

# Glide path effect on Direct R Gold's mechanical performance and ability to reach full working length: an ex vivo study

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## Abstract

**Objective:** To inquire the effect of glide-path (GP) preparation on reaching the working length and its influence on the cyclic fatigue and torsional stress of new Direct R MI gold files.

**Methods:** A total of eighty Direct R MI gold files were split into two groups (n=40) according to the establishment of the GP: the GP group with the GP performed with #8, #10, and #15 K hand files, and the Without GP group (WGPG). The files from each group were randomly divided into two subgroups (n=20). Subgroups of each group were subjected to cyclic fatigue tests at a curvature of 90° angle and a 5 mm radius along with a torsional resistance test (torque to fracture [TtF]) through a static torsional test device by blocking the file at 3 mm from the tip. The time to fracture (TF), number of cycles to failure, fractured tip length segments for both cyclic and torsional tests, and TtF were recorded. One-way analysis of variance, and Tukey's multiple comparison tests were performed, with the significance level set at 0.05.

**Results:** All the instruments reached working length. There were no statistically significant differences between subgroups of GP and WGPG in terms of TF, number of cycles to failure, TtF, or fractured tip length ( $P > 0.05$ ). Deformations were observed in only one file in the WGPG.

**Conclusion:** The creation of a GP did not impact the cyclic fatigue or torsional resistance of Direct R gold files. The novel reciprocating single-file system achieved full working length in all cases, even without a prior GP.

**Keywords.** Cyclic fatigue, dentistry, endodontics.

## Introduction

The key points of an accomplished root canal treatment are adequate shaping and cleaning. Abrupt breakage of files during endodontic treatment is one of the most frustrating problems faced by clinicians (1). The operation speed, varying kinematics, metal surface finishing, and metallurgical characteristics are some factors that can affect file lifespan (2-4).

In 2008, Yared announced an innovative canal forming method using only one ProTaper F2 file (Tulsa Dentsply, Tulsa, OK, USA) in a reciprocating motion. This motion consisted of clockwise rotation of 4/10 circles and counterclockwise rotations of 2/10 circles. It was commercialized as a single-file reciprocating technique with an inversed flute design, cutting counterclockwise and moving within a range of 30–150° (5). Over time,

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## How to Cite

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numerous single-file NiTi systems with different designs, such as cross sections, tapers, alloys, and movement kinematics, have been introduced to the market. While continuous rotation causes the instrument to bind to the canal walls, reciprocal movement with uneven clockwise and counterclockwise angles reduces engagement and curtails the taper-lock and screw-in effect (6). However, not all cases can be treated predictably with a single file, and some manufacturers have suggested the clinical use of rotary/reciprocating glide-path (GP) files. In recent years, new heat-treated Ni–Ti instruments with superior flexibility and resistance to breakage have prompted interest in the use of this new technique in clinical practice (7). Despite this, manufacturers still recommend a GP using either stainless steel or Ni–Ti files with small tip diameters to reach the apical triplet area, aiming to prevent instrument breakage and reduce torsional stress (8,9). The improved performance of these new heat-treated reciprocating single files also suggests the possibility of shaping root canals without a prior GP, utilizing a single file using asymmetrical reciprocal motion. Some studies have indicated similar results with and without GP management regarding centering ability (10) and debris extrusion (11), while also showcasing better results in negotiating canals without GP (12).

Direct R gold (DirectEndodontics®, Paris, France) files are recently developed reciprocating files with smaller tapers, aiming to achieve minimally invasive shaping and facilitate negotiation. Proprietary heat treatment provides high flexibility and fatigue resistance. Theoretically, these properties allow easier and safer instrumentation of complex cases and avoid the use of a GP, simplifying the procedure, improving its efficiency, and rendering it as a “real single-file instrumentation technique.” This study assessed the safety and efficiency of the technique by evaluating the ability of the instruments to reach the working length in molar cases with or without a GP, while testing the mechanical properties of the instruments used with and without a GP. The null hypothesis posited no difference in efficiency (canal negotiation) and safety (resistance to cyclic fatigue and torsion) between the GP and no-GP groups.

