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Comparison of canal transportation and centering ability of manual K-files and reciprocating files in glide path preparation: a micro-computed tomography study of constricted canals

Jing-Yi Liu^{1*} , Zhi-Xiong Zhou², Wei-Ju Tseng³ and Bekir Karabucak³

Abstract

Background: Optimum Glide Path (OGP) is a new reciprocating motion aiming to perform efficient glide path preparation in constricted canals. The aim of this study was to investigate and compare manual and OGP movement in terms of canal transportation and centering ability in glide path preparation of constricted canals.

Methods: Thirty constricted mesial root canals of mandibular molars, with initial apical size no larger than ISO#8, were selected and negotiated with #6–#8 K-files under the microscope. Canals were randomly divided into two experimental groups: Group 1 (MAN, n = 15): Glide path was established by using #10–#15 stainless steel K-files manually; Group 2 (OGP, n = 15): #10–#15 Mechanical Glide Path super-files were used with OGP motion (OGP 90°, 300 rpm). Each instrument was used to prepare only 2 canals (as in one mesial root). Canals were scanned before and after glide path preparation with micro-computed tomography (micro-CT) to evaluate root canal transportation and centering ratio at 1, 3 and 5 mm levels from the root apex. File distortions and separations were recorded. Paired *t*-test was used to statistically evaluate the data ($P < .05$).

Results: Group 2 showed a significantly lower transportation value than group 1 at 1-mm and 3-mm levels ($P < .05$), however the difference at 5-mm level was not significant. There was no significant difference regarding the centering ratio between the groups. Six #10 K-files were severely distorted in group 1, while no file separation or distortion was found in group 2.

Conclusions: OGP motion performed significantly less canal transportation (apical 3 mm) and file distortion during glide path establishment in constricted canals comparing to manual motion, while the centering ability between the two was similar.

Clinical relevance: OGP reciprocating motion provides a safer and efficient clinical approach compared to traditional manual motion in glide path establishment with small files in constricted canals.

Keywords: Glide path, Reciprocating motion, Optimum Glide Path (OGP), Manual motion, Micro-computed tomography (Micro-CT)

*Correspondence: liujingyizzx@163.com

¹ Center of Dental Medicine, China-Japan Friendship Hospital, 2 Ying-Hua-Yuan East Street, Chaoyang District, Beijing 100029, China
Full list of author information is available at the end of the article



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Background

The term “glide path” has been addressed in endodontics since the early 2000s, referring to a smooth tunnel pathway from the canal orifice toward the physiologic terminus [1]. Glide path establishment has been considered a crucial and initial step for safer and efficient biomechanical root canal preparation [2–4]. It could secure an open pathway to the canal terminus that subsequent instruments can follow [1]. Establishing a glide path may significantly reduce the risk of canal modifications like canal transportation, ledging, and zipping, also prevent rotary instrument separation by decreasing torsional stress to a certain extent [4–6]. In narrow, tight, and calcified canals, canal negotiation and glide path preparation may face a significant challenge; meanwhile, the previously mentioned procedural errors are more prone to occur [7]. Cvek et al. [8] not surprisingly found that irretrievable instrument separation mostly happens in constricted and calcified root canals.

Instruments like stainless steel #10–#20 K-files have been recommended to establish a glide path, with a manual watching-winding or balanced force motion [5, 6]. However, establishing a glide path with stainless steel files in such manner could be very time-consuming, especially in advanced cases; also, it has many limitations and drawbacks, including an increased incidence of canal transportation [9, 10]. To overcome some of the problems with manual motion, for faster preparation and superior anatomy preservation, NiTi rotary glide path files with continuous rotation have been introduced [11, 12]. Yet in calcified and constricted canals, the screw-in effect of continuous rotation motion may cause instantaneous torsional overload, leading to file breakage [3].

A slow-speed handpiece combining alternate reciprocation and rotating reciprocation, the “Optimum Glide Path (OGP)”, was introduced by J. Morita (Osaka, Japan). The OGP kinematics mainly aims to mimic the watch-winding and balanced force motion [13]. Briefly, file motion starts with alternate movement, with a same angle followed by reciprocating movement in which the counterclockwise angle is larger than the clockwise ($90^\circ/120^\circ$, $180^\circ/270^\circ$, and $240^\circ/330^\circ$). Then OGP kinematics continuously alternates between the alternate and rotating reciprocation motions. OGP with the smallest angular increment has shown the highest mean time-to-fracture when compared with continuous rotation or other rotation angles, indicating a much safer use in difficult cases [14]. However, the performance of OGP motion regarding canal transportation and centering ability in constricted canals still remains unclear. Therefore, the purpose of this study was to investigate and compare manual and OGP movement in terms of canal

transportation and centering ability in glide path preparation of constricted canals.

