Berutti E, Alovisi M, Pastorelli MA, Chiandussi G, Scotti N, Pasqualini D. Energy consumption of ProTaper Next X1 after glide path with PathFiles and ProGlider. J Endod. 2014 Dec;40(12):2015-8. doi: 10.1016/j.joen.2014.08.011

Energy consumption of ProTaper Next X1 after glide path with PathFiles and ProGlider.

E. Berutti[1], M. Alovisi[1], M. Pastorelli[2], G. Chiandussi[3], N. Scotti[1], D. Pasqualini[1]

1. University of Turin, Department of Surgical Sciences, Dental School, Endodontics, Turin, Italy.

2. Department of Electrical Engineering, Politecnico di Torino, Turin, Italy

3. Department of Mechanics, Politecnico di Torino, Turin, Italy.

Conflict of interest: E. Berutti declares financial involvement (patent licensing arrangements) with Dentsply Maillefer with direct financial interest in the materials discussed in this manuscript.

Address for Correspondence:
Dr. Damiano Pasqualini, via Nizza, 230 – 10126 Torino Italy
Tel: +39(0)11/6331569
e-mail: damiano.pasqualini@unito.it

Running head: Energy consumption after glide path.

Abstract word count: 249

Text word count: 2249

Tables/Figures: 2

Acknowledgements: the authors would like to thank Dr. Alessandra De Sanctis and Dr. Lucia Ciaccio (Post-graduate Master Course in Clinical and Surgical Micro-Endodontics, University of Turin Dental School) for their active cooperation. The authors thank Dentsply-Maillefer for the donation of the instruments used in this study.

Highlights

- We compared the effect of glide path performed with PathFiles and ProGlider on torque, time and pecking motion required for ProTaper Next X1 to reach full working length in simulated root canals.
- The required torque for root canal instrumentation was analyzed by evaluating the electrical power consumption of the endodontic engine.
- ProGlider appears to perform more efficiently than PathFiles in decreasing electric power consumption of ProTaper Next X1 to reach full working length.
- ProGlider seems to reduce stress in ProTaper Next X1 during shaping through glide path and preliminary middle and coronal preflaring.

Abstract

Introduction: Instrument failure due to excessive torsional stress can be controlled by creating a manual or mechanical glide path. The ProGlider single file system was recently introduced to perform mechanical glide path. This study was designed to compare the effect of glide path performed with PathFiles and ProGlider on torque, time and pecking motion required for ProTaper Next X1 to reach full working length in simulated root canals. **Material and methods:** Forty Endo Training Blocks were utilized. Twenty were prepared with a mechanical glide path using PathFiles 1 and 2 (PF group) and twenty were prepared with a mechanical glide path using ProGlider single file (PG group). All samples were shaped with ProTaper Next X1 driven by an endodontic motor connected to a digital wattmeter. The required torque for root canal instrumentation was analyzed by evaluating the electrical power consumption of the endodontic engine. Electric power consumption (mW/h), elapsed time (s) and number of pecking motions required to reach full working length with ProTaper Next X1 were calculated. Differences among groups were analyzed with parametric Student's t test for independent data ($P < .05$).

Results: Elapsed time and electric power consumption were significantly different between groups ($P = .0001$ for both). ProGlider appears to perform more efficiently than PathFiles in decreasing electric power consumption of ProTaper Next X1 to reach full working length.

Conclusion: This study confirmed the ability of ProGlider to reduce stress in ProTaper Next X1 during shaping through glide path and preliminary middle and coronal preflaring.

Key words

Nickel-Titanium; Ni-Ti rotary instrumentation; ProGlider; glide path; electric power consumption

Introduction

Nickel-titanium (NiTi) rotary instruments were introduced to reduce operator tiredness, shaping time and risk of procedural errors when performing root canal shaping (1). Although several studies have shown that shaping outcomes with NiTi rotary instruments are mostly predictable (1–3), mechanical failure is a major concern (4, 5). The life of a NiTi rotary instrument is proportional to its operational stress state (6–9). In clinical practice the risk of instrument failure is mainly determined by bending and torsional stresses (10, 11). Canal curvature is the predominant risk factor for increased bending stresses and this cannot be influenced by the clinician (12–14). Torsional stresses are proportional to the compression force applied by the operator to the handpiece (15), and to the width of the contact area between the canal walls and instrument cutting blade (16, 17). These significantly increase if the canal cross section is smaller than that of the instrument non-cutting tip (18, 19). Although bending stresses are significant for cyclic fatigue, instrument failure is chiefly due to excessive torsional stresses (20) and the clinician can drastically reduce these by creating a smooth glide path, by either manual or mechanical preflaring (18–20). Previous studies suggest that mechanical instrumentation with NiTi rotary PathFiles (Dentsply Maillefer, Ballaigues, Switzerland) represents an easier and less invasive method to provide an adequate glide path (21).

