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Shaping Ability of the *WaveOne Gold* Instrument in Torque Generation with and without Establishing Different Glide Paths

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Abstract

Purpose: The present study investigated the shaping ability of the *WaveOne Gold* (WOG) in torque generation with and without establishing different glide paths.

Materials and Methods: Endo-training resin, blocks were divided into three groups: two glide-path groups (*ProGlider* (PG), *WaveOne Gold Glider* (WGG)), and a no-glide-path group. Each group was subdivided into two subgroups for the shaping instrument WOG and the *ProTaper Next* (PTN) as the control. The shaping time and torque generation were calculated, and the canal centering ability was compared between the different glide paths and the no-glide-path group.

Results: The shaping time and total generated torque for the WOG were significantly reduced by a glide path ($p<0.05$). The WOG generated a higher maximum torque than the PTN regardless of the glide path ($p<0.05$). The canal centering ratio of the WOG for both glide paths was significantly lower than that for the no-glide-path group, although that of the PTN for both glide paths was not different.

Conclusions: The establishment of a glide path (PG, WGG) and the mechanical properties of the WOG significantly affect the shaping time, torque generation and canal centering ability.

Key words: glide path, torque generation, *WaveOne Gold*, *ProTaper Next*, centering ratio

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Introduction

Nickel-titanium (NiTi) rotary files are widely used for root canal preparation because of their flexibility, improved cutting efficiency, and quicker and more centered canal shaping compared with stainless-steel files[1–5]. Although NiTi files have numerous advantages, unexpected fracture and vertical root fracture sometimes occur due to cyclic fatigue and excessive torsional stress[6,7].

A glide path may reduce the torsional stress and thereby increase the fatigue life of the NiTi rotary instrument[8]. The establishment of a glide path with NiTi instruments allows the glide path to be created more quickly, leads to smaller canal modifications, and preserves the original canal anatomy compared with manual glide path instrumentation[9–11]. Several studies have reported that the glide path with NiTi rotary instruments before canal instrumentation has advantages, such as less sensitivity to the clinician's expertise[9], less production of apically extruded debris, and less postoperative pain[10]. The *ProGlider* (PG, Dentsply Sirona, Tokyo, Japan) is a single mechanical glide path file manufactured using M-Wire. It has a square cross section with a diameter of 0.16 mm at D0 and progressively tapers from 2% to 8% over its length. Another instrument is the *WaveOne Gold Glider* (WGG, Dentsply Sirona), which is produced using gold-wire technology and has a diameter of 0.17 mm at D1 and 0.85 mm at D16 and progressively tapers from 2% to 6%. The mechanical properties of these glide path instruments are important for successful clinical performance.

The *WaveOne Gold* (WOG, Dentsply Sirona) and *ProTaper Next* (PTN, Dentsply Sirona) systems are based on innovative metallurgy in which NiTi alloy is heat-treated to improve fatigue life and flexibility, and offer good canal centering ability[12–15]. Centering ability is influenced by the instrument design and the canal anatomy. The straighter the root canal, the less the instrument is constrained and the more centered it is[16].

The WOG is a single-file system, and it has a unique alternating off-centered parallelogram-shaped cross section and a progressively decreasing percentage taper design[17]. This design limits contact between the file and dentin to only one or two points at any given stage of canal preparation, which improves the safety of the file with less taper lock and a weaker screw-in effect. The cross-sectional design of the file also allows for more debris extrusion during canal preparation[18]. PTN, which is manufactured by M-Wire, is a multi-file system comprising two instruments: X1 (17.04) and X2 (25.06), which are both characterized by a rotational phenomenon known as precession or swagger[19]. According to the manufacturer, most canals can be prepared using only the first two files.

Many studies of the WOG and PTN file systems showed improved fatigue resistance compared with other file systems[19,20]. The magnitude of the torque generated within the NiTi instrument during canal instrumentation is affected by the area of contact between the file and canal wall, the applied apical force, and the preoperative canal volume[21]. Decreasing the contact area and increasing the total volume of the canal by preparing a glide path may reduce torque generation and the stress acting on dentin. Therefore, the importance of preparing the glide path should be emphasized further. The manufacturer recommends creating a different glide path before using the WOG and PTN systems.

