https://journal.umy.ac.id/index.php/di/article/view/29089

Insisiva Dental Journal:

Majalah Kedokteran Gigi Insisiva

INSISIVA DENTAL JOURNAL | Vol. 7 | No. 1 | Hlm. 1-36 | Yogyakarta | Mei 2018 | ISSN 2252-9764

Editorial Team

Vol. 15 No. 1 (2026): May

Published: 2026-05-26

Articles

Case Report

Literature Review

IDJ
Insisiva Dental Journal: Majalah Kedokteran Gigi Insisiva

Insisiva Dental Journal: Majalah Kedokteran Gigi Insisiva
Website: http://journal.umy.ac.id/index.php/di/index

Research Article

Effect of Glide Path Preparation on Centering Ability and Canal Transportation of Blue-Treated Flat-Designed Single File Systems

Gary Hadrian[1], Tien Suwartini[1*], Dina Ratnasari[1], Johan Arief Budiman[2]

[1]Department of Conservative Dentistry, Faculty of Dentistry, Universitas Trisakti, Jakarta 11440, Indonesia
[2]Department of Orthodontics, Faculty of Dentistry, Universitas Trisakti, Jakarta 11440, Indonesia

Received date: April 14th, 2026; revised date: April 29th, 2026; accepted: May 5th, 2026
DOI: 10.18196/di.v15i1.29089

Abstract

Maintaining the original root canal anatomy during shaping is crucial to prevent procedural errors, such as canal transportation and ledge formation. The development of heat-treated blue NiTi instruments can improve flexibility, resistance to cyclic fatigue, and the ability to maintain root canal curvature. This study aimed to evaluate the effect of glide path (GP) on canal centering and canal transportation using a single-file system of blue NiTi with a conventional S-shaped cross-section design (AF S) and a flat design (AF F). Forty J-shaped canal simulation resin blocks were randomly divided into four groups: AF F+GP, AF F, AF S+GP, and AF S (n = 10 each group). In the group using the glide path (AF F+GP and AF S+GP), ProGlider #16.02 was used before instrumentation. Pre- and post-instrumentation images were analyzed using Adobe Photoshop CS6 software to measure canal centering and transportation at the apical, middle, and coronal thirds. Data were analyzed using one-way ANOVA and Tukey's post hoc test ($p<0.05$). Significant differences were found in canal centering and canal transportation in the apical and middle thirds ($p<0.05$), while no significant differences were found in the coronal third ($p>0.05$). The use of a glide path significantly improved centering ability and reduced transportation. Furthermore, the flat design of the Blue NiTi single-file system demonstrated better centering ability and reduced canal transportation than conventional S-shaped systems. All systems could shape curved simulated root canals without iatrogenic error.

Keywords: Canal centering; canal transportation; glide path; flat design

INTRODUCTION

The endodontic triad consists of cleaning and shaping, disinfection, and obturation of the root canal system.[1] Among these, cleaning and shaping represent critical steps because they facilitate effective disinfection and enable three-dimensional obturation.[2,3] The ideal outcome of biomechanical preparation is a tapered canal following the original anatomy. It is often challenging to achieve this due to anatomical variations in teeth, especially in curved root canals. The nature of the instrument tends to return to its straight shape, which can cause canal transportation and decreased centering ability.[4] Inadequate root canal shaping can result in over-preparation, dentin walls thinning, microcrack formation, or even strip perforation.[5]

Introduction of nickel-titanium (NiTi) alloys in the late 1980s revolutionized endodontics, as these files were 2–3 times more flexible than stainless steel, better preserved canal anatomy and provided safer instrumentation.[6] Although conventional NiTi instruments have various advantages, they still show some limitations, such as shape memory effect, decreased fatigue resistance, and a tendency to fracture.[7,8] To overcome those limitations, heat-treated NiTi alloys have been developed to increase durability, resistance to cyclic fatigue, and the ability

* Corresponding author, email: tien.s@trisakti.ac.id

to adapt to root canal curvature.[9] Blue NiTi instruments, manufactured at 500 °C and coated with a titanium oxide layer of 60–80 nm thickness, demonstrated superior canal centering compared with gold treatment.[10,11]