Methods

Sample selection

Research protocol was approved by the Research Ethics Committee (PKUSSIRB-201417105). Fifteen extracted mandibular molars with intact mesial roots and closed apices were chosen, based on the power analysis calculation in a previous study by our institution [15]. Briefly, an effect size of 1.93, an alpha-type error of 0.05 and a power beta of 0.95 were input together into an independent samples test from the *t*-test family (G*Power 3.1.9.3 for Macintosh; Heinrich Heine, Dusseldorf, Germany). The results implied a minimum sample size of 9 samples/group. Taking another canal transportation and centering ability study into consideration [16], a sample size of 15 canals/group was eventually decided. Teeth with fractures, restorations or caries were excluded. Pre-operative radiographs from different angles (a horizontal angle of 0° and a 30° from the mesial) were taken to make sure all mesial root canals were separated and narrow, with curvatures of 20° to 40° [17].

Pre-operative micro-CT scan

The teeth were decoronated approximately 2 mm above the cemento-enamel junction (CEJ) using diamond burs.

A micro-CT system (vivaCT-40, Scanco Medical, Bassersdorf, Switzerland) at 21 μm nominal voxel size, 56 kVp energy, 142 μA intensity, and 200 ms integration time was used to acquire scans. The region of interest extending from the CEJ to the apex were analyzed and reconstructed by Scanco evaluation software (v6.6, Scanco Medical). Samples were verified that the selected canals were separate and constricted, with initial apical size not larger than #8.

Glide path preparation

A total of 30 canals, 15 mesiobuccal (MB, $n=15$) and 15 mesiolingual (ML, $n=15$) canals, were selected from the sample teeth and negotiated with #6–#8 stainless steel K-files (Roydent, Johnson City, TN, USA) to achieve apical patency. The working length was determined under an operating microscope by inserting #8 K-file slightly passing the canal terminus and subtracting 0.5 mm from this measurement.

Canals were randomly assigned into two experimental groups (www.random.org) [18]. Briefly, stratification random sampling was applied, with canals being stratified as MB and ML first and followed by simple random sampling. **Group 1:** Glide path was established by using pre-curved #10–#15 stainless steel K-files (Roydent) manually to the working length; **Group 2:** Mechanical Glide Path

(MGP) super-files #10-#15 (MANI Inc., Japan) were used with OGP setting (OGP 90°, 300 rpm) on Tri-Auto ZX2 cordless motor (J. Morita CORP.). Following the manufacturer’s recommendations, in-and-out pecking movement as well as horizontal reciprocating movement were carefully combined and conducted.

RC-Prep (Premier, Plymouth Meeting, PA, USA) was used as a lubricating agent and the canals were irrigated with copious 3% sodium hypochlorite. Each instrument, manual or mechanical, was used to prepare only 2 canals (as in one mesial root). Any file distortion and separation were observed under microscope and recorded in both groups, and specimens with separated files were excluded at this point. All the preparation was performed by a single dentist with expertise in both preparation techniques.

Post-operative micro-CT scan and image analysis

A total of 30 canals (n=15 in each group) was scanned post-operatively. To ensure the standardization of the specimens during scanning, silicon rubber discs were used as positioners to keep specimens in the same relative positions for both pre- and post-operative scans, with the same protocol and parameter settings.

3D Slicer 4.6.2 software [19] was used to co-register the pre- and post-operative scans, followed by the application of ITK-SNAP 3.6.0 software to overlap the co-registered images (Fig. 1). Fiji 1.46r software (ImageJ, Madison, WI) was used to do the measurements, so that canal transportation and the centering ratio were calculated at three cross-section levels that corresponded to 1-mm, 3-mm, and 5-mm distance from the root apex by using the equations described by Gambill et al. [20].

Statistical analysis

Statistical analysis was performed with GraphPad Prism 6.2 software (GraphPad Software Inc., San Diego, CA, USA). Shapiro–Wilk normality test was applied to confirm the normality distribution of data ($P > 0.05$), followed by paired *t*-test to compare between two groups at different levels. Values of *P* less than 0.05 were considered statistically significant.