A few studies have examined torque generation during canal shaping procedures in root dentin using a stress-strain gauge[22–24]. However, there is no report on simultaneous torque measurements during WOG canal shaping, probably because of the difficulty of measuring actual torque. The present study compared the torque generation and shaping ability during WOG canal shaping with and without establishing different glide paths.

Material and Methods

1. Experimental design

Ninety Endo-training resin J-shaped blocks (REF A 0177, Dentsply Sirona) with a curvature of 35°, an initial size of ISO #15, and a 0.02 taper were used in this study. The J-shaped canal blocks were randomly divided into three groups: a group for which a glide path was established with a PG, a group for which a glide path was established with a WGG, and a group for which there was no glide path (without). Each group was then further subdivided into two subgroups according to the shaping file used: WOG Primary vs. PTN (X1, X2) (n=15 each), resulting in six glide path/

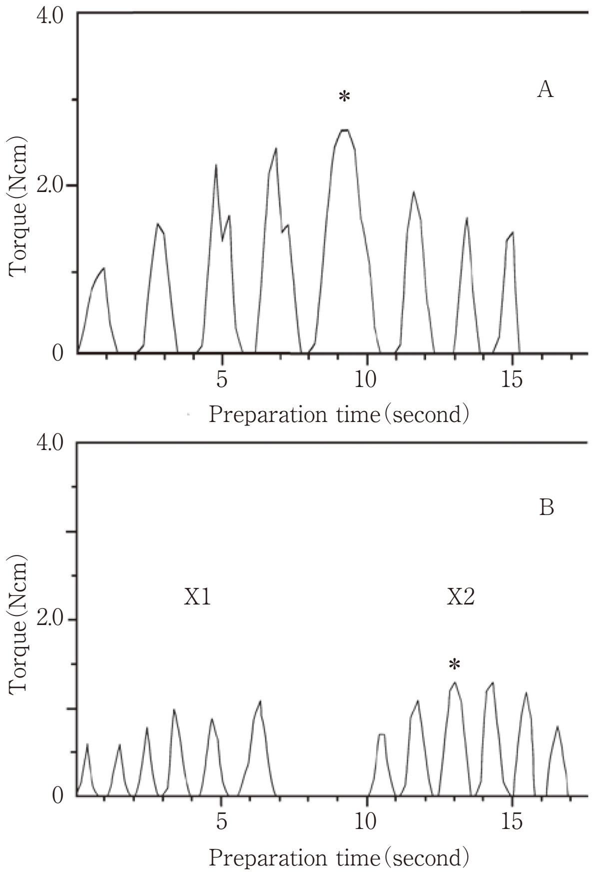

Fig. 1 Representative torsional loading curve during the preloading for *WaveOne Gold* Primary (A) and *ProTaper Next* X1, X2 (B)
* : maximum torque.

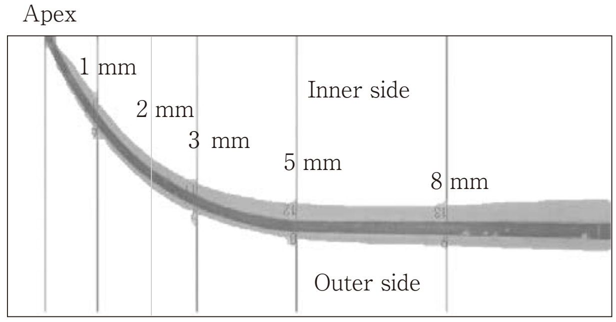

Fig. 2 Superimposition of pre- and post-operative images
The difference between the canal configuration pre- and post-operation was measured for each of the five trace d levels.

shaping groups: PG/PTN, PG/WOG, without/PTN, WGG/WOG, WGG/PTN and without/WOG. After canal preparation with the shaping instruments, the torque generation and shaping ability were measured for each specimen.

2. Patency and glide path

The canals were first scouted with an ISO #10 stainless-steel K-file (Dentsply Sirona) to check patency and to precisely determine the working length (16.5 mm). The glide paths were created by a single operator using the PG and WGG in strict accordance with the manufacturer's recommendations for each system (300 rpm, 5 N・cm). The rotary PG or reciprocating WGG glide path files were operated via a 16 : 1-gear-reduction hand-piece powered by an X-Smart IQ codeless motor system (Dentsply Sirona).