More recently, flat-design blue NiTi instruments were introduced, with a modified S-shaped cross-section and a flat surface to reduce torsional stress, minimize metal mass, and enhance flexibility and resistance to cyclic fatigue.[12] The flat-design single-file system improves centering ability and reduces canal transportation compared with conventional single-file systems.[13]

In addition to instrument design, shaping systems are classified into multiple-file and single-file systems.[14] Single-file systems offer shorter preparation times up to 40% less—while providing similar shaping ability compared with multiple-file systems.[15,16] However, controversy persists regarding the necessity of preparing a glide path. While some studies demonstrated that glide path creation reduced canal transportation and improved centering ability[17], other reports showed no significant influence.[18,19]

Given the pros and cons of the glide path and maintaining the original canal anatomy, further research is needed. Therefore, this study evaluated the effect of glide path preparation on canal centering and transportation using heat-treated blue NiTi rotary single-file systems with both conventional and flat designs. To our knowledge, no study has directly compared the effect of glide path creation between these two blue NiTi single-beam systems, thus confirming this study's novelty and clinical relevance.

MATERIALS AND METHOD

Forty simulated J-shaped root canals in resin blocks (ISO #10, 0.02 taper; REF: BDDBLC0A30010, Endo Training Block, Dentsply Sirona, Ballaigues, Switzerland) with a 40° curvature and a working length of 16 mm were used in this study. All resin blocks were pre-fabricated with a standardized 40° canal curvature according to the manufacturer's specifications. To make sure the consistency, the curvature of each canal was verified prior to instrumentation using Schneider's method based on pre-instrumentation images. Canal patency was confirmed using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The samples were stained with Methylene blue (MB, CI 52015, from Merck KGaA, Darmstadt, Germany). Images of the samples before instrumentation were captured with a camera (Sony Mirrorless A7II, Sony, Tokyo, Japan), mounted in a standard setup using a metal holder to stabilize the blocks. Then, all the samples were randomly divided into four experimental groups.

Experimental groups and shaping procedures:

Two types of NiTi rotary files were used in this study: AF Blue F One and AF Blue S One (Fanta Dental, Shanghai, China). In the groups with glide path preparation, ProGlider (PG) #16.02 (Dentsply Sirona, Ballaigues, Switzerland) was used before shaping. All groups were prepared using the same standardized simulated canals. Samples were assigned into 4 equal groups (n = 10), as detailed below:

1) Group 1 (AF F + GP): Glide path prepared with ProGlider, followed by shaping with AF Blue F One.
2) Group 2 (AF F): Prepared with AF Blue F One without glide path preparation.
3) Group 3 (AF S + GP): Glide path prepared with ProGlider, followed by shaping with AF Blue S One.
4) Group 4 (AF S): Prepared with AF Blue S One without glide path preparation.

Each simulated canal was prepared using a new single-use instrument. All instruments were operated using an endodontic motor (X-smart Plus, Dentsply Sirona, Ballaigues, Switzerland). Irrigation was performed using 3 mL of distilled water delivered through a 30-gauge side-vented needle during instrumentation to ensure standardization and debris removal.

Analysis of centering ability and canal transportation

Adobe Photoshop CS6 software (Adobe Systems Inc., USA) was used to identify nine reference points (levels) along the length of the simulated J-shaped canals (Figure 1). The reference points identified in the pre- and post-instrumentation images were combined and superimposed. Measurements were performed using concentric circles at 1-mm intervals, and perpendicular lines were drawn from the prepared surface to establish the measurement points. Point A represented the most apical level, whereas point I represented the most coronal level. Image contrast, color, and sharpness were adjusted, and measurements were taken to assess differences in the inner and outer canal walls at each reference line after preparation. The canal widths were measured at the 3-, 5-, and 7-mm levels of the simulated canals both before and after instrumentation. Canal transportation values were calculated by subtracting the amount of resin removed from the inner aspect from that removed from the outer aspect. At the same time, canal centering was also analyzed for each group.

