Torque and Force Induced by ProTaper Universal and ProTaper Next during Shaping of Large and Small Root Canals in Extracted Teeth

Ana Arias, DDS, PhD, Rupinderpal Singh, DDS, and Ove A. Peters, DMD, MS, PhD

Abstract

Introduction: The purpose of this study was to compare peak torque and force between ProTaper Universal (PTU) and ProTaper Next (PTN) instruments during the preparation of large and small root canals in extracted teeth. **Methods:** Twelve maxillary incisors and each independent canal of 6 mesial roots of mandibular molars were randomly assigned to be prepared with a new set of either PTU or PTN instruments after a glide path was achieved. A total of 12 new sets of each instrument system were used. The tests were run in a standardized fashion in a torque-testing platform. Peak torques (Ncm) and force (N) were registered; analysis of variance and Tukey post hoc tests were then applied. **Results:** Among instruments in the same sequence, no significant differences in peak torque and force were found among PTN instruments when shaping small or large root canals, but some PTU instruments showed statistically lower peak torque and force ($P < .01$) than others for both types of canals. Whereas PTU instruments showed significant differences in peak torque and force ($P < .05$) between large and small root canals, PTN instruments showed significantly lower force ($P < .04$) in large canals, but peak torque was not significantly different for upper central incisors or mesial mandibular root canals. **Conclusions:** Under the conditions of this study, instruments in ProTaper Next set showed greater regularity in peak torque for small and large canals than ProTaper Universal instruments. *(J Endod 2014;40:973–976)*

Key Words

M-Wire, ProTaper Next, ProTaper Universal, torque

From the Department of Endodontics, Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, California.

Address requests for reprints to Dr Ana Arias, University of the Pacific, Arthur A. Dugoni School of Dentistry, 2155 Webster Street, San Francisco, CA 94115. E-mail address: aa@ana-arias.com
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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). They have become popular because of their greater flexibility, their cutting ability, and their more rapid and centered root canal shaping (2–4). However, they tend to unexpectedly break by flexural fatigue or torsional failure. Flexural fatigue is caused by the alternating tension-compression cycles to which they are subjected when flexed in the maximum curvature of the canal and rotated, and torsional failure occurs when the tip of the instrument binds, but the shank of the instrument continues to rotate (5).

During the past decades the development of NiTi rotary instruments with different approaches has occurred. Manufacturers have changed cross-sectional designs and geometrical properties of NiTi rotary instruments, but the latest strategies are focusing on the improvement of the conventional NiTi alloy. Subtle changes in the ratio of the elements (nickel and titanium) and in heat treatment during or after manufacture allowed the development of instruments with better fracture resistance (6–14). M-Wire (Sportswire LLC, Langley, OK) is a new, more flexible alloy that has been reported to increase the resistance to cyclic fatigue by almost 4-fold (13); however, torsional resistance of M-Wire or other thermally treated alloys does not appear to be significantly improved (15–20).

Previous studies have reported that the torque induced by a rotary instrument during root canal shaping depends mainly on the amount of contact between the instrument and the canal walls, the apical force applied to the instrument, the diameter of the instrument, and the volume of the canal (21–23). Dynamic torque of instruments made with different manufacturing methods or new treated alloys have been previously analyzed (24–26). However, the benefits in dynamic torsional behavior of instruments made of M-Wire compared with conventional NiTi have not been thoroughly studied.

ProTaper Universal (PTU) (Dentsply Tulsa Dental, Tulsa, OK) is a well-described NiTi rotary system of instruments manufactured with progressive taper over the length of the cutting blades, convex triangular cross sections, and noncutting tips. Recently, ProTaper Next (PTN) (Dentsply Tulsa Dental) was introduced; this instrument is made from M-Wire alloy, and its design features include variable tapers and an off-centered rectangular cross section.

As per directions for use, clinicians should take all instruments in both series, except ProTaper SX, passively to working length after preparing a glide path (27, 28). Instruments that use such a concept of a single length technique are supposed to require a higher torsional strength; this is likely due to the greater stress originating from greater contact of the active surface of the instrument with the root canal walls (22). Despite the similarity in the operation of both systems, the different cross sections of the instruments could affect the stress distribution pattern and the torsional behavior (29, 30).