## Methods

This ex vivo study received approval from the Ethics Committee of Sapienza University of Rome (Ethical Committee 528/17). Utilizing data from a study by Di Nardo et al. (13), power analysis was conducted using G\* Power 3.1.9.7 software from Heinrich Heine University, Dusseldorf, Germany. The determined minimum sample size was three per group (alpha probability of error=0.05, power=95%), and our study achieved a power of 100% with 20 samples per group. A total of 80 Direct R Direct R MI gold L25 files were inspected under a 20x microscope (Carl Zeiss Microimaging, Göttingen, Germany) to eliminate any damaged files from manufacturing, with none being discarded. The files were grouped, and 80 extracted lower molar teeth were picked and randomly assigned to the two groups; Glidepath Group (GP) and Without GP Group (WGPG). The teeth were selected based on their similarity in anatomy (such as canal curvature, transverse diameter, and root length). Teeth that were

endodontically treated, restored, containing posts, or displaying resorption or altered morphology were excluded from the study. Canals that were not patented using a 0.06 manual K-file were also excluded. In the GP group, after GP preparation with #8, #10, and #15 K files, the extracted molar teeth (n=40) were shaped using Direct L25. The files underwent reciprocal motion (30°/150°) at 350 revolutions per minute (rpm) using an electronic endomotor (E-Connect S, Eighteenth, Jiangsu, China), according to the manufacturer's recommendations (www.directendo.com). The reciprocal instruments were gently inserted and activated by applying minimal inward pressure for one second, allowing for a short 1–2 mm apical progression, according to the MIMERACI technique described in previous studies (14,15). After controlling apical progression, the file was immediately removed from the canal. A sterile gauze was used to clean the debris and reduce the high production of debris within the canals. Before each reinsertion, the canals were irrigated with a syringe and 2 mL of 5% NaOCl solution. Each step was repeated until the working length was attained. In the Without GP Group (WGPG), files (n=40) were directly inserted into the root canals of molars without prior GP management, and the canals were shaped using the Mimeraci technique.

In each group, one molar case (extracted tooth) was prepared for each instrument. No instruments were fractured during intracanal use. Only one of the WGPG showed elongation of flutes, which was discarded and not subjected to static mechanical testing.

For each group, the instruments were then randomly divided into two subgroups according to the static mechanical test selected: cyclic fatigue test and torsional resistance test.

### *Cyclic Fatigue Test*

The instruments underwent a static cyclic fatigue test using an appliance previously validated in studies published in indexed dental journals (16–18). The device consisted of a tapered stainless-steel artificial canal measuring 16 mm, characterized by a curvature of 90° and a 5 mm radius of curvature. The canal was 1.5 mm wide and 3.0 mm depth. The testing device was allowed to maintain a fixed temperature of 35.5°C (intracanal temperature). A constant water spray, administered with a syringe, was employed to minimize friction and emulate in vivo conditions, in accordance with the methodology outlined by De Hemptinne et al. (19). An endomotor applied reciprocal motion at 350 rpm within angles of 30°–150° until the file fractured. A digital chronometer was used to record the time to fracture (TF) of the instruments. The TF was noted in seconds as the time spent on the digital chronometer when the separation of files was observed visually and audibly. A digital caliper (Mitutoyo, Kawasaki, Japan) was used to measure the length of the fractured (fractured tip length [FL]) segments of the files, and the FL was statistically analyzed to ensure that the files were in the correct position and to assess the quality of the test. The number of cycles to fracture (NCF) was calculated using the formula:  $NCF = \text{revolutions per minute (rpm)} \times \text{TF (s)} / 60$  (20). Subsequently, three instruments were randomly selected and observed using a scanning electron microscope (Hitachi S-2500, Hitachi, Japan) to confirm fracture resulting from cyclic fatigue.