3. Canal shaping using the WOG and PTN files

The reciprocating instrumentation procedure using the Primary WOG comprised no more than 15 pecking strokes, with each pecking depth limited to less than 2 mm. After every three strokes, debris was removed from the flutes of the NiTi file and the canal was irrigated with saline. The apical foramen in the mesial canals was determined to be of #25/07 size. Each file was changed after five canal shapings.

In the PTN shaping group, once a #10 stainless-steel K-file was confirmed to be loose at length, the PTN X1 file was used to prepare the shape of the root canal following the glide path, until the full working length was reached. After the canal was irrigated with saline, the #10 K-file was again used for recapitulation to break up residual debris and move the debris into solution. The next file used was the PTN X2, again until the working length was reached. The apical foramen in the canals was determined to be of #25/06 size. Each file was changed after five canal shapings.

4. Torque measurement and shaping times

An artificial canal resin block was fixed in a metal jig, and the instrumentation was conducted. The data acquisition module allows the collection of real-time torque data from the X-Smart IQ endodontic motor during instrumentation. Data of the maximum torque, total torque and shaping time were obtained from real-time torque data recorded by an iPad and the X-Smart IQ system (Fig. 1).

5. Image analysis of the canal centering ability

Methylene blue dye was introduced into the canals before and after instrumentation. The enlargement of the canals was assessed by subtracting the pre-instrumentation images from the post-instrumentation images

Table 1 Total shaping times for WOG and PTN by the three glide path groups

Glide path	WOG Total shaping time (s)	PTN Total shaping time (s)
PG	16.5±3.5	18.0±2.5
WGG	12.3±1.1	17.8±1.6
Without	27.0±4.9	21.4±1.7

＊：Significant difference between PG/WOG and WGG/WOG (p<0.05).
＊＊：Significant difference between PG/WOG and without/WOG (p<0.05).
#：Significant difference between WGG/WOG and without/WOG (p<0.05).

(Fig. 2), which were recorded in a standardized manner using a stereomicroscope (magnification, ×10) (SZX16; Olympus, Tokyo, Japan) connected to a charge-coupled-device camera (DP71; Olympus). For each sample, two images of the lateral view and one of the apical part were recorded. At five measuring points (1, 2, 3, 5 and 8 mm from the apex) located at the coronal and apical curvature, canal widths were assessed by measuring the distance from the wall of the original canal to the shaped canal with an accuracy of ±0.01 mm using image analysis software (WinRoof, MITANI, Tokyo, Japan). We measured ①the distance between the shaping and original inner canal wall, ②the distance between the shaping and original outer canal wall, and ③the canal width of the shaped canal. The centering ability of the instruments was calculated as a centering ratio, which was calculated by the equation ((①−②)/③)[16]. The shaping becomes more centered as the centering ratio approaches zero.

6. Statistical analysis

The mean and standard deviations were determined for each group, and two-way analysis of variance was adopted to compare the experimental groups. The total and maximum torque generation or shaping ability (shaping time and centering ratio) were compared between the glide path preparations and the two types of NiTi files. The significance level was set at 95% and the analysis was conducted using SPSS software (Version 22.0; IBM, Armonk, NY, USA).

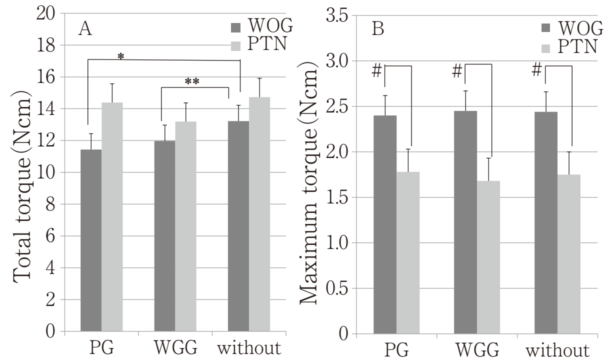

Fig. 3

A) Total torque generated during preparation for *WaveOne Gold* and *ProTaper Next* by the three glide path groups. There was a significant difference between the glide path (*PG, **WGG) groups and no-glide-path group. B) Maximum torque generated during preparation for *WaveOne Gold* and *ProTaper Next* by the three glide path groups. #：Significant difference between WOG and PTN in each glide path group.