Results

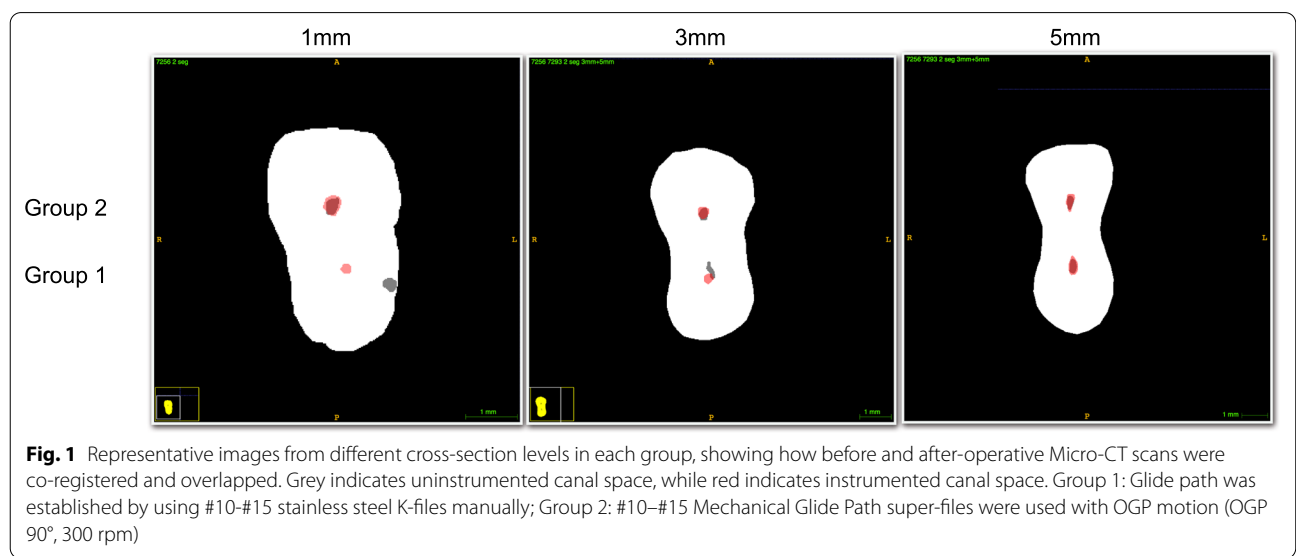
Nine MB and six ML canals were included in group 2, and group 1 contained six MB and nine ML canals. Group 2 showed a significant lower transportation value than group 1 at both 1-mm and 3-mm cross-section levels ($P < 0.05$), while the difference at 5-mm level was not significant (Fig. 2). Regarding to the ability of maintaining within the central axis of the root canal, the differences between the OGP reciprocating motion and manual preparation at all three cross-sections studied were not statistically significant (Fig. 3).

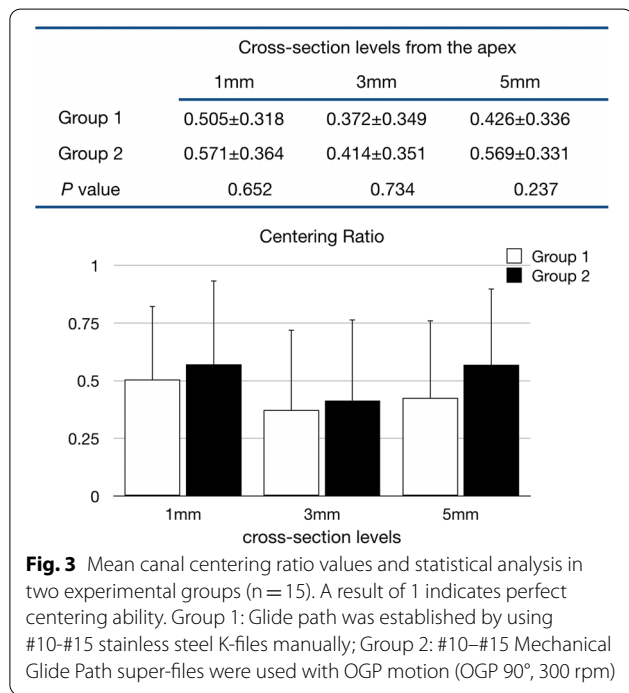
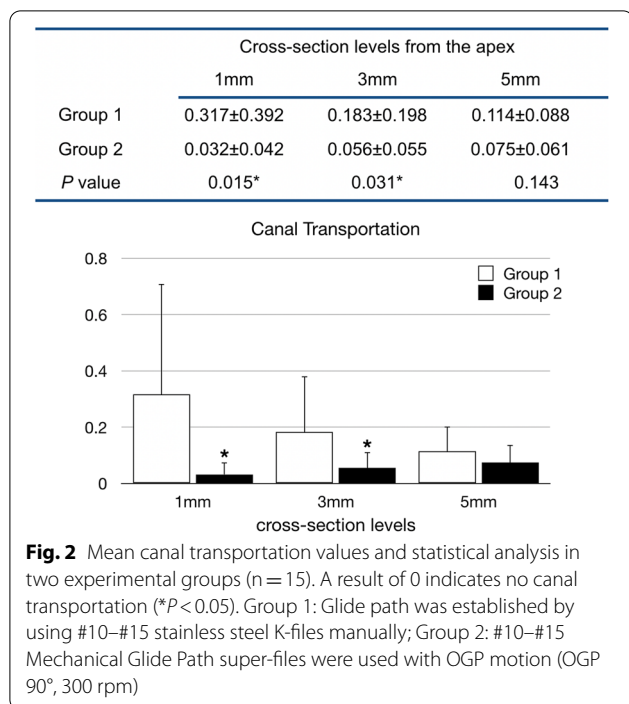
A total of six #10 K-files were severely distorted in group 1, at the apical 1 to 3-mm of the files; whereas no file distortion or separation was found in group 2.

