Clin Exp Dent. 2023;15(3):e250-8.
24. Abdel-Baset ST, Fahmy SH, Obeid MF. Can instrumentation kinematics affect postoperative pain and substance P levels? A randomized controlled trial. BMC Oral Health. 2024;24(1):102.
25. Comparin D, Moreira EJL, Souza EM, De-Deus G, Arias A, Silva EJNL. Postoperative pain after endodontic retreatment using rotary or reciprocating instruments: a randomized clinical trial. J Endod. 2017;43(7):1084-8.
26. Vijayran VK, Khetarpal A, Vats A, Ahlawat M, Singhal N. Comparison of the incidence of postoperative pain in single sitting root canal treatment after using two reciprocating systems and two continuous rotary systems: an in vivo study. J Conserv Dent Endod. 2023;26(1):12-9.
27. Nobar BR, Dianat O, Nobar BR, Shirvani A, Zargar N, Kazem M, et al. Effect of rotary and reciprocating instrumentation motions on postoperative pain incidence in non-surgical endodontic treatments: a systematic review and meta-analysis. Eur Endod J. 2021;6(1):3-12.
28. Alhilou AM. Factors reducing postoperative pain related to root canal treatment: a narrative review of systematic reviews. Dent J (Basel). 2025;13(3):115.
29. Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. J Endod. 2005;31(12):845-50.
30. Srikumar GPV, Gadbail V, Alexander AK, Nishad G, Rahane S, Beautlin JS. An in vitro comparative evaluation of cyclic fatigue resistance of two rotary and two reciprocating file systems. J Conserv Dent Endod. 2024; 27 (7):774-9.
31. Martins JNR, Silva E, Baruwa AO, Pereira da Costa R, Braz Fernandes FM, Versiani MA. Comparative analysis of reciprocating and flat-side heat-treated rotary single-file systems: design, metallurgical characteristics, and mechanical performance. Int Endod J. 2023;56(7):896-908.
32. Immich F, de Araújo LP, da Gama RR, da Rosa WLO, Piva E, Rossi-Fedele G. Fifteen years of engine-driven nickel-titanium reciprocating instruments, what do we know so far? An umbrella review. Aust Endod J. 2024; 50 (2):409-63.
33. So GB, Siocheta G, Calefi P, Alcalde M, Vivan RR, Duarte MAH, et al. Cyclic and torsional fatigue resistance of a new rotary file on a rotary and reciprocating motion. Microsc Res Tech. 2023;86(12):1635-41.
34. Kwak SW, Ha JH, Cheung GS, Kim SK, Kim HC. Comparison of in vitro torque generation during instrumentation with adaptive versus continuous movement. J Endod. 2019;45(6):803-7.
35. Ashwinkumar V, Krithikadatta J, Surendran S, Velmurugan N. Effect of reciprocating file motion on microcrack formation in root canals: an SEM study. Int Endod J. 2014;47(7):622-7.
36. Mustafa M, Attur K, Menon SS, Attur S. Assessing dentinal microcracks using micro-CT after root canal preparation with different rotary endodontic file systems. J Pharm Bioallied Sci. 2024;16(Suppl 4):S3796-802.
37. Almeida A, Romeiro K, Cassimiro M, Gominho L, Dantas E, Silva S, et al. Micro-CT analysis of dentinal microcracks on root canals filled with a bioceramic sealer and retreated with reciprocating instruments. Sci Rep. 2020;10(1):15264.
38. Lup VM, Malvicini G, Gaeta C, Grandini S, Ciavoi G. Glide path in endodontics: a literature review of current knowledge. Dent J (Basel). 2024;12(8):257.
39. Dias PS, Kato AS, Bueno C, Vivan RR, Duarte MAH, Calefi PHS, et al. Comparative analysis of torsional and cyclic fatigue resistance of ProGlider, WaveOne Gold

Glider, and TruNatomy Glider in simulated curved canal. Restor Dent Endod. 2023;48(1):e4.

40. Woo JY, Jang JH, Chang SW, Oh S. Screw-in force, torque generation, and performance of glide-path files with three rotation kinetics. Odontology. 2024; 112(3): 761-72.

