

Influence of operator expertise on glide path and root canal preparation of curved root canals with rotary and reciprocating motions

ABSTRACT

This study intended to help practitioners selecting the appropriate motion according to their level of expertise for glide path and complete root canal preparation of curved canals in terms of instrument fracture and preparation time. A total of 160 curved root canals (angle $>30^\circ$, radius $<6\text{mm}$) were allocated randomly to 4 groups: A/ B for expert operators and C/D for non-expert operators. A/C were shaped with rotary and B/D with reciprocating instruments. Preparation time was registered and compared with Kruskal-Wallis non-parametric test and Dunn's post-hoc test. Instrument separation was also registered and compared with Chi-square test. A fractographic analysis was performed with scanning electron microscopy. The use of reciprocation motions allowed non-expert operators to avoid instrument breakage during glide path and to prepare root canals faster. Experts were equally effective in rotary/reciprocating root canal shaping and faster with rotary motions than non-expert operators, who also fractured significantly more rotary instruments.

KEYWORDS:

Glide-path; fracture; nickel-titanium; preparation time; reciprocating motion; rotary motion

INTRODUCTION

One of the most important advancements of the 1980s in the field of preparation of root canals was the development of nickel-titanium (NiTi) endodontic instruments (1). The introduction of nickel-titanium (NiTi) rotary instruments allowed the simplification of root canal preparation for both expert and nonexpert operators (2). Despite the superiority of NiTi instruments over manual steel instruments, the possibility of instrument fracture inside the root canal remains a risk that can alter the success of endodontic treatment (3). Such fracture can be due to torsional stress or cyclic fatigue (4). Many studies have reported that factors such as the angle and radius of root canal curvature (5), instrument design (6), operator experience, rotational speed, and torque (7) can relate to instruments fracture. At the same time, the establishment of a glide path has been suggested to prevent the torsional failure of NiTi instruments (8). The so-called glide path is the initial, smooth, and centered preparation of the root canal to the apical foramen (8) that enable a safe root canal instrumentation with NiTi rotary instruments (9) while preventing the occurrence of errors and complications (such as taper lock, ledging, canal transportation, instrument fracture⁹, and detritus extrusion (10)).

The development of new alloys, introduction of new cross-sectional designs, and modification of kinematics have helped to increase the resistance of NiTi rotary instruments (11). New heat treatments for NiTi alloys and the use of reciprocating motions increased the cyclic fatigue resistance of instruments (11). M-wire alloy showed greater resistance to cyclic fatigue and increased flexibility when compared to conventional NiTi (12). This alloy was used to manufacture ProGlider (Dentsply Sirona, Ballaigues, Switzerland), an instrument designed for

the establishment of a glide path with a continuous rotation motion. Recently, WaveOne Gold Glider (Dentsply Sirona, Ballaigues, Switzerland) manufactured with gold-wire has also been launched for the same purpose. In fact, gold-wire alloy has improved flexibility compared to conventional NiTi and M-Wire alloys (13). Moreover, the instrument operates with reciprocating motions that supposedly reduce stress accumulation when compared to continuous rotation (14). Same combination of alloy and kinematics can be found in specific root canal shaping instruments: ProTaper Next (PTN) (Dentsply Sirona, Ballaigues, Switzerland) is manufactured with M-wire alloy and is used in continuous rotation; while WaveOne Gold (WOG) (Dentsply Sirona, Ballaigues, Switzerland) is made of gold-wire alloy and used in reciprocation (15).

At the same time, the level of expertise seemed to influence operators' performance with NiTi shaping instruments, mainly in terms of instrument fracture and instrumentation time (16). Clinical skills and experience helped operators to anticipate the risks of rotary instrumentation in root canals with pronounced curvature, and to prevent instrument fracture (17). Some studies have shown how nonexpert operators fractured more NiTi instrument than expert operators when using continuous rotary motions (3,4) or how the level of expertise did not affect the rate of WaveOne instruments fracture (17). In fact, obturation quality in terms of length and taper improved, as well as treatment time and the incidence of ledging during root canal preparation were reduced, when reciprocation motions were incorporated to dental student clinic settings (18). However, it has not been explored the influence of the level of expertise in operator's performance when both glide path and complete root preparation of curved canals are performed with a full rotation or reciprocation sequence. It would be desirable to help practitioners selecting the appropriate motion for an efficient root canal treatment of curved canals according to their level of expertise. Therefore, the purpose of this study was to evaluate the influence of operator expertise in the incidence of instrument fracture and time required for glide path and root canal preparation in

curved canals when using rotary (ProGlider + PTN) and reciprocating motions (WaveOne Gold Glider + WOG).