Discussion

The present study revealed that OGP motion has a significant advantage and positive impact on the preservation of apical canal anatomy during glide path establishment in constricted canals, with significant less canal transportation and file distortion.

It is essential to address the differences between a glide path establishment and maintaining apical patency, in terms of their major goals and procedures. Glide path





development is an enlargement to a size approaching the subsequent rotaries’ tips, at least larger than the file’s core diameter, therefore to ensure a safe and smooth passage [1]. The concept of apical patency can be defined as ‘the repeated penetration of the apical foramen with a small

file during instrumentation to prevent the accumulation of debris and leave the foramen unblocked, i.e., patent’ [21]. The patency file should be smaller than the instrument that binds to the foramen, to be effective in offering a lesser risk of extruding toxic products and dentin fragments into periapical space [21]. In most of the cases, a size #8 file taken 0.5–1 mm long to establish patency contacts the desired endpoint of the preparation with a diameter approaching the tip size of a #10 file [1].

American Association of Endodontists defines transportation as ‘removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation’ [22]. Our study showed that MGP super-files together with OGP 90° motion created significantly less canal transportation in the apical 3 mm of constricted canals than traditional K-files. Wu et al. [23] stated that apical transportation of more than 300 µm may have a negative effect on the seal of root fillings. Canal transportation can lead to inappropriately dentin removal, with a higher risk of canal curvature modification and ledge formation. Many factors may contribute to certain degrees of canal transportation, such as motion type, canal morphology, design, and alloy of the instrument [24]. According to a new classification scheme proposed by Gambarini et al. [14], OGP is a combined motion of alternate and rotating reciprocation. Alternate reciprocation can be considered the safest motion, as it features clockwise = counterclockwise (usually less than 90°) and does not result in a full rotation. Whereas one angle of motion is larger than the other in rotating reciprocation, like Reciproc (150°/30°, Dentsply VDW, Munich, Germany) and WaveOne (170°/50°; Dentsply Maillefer) [25], and a series cycles ultimately form a full rotation inside the canal. It’s worth noting that the rotating effect given by this difference between clockwise and counterclockwise movements is important since it maintains the cutting efficiency and apical progression; moreover, this asymmetry in rotating reciprocation has the advantage of limiting the angel of rotation in the cutting verse under the endurance limit of the instrument [25]. Our finding indicates that the combination of watch-winding, and balanced force motion of OGP certainly has easier and better control during glide path preparation; whereas manual motion requires much more effort to maintain the original anatomy.

The mean centering ratio is a measure of the ability of the instrument to stay centered in the canal. A previous study revealed that reciprocating motion may promote the canal centering ability, and reduce the risk of root canal deformity [26]. Our data demonstrated similar findings, as OGP has a better centering ratio in apical 5 mm, however the results were not statistically significant.