The new ProGlider (Dentsply Maillefer, Ballaigues, Switzerland) single file system has been recently introduced to perform mechanical glide path (22) (Fig. 1). Its exclusive design and mechanical features enable the glide path to be created by a single instrument of one size (tip size 0.16 mm). Additional features include a progressive taper (.02 at tip level up to .085) with a cutting surface of 18 mm. To perform glide path, ProGlider must be used in continuous rotation (suggested settings 300 rpm with a 2–5.2 Ncm torque). Due to its progressively tapered design, the instrument also provides a preliminary preflaring of the middle and coronal portions of the canal.

Dedicated endodontic motors for use in any rotary NiTi system must maintain a constant rotational speed, limit torque and keep the instrument stress state within constant and acceptable levels (23).

The handpiece is capable to withstand the lateral pressure on the revolving instrument by increasing the torque, without decreasing its speed and cutting efficiency (24). Thus the engine increases torque when the instrument undergoes an increased workload in order to keep a constant speed (23, 24). Variations in torque result in different electrical power consumption by the endodontic engine (25, 26). Therefore, electric power consumption can be considered a reliable surrogate parameter to evaluate the stress state of the instrument during shaping (15, 25, 26). The aim of this study was to evaluate the influence of mechanical glide path performed with rotary PathFiles and ProGlider on the electric power consumption of the endodontic engine during root canal shaping with ProTaper Next X1 in simulated root canals.

Materials and methods

Forty standardized ISO 015 (apical), .02 taper, 40 degrees curvature, 16 mm working length (WL) Endo Training Blocks (Dentsply Maillefer, Ballaigues, Switzerland) were utilized for this study. Sample size calculation was carried out in G*Power 3.1.4 (Kiel University, Germany) to set study power at 80%. One expert operator, previously calibrated for pecking speed and pressure on the handpiece, carried out all the instrumentation phases of this study. The Endo Training Block canals were scouted up to working length with a #10 stainless steel K-File (Dentsply Maillefer, Ballaigues, Switzerland) and randomly assigned to one of two groups:

- PathFile (PF) Group (n = 20): mechanical glide path was carried out with PathFile rotary instruments #1 (013, .02) and #2 (016, .02) (Dentsply Maillefer. Ballaigues, Switzerland), according to the manufacturer’s instructions, before using ProTaper Next X1 at WL.
- ProGlider (PG) Group (n = 20): mechanical glide path was carried out with ProGlider (Dentsply Maillefer. Ballaigues, Switzerland) rotary single file (016, .02 at tip level, with progressive taper up to .085) at WL.

Mechanical glide path was performed using Glyde (Dentsply Maillefer, Ballaigues, Switzerland) as a lubricating agent and an endodontic engine (X-Smart, Dentsply Maillefer, Ballaigues, Switzerland) with a 16:1 contra angle at the suggested setting (300 rpm on display, 5 Ncm). New instruments were utilized for each Endo Training Block.

Prepared specimens from both groups were shaped with a new ProTaper Next X1 (Dentsply Maillefer, Ballaigues, Switzerland) rotary file (017, .04) at WL. The endodontic motor used for shaping was the Tecnika digital motor (ATR, Muggiò, Italy) with a 16:1 reduction handpiece. In all cases, speed of rotation was set to 300 rpm and the torque to 5.2 Ncm. The endodontic motor was connected to a digital wattmeter (WT 20130 Digital Power Meter, Yokogawa, Japan) and an electronic schedule in order to evaluate the electric power consumption required to reach full WL. The electronic schedule was designed to quantify and subtract the electrical and mechanical power disturbances. The electrical power consumption (mW/h), number of pecking motions and time (s) required to reach the full WL with a ProTaper Next X1 was calculated for every specimen belonging to the two groups (PF and PG). The Kolmogorov-Smirnov test for normality revealed a normal data distribution and differences between groups were analyzed using the parametric Student's t test for independent data. Differences were considered statistically significant when $P < .05$. All statistical analyses were performed using the SPSS for Windows 12.0 software package (SPSS, Inc. Chicago, IL)**.**