METHODS AND MATERIALS

This study was performed with the approval of the Ethics Committee USC 09/2020. A sample size calculation was performed based in the results of two published studies (19,20). Mean preparation times reported by Mesgouez et al. (19) for expert and non-expert operators as well as the instrument fracture rates reported by Mandel et al. (20) were used for the analysis. For preparation times, a minimum sample size of 12 specimens per group was estimated to detect differences for an effect size of 0.80 with an alpha error of 0.05 adjusted for 0.20 dropout. A larger sample size was estimated for the incidence of instrument fracture. Accepting the same effect size, alpha error and dropout adjustment, a sample size of 40 specimens per group was required.

A total of 160 root canals with an angle of curvature $>30^\circ$ and radius of curvature $<6\text{mm}$, according to Pruett (5) were selected for the study. All roots were standardized to 22mm. Root canals were negotiated with #8 and #10 C-files (Dentsply Sirona, Ballaigues, Switzerland). To establish working length (WL) a #10 K-file (Dentsply Sirona, Ballaigues, Switzerland) was inserted until it was visible through the apical foramen, and 0.5 mm were subtracted from that distance. Each sample was then placed in a Pro-Train Endodontics model (Endo-4-you; Dentsply, Maillefer) and a periapical radiograph was then taken for each specimen to confirm WL.

At this moment, samples were allocated randomly to four groups of 40 root canals each (A–D): groups A/ B were assigned to 2 expert operators with more than 10 years of experience (professors at the postgraduate program in Endodontics) and C/D to 2 nonexpert operators (undergraduate

students with a preclinical training of 10 root canals shaped with each system used in the study). All participants voluntarily offered to participate in the study. Groups A and C were shaped with rotary instruments (ProGlider for glide path and PTN (X1 and X2) for root canal preparation); groups B and D were shaped with reciprocating instruments (WaveOne Gold Glider for glide path and WOG Primary for root canal preparation). A set of new instruments was used for each sample. A total of 400 instruments (80 of each: ProGlider, WaveOne Gold Glider, PTN X1, PTN X2, WOG Primary) were used in the study.

A digital chronometer was activated simultaneously to the insertion of rotary/reciprocating instruments into the root canal. A maximum of three "in/out" movements were allowed until resistance was encountered before the instrument was removed and cleaned. This cycle was repeated as often as necessary until WL was reached with each instrument in the sequence. The chronometer was stopped after the action of each instrument and reactivated with the insertion of the following instrument in the sequence. Time was registered. Root canals were irrigated with 5.25% sodium hypochlorite (NaOCl) for 20 seconds, and apical patency confirmed with a #10 K-file at the beginning of the procedure and after the use of every rotary/reciprocating instrument when the chronometer was stopped.

The number of fractured instruments per group was also recorded. The coronal portion of fractured instruments were collected, examined under a scanning electron microscope (SEM) and energy dispersive X-ray (EDX), and a fractured surface analysis performed by a trained examiner. An Electroscan JSM-54 model JEOL 5410 equipped with an energy dispersive X-ray detector Link ISIS 30 was used. Furthermore, the SEM digital images of the fractured instruments were then collected and mounted randomly. Two blinded and calibrated examiners separately rated if instrument fractures were compatible with either torsional or flexural failure according to the presence or absence of plastic deformation along the cutting edge near the fracture site.

Time required for glide path and subsequent root canal preparation was compared among groups with Kruskal-Wallis non-parametric test, after confirmation of the violation of compatibility with a normal distribution of data. Dunn's post-hoc test was used to compare subgroups. The incidence of instrument separation during glide path and root canal preparation among groups was compared with Chi-square test. Kappa coefficient (K) was calculated to determine inter-observer agreement in terms of type of fracture. Descriptive statistics was further calculated in search of a pattern of fracture for the type of instruments used in the study.