For canal centering, the calculation was performed using the following formula: X1/X2 or X2/X1. X1 represented the amount of resin removed from the inner wall, and X2 represented the amount removed from the outer wall. The ratio was obtained by dividing the smaller resin removal value by the larger one for each canal aspect.[20] A value of 1 represented perfect centering, whereas 0 indicated complete deviation from the canal center.[21]

Canal transportation was calculated using the formula (X1–X2). A positive value indicated transportation toward the inner wall of the root canal, whereas a negative value indicated transportation toward the outer wall.[22]

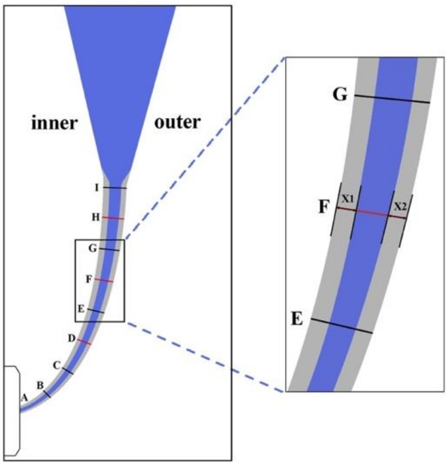

Figure 1. Pre- and post-instrumentation images were superimposed, and measurements were taken Simulated J-shaped canal showing nine reference levels (A–I) at 1-mm intervals, from apical (A) to coronal (I). Measurements were performed at three reference points—D, F, and H—3 mm, 5 mm, and 7 mm from the apex, respectively, to determine the amount of resin removal. X1 represents the amount of resin removed from the inner wall, and X2 represents the amount removed from the outer wall.

Statistical Analysis

Statistical software (SPSS for Mac, Version 26.0, Chicago, USA) was used to analyze the statistical data. Levene's test was used to assess homogeneity of variance, and the Shapiro–Wilk test was used to assess normality. The analysis results showed that the data were normally distributed and had homogeneous variance. Therefore, the analysis continued with a one-way ANOVA and Tukey's post hoc test. The significance level for all statistical tests was $p<0.05$.

RESULTS

The results demonstrated that canal centering and canal transportation varied with the level of instrumentation. In the apical and middle thirds, statistically significant differences were observed among the groups ($p < 0.05$), whereas in the coronal third, no significant differences were detected for either parameter ($p > 0.05$).

Table 1. Canal centering mean value for apical, middle, and coronal thirds after instrumentation

Distance from the apex	Canal centering (Mean±SD) (mm)				
	AF F +GP	AF F	AF S +G	AF S	p
3 mm	0.896±0.072	0.910±0.081	0.887±0.069	0.579±0.053	0.000*
5 mm	0.760±0.046	0.700±0.036	0.687±0.036	0.452±0.030	0.000*
7 mm	0.933±0.038	0.944±0.047	0.918±0.062	0.897±0.055	0.218

Values with different superscripts indicate a statistically significant group difference *significant ($p<0.05$).

For canal centering (Table 1), in the apical third, AF F+GP (0.896 ± 0.072 mm), AF F (0.910 ± 0.081 mm), and AF S+GP (0.887 ± 0.069 mm) showed significantly better centering ability compared with AF S (0.579 ± 0.053 mm; p = 0.000). Post hoc Tukey analysis revealed no significant differences among AF F+GP, AF F, and AF S+GP ($p > 0.05$). In contrast, all three groups demonstrated significantly superior centering compared with AF S (p = 0.000), with mean differences ranging from 0.308 to 0.331 mm. In the middle third, AF F+GP (0.760 ± 0.046 mm), AF F (0.700 ± 0.036 mm), and AF S+GP (0.687 ± 0.036 mm) also exhibited significantly higher centering values compared with AF S (0.452 ± 0.030 mm; p = 0.000). Post hoc analysis indicated that AF F+GP performed significantly better than AF F (p = 0.005) and AF S+GP (p = 0.001), while AF F and AF S+GP did not differ significantly (p = 0.866). In the coronal third, no significant differences were observed among the groups (p = 0.218).