**Static Torsional Test**

The examination was carried out employing an apparatus that had been previously verified in research published in accredited dental journals (21-23). The files were tested using a static torsion test device by blocking the file 3 mm from the tip. A dedicated endodontic motor (Kavo, Biberach, Germany) was configured with continuous reverse rotation at a speed of 350 rpm and a torque limit of 5.5 Ncm. The files were rotated until fracture occurred. The torque to fracture (TtF) was registered using the aforementioned dedicated endodontic motor, allowing for real-time (0.1 s) torque measurements with a sensitivity of 0.05 Ncm. All procedures were performed at a controlled temperature of 35.5° C, confirmed by a digital thermometer. The FL of the instrument was determined using a digital caliper with a sensitivity of 0.01 mm. Subsequently, three instruments were randomly selected and observed using scanning electron microscopy to confirm fracture resulting from torsional causes.

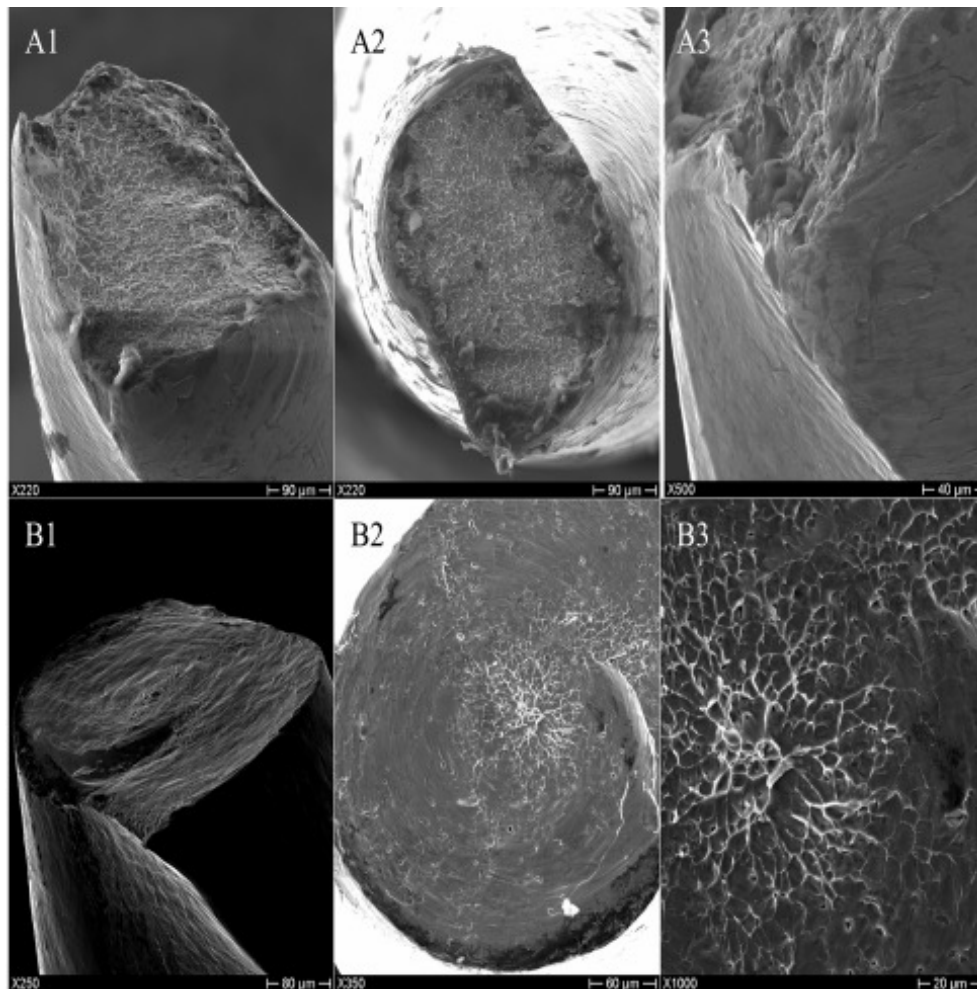
**Statistical Analysis**

SciPy v1.2.3 (<https://www.scipy.org/>) was used for statistical analyses. The data were first analyzed using the Shapiro–Wilk test to verify the assumption of

normality. One-way analysis of variance and Kruskal–Wallis tests were performed, with a significance level of 0.05.