Currently, usage parameters for PTN are established beyond manufacturer's recommendations, which are 300 rpm and torque preset between 2 to 5.2 Ncm, but independent data in this regard are scarce (31). For safe and effective clinical application, more specific knowledge of the best torque recommendations for different canal anatomies is desirable. In fact, currently there are no data available on torque and force during canal preparation with PTN compared with PTU during canal preparation in teeth. Therefore, the aim of this study was to compare baseline torque and force between PTU and PTN instruments during the preparation of large and small human root canals.

Materials and Methods

Twelve extracted single-rooted maxillary incisors and 6 mandibular molars with 2 independent canals in the mesial root were selected from the department's pool of extracted teeth. They were stored in 0.1% thymol and decoronated to obtain similar working lengths, and digital radiographs were taken. Canals were negotiated with a #10 K instrument in the presence of Glyde (Dentsply Maillefer, Ballaigues, Switzerland). When the tip of the instrument was visible through the main foramen, 0.5 mm was subtracted to determine working length. Glide path shaping was achieved in all canals with Pathfile (Dentsply Maillefer) instruments #1 (0.13 mm at the tip, 0.02 taper) and #2 (0.16 mm at the tip, 0.02 taper). The apical thirds of the roots were covered with wax, and the specimens were mounted on scanning electron microscopy stubs (014001-T; Balzers Union AG, Balzers, Liechtenstein).

Six maxillary incisors (I) were randomly assigned to 1 of the 2 different groups. Group 1I was shaped with PTU with the following sequence: S1, S2, F1, F2, F3, F4, F5. Group 2I was shaped with PTN with the following sequence: X1, X2, X3, X4, X5, all taken to working length.

Similarly, each independent canal of the same mandibular molar mesial root (M) was randomly assigned to 2 different groups. Root canals in group 1M were shaped with PTU with the following sequence: S1, S2, F1, F2, F3 and in group 2M with PTN with the following sequence: X1, X2, X3.

The same endodontist with 15 years of experience in rotary canal instrumentation (A. A.) shaped all root canals. Tap water delivered after each instrument through a 27-gauge needle acted as the irrigant. No effort was made to enlarge canal orifices previous to the action of the rotary instruments. Each canal preparation was performed with a new set of instruments. Thus, a total of 12 new sets of PTU and 12 of PTN were used.

The tests were run in a standardized manual fashion in a torque-testing platform, which has been described in detail earlier (32). The bench was configured to determine torque and force during canal preparation that was accomplished via 4 insertions per instrument. Peak torques (Ncm) as well as positive peak forces (N) were registered by using the custom-made Endotest software package and collected for off-line analysis.

Data for peak torque as well as peak force were found to be compatible with normal distribution, and standard deviations of subgroups were similar. Results were analyzed with analysis of variance, and when appropriate, Tukey post hoc tests were used to compare subgroups.

Results

In the course of the study, one X1 instrument fractured in a small root canal, and a plastic deformation after use was detected through visual inspection for another X1.

Shaping of small and large root canals resulted in specific patterns, as illustrated in real-time torque and force curves (Fig. 1).

Mean values of peak torque (Ncm), force (N), and standard deviations for each instrument and type of root canals are shown in Table 1. The first set of analyses examined differences in peak torque and forces between the instruments for each system in large or small canals independently. There were no significant differences in peak torque and force among the 3 different PTN instruments (X1/X2/X3) when shaping small root canals or between the 5 (X1/X2/X3/X4/X5) when shaping large root canals. However, there were significant differences in both peak torque ($P < .001$) and force ($P = .01$) among PTU instruments when shaping large canals and in peak torque ($P < .001$) when shaping small canals. In small canals, S2 and F1 showed significantly lower peak torque than S1 and F2, and these were significantly lower than F3. In large canals, S1 showed significantly higher torque than the rest of the instruments. S2 and F1 showed significantly lower force, and F5 showed the significantly highest force.