Results

1. Canal shaping times

An analysis of variance ($p<0.05$) showed that prior establishment of the glide path significantly reduced the final canal shaping time when the Primary WOG file was used compared with when there was no glide path (27.0±4.9 s) for both glide path preparation groups (WGG; 12.3±1.1 s, PG; 16.5±3.5 s) ($p<0.05$). The minimum shaping time was achieved with the combination of WGG and WOG files (Table 1). The shaping time for the PTN file using either the PG (18.0±2.5 s) or WGG (17.8±1.6 s) was slightly less than that for no glide path (21.4±1.7 s), and there was thus no statistically significant difference among the groups (Table 1).

2. Total torque and maximum torque during canal preparation

The total torque generated by the WOG was significantly reduced by establishing a glide path ($p<0.05$) (Fig. 3A), whereas establishing a glide path did not significantly affect the maximum torque for either file system (Fig. 3B). The WOG with a PG glide path had the lowest total torque generation among all groups ($p<0.05$) (Fig. 3A). The WOG generated a higher maximum torque than the PTN with or without a glide path ($p<0.05$) (Fig. 3B).

Table 2 Statistical analysis of canal centering ratios at different levels after root canal preparation by WOG and PTN with glide path

Level (mm)	PG/WOG	WGG/WOG	without/WOG	PG/PTN	WGG/PTN	without/PTN
1	−0.04*	−0.05#	0.01*,#	0.01	−0.01	−0.02
2	0.02*	0.00#	0.11*,#	0.02	0.01	0
3	0.11*	0.12#	0.21*,#	0.08	0.05	0.08
5	0.17*	0.18#	0.27*,#	0.24	0.20	0.24
8	−0.03*	0.02#	0.10*,#	0.05	0.01	0.01
Mean+SD (mm)	0.05±0.09*	0.05±0.08#	0.14±0.10*,#	0.08+0.09	0.05±0.09	0.06±0.11

*: Significant difference between PG/WOG and without/WOG ($p<0.05$).
#: Significant difference between WGG/WOG and without/WOG ($p<0.05$).

3. Canal centering ratio

The mean centering ratio of the WOG file was 0.05±0.09, 0.05±0.08, and 0.14±0.10 in the PG, WGG, and no-glide-path groups, respectively. The centering ratio for the WOG file used with both the PG and WGG was significantly reduced compared with the no-glide-path group (ANOVA: $p<0.05$). No statistically significant difference was found when comparing the centering ratio in WOG shaping for both the PG and WGG (Table 2).

The mean centering ratio of the PTN file was 0.08±0.09, 0.05±0.09, and 0.06±0.11 in the PG, WGG, and no-glide-path groups, respectively, with no statistical difference (ANOVA ($p<0.05$); Table 2). Meanwhile, the centering ratio after root canal preparation using the PTN was not significantly affected by the presence or absence of a glide path.

Discussion

The present study compared the shaping ability and torque generation during WOG canal shaping with and without establishing different glide paths. The glide path was prepared using the rotary PG and reciprocating WGG. The total torque, shaping time and centering ratio for the WOG were significantly reduced by establishing the glide path using either the WGG or PG, whereas the maximum torque generation was unaffected by establishing the glide path. The final shaping time for the WOG was statistically shorter after preparation of the glide path with either the PG or WGG; the shaping time was reduced more for preparation with the WGG than for preparation with the PG. Our results support those reported by Vorster et al[25] who found that the final shaping times for the WOG were significantly shorter after establishing a glide path using the WGG. The difference in final preparation time seems to be affected by the fact that the diameter of the root apical part and the diameter of the D16 site by the glide path are as large as 0.82 mm for the PG and 0.85 mm for the WGG[26,27]. Meanwhile, establishment of the glide path similarly decreased the final shaping time when using the PTN and when using the WGG, but there was no significant difference between the PG and WGG. The final shaping using the PTN was performed by multi-files (X1 and X2) and the torque applied to the files was thus dispersed and the effect on the final shaping time was such that the flare formation of the orifice root. The effect on the final shaping time was measured for the total torque value and the maximum torque value, but the maximum torque of the file did not change before and after establishing the glide path and there was thus no involvement of the maximum torque. However, the maximum file torque was predominantly higher for the WOG than for the PTN. The reason why the maximum torque was low for the PTN is considered to be related to the multi-file system and file form. The cross-sectional forms of the WOG and PTN files are the same parallelogram but the PTN file has reduced torque because the central axis of the file is displaced from the center[28,29].