Results

No damage or separation of PathFile and ProGlider instruments occurred during glide path phase. PathFile system (#1 and #2) required the same number of total passes to reach apex (N = 1+2, respectively) as the ProGlider single file (N = 3). Electrical power consumption during the shaping operations with ProTaper Next X1 was significantly different between the groups (P = .0001). The endodontic motor consumed 4.89 mW/h (SD = .52) and 4.16 mW/h (SD = .56) in the PF and PG groups, respectively (Table 1). The mean time required to reach full WL with ProTaper Next X1 was also significantly different between the two groups (P = .0001) (Table 1). The mean time required to complete the shaping operation with ProTaper Next X1 in the PF group was 7.99 s compared with 5.91 s in the PG group. Pecking motion was not statistically different between groups (Table 1). No instrument unwinding or failure was recorded during the shaping operations with ProTaper Next X1.

Discussion

The risk of instrument failure is a concern when using NiTi rotary instruments, particularly the potential difficulty of removing instrument fragments and the perceived adverse prognostic effect of this procedural complication (5, 27). Prediction of this risk is a continued source of debate. After initial canal scouting with manual K-files to determine the first WL and to guarantee the foraminal patency, the creation of a glide path is mandatory to increase the shaping performances of NiTi rotary or reciprocating instruments (17, 18, 28). Instrument life is strictly related to the stress state and failure may result from incorrect or excessive use (6–9, 29). A manual or mechanical glide path is necessary to reduce the effect of torsional stresses along the canal and the risk of instrument failure (5, 16–18). In order to avoid instrument failure from excessive torque, the root canal diameter should be larger than, or at least equal to, the non-cutting tip of the first shaping instrument used. Previous studies have reported that mechanical glide path is more effective at maintaining the original canal anatomy than manual glide path with K-Files (21, 30). Moreover, mechanical glide path may be less time-consuming and is associated with a lower prevalence and severity of post-operative pain, making it particularly suitable for inexperienced clinicians (21, 31).

This study compared PathFile and ProGlider systems for performing mechanical glide path. The electric power consumption required by the endodontic engine during canal root shaping for the full WL with ProTaper Next X1 was recorded in simulated root canals for both systems. ProTaper Next X1 is a new generation rotary shaping instrument designed to perform the same coronal and middle root canal shaping with a single file as the first two ProTaper Universal S1 and S2 insruments. Consequently, it may benefit from a preflaring of the middle and coronal portion of the root canal in order to decrease torsional stresses. Although results obtained from resin blocks do not fully reflect those in real teeth, where dentine is involved, the use of simulated root canals has demonstrated the advantages of providing standardized experimental conditions as a reproducible and widely used model (3, 21, 32). Specific endodontic engines for NiTi rotary instruments have been developed (23, 24) to keep the same rotational speed (33, 34) by controlling the applied torque. NiTi rotary shaping instruments with a variable taper are designed to cut dentin in correspondence of their larger cross sections and require a larger torque (15), mainly due to dentin hardness, root canal anatomy and the presence or absence of an adequate preflaring (21, 23–25, 33, 34). The torque applied to the endodontic file driven in a continuous rotary mode is proportional to the power consumption of the endodontic engine (26). As a consequence, power consumption is a representative parameter of the instrument life (15, 25, 26) if instrument failure due to excessive torque is avoided.

Resin block glide path in the PF Group was performed mechanically with PathFiles 1 and 2 before shaping with ProTaper Next X1 according to the manufacturer's instructions. In the PG Group, the ProGlider system was employed, a single instrument made of M-Wire NiTi alloy with a progressive taper and a square cross section characterized by a semi-active tip in order to ensure super-elasticity properties and a cutting surface of 18 mm (Fig. 1). As well as creating glide path, the ProGlider system may also create preliminary root canal middle and coronal preflaring due to its progressive taper (.02 up to .085), potentially decreasing shear stresses for every type of NiTi rotary shaping instrument. Preliminary preflaring by the ProGlider system thereby reduces the NiTi instrument work during shaping. Preflaring is the preliminary enlargement of the root canal, usually in the coronal and middle portions, which has previously required the use of curved instruments to reach full WL (1, 17). Whereas glide path creates a smooth canal tunnel, usually with a small taper (.02), to prevent instrument blockage or taper lock (18–21). As the tip size of ProGlider is 0.16 mm, the instrument is recommended for ProTaper Next X1 (tip size 0.17 mm) and may be suitable for any subsequent NiTi rotary shaping instrument with a similar tip size.