**Results**

None of the instruments were discarded because of file separation during shaping of the extracted molar teeth. Flute elongation was observed only in a single file from the WGPG, which was not subjected to the test devices. In the cyclic fatigue test subgroup, n=20 was in each group, while in the static torsional test subgroup, n=19 was in the WGPG and n=20 in the GP subgroup. There were no statistically significant differences in FL between the cyclic fatigue and static torsional test subgroups (P > .05). Table 1 presents the TF, NCF, and Ttf values with mean values and standard deviations. TF values were 11.11 ± 1.98 and 10.90 ± 2.05, NCF values were 64.82 ± 11.56 and 63.56 ± 12.00, Ttf were 0.85± 0.13 and 0.84 ± 0.13 in GP and WGPG, respectively. There were no statistically significant differences between the GP group and WGPG (P > .05). Scanning electron microscope observations confirmed that the reasons of fracture were cyclic fatigue and excessive torsional loads (Fig. 1).



**Figure 1.** Scanning electron microscope observations of randomly selected instruments subjected to static cyclic fatigue and torsional tests. Images denominated with the letter “a” showed the fractographic pattern due to cyclic fatigue failure characterized by dimples on the cross-sectional surface and crack lines on the outer surface of the fragments. (a1) oblique view of the fractured surface at x220 magnification, (a2) transversal view of the fracture surface at x220 magnification, (a3) marginal portion of the fractured instrument in which peripheral crack lines are evident at higher magnification x1000. Images denominated with the letter “b” showed the fractographic pattern due to torsional failure characterized by a central area with irregular dimples and a peripheral zone of circular abrasion marks. (b1) oblique view of the fractured surface at x220 magnification, (b2) transversal view of the fracture surface at x220 magnification in which the central zone of dimples and the peripheral zone of circular abrasion marks are highlighted, (b3) higher magnification (x1000) of the central dimples.

**Table 1.** Schematic representation of mean values and standard deviations of TF, NCF, and TtF of Direct-R Gold used with and without glide path.

|           | GP mean± SD   | WGPG mean± SD | P-value |
|-----------|---------------|---------------|---------|
| TF (sec)  | 11.11 ± 1.98  | 10.90 ± 2.05  | 0.738   |
| NCF       | 64.82 ± 11.56 | 63.56 ± 12.00 | 0.739   |
| Ttf(g/cm) | 0.85 ± 0.13   | 0.84 ± 0.13   | 0.704   |

\*TF, time to fracture; NCF, number of cycles to fracture; Ttf, torque to fracture; GP, glide-path; WGPG, without glide-path group; SD, standard deviation.

## Discussion

Rotary, reciprocating, or manual GP preparation is usually performed to improve the efficiency and safety of root canal instrumentation and optimize root canal therapy (24). There is consensus on the benefits of GP in rotary techniques, yet controversy persists regarding the clinical advantages of GP concerning the shaping ability of single-file systems (24). A proficiently utilized GP could extend the longevity of rotary-shaping instruments, facilitating the preparation of additional canals and mitigating the torsional and flexural stresses encountered during the shaping of highly curved canals (25).

Several studies evaluated the introduction of GPs. Various parameters were examined, including the ability to reach the working length, centering ability, canal transportation, debris extrusion, and effects on the later canal instrumentation systems (such as cyclic fatigue and torsion resistance) (24). A recent study conducted with One Curve (a single rotary file; Micromega, Besançon, France) and Reciproc blue (a single reciprocating file; WDV, Munich, Germany) showed that a GP enhanced the shaping ability of these single file systems and strengthened the canal curvature in all groups (26). Keskin et al. (27) found that GP preparation using GP with the Proglider rotary instrument (Dentsply Maillefer, Ballaigues, Switzerland) improved the shaping ability of Reciproc Blue, resulting in reduced transportation and maintaining centering ability in simulated S-shaped root canals. Conversely, a systematic review by Hartmann et al. (28) concluded that the absence of a GP creates similar or better apical transportation quality and centering ability ratios. Plotino et al. (24) noted in their systematic review that debris extrusion decreases and instruments maintain root canal anatomy with prior use of the GP. However, they mentioned that GP preparation has no effect on the ability of Reciproc files (VDW, Munich, Germany) to reach working length. Rodrigues et al. (29) and De-Deus et al. (30) showed that reciprocating instruments can negotiate and shape the root canal system without prior hand or rotary GP preparation. Our results are in accordance with those of Plotino et al. (24), Rodrigues et al. (29), Bartols et al. (31), and De-Deus et al. (30) concerning safely reaching the working length and shaping the root canal system safely in the WGPG. These studies determined that a GP is not mandatory for reciprocal motion files, possibly because reciprocal