Endodontic instrument separation may be created as a result of two distinct modes or their combination. While cyclic flexural fatigue may happen when continuous tension–compression cycles generate in curved canals overtime, torsional failure occurs when the file tip gets locked in the calcified canal; however, file shank continues to rotate [27]. Our study demonstrated a notable difference between the two experimental groups. As each instrument investigated was used to prepare only 2 canals (as in one mesial root), not a single MGP super-file under OGP 90° motion distorted or broke, while there were 6 K-files severely distorted in group 1. Several underlying mechanisms might contribute to this phenomenon. The combined alternate + rotating reciprocation movement acts to reduce the stresses of taper lock and screw-in effect, minimizes torsional and flexural stresses on the instrument, thus decreases the chance of instrument breakage [28, 29]; moreover, studies have shown that rotation angle and angular increment are related to the distribution of stress [30, 31]. OGP 90° has better cyclic fatigue and torsional resistance than OGP 180°, OGP 240°, and continuous rotation motion [14]. The up-and-down pecking motion of the handpiece with 1 mm short pecking depth may also lower the torsional stress accumulation and overload during glide path establishment since the contact time, and binding area between the instrument and dentin walls become short and small [32, 33].

Further research is still in need to evaluate other aspects of OGP motion using NiTi instruments, with comparison not just to manual motion but more importantly to continuous rotation and other single rotating reciprocation motions, so that we can have a complete understanding and clinical approach regarding the glide path establishment in constricted canals.

Conclusion

It can be concluded that OGP reciprocating movement performed significantly less canal transportation (apical 3 mm) and file distortion during glide path establishment in constricted canals comparing to manual motion, while the centering ability between the two was similar. These favorable results of OGP movement indicate its potential application as a viable alternative to manual motion in glide path preparation of constricted canals, yet further research is needed to compare this novel motion with other rotary movements and on other parameters.

Abbreviations

OGP: Optimum glide path; CEJ: Cemento-enamel junction; MGP: Mechanical glide path.

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Authors' contributions

The study conception and design were mainly contributed by BK and JL. Material preparation, data collection and analysis were performed by JL and ZZ. Micro-CT instruction was given by WT. The first draft of the manuscript was written by JL, and BK helped to review and revise previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

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

Ethics approval and consent to participate

All procedures performed in this study was approved by the relevant institutional review board (Ethics Committee of Peking University Health Science Center, PKUSSIRB-201417105), and was in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests related to the authorship and/or publication of this article.

Author details

¹ Center of Dental Medicine, China-Japan Friendship Hospital, 2 Ying-Hua-Yuan East Street, Chaoyang District, Beijing 100029, China. ² Department of Pediatric Dentistry, School and Hospital of Stomatology, Peking University, 22 South Zhongguancun Avenue, Haidian District, Beijing 100081, China. ³ Department of Endodontics, School of Dental Medicine, University of Pennsylvania, 240 S 40th St, Philadelphia, PA 19104, USA.

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References

- Peters OA, Peters CI, Basrani B. Cleaning and shaping of the root canal system. In: Hargreaves KM, Berman LH, editors. Cohen's pathways of the pulp. 11th ed. St. Louis: Elsevier; 2006. p. 209–79.
- Kwak SW, Ha JH, Cheung GS, Kim HC, Kim SK. Effect of the glide path establishment on the torque generation to the files during instrumentation: an in vitro measurement. *J Endod*. 2018;44(3):496–500.
- Ha JH, Park SS. Influence of glide path on the screw-in effect and torque of nickel–titanium rotary files in simulated resin root canals. *Restor Dent Endod*. 2012;37(4):215–9.
- West J. The magic of mastering the glide path: what every endodontist should know. CA: American Association of Endodontists Annual Session. San Diego; 2010.
- Berutti E, Cantatore G, Castellucci A, Chiandussi G, Pera F, Migliaretti G, et al. Use of nickel–titanium rotary PathFile to create the glide path: comparison with manual preflaring in simulated root canals. *J Endod*. 2009;35(3):408–12.
- Patiño PV, Biedma BM, Liébana CR, Cantatore G, Bahillo JG. The influence of a manual glide path on the separation rate of NiTi rotary instruments. *J Endod*. 2005;31(2):114–6.
- McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. *Int Endod J*. 2012;45(2):177–97.