Then torque and force for different root canal sizes were compared in relation to the two for each instrument type. PTU instruments showed significantly lower peak torque ($P < .05$) and force ($P \leq .01$) values for large compared with small root canals; an exception was S1, where force was also significantly lower when shaping small root canals ($P = .02$), but peak torque was higher ($P = .002$). Conversely, PTN instruments showed significantly lower force ($P < .04$) in large canals, but peak torque was not significantly different for upper central incisors or mesial mandibular root canals.

Discussion

This study set out to assess differences in peak torque and force between a widely used rotary system (PTU) and a recently developed one (PTN) when preparing large and small root canals in extracted teeth.

Both systems have some similarities, for example, the clinical strategy (ie, single length technique) and the variable taper along the active cutting blades. Therefore, it was expected that comparable peak torque and force would be generated during preparation of similarly sized root canals. Generally, a higher peak torque and force are expected when root canals are shaped with a single length preparation technique because of the greater contact of the instrument with the walls of the root canal (21, 22).

On the other hand, PTN has been designed with a different cross section and M-Wire NiTi alloy. It is well-known that cross section affects the torsional behavior of instruments (29, 30). The off-centered cross section may induce different patterns of forces and torques because of the asymmetric contact of the instrument and the dentin.

Dynamic torque and force of different instruments have been previously analyzed in plastic blocks with this same device (22, 24, 33). Two rotary systems with different cross sections have also been tested in the same device but in human dental roots, the radial landed ProFile instruments (32) and the non-radial landed PTU (21). In this study, a third system with a new non-radial landed and off-centered cross section is tested. Such a modification in the cross section should involve a reduction of the contact area with the canal and therefore in the cutting efficiency and torsional loads (34).

In this study, some instruments in the sequence that the manufacturer recommends for PTU were found to induce significantly lower torque and force than those used before or after them, whereas all instruments in the PTN sequences developed similar force and torque. An example of this situation is S2, which needed 18% of the mean peak torque and 57% of the mean force that S1 induced to reach working length. These results are consistent with those of previous studies that analyzed PTU torsional behavior (21).

A possible explanation for this finding might be that whereas each of the files in PTN sequence played an effective role in shaping the canal, some instruments of the PTU set were not essential in taking the next file to working length. These findings further support the idea of a potential simplification in the sequence of PTU instruments. In fact, reducing the number of instruments needed to shape root canals is one of the strategies that manufacturers are implementing in the development of new rotary systems.