Table 2. Canal transportation mean value for apical, middle, and coronal thirds after instrumentation

Distance from the apex	Canal transportation (Mean±SD) (mm)				
	AF F +GP	AF F	AF S +G	AF S	p
3 mm	0.017±0.011	0.015±0.014	0.019±0.011	0.083±0.011	0.000*
5 mm	0.049±0.009	0.064±0.009	0.067±0.009	0.136±0.009	0.000*
7 mm	-0.014±0.008	-0.012±0.010	-0.017±0.013	0.022±0.012	0.234

Values with different superscripts indicate a statistically significant group difference *significant ($p<0.05$)

For canal transportation (Table 2), in the apical third, AF F+GP (0.017 ± 0.011 mm), AF F (0.015 ± 0.014 mm), and AF S+GP (0.019 ± 0.011 mm) demonstrated significantly lower transportation compared with AF S (0.083 ± 0.011 mm; p = 0.000). Post hoc Tukey analysis confirmed that AF 'F+GP, AF F, and AF S+GP did not differ significantly from one another ($p > 0.05$). Still, all three groups exhibited significantly reduced transportation compared with AF S (p = 0.000), with mean differences ranging from –0.064 to –0.068 mm. In the middle third, AF F+GP (0.049 ± 0.009 mm), AF F (0.064 ± 0.009 mm), and AF S+GP (0.067 ± 0.009 mm) showed significantly less transportation than AF S (0.136 ± 0.009 mm; p = 0.000). Post hoc analysis further revealed that AF F+GP had significantly lower transportation than AF F (p = 0.007), AF S+GP (p = 0.001), and AF S (p = 0.000). At the same time, AF F and AF S+GP did not differ significantly (p = 0.899). In the coronal third, no statistically significant differences were observed among the groups (p = 0.234).

DISCUSSION

The root canal system is cleaned and shaped during endodontic therapy while maintaining its original anatomical structure. Curved root canals increase the risk of iatrogenic errors, including ledge formation, perforation, transportation, instrument fracture, asymmetric dentin removal, and changes in the internal anatomy of the root canal.[23,24]

A heat-treated single-file system of blue NiTi, specifically AF Blue S One and AF Blue F One, was used in this investigation to prepare the root canal. The AF Blue F One has the benefit of a flat design, but both instruments are constructed of AF-R wire with an S-shaped cross-section and a non-cutting tip.[25] Compared to multiple file systems, using a single file system with continuous motion offers several benefits, including a 40% reduction in preparation time, reduced risk of instrument breakage, and improved root canal centering.[2] These findings align with previous research indicating that flat-designed instruments enhance shaping efficiency and improve procedural safety.[13]

Establishing a glide path reduces the risk of instrument fracture, facilitates accurate shaping, and enhances the centering ability of instruments, particularly in narrow and curved canals, thereby improving the predictability of single-file system preparation.[10] Rotary NiTi instruments, such as the ProGlider (Dentsply Maillefer, Ballaigues, Switzerland), were developed to replace the time-consuming, technique-sensitive nature of manual glide path preparation, providing a more efficient, predictable approach.[26]

The evaluation of shaping ability, including centering ability and canal transportation, was performed at the apical, middle, and coronal thirds, representing areas of curvature most susceptible to iatrogenic mishaps.[27] A superimposition technique on simulated resin block canals was employed, providing standardized curvature and radius as well as reproducible photographic documentation for precise comparison of canal morphology before and after preparation.[28] The analysis was further enhanced using Adobe Photoshop software to outline and assess canal shaping accurately. This method has been validated in previous studies as a reliable approach for evaluating the shaping performance of different instrumentation techniques.[29]

Extracted teeth were not used due to difficulties in standardizing dentin hardness and irregular canal anatomy, which would have limited reproducibility across samples.[30] Instead, simulated resin block canals were utilized, offering the advantage of controlled standardization.[15] However, resin blocks also have limitations. The heat generated during instrumentation can soften the resin block, increasing the risk of binding the cutting blade and potentially fracturing the instrument. To minimize this effect, recapitulation with a #10 K-file and irrigation after each file change were performed to dissipate heat and remove resin debris.[22]

The final instrumentation size in this study was standardized to a #25 tip. The effectiveness of #25 files in reducing bacterial counts did not differ significantly from that of larger-apical-diameter files.[31] However, the larger the taper, the more significant the dentin reduction toward the danger zone, ultimately increasing canal transportation.[32]

Significant differences in canal centering and transportation were observed in the apical and middle thirds among the groups instrumented using the blue NiTi single-file system with a flat design, both with and without glide path preparation. These results are consistent with the findings that flat-design files have a superior ability to maintain canal shape.[13] The flat design system has been reported from a previous study to reduce metal debris on instruments, increase flexibility, and improve resistance to cyclic fatigue. In addition, the lower binding tendency of its cutting blades, attributed to a smoother cross-sectional design, may explain its more conservative shaping ability.[33] Glide path preparation in the conventional S-shaped (AF S) group also enhanced canal centering and reduced transportation. These findings corroborate previous studies that glide path preparation minimizes canal deviation and helps instruments remain centered within the canal.[34,35] No significant differences were observed among the groups at the coronal third.

Canal transportation was detected in all groups, coronal, middle, and apical thirds; however, the extent did not exceed 0.3 mm. Transportation greater than 0.3 mm may compromise the apical seal and negatively affect the prognosis of endodontic treatment.[36] Importantly, none of the groups in this study demonstrated canal transportation beyond this threshold, indicating that all systems could shape curved root canals effectively without compromising apical sealing ability. Moreover, no iatrogenic mishaps, such as ledges or instrument fractures, were observed, further demonstrating the safety of the systems tested. These results support the ability of single-file continuous motion systems to shape moderately curved root canals with predictable outcomes.

Among all groups, group 1 (AF F + GP) system demonstrated the highest mean canal centering and the lowest transportation values, indicating superior shaping performance compared with the others. This suggests that the system may help clinicians reduce iatrogenic errors, achieve more predictable shaping, and preserve natural canal morphology.

A limitation of this study was the difference in hardness between the acrylic resin used and natural teeth. Therefore, further research is recommended to use extracted human teeth as samples to obtain results that are more representative of clinical conditions.

CONCLUSION

A glide path significantly improved canal centering ability and reduced transportation when using the blue NiTi single-file system. Moreover, the flat design demonstrated superior canal centering and minimized transportation compared with conventional S-shaped files. A limitation of this study was the difference in hardness between the acrylic resin used and natural teeth. Further research on canal centering and transportation is recommended to facilitate the extraction of human teeth.

ACKNOWLEDGMENT

The authors would like to thank Dr. Bernard Ongki Iskandar and Dr. Anastasia Elsa Prahasti for their valuable scientific input in conducting this research. Financial support for this study was provided by the authors.

REFERENCES

1. Ragul P, Dhanraj M, Jain A. Irrigation technique used in cleaning and shaping during endodontic treatment: A review. Drug Invention Today. 2018;10:739–743. https://www.researchgate.net/publication/326030915_Irrigation_technique_used_in_cleaning_and_shaping_during_endodontic_treatment_-_A_review
2. Fatima A, Shabir H, Goyal A, et al. A literature review of single file NiTi rotary system in endodontics. IP Indian J Conserv Endod. 2021;6(2):85–87.
3. Hazar E, Geduk G, Coşkun E, Koçak S, Sağlam BC, Koçak MM. Comparison of centering ability and canal transportation of TruNatomy files with different file systems. J Dent Indones. 2023;30(2):81–86. https://scholarhub.ui.ac.id/jdi/vol30/iss2/2/
4. Yalniz H, Koohnavard M, Oncu A, Celikten B, Orhan AI, Orhan K. Comparative evaluation of dentin volume removal and centralization of the root canal after shaping with the ProTaper Universal, ProTaper Gold, and One-Curve instruments using micro-CT. J Dent Res Dent Clin Dent Prospects. 2021;15(1):47–52. https://pubmed.ncbi.nlm.nih.gov/33927841/
5. Hülsmann M. A critical appraisal of research methods and experimental models for studies on root canal preparation. Int Endod J.