8. Cvek M, Granath L, Lundberg M. Failures and healing in endodontically treated non-vital anterior teeth with posttraumatically reduced pulpal lumen. *Acta Odontol Scand.* 1982;40(4):223–8.
9. Ferraz CC, Gomes NV, Gomes BP, Zaia AA, Teixeira FB, Souza-Filho FJ. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. *Int Endod J.* 2001;34(5):354–8.
10. Kuhn WG, Carnes DL Jr, Clement DJ, Walker WA III. Effect of tip design of nickel–titanium and stainless steel files on root canal preparation. *J Endod.* 1997;23(12):735–8.
11. Glossen CR, Haller RH, Dove SB, del Rio CE. A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. *J Endod.* 1995;21(3):146–51.
12. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centering ability of four instrumentation techniques. *J Endod.* 1997;23(8):503–7.
13. Roane JB, Sabala CL, Duncanson MG Jr. The “balanced force” concept for instrumentation of curved canals. *J Endod.* 1985;11(5):203–11.
14. Gambarini G, Piasecki L, Miccoli G, Gaimari G, Giorgio RD, Nardo DD, et al. Classification and cyclic fatigue evaluation of new kinematics for endodontic instruments. *Aust Endod J.* 2019;45(2):154–62.
15. Poly A, AlMalki F, Marques F, Karabucak B. Canal transportation and centering ratio after preparation in severely curved canals: analysis by micro-computed tomography and double-digital radiography. *Clin Oral Investig.* 2019;23(12):4255–62.
16. Hassan R, Roshdy N, Issa N. Comparison of canal transportation and centering ability of XP Shaper, WaveOne and Oneshape: a cone beam computed tomography study of curved root canals. *Acta Odontol Latinoam.* 2018;31(1):67–74.
17. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol.* 1971;32(2):271–5.
18. RANDOM.ORG. <https://www.random.org>. Accessed Oct 1998.
19. Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin JC, Pujol S, et al. 3D Slicer as an image computing platform for the quantitative imaging network. *Magn Reson Imaging.* 2012;30(9):1323–41.
20. Gambill JM, Alder M, del Rio CE. Comparison of nickel–titanium and stainless steel hand-file instrumentation using computed tomography. *J Endod.* 1996;22(7):369–75.
21. Souza RA. The importance of apical patency and cleaning of the apical foramen on root canal preparation. *Braz Dent J.* 2006;17(1):6–9.
22. Guide to clinical Endodontics, 6th edition. American Association of Endodontists. 2019. <http://aae.org>.
23. Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved root canals. Part I: effects of apical transportation on seal of root fillings. *J Endod.* 2000;26(4):210–6.
24. Aydin U, Karataslioglu E. Evaluation of canal transportation after preparation with Reciproc single-file systems with or without glide path files. *J Conserv Dent.* 2017;20(4):230–3.
25. Grande NM, Ahmed HM, Cohen S, Bukiet F, Plotino G. Current assessment of reciprocation in Endodontic preparation: a comprehensive review—part I: historic perspectives and current applications. *J Endod.* 2015;41(11):1778–83.
26. Lim YJ, Park SJ, Kim HC, Min KS. Comparison of the centering ability of WaveOne and Reciproc nickel–titanium instruments in simulated curved canals. *Restor Dent Endod.* 2013;38(1):21–5.
27. McGuigan MB, Louca C, Duncan HF. Endodontic instrument fracture: causes and prevention. *Br Dent J.* 2013;214(7):341–8.
28. Tokita D, Ebihara A, Nishijo M, Miyara K, Okiji T. Dynamic torque and vertical force analysis during nickel–titanium rotary root canal preparation with different modes of reciprocal rotation. *J Endod.* 2017;43(10):1706–10.
29. Htun PH, Ebihara A, Maki K, Kimura S, Nishijo M, Tokita D, et al. Comparison of torque, force generation and canal shaping ability between manual and nickel–titanium glide path instruments in rotary and optimum glide path motion. *Odontology.* 2020;108(2):188–93.
30. Saber Sel D, Abu El Sadat SM. Effect of altering the reciprocation range on the fatigue life and the shaping ability of WaveOne nickel–titanium instruments. *J Endod.* 2013;39(5):685–8.
31. Gambarini G, Rubini AG, Al Sudani D, Gergi R, Culla A, Angelis FD, et al. Influence of different angles of reciprocation on the cyclic fatigue of nickel–titanium endodontic instruments. *J Endod.* 2012;38(10):1408–11.
32. Ha JH, Kwak SW, Sigurdsson A, Chang SW, Kim SK, Kim HC. Stress generation during pecking motion of rotary nickel–titanium instruments with different pecking depth. *J Endod.* 2017;43(10):1688–91.
33. Maki K, Ebihara A, Kimura S, Nishijo M, Tokita D, Okiji T. Effect of different speeds of up-and-down motion on canal centering ability and vertical force and torque generation of nickel–titanium rotary instruments. *J Endod.* 2019;45(1):68–72.e1.

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