The present study suggests that, due to its progressive taper, the NiTi rotary ProGlider achieves a greater preflaring of the coronal and middle portions of the root canal compared with PathFiles 1 and 2. This results in decreased electric consumption and stress state supported by ProTaper X1 during shaping. In addition, the time required to reach full WL with ProTaper Next X1 was statistically lower in the PG group compared with the PF Group. However, the required number of pecking motions did not differ between groups. No difference in the total number of passes was noted between PF and PG during glide path creation. However, it is expected that PG may require a higher energy consumption due to its greater tapered design. The greater stress that PG could encounter during operation should be compensated by its highly performant m-Wire alloy. Moreover, several studies have shown that root canal preflaring might allow WL files to more consistently reach the apical foramen, significantly increasing the precision of electronic apex locators to determine the real WL (35).

In conclusion, our results confirm the capability of ProGlider to perform glide path as well as middle and coronal preflaring, reducing the amount of stress stored by ProTaper Next X1 during shaping. Further research is required to find a valid and quantitative indicator of instrument life which can register and record the stress stored by each instrument during shaping, thereby indicating the appropriate moment to discard it in clinical practice.

References

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30:559–67.
2. Gambill JM, Alder M, del Rio CE. Comparison of nickel-titanium and stainless steel hand-file instrumentation using computed tomography. J Endod 1996;22:369–75.
3. Hülsmann M, Peters, OA, Dummer P. Mechanical preparation of root canals: shaping goals, techniques and means. Endodontic Topics 2005;10:30–76.
4. Kuhn G, Jordan L. Fatigue and mechanical properties of nickel-titanium endodontic instruments. J Endod 2002;28:716–20.
5. Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. J Endod 2006;32:1031–43.
6. Yared GM, Bou Dagher FE, Machtou P. Cyclic fatigue of Profile rotary instruments after simulated clinical use. Int Endod J 1999;32:115–9.
7. Zuolo ML, Walton RE. Instrument deterioration with usage: nickel-titanium versus stainless steel. Quintessence Int 1997;28:397–402.
8. Al-Sudani D, Grande NM, Plotino G, et al. Cyclic fatigue of nickel-titanium rotary instruments in a double (S-shaped) simulated curvature. J Endod 2012;38:987–9.
9. Gambarini G. Cyclic fatigue of ProFile rotary instruments after prolonged clinical use. Int Endod J 2001;34:386–9.
10. Alapati SB, Brantley WA, Svec TA, et al. SEM observations of nickel-titanium rotary endodontic instruments that fractured during clinical use. J Endod 2005;31:40–3.
11. Berutti E, Chiandussi G, Gaviglio I, Ibba A. Comparative analysis of torsional and bending stresses in two mathematical models of nickel-titanium rotary instruments: ProTaper versus ProFile. J Endod 2003;29:15–9.
12. Loizides AL, Kakavetsos VD, Tzanetakis GN, Kontakiotis EG, Eliades G. A comparative study of the effects of two nickel-titanium preparation techniques on root canal geometry

assessed by microcomputed tomography. J Endod 2007;33:1455–9.

13. Ounsi HF, Salameh Z, Al-Shalan T, et al. Effect of clinical use on the cyclic fatigue resistance of ProTaper nickel-titanium rotary instruments. J Endod 2007;33:737–41.
14. Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod 1997;23:77–85.
15. Blum JY, Machtou P, Ruddle C, Micallef JP. Analysis of mechanical preparations in extracted teeth using ProTaper rotary instruments: value of the safety quotient. J Endod 2003;29:567–75.
16. Roland DD, Andelin WE, Browning DF, Hsu GH, Torabinejad M. The effect of preflaring on the rates of separation for 0.04 taper nickel titanium rotary instruments. J Endod 2002;28:543–5.
17. Berutti E, Negro AR, Lendini M, Pasqualini D. Influence of manual preflaring and torque on the failure rate of ProTaper rotary instruments. J Endod 2004;30:228–30.
18. Patiño PV, Biedma BM, Liébana CR, Cantatore G, Bahillo JG. The influence of a manual glide path on the separation rate of NiTi rotary instruments. J Endod 2005;31:114–6.
19. Peters OA, Peters CI, Schönenberger K, Barbakow F. ProTaper rotary root canal preparation: assessment of torque and force in relation to canal anatomy. Int Endod J 2003;36:93–9.
20. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 2000;26:161–5.
21. Berutti E, Cantatore G, Castellucci A, et al. Use of nickel-titanium rotary PathFile to create the glide path: comparison with manual preflaring in simulated root canals. J Endod 2009;35:408–12.
22. http://www.dentsplymaillefer.com/#/218x624/line_218x7950/product_218x9225/
23. Yared GM, Bou Dagher FE, Machtou P. Influence of rotational speed, torque and operator's

proficiency on ProFile failures. Int Endod J 2001;34:47–53.

24. Marzouk MA, Simonton AL, Gross RD. Operative dentistry in modern theory and practice. 1997; Ishiyaku Euro America, Inc/Dental Series, I Edition; pp. 71.

25. Blum JY, Cohen A, Machtou P, Micallef JP. Analysis of forces developed during mechanical preparation of extracted teeth using Profile NiTi rotary instruments. Int Endod J 1999;32:24–31.

26. Deshpande M.V. Electric motors Applications and Controls. New Delhi 2010. PHI Learning Private Limited.

27. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. J Endod 2004;30:722–5.

28. Berutti E, Paolino DS, Chiandussi G, et al. Root canal anatomy preservation of WaveOne reciprocating files with or without glide path. J Endod 2012;38:101–4.

29. Shen Y, Cheung GS, Bian Z, Peng B. Comparison of defects in ProFile and ProTaper systems after clinical use. J Endod 2006;32:61–5.

30. Pasqualini D, Bianchi CC, Paolino DS, et al. Computed micro-tomographic evaluation of glide path with nickel-titanium rotary PathFile in maxillary first molars curved canals. J Endod 2012;38:389–93

31. Pasqualini D, Mollo L, Scotti N, et al. Postoperative pain after manual and mechanical glide path: a randomized clinical trial. J Endod 2012;38:32–6.

32. Kum KY, Spängberg L, Cha BY et al. Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. J Endod 2000;26:719–23.

33. Gambarini G. Cyclic fatigue of nickel-titanium rotary instruments after clinical use with low- and high-torque endodontic motors. J Endod 2001;27:772–4.

34. Sattapan B, Palamara JE, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod 2000;26:156–60.

35. Ibarrola JL, Chapman BL, Howard JH, Knowles KI, Ludlow MO. Effect of preflaring on Root ZX apex locators. J Endod 1999;25:625–6.

Figure legends

Fig. 1: ProGlider NiTi rotary system. A single instrument of one size (016 .02) and a progressive taper (up to .085) with an active part of 18 mm, available in three different lengths: 21, 25 and 31 mm.

Tables

Table 1: Electric power consumption (mW/h), time (s) and number of pecking motions required to reach full working length (WL) with ProTaper Next X1 in simulated root canals following glide path by PathFile (PF) or ProGlider (PG).

Table 1

	PF Group (n=20)	PG Group (n=20)
Electric power consumption (mW/h)		
Mean	4.88	4.15
Std. deviation (SD)	0.51	0.56
Std. error of mean (SEM)	0.11	0.12
Lower 95% conf. interval	4.64	3.89
Upper 95% conf. interval	5.13	4.41
Pecking motions (n)		
Median	4	4
Time (s)		
Mean	7.99	5.91
Std. Deviation (SD)	1.73	1.28
Std. Error of mean (SEM)	0.38	0.28
Lower 95% conf. interval	7.18	5.30
Upper 95% conf. interval	8.80	6.51

Table 1 Electric power consumption (mW/h), time (s) and number of pecking motions required to reach full working length (WL) with ProTaper Next X1 in simulated root canals following glide path by PathFile (PF) or ProGlider (PG).

Figure 1