RESULTS

Time

Table 1 shows mean (standard deviation) times required for glide path and root canal preparation with the instruments used in this study. Significant differences were observed in the first set of analyses for both the time required to establish a glide path and root canal preparation ($p < 0.001$). Specifically, no significant difference was detected between expert and nonexpert operators if using WaveOne Gold Glider and ProGlider; however, both expert and nonexpert ($p < 0.001$) operators required significantly more time for glide path preparation when using ProGlider than WaveOne Gold Glider.

After glide path, the time required for the complete root canal preparation did not differ significantly between expert and nonexpert operators if using WOG; however, expert operators required significantly less time than nonexpert operators ($p < 0.001$) when shaping with PTN. In addition, nonexpert operators required significantly more time when shaping root canals with PTN than when using WOG ($p = 0.008$); but no significant difference was observed for expert operators using the two systems.

Instrument fracture

Total number of instruments fractured during glide path establishment and root canal preparation for the two levels of operator expertise are shown in Table 1. A total of 3 ProGlider instruments fractured during glide path preparation; all of them by nonexpert operators, a significantly higher rate than that of expert operators using the same instruments ($p = 0.03$). No WaveOne Gold Glider instrument fractured in this study. Furthermore, no significant difference was found between groups in the instrument fracture rate during root canal preparation; although nonexpert operators fractured 2 WOG Primary instruments and 4 PTN instruments (3 X1 and 1 X2), and expert operators fractured 2 PTN instruments (1 X1 and 1 X2) and no WOG Primary instrument. When the pattern of fracture was evaluated, there was perfect agreement between evaluators ($K=1$). Fractographic analysis of SEM images determined that the pattern of fracture of the 3 ProGlider, 4 PTN and 1 WOG instruments corresponded to a flexural cyclic fatigue failure showing crack initiation areas and marks of crack propagation in cross-sectional images, and multiple micro-cracks near the fracture margin and across the machining grooves in longitudinal images (Fig. 1 A, B). On the contrary, 2 PTN and 1 WOG were rather catalogued as torsional fractures showing circular abrasion marks and skewed dimples near the center of rotation in cross-sectional images, and irregularly curved (wave-like) machined grooves at the unwinding area with reverse helix in longitudinal images (Fig. 1 C).

DISCUSSION

The present study was designed to assess the influence of operator expertise during glide path and root canal preparation of curved canals with novel instruments. Both, the time required for completion and the fracture rate of specific instruments (ProGlider or WaveOne Gold Glider for glide path and PTN and WOG for root canal preparation) were compared between expert and novel operators. The lack of standardization due to the great variability that natural teeth exhibit

in root canal dimensions, length, and morphology might be one of the limitations of this kind of studies. In fact, resin blocks or tooth replicas can be used to create simulated root canals with standardized dimensions; however, they do not accurately reflect the clinical behaviour of instruments due to the different hardness between resin and dentin (21,22). While dentin hardness ranged from 40 to 72 on the Knoop Scale (21), hardness close to 36 was reported for resin blocks (22). For this reason, natural teeth were used in this study. To overcome the limitation in terms of anatomical variability, very restrictive inclusion criteria were established to standardize the sample in relation to root curvature (angle and radius) and root length. Moreover, teeth were mounted in a Pro-Train Endodontics model for further standardization of the procedure.

It has been shown that operator experience influences treatment quality and performance speed (19). Nonexpert operators are expected to require more time than expert operators using the same tools. The results of the present study showed that expert operators were able to perform root canal preparation significantly more rapidly than nonexpert operators when using a multi-instrument system and rotary motions, but not when using a single-file reciprocating instrument. At the same time, no differences were detected in the time required for glide path preparation between the two groups when using a single-instrument rotary or reciprocating system. Mesgouez et al. observed how nonexpert operators decreased preparation times when increasing experience, a phenomenon not observed among expert operators (19). To avoid differences related to the progressive acquisition of skills with repeated performance, the present study included nonexpert operators who had performed exactly 10 canal preparations using each system.

Moreover, the results of the present study further support the idea that operator expertise is not the only factor contributing to preparation time. In addition to operator expertise, time required for canal preparation also rely on factors such as the instrumentation technique and number of instruments used (23). In fact, glide path preparation was faster with WaveOne Gold Glider than

ProGlider indistinctly for both nonexpert and expert operators in curved canals in the present study. Even though both systems use only one instrument, reciprocating motions seemed to be faster.

At the same time, the influence of operator expertise was more evident during root canal preparation than glide path in terms of preparation time. Cassimiro et al. (24) reported significant differences in canal preparation time with WOG and PTN and related the finding to the use of two files (instead of one) in PTN system. However, the level of expertise played an important role during root canal preparation with a rotary multi-instrument system in the present study. Only nonexpert operators required significantly more time when shaping root canals with PTN than when using WOG; but no significant difference was observed for expert operators using the two systems despite the difference in the number of instruments.

Regarding instrument failure, the results of the present study are consistent with those of previous studies (20). Nonexpert operators had a higher rate of instrument fracture than expert operators during glide path preparation. Mandel et al. (20) suggested that the higher fracture rate might be associated to the longer preparation time that the procedure may take to nonexpert clinicians. In the presence of a severe curvature (like the ones used in the present study), it seems reasonable to think that the longer the instrument stays rotating in the canal, the higher the chances for instrument breakage due to the higher number of alternating compressive and tensile forces that the instrument is subjected to. However, in the present study no significant differences were detected between expert and nonexpert operators in the time required for glide path preparation; but while expert operators did not experience any instrument fracture, 3 ProGlider instruments were separated by nonexpert operators. Time inside the root canal might not be the main reason for fracture; but the mode of use or the pressure exerted. Curiously, fractographic analysis of SEM images determined that the pattern of fracture of the 3 ProGlider instruments corresponded to a

flexural cyclic fatigue failure rather than the torsional type of failure that should be expected during glide path preparation. This might be attributed to the paradigm shift in the evolution of glide path instruments. The original concept included small instruments to only prepare enough space in the last millimetres for the easy advancement of rotary or reciprocating shaping instruments; however, ProGlider emerged to achieve glide path with the use of a single instrument with a variable tapered design and larger flute diameters at middle and coronal levels increasing the contact between the instrument and the canal walls and the force induced in the canal (25).

Many factors have been related to the fatigue resistance of endodontic instruments, including movement kinematics, metal alloy type, heat treatment and instrument dimensions and design. Regarding kinematics, reciprocating motions has demonstrated increased cyclic fatigue resistance when compared to continuous rotation (26,27). Consequently, in the present study, fracture rate was also higher for rotary instruments. During glide path preparation, ProGlider instruments fractured more than WaveOne Gold Glider instruments. Keskin et al. (28) also reported that reciprocating motions during glide path conferred significantly more resistance to cyclic fatigue than continuous rotation. At the same time, in the present study PTN instruments exhibited higher fracture rate than WOG. No previous study has directly compared the fracture rates of these two systems; however, Varghese et al. (29) compared the fracture rate of PTN with WaveOne (the predecessor of WOG) and concluded that the reciprocating motion of WaveOne conferred more resistance to cyclic fatigue. Moreover, it has been reported the higher fatigue resistance of WOG when compared to WaveOne (30), probably due to the influence of the alloy in cyclic fatigue resistance (31). Gold-wire alloy has exhibited greater resistance to cyclic fatigue than M-wire alloy (31). In fact, the increased resistance to cyclic fatigue has been demonstrated for both reciprocating motions— WOG (gold-wire alloy) versus WaveOne (M-wire alloy) (30)—and continuous rotary motion—the ProTaper Gold (gold-wire alloy) versus PTN (M-wire alloy) (32). These findings further suggest that the type of alloy has considerable influence on resistance to

cyclic fatigue and the fracture rates of pre-instrumentation systems. Moreover, WaveOne Gold Glider fractured less often than ProGlider in the present study. Similar results were shown recently when CF resistance of WaveOne Gold Glider was compared with ProGlider in different irrigation solutions at body temperature (33).

Only three instruments (ProGlider) out of 160 fractured during glide path preparation in the present study, whereas eight instruments (2 WOG and 6 PTN instruments) fractured during root canal preparation. Although the rate of separated instruments was low, nonexpert operators were responsible for all instrument fractures during glide path establishment and most of the fractures occurred during root canal preparation. The literature indicates that instruments are more resistant when used with reciprocating motions than when used with continuous rotation (26,28,29,33). Moreover, gold-wire alloy is more resistant than M-wire alloy (10, 30-33). In combination, these characteristics are useful for nonexpert operators; but expert operators seem not to gain time or safety in terms of instrument fracture with the use of novel technology. On the other hand, the use of novel technology may enhance the performance of clinicians in other characteristics not analysed in the present study. In fact, one of the advantages of the concept of single reciprocating instruments is that it shortens the learning curve for nonexpert operators (18) who preferred reciprocating over rotating motions (34); however, when experienced endodontists were surveyed, 91% selected rotary instruments for their daily practice (35).

Within the limitations of this study the following can be concluded:

- Both expert and nonexpert operators performed significantly more rapid glide path preparations with reciprocating than rotary instruments.
- For complete root canal shaping, expert operators were equally effective with rotary/reciprocating motions while nonexpert operators required significantly more time when using rotary instruments.

- Nonexpert operators fractured significantly more rotary glide path instruments, while in the hands of expert operators there was no instrument fracture during glide path preparation of curved root canals.

Figure legends:

Figure 1. Examples of breakage for each type of instrument (A= ProGlider, B=PTN, C=WOG): a, b represent respectively preoperative and postoperative radiographs; c, d, e show SEM digital images of the fractured instruments. Notice typical fractographic patterns for flexural cyclic fatigue failure (A, B) and torsional fracture (C). SEM images of cases A and B show the typical crack initiation areas and over loaded fast fracture zone of fatigue failures (e) and micro-cracks near the fracture margin (c, d). Cross-sectional images in case C (e) show circular abrasion marks and skewed dimples near the center of rotation (e), as well as distortion and reverse winding near the fracture level (c, d).

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Table 1: Number of instruments fractured and time (mean and SD) to achieve glide path and complete root canal preparation for the two levels of expertise of operators.

	System	Expert operators		Non-expert operators	
		Time (s)	Fracture (n)	Time (s)	Fracture (n)
Glide Path	ProGlider	67.40 ± 24.36	-	74.43 ± 26.89	3
	WaveOne Glider	48.32 ± 4.55	-	47.75 ± 3.20	-
Root canal prep	ProTaper Next	109.54 ± 59.60	2	157.18 ± 74.57	4
	WaveOne Gold	91.93 ± 32.27	-	112.96 ± 54.16	2

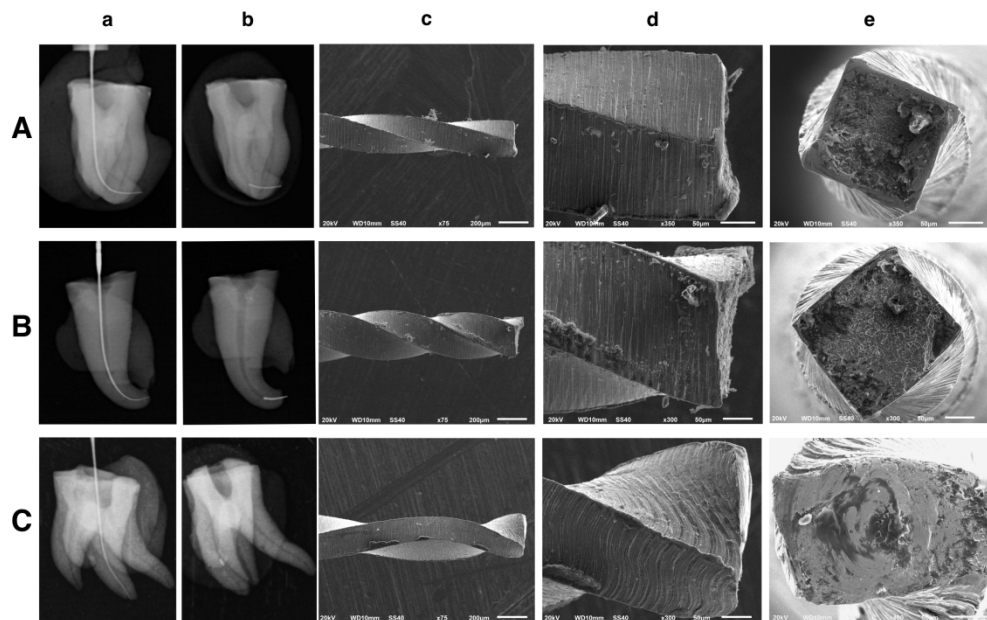


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