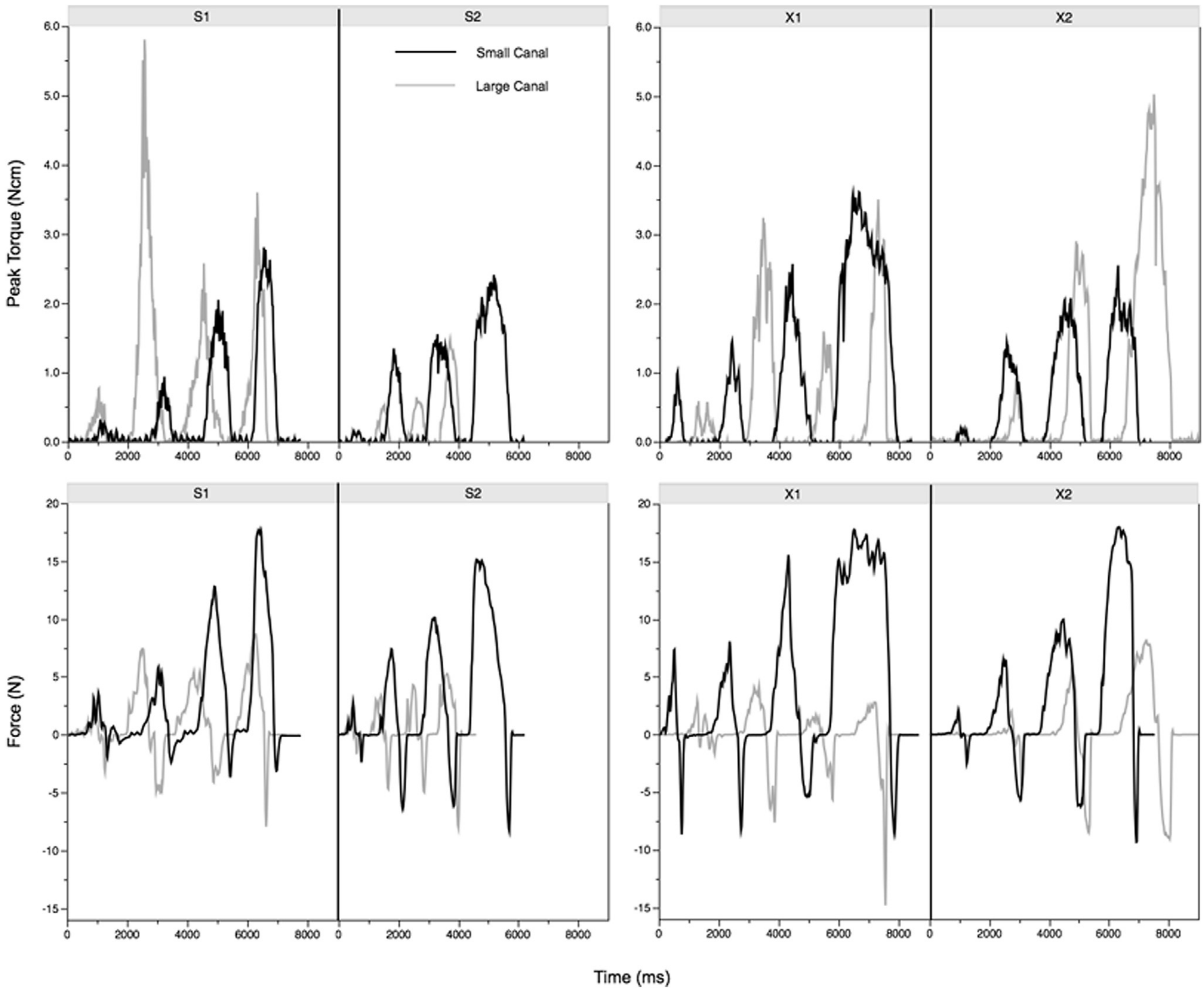

Figure 1. Real-time torque and force curves of PTU (S1 and S2) and PTN (X1 and X2) rotary systems in small and large canals.

Another interesting finding was that there were no statistical differences between PTN and PTU instruments in peak torque and force developed to shape small canals, but there were differences when shaping large canals. It is likely that the new off-centered design of PTN cross section allowed the smallest instrument X1 to have less contact with the canal walls in large canals where there is more space for the different movement in a root canal. However, several of the larger-size PTN instruments produced more force, probably because fewer instruments are part of the sequence.

Interestingly, no differences in peak torque were found between PTN instruments when shaping small and large canals. In agreement with a previous study (21), PTU instruments in the present experimental conditions showed variable torsional behavior, depending on the type of root canal instrumented. This finding suggests that because of the innovative features of PTN instruments, the torque required to reach working length is less dependent on the characteristics of the root canal.

Recently, differences in peak torque were found among PTN instruments when shaping plastic block canals with different settings (31). In fact, X2 showed higher torque than the other instruments. This rotary also showed the highest torque and force in the present study, although the results were not statistically significant.

Cutting of dentin is different than cutting plastic; however, torque values obtained during canal preparation with radial landed instruments in plastic blocks with curved canals were similar to those in human mandibular incisors in an earlier study (32). There are 2 different possible explanations for the differences in the results of these 2 studies in which the same device was used to test the instruments. On the one hand, there is no evidence that a non-radial landed instrument, for example PTN, needs similar torques to cut plastic than dentin. On the other hand, in the study by Pereira et al (31), instruments were reused, whereas in the present study a new set of instruments was used to prepare each canal. Previous studies with different rotary systems had already demonstrated that the torsional profile was affected significantly when instruments were reused (17, 25).

One PTN instrument, specifically X1, fractured when shaping a small canal; however, this fact should be interpreted with caution. In devices that are used to study the torsional profile of endodontