Hand-operated and Rotary ProTaper Instruments: A Comparison of Working Time and Number of Rotations in Simulated Root Canals

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Abstract

The aim of this study was to compare the effective shaping time and number of rotations required by an endodontist working with hand and rotary ProTaper instruments to completely shape simulated root canals. Eighty Endo Training Blocks (curved canal shape) were used. Manual preflaring was performed with K-Flexofiles #08-10-12-15-17 and #20 Nitiflex at a working length of 18 mm. Specimens were then randomly assigned to 2 different groups (n = 40); group 1 was shaped by using hand ProTaper and group 2 with ProTaper rotary. The number of rotations made in the canal and the effective time required to achieve complete canal shaping were recorded for each instrument. Differences between groups were analyzed with the nonparametric Mann-Whitney *U* test ($P < .05$). Hand ProTaper required significantly fewer rotations ($P < .001$) than rotary ProTaper, whereas the effective working time to fully shape the simulated canal was significantly higher ($P < .001$) with hand ProTaper. *(J Endod 2008;34:314–317)*

Key Words

Hand instruments, nickel-titanium, ProTaper, rotary instruments

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0099-2399/$0 - see front matter

doi:10.1016/j.joen.2007.12.017

Nickel-titanium (NiTi) rotary instruments were introduced to improve root canal preparation. In clinical practice, these instruments might suffer from a risk of fracture, mainly as a result of flexural (fatigue fracture) and torsional (shear failure) stresses (1–3). Fatigue fracture is caused by crack initiation at the surface, which proceeds intergranularly when the instrument is rotating within a curved space (3). Flexural stresses depend on the root canal anatomy and on its angle and radius of curvature; thus they are not significantly influenced by the clinician. Canal curvature is suspected to be the predominant risk factor for instrument failure; thus it has been hypothesized that when working in a curved canal, the instrument should perform as few rotations as possible to enable complete shaping to be achieved (4–7). Shear failure might result from torsional stresses exceeding the elastic limit of the alloy, producing plastic deformation and, ultimately, fracture (3). Torsional stresses might dramatically increase if there is excessive pressure on the handpiece (8), a wide contact surface between the canal walls and the cutting edge of the instrument (9, 10), or if the canal section is smaller than the dimension of the nonactive tip of the instrument (9, 10), which can cause what has been described as taper lock, especially with regularly tapered instruments (11).

The ProTaper System is also available in the form of hand-operated instruments with identical design to the rotary instruments. They are recommended for use in reaming or "modified balanced forces" motion (12). The mechanical stresses acting on a hand-operated instrument might differ from those on engine-driven instruments. Engine-driven instruments operate in continuous rotation and are mainly subjected to unidirectional torque; hand ProTaper (HPT) instruments can be used in alternated clockwise and counterclockwise motion. Preliminary studies on the failure mode of HPT instruments indicated that shear failure caused by torsional stresses was prevalent, whereas rotary ProTaper (RPT) instruments were more affected by fatigue failure (13, 14). Furthermore, the 2 types of ProTaper instruments appeared to differ in terms of working time and number of rotations required to completely shape the root canal, although no systematic data are yet available. The objective of this study was to compare the working time and number of rotations of HPT and RPT Protaper instruments required to achieve complete shaping of simulated root canals.

Materials and Methods

Eighty Endo Training Blocks ISO 15 (Dentsply Maillefer, Ballaigues, Switzerland), 2% taper, 10-mm radius of curvature and 20-degree angle of curvature, were mounted on a support in a stable vertical position. For each specimen, manual preflaring with K-Flexofiles (Dentsply Maillefer) #08-10-12-15-17 and #20 Nitiflex (Dentsply Maillefer) was performed by an endodontist at 18-mm working length. Specimens were then randomly assigned to 2 different groups (n = 40) by using a random numbers table.