41. Lup VM, Marcu OA, Gaeta C, Ciavoi G. Impact of different glidepath techniques on the overall performance of WaveOne Gold in an artificial S-shape canal. Dent J. 2024;12(6):182.

42. Keskin C, Sivas Yilmaz H, Inan U, Özdemir Ö. Postoperative pain after glide path preparation using manual, reciprocating and continuous rotary instruments: a randomized clinical trial. Int Endod J. 2019;52(5):579-87.

43. Adıgüzel M, Yılmaz K, Tüfenkçi P. Comparison of postoperative pain intensity after using reciprocating and continuous rotary glide path systems: a randomized clinical trial. Restor Dent Endod. 2019;44(1):e9.

44. De-Deus G, Cardoso ML, Simões-Carvalho M, Silva E, Belladonna FG, Cavalcante DM, et al. Glide path with reciprocating driven pathfinding instrument: performance and fracture rate. J Endod. 2021;47(1):100-4.

45. Middleton I, Vorster M, Van der Vyver PJ. A comparison of preparation times between manual, rotary, and reciprocating files in primary molar pulpectomy. Indian J Dent Res. 2024;35(1):45-8.

46. Ginjeira A, Baruwa AO, Baumotte K. Evaluation and comparison of manual and mechanical endodontic instrumentation completed by undergraduate dental students on endodontic blocks. Dent J. 2024;12(11):363.

47. Figueira VZ, Vivacqua FD, Duarte MAH, Vasconcelos BC, Vivacqua-Gomes N. Ex vivo evaluation of the influence of cervical preflaring on choice of apical reciprocating file. Gen Dent. 2023;71(3):73-7.

48. Jitesh S, Surendran S, Natanasabapathy V. Efficacy of two instrument retrieval techniques in removing separated rotary and reciprocating nickel-titanium files in mandibular molars: an in vitro study. J Conserv Dent Endod. 2024;27(12):1240-5.

49. Monteiro TM, Cortes-Cid VO, Marceliano-Alves MF, Campello AF, Bastos LF, Lopes RT, et al. Intracanal removal and apical extrusion of filling material after retreatment using rotary or reciprocating instruments: a new approach using human cadavers. Int Endod J. 2024;57(1):100-7.

50. Madarati AA, Sammani AM, Alnazzawi AA, Alrahlah A. Efficiency of the new reciprocating and rotary systems with or without ultrasonics in removing root-canals filling with calcium silicate-based sealer (MTA). BMC Oral Health. 2023;23(1):5.

51. Das D, Barai S, Kumar R, Bhattacharyya S, Maity AB, Shankarappa P. Comparative evaluation of incidence of dentinal defects after root canal preparation using hand, rotary, and reciprocating files: an ex vivo study. J Int Oral Health. 2022;14(1):78-85.

52. Spinelli A, Zamparini F, Lenzi J, Gandolfi MG, Prati C. Three-year clinical outcome of root canal treatment using a single-cone technique and Ceraseal premixed bioceramic sealer: a prospective cohort study. Eur Endod J. 2024; 9 (4):383-93.

53. Marques RPS, Oliveira NM, Barbosa VRP, Bresolin CR, Mello-Moura ACV, Lara JS, et al. Reciprocating instrumentation for endodontic treatment of primary molars: 24-month randomized clinical trial. Int J Paediatr Dent. 2023;33(4):325-34.

54. Machado R, Moreira G, Comparin D, Barroso AP, Nascimento J, Ferraz CCR, et al. Postoperative pain after single-visit root canal treatments in necrotic teeth comparing instruments' kinematics and apical instrumentation limits: a prospective randomized multicenter clinical trial. BMC Oral Health. 2024; 24(1): 481.

55. Medina-Torres L, Cochran C 2nd, Bauer PA, Valcanaia AJ, Sindu D, Cavalcanti B, et al. Effect of different instrumentation techniques on students' performance and outcomes of nonsurgical root canal treatment. J Dent Educ. 2024;88(7):940-8.