2022;55(Suppl 1):95–118. https://pubmed.ncbi.nlm.nih.gov/34800299/

6. Tabassum S, Zafar K, Umer F. Nickel-titanium rotary file systems: What's new? Eur Endod J. 2019;4(3):111–117. https://pubmed.ncbi.nlm.nih.gov/32161896/
7. Drukteinis S, Peciuliene V, Bendinskaite R, Brukiene V, Maneliene R, Rutkunas V. Shaping and centering ability, cyclic fatigue resistance and fractographic analysis of three thermally treated NiTi endodontic instrument systems. Materials (Basel). 2020;13(24):5823. https://pmc.ncbi.nlm.nih.gov/articles/PMC7766619/
8. Delgoshayi N, Abbasi M, Bakhtiar H, Sakhdari S, Ghannad S, Ellini MR. Canal transportation and centering ability of ProTaper and SafeSider in preparation of curved root canals: A CBCT evaluation. Iran Endod J. 2018;13(2):240–245. https://pubmed.ncbi.nlm.nih.gov/29707022/
9. 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):1645–1651. https://pubmed.ncbi.nlm.nih.gov/31132156/
10. Biasillo V, Castagnola R, Colangeli M, et al. Comparison of shaping ability of the Reciproc Blue and One Curve with or without glide path in simulated S-shaped root canals. Restor Dent Endod. 2022;47(1):e3. https://pmc.ncbi.nlm.nih.gov/articles/PMC8891470/\
11. Dablanca-Blanco AB, Castelo-Baz P, Miguéns-Vila R, Álvarez-Novoa P, Martín-Biedma B. Endodontic rotary files: what should an endodontist know? Medicina (Kaunas). 2022;58(6):719. https://pubmed.ncbi.nlm.nih.gov/35743982/
12. Silva EJNL, Martins JNR, Lima CO, Vieira VTL, Braz Fernandes FM, De-Deus G, Versiani MA. Mechanical tests, metallurgical characterization, and shaping ability of nickel-titanium rotary instruments: a multimethod research. J Endod. 2020;46(10):1485-1494. https://pubmed.ncbi.nlm.nih.gov/32721485/
13. Di Nardo D, Miccoli G, Mazzoni A, Seracchiani M, Gambarini G, Testarelli L. Centering ability of a new nickel-titanium rotary instrument with a peculiar flat-side design: an in vitro study. J Contemp Dent Pract. 2020;21(5):539-542. https://pubmed.ncbi.nlm.nih.gov/32690836/
14. Arias A, Peters OA. Present status and future directions: canal shaping. Int Endod J. 2022;55(Suppl 3):637-655. https://pubmed.ncbi.nlm.nih.gov/35118683/
15. Kaddoura R, Madarati AA, Al-Tayyan M. Shaping ability of different single-file rotary systems in simulated S-shaped canals by a new investigation approach: an in vitro study. Saudi Endod J. 2021;11(2):173. https://journals.lww.com/senj/fulltext/2021/11020/shaping_ability_of_different_single_file_rotary.7.aspx
16. Yared G, Ramli GA. Single file reciprocation: a literature review. Endo (Lond Engl). 2013;7(3):171-178. https://hodsollhousedental.co.uk/wp-content/uploads/2014/01/Single-file-reciprocation-review_Yared.pdf
17. Hage W, Zogheib C, Bukiet F, Sfeir G, Khalil I, Gergi R, Naaman A. Canal transportation and centring ability of Reciproc and Reciproc Blue with or without use of glide path instruments: a CBCT study. Eur Endod J. 2020;5(2):118-122. https://pubmed.ncbi.nlm.nih.gov/32766521/