Each specimen in group 1 was shaped with new HPT instruments (Dentsply Maillefer) S1, S2, F1, F2, F3 at the working length by using the reaming technique, accomplished with bidirectional motion. Each specimen in group 2 was shaped with new RPT instruments (Dentsply Maillefer) S1, S2, F1, F2, F3 at the working length by using an endodontic engine (X-Smart; Dentsply Maillefer) with a 16:1 contra-angle at the suggested setting (300 rpm on display, 4 Ncm). In both groups, Glyde-Prep

TABLE 1. HPT (n = 40) vs RPT (n = 40): Number of Rotations Required to Achieve Complete Shaping with Each Instrument

Group	S1		S2		F1		F2		F3	
	Hand	Rotary	Hand	Rotary	Hand	Rotary	Hand	Rotary	Hand	Rotary
Mean	7.4	39.2	3.5	19.5	3.3	22.7	7.1	45.8	7.3	42.1
Standard deviation	1.3	9.4	1.1	3.6	1.2	5	1.5	9.1	1.2	9
Median	7.5	38	3.3	18.7	3	22.2	7	45.7	7	40.5
Minimum	5	21.8	2	13.7	2	15	4.5	32.4	5	31.9
Maximum	9	56.7	6	25.9	6	35.2	9.5	68.1	9	60.3
Upper 95% CI	6.79	35.1	2.95	17.88	2.78	20.52	6.43	41.86	6.77	30.14
Lower 95% CI	8.30	42.33	4.74	21.15	4.69	24.85	8.21	48.59	8.21	44.92

CI, confidence interval; HPT, hand ProTaper; RPT, rotary ProTaper.

(Dentsply Maillefer) was used as lubricant, and canal patency was frequently checked with a K-Flexofile #10 (Dentsply Maillefer). A notch was made on the top of the handle of each HPT instrument; a professional video camera (Sony DXC-C33P; Sony Co, Tokyo, Japan) was positioned so as to view the handle along the axis of the instrument, and the number of complete rotations was recorded, adding clockwise and counterclockwise quarter rotations.

The number of rotations for each RPT was calculated from the measurement of the real speed in function of the "speed on display" and the "range of external applied torque" (0–4 Ncm) furnished by the manufacturer (15). The deviation of real speed from display speed ranged from 0.7%–11.2%, with a mean real speed of 282.46 rpm, equivalent to 4.7 rotations per second.

The effective working time of each instrument (considering only the operative phases, when the instrument was effectively working inside the simulated root canal) was recorded with an electronic chronograph (PM 665; PHILIPS, Best, The Netherlands), approximated to the first decimal unit.

The Kolmogorov-Smirnov for normality test revealed a non-normal data distribution. For this reason, differences among groups were analyzed with the nonparametric Mann-Whitney *U* test. Differences were considered statistically significant when $P < .05$. All statistical analyses were performed with the SPSS for Windows 12.0 software package (SPSS, Inc, Chicago, IL).

Results

Descriptive statistics of the number of rounds are summarized in Table 1, whereas Table 2 reports the results concerning the effective working time for each instrument. RPT instruments achieved complete shaping in a significantly shorter time ($P < .001$) but with a greater number of rotations ($P < .001$) than HPT. The mean total effective working time to completely shape a simulated root canal was 169.3 seconds with the HPT series, compared with 36 seconds with the RPT series of instruments. No instrument fractures occurred in either group.

Discussion

The NiTi ProTaper system comprises 5 instruments with multiple taper design. The shaping files are designed for the purpose of enlarging the coronal and middle third of the root canal. The finishing files prepare the apical third after most of the dentin has been removed with the shaping files. ProTapers are at present the only multiple taper instruments that are available in both engine-driven and hand-operated versions; the study evidences the significant difference in working time and number of rotations between the engine-driven and hand-operated versions. Hand instruments perform complete shaping with significantly fewer rotations, but they take longer.

This difference might partially explain the current paucity of literature concerning HPT, in particular the scarce understanding of different failure modes compared with RPT. Cheung et al (13) evidenced similar failure rates (14% of instruments fractured in both groups) for HPT and RPT after clinical use, but the failure mode appeared to be very different. Shear failure was predominant in HPT, with circular abrasion marks on the fracture surface, surrounding a central area of microscopic dimples. The majority of the RPT of the same brand showed evident signs of fatigue failure, with clusters of short, near-parallel striation marks. The prevalent fatigue fracture in the RPT group could be due to the higher number of load cycles, subjecting the material to repeated stretching-compressive cycles when operating within a curved canal (16, 17). This factor is considered the main determinant of fatigue life (18); thus it has been hypothesized that when working in a curved canal, the instrument should perform as few rotations as possible to achieve proper shaping (4–7).

In our study, the use of HPT fulfilled this criterion. Furthermore, some HPT instruments (7%) were discarded while still intact because they manifested unwinding of flutes, which rarely occurred with rotary instruments. These results confirmed the very low tendency of RPT to show warnings signs before fracture (2, 19). Analyses were also conducted on the same batch of HPT instruments, with the aim of evaluating

TABLE 2. HPT (n = 40) vs RPT (n = 40): Time (seconds) to Reach Complete Shaping with Each Instrument

Group	S1		S2		F1		F2		F3	
	Hand	Rotary	Hand	Rotary	Hand	Rotary	Hand	Rotary	Hand	Rotary
Mean	45	8.3	20.9	4.1	21.6	4.8	42.6	9.8	47.7	9
Standard deviation	11	2	7	0.8	8.5	1.1	11.6	1.9	8.6	1.9
Median	43	8.1	20.6	4	23	4.7	43	9.7	48.9	8.6
Minimum	30.2	4.6	9.8	2.9	8.8	3.2	25.6	6.9	34.5	6.8
Maximum	69.6	12.1	35	5.5	44.4	7.5	68.4	14.5	65	12.8
Upper 95% CI	40.17	7.47	17.85	3.81	17.85	4.37	37.51	8.91	43.96	8.11
Lower 95% CI	48.39	9.78	24.12	4.92	25.50	5.82	46.32	11.02	50.29	10.27

CI, confidence interval; HPT, hand ProTaper; RPT, rotary ProTaper.

the type and location of defects through scanning electron microscopy fractographic examination (14). Of the discarded instruments, 16%, either intact or broken, were affected by shear failure, whereas 6% failed as a result of fatigue. The most frequently discarded instrument was S1 followed by F1. S1 instruments also evidenced the highest overall defect rate, probably because S1 is the first instrument to work in the root canal, when most dentin removal is required, and thus it is subjected to the highest mechanical stress. The apical third of the root canal was the most frequent site of fracture.

At fractographic analysis, HPT showed peculiar signs of axial crack patterns on the surface. An HPT instrument starts to rotate when the moment of force is sufficient to overcome the static friction and the work required to cut the dentin away from the root canal wall (13). On the contrary, the RPT instrument is already rotating before entering the root canal and thus must only overcome kinetic friction, which is always lower than static friction (20). This could explain the type of defect evidenced in HPT and their prevalent susceptibility to torsional stresses. In this study, HPTs were used with a reaming technique, alternating clockwise and anticlockwise motion. As has been shown with the balanced forces technique (21), the anticlockwise phase during the use of a NiTi file might decrease the instrument's susceptibility to mechanical stress (22), while respecting root canal anatomy (21).

The life of a NiTi rotary instrument is directly proportional to the stresses it undergoes while working inside the canal; thus each type of instrument appears to have an expected average life (23–25). One of the operator's main concerns when using NiTi instruments, whether rotary or hand-operated, is to avoid their fracture inside the root canal. Because rotary instruments are at risk of both torsional and flexural fracture (1), the clinician should control their determinants; the operator's experience and sensitivity play relevant roles in preventing torsional stresses. It has been demonstrated that lack of experience is a major risk factor in rotary file separation (11, 26–29), and the time required for root canal preparation depends inversely on experience (30). Thus the inexperienced clinician tends to perform a larger number of rotations within the curve.

A wide contact surface between canal wall and the instrument's cutting edge (11) represents another risk factor for torsional fracture. This risk might be reduced by performing coronal enlargement (31, 32) and manual preflaring before using NiTi rotary instrumentation (33, 34).

Flexural stresses depend on the root canal anatomy (4–7) and on its angle and radius of curvature. Although manual preflaring and prior coronal enlargement might somewhat enhance the performance of NiTi files in a situation of complex root canal anatomy, this factor cannot be significantly influenced by the clinician. Canal curvature and number of stretching-compressive cycles appear to be important factors that increase the risk of instrument failure; thus fewer rotations within a curve would reduce harmful patterns of cyclic fatigue stress accumulation (1, 4–7).

The mean overall working time (effective) was significantly longer with HPT (169.3 seconds, almost 5 times as long as with RPT). In our opinion, this difference does not significantly affect the length of the clinical session, whereas it is beneficial for cleaning of the root canal, increasing the time of contact between the irrigants and their substrate.

In conclusion, within the limits of this study, HPT required a longer time but fewer rotations to shape the simulated root canal compared with RPT.

Acknowledgments

The authors gratefully thank Dentsply Maillefer Co Laboratories, Ballaigues, Switzerland, for valuable support, in particular Mr Gilbert Rota, Project Manager, for special cooperation.

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