motion with engine-driven balanced force kinematics decreases the taper lock (24). Some studies have investigated the correlation between GP preparation and cyclic fatigue resistance of instruments. Ates et al. (32), Webber et al. (33), and Ozyurek et al. (34) concluded that GP preparation did not influence the cyclic fatigue resistance for Xp-endo Shaper (FKG Dentaire, La Chaux-de-Fonds, Switzerland) and Reciproc Blue (WDV, Munich, Germany) instruments, which aligns with our results.

This research evaluated the effect of GP preparation on the cyclic fatigue and torsional stress of Direct R L25 instruments after shaping a single molar-extracted tooth. All instruments successfully treated the canals, regardless of whether a GP was used or not. There were no statistically significant differences in cyclic fatigue and static torsion test results between subgroups with and without a glide path. Therefore, the null hypothesis was accepted.

The main restriction of this study was that the same instrument system was used in all groups; however, this permitted more accurate results in assessing the importance of GP procedures using these new flexible heat-treated files. The strengths of this study include the use of a clinically relevant temperature of 35.5°C (intracanal temperature) and employing extracted molar teeth instead of acrylic resin blocks for shaping procedures.

Some conflicting results among studies on the influence of the GP may be explained by the fact that successful root canal instrumentation is multifactorial: instrument design, heat treatment, motions, sequences (including the GP), and operative technique (i.e., Mimeraci) all influence outcomes. Evaluating which factors most notably affect efficiency and safety is challenging due to their interactions. Single-file reciprocation was proposed to simplify treatments and provide excellent results. Our study demonstrated that even without a GP, the selected instruments successfully negotiated canals with high precision and without higher instrumentation stress, using a “real single-file technique.” These positive results are related to the instruments’ combined heat treatment, design, and dimensions (smaller tapers aiding progression and reducing both torsional and flexural loading, while heat treatments improve flexibility and fracture resistance). Additionally, the use of the Mimeraci operative technique aimed at reducing intracanal stress and debris production contributed to these outcomes. Reciprocation has been proven to reduce both torsional and flexural stress by alternating the cutting and releasing action of the blades against dentinal walls. However, it also tends to push more debris inside canals and beyond the apex, as one angle removes debris coronally while the opposite pushes them apically. Hence, we conclude that single-file reciprocation can be performed without a GP, provided preoperative techniques and minimally invasive heat-treated instruments are used.

## Conclusion

The creation of a GP did not impact the cyclic fatigue or torsional resistance of Direct R gold files. This novel endodontic instruments achieved full working length in all cases, even without a prior GP.

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Not applicable.

## Author Contributions

Conceptualization, A.A. and G.G.; methodology, L.S., E.O. and C.T.; software, E.O., A.A.; validation, D.N. and G.G.; formal analysis, C.T.; and D.N investigation, A.A.; resources, A.A., G.G.; data curation, A.A.; writing—original draft preparation, A.A.; writing—review and editing, A.A., D.N., E.O.; visualization, G.G.; supervision, G.G.; project administration, G.G. All authors have read and agreed to the published version of the manuscript.

## Competing Interests

The authors declare no conflict of interest.

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## Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Sapienza University of Rome (protocol 528/17).

## Informed Consent Statement

Informed consent was obtained from all subjects involved in this study.

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