18. Susantio C, Hanafi W, Widyastuti W, Prahasti AE, Amtha R. Differences in preparation results of two reciprocal NiTi files with and without glide path on changes in root canal curvature. Sci Dent J. 2021;5(3):84. https://www.researchgate.net/publication/352687287_Differences_in_Preparation_Results_of_Two_Reciprocal_NiTi_Files_with_and_Without_Glide_Path_to_the_Changes_on_Root_Canal_Curvature
19. Kuden C, Yoldas O, Evlice B, Yilmaz S, Dumani A. Influence of establishing a glide path on the amount of apically extruded debris and the preservation of root canal anatomy. Cukurova Med J. 2022;47(1):241-249. https://dergipark.org.tr/en/pub/cumj/issue/68810/1024096
20. Karaca Sakallı A, Ekici MA. Evaluation of shaping ability, apical transportation and centering ratio of T-Endo Must, WaveOne Gold, and TruNatomy in resin blocks. PeerJ. 2024;12:e18088. https://pubmed.ncbi.nlm.nih.gov/39421425/
21. Kanujaya I, Widyastuti W, Prahasti AE, Budiman JA. Centering ability and canal transportation of three reciprocal files in moderately curved canals. Insisiva Dent J. 2025 May;14(1):63–70. https://journal.umy.ac.id/index.php/di/article/view/25807/11608
22. Shi L, Yang Y, Wan J, Xie W, Yang R, Yao Y. Shaping ability of rotary and reciprocating single-file systems in combination with and without different glide path techniques in simulated curved canals. J Dent Sci. 2022 Oct;17(4):1520-1527. https://pubmed.ncbi.nlm.nih.gov/36299306/
23. Vallabhaneni S, Fatima K, Kumar TH. Cone-beam computed tomography assessment of root canal transportation using WaveOne Gold and Neoniti single-file systems. J Conserv Dent. 2017;20(6):434-438. https://pubmed.ncbi.nlm.nih.gov/29430097/
24. Parikh H, Bharatiya R, Ujariya U, Kothari A. Curved paths: a comprehensive review and case insights into root canal anatomy. J Conserv Dent Endod. 2024;27(12):1310-1314. https://pubmed.ncbi.nlm.nih.gov/39959025/
25. Martins JNR, Silva EJNL, 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. https://pubmed.ncbi.nlm.nih.gov/37029571/
26. 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. https://pubmed.ncbi.nlm.nih.gov/39195101/
27. Roshdy N, AbdelWahed A. Shaping ability of WaveOne Gold and Reciproc Blue with and without the use of glide path in curved canals: a CBCT study. Egypt Dent J. 2022;68(1):1073-1081. https://edj.journals.ekb.eg/article_218754.html
28. Sharawy WW, El Shater WH. Shaping ability of ProTaper Gold and ProTaper Ultimate in simulated root canals: a comparative study. Sch J Dent Sci. 2023;10(1):12-19. https://saspublishers.com/media/articles/SJDS_101_12-19_FT.pdf
29. Alshahrani MO, Al-Omari M. Shaping ability of ProTaper Next and Navigator EVO rotary nickel-titanium file systems in simulated L-shaped and S-shaped root canals. Saudi Endod J. 2019;9(3):161-168. https://journals.lww.com/senj/fulltext/

2019/09030/shaping_ability_of_protaper_next_and_navigator_evo.1.aspx
30. Gambarini G, Miccoli G, Seracchiani M, Khrenova T, Donfrancesco O, D'Angelo M, Galli M, Di Nardo D, Testarelli L. Role of the flat-designed surface in improving the cyclic fatigue resistance of endodontic NiTi rotary instruments. Materials (Basel). 2019;12(16):2523. https://pubmed.ncbi.nlm.nih.gov/31398814/
31. Aminoshariae A, Kulild J. Master apical file size—smaller or larger: a systematic review of microbial reduction. Int Endod J. 2015;48(11):1007-1022. https://pubmed.ncbi.nlm.nih.gov/25387434/
32. De-Deus G, Rodrigues EA, Lee JK, Kim J, Silva EJNL, Belladonna FG, Simões-Carvalho M, Souza EM, Versiani MA. Taper 0.06 versus taper 0.04: the impact on the danger zone. J Endod. 2023;49(5):536-543. https://pubmed.ncbi.nlm.nih.gov/36841384/
33. Mokhtari H, Razi S, Rahimi S, Haghighat P, Abedi A, Behrouzpour E. Evaluation of canal transportation and centering ability of RaCe and AF F-One systems by cone-beam computed tomography: an in vitro study. Iran Endod J. 2024;19(3):193-198. https://pmc.ncbi.nlm.nih.gov/articles/PMC11287041/
34. El-Azazy A, Hassanien E, Yehia T. Effect of glide path preparation on the shaping ability of two different reciprocating NiTi files: an in vitro study. Egypt Dent J. 2023;69(3):2495-2503. https://edj.journals.ekb.eg/article_307635.html
35. Keskin C, Sivas Yilmaz Ö, Inan U. Apically extruded debris produced during glide path preparation using R-Pilot, WaveOne Gold Glider, and ProGlider in curved root canals. Aust Endod J. 2020;46(3):439-444. https://pubmed.ncbi.nlm.nih.gov/32820600/
36. Karkehabadi H, Siahvashi Z, Shokri A, Haji Hasani N. Cone-beam computed tomographic analysis of apical transportation and centering ratio of ProTaper and XP-endo Shaper NiTi rotary systems in curved canals: an in vitro study. BMC Oral Health. 2021;21(1):277. https://pubmed.ncbi.nlm.nih.gov/34034735/