The NiTi file form also effectively maintains the centering ratio during root canal preparation[30,31]. In the present study, the measured centering ratio of the PTN did not change with and without the glide path. Meanwhile, it was clear that the centering ratio of the WOG was greatly improved by the glide path. There was no change due to the use of different files for the glide path. It is suggested that the results of the final shaping time and the centering ratio for the WOG were affected by total torque generation, because both glide path techniques significantly reduced the total torque generation. In the case of the WOG of the single NiTi file system, a reduction in the excess total torque acting on the file reduced biting into the root canal, allowed accurate root canal preparation and shortened the shaping time.

In the present study, we analyzed the effects of two different glide paths on root canal formation before using the WOG and PTN from the relation of the total torque and maximum torque. The effect of using the WOG on the final root canal configuration after different glide path formations was analyzed to examine the correlation with the total torque for the file during root canal preparation. It was found that the final root canal form produced with the WOG had significantly less displacement owing to the formation of the glide path and a reduced risk of transportation. There was no difference between the PG and WGG depending on the glide path technique, and no significant change between the two glide paths. Additionally, the final root canal form of the PTN taken as a control group showed that the root canal displacement was about the same regardless of whether a glide path was formed, and the flexibility of the PTN file was excellent. PTN files produce an asymmetrical rotary motion and, at any given cross-section, the file only makes contact with the wall at two points. These file forms mean that a smaller and more flexible PTN file can cut a preparation of the same size as a larger and stiffer file with a centered mass and axis of rotation. It is considered that these PTN multi-file system and file forms lead to the reduction of maximum torque compared with the WOG file.

Both WOG[32–34] and PTN[28,29] files perform well in terms of fatigue resistance (WOG: G-Wire, PTN: M-Wire) owing to the file cross-sections and material improvements, but the precession and swagger, in particular for the PTN files, are features of the file itself, and are accurate even without establishing a glide path. It was shown that preparation of the root canal is possible. However, it was also shown that establishing the glide path reduces the total torque acting on the file when a root canal is formed by either file, and it is important to prevent file fracture as well as cracks and fractures in root canal dentin.

Conclusion

The establishment of a glide path and the mechanical properties of the WOG significantly affect the shaping time, torque generation and canal centering ability. The present study showed that the establishment of a glide path is essential during preparation of a root canal using the WOG, and that this procedure allows accurate root canal preparation.

Conflict of Interest

The corresponding author received the compensation of lecture from Dentsply Sirona.

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グライドパスによるファイル荷重制御が *WaveOne Gold* の根管形成に及ぼす影響

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抄録

目的：本研究は，*WaveOne Gold*（WOG）による根管形成時のファイル回転力（トルク）と形成能力を検討することを目的として，2種類のグライドパス形成時とグライドパス未形成時で解析した．

材料と方法：根管形成にはエンドトレーニングブロックを使用し，グライドパス形成群（*ProGlider*（PG），*WaveOne Gold Glider*（WGG）），およびグライドパス未形成群の3群に分類した．各群は，WOGによる根管形成の対照群として *ProTaper Next*（PTN）による根管形成を加えて，合計6群で比較検討した．各実験群は，根管形成時間とファイルトルク値を測定した．さらに，2種類のグライドパス形成群とグライドパス未形成群間で根管形成後の根管中央値を測定した．

結果：WOGの根管形成時間とファイル総トルク値は，PGおよびWGGファイルによるグライドパス形成によって顕著に減少した（$p<0.05$）．WOGはグライドパスの相違にかかわらず，PTNよりも高い最大トルク値を示した（$p<0.05$）．WOGによる根管形成後の根管中央値は，PGおよびWGGファイルによるグライドパス形成後にグライドパス未形成と比較して有意に減少した．一方，PTNによる根管形成後の中央値はグライドパス形成の有無にかかわらず有意差が認められなかった．

結論：WOGファイルによる根管形成はグライドパス形成（PG，WGG）によって，根管形成時間，ファイルトルク値，および根管形成変移量が顕著に減少することが示された．

キーワード：グライドパス，回転力（トルク）発生，*WaveOne Gold*，*ProTaper Next*，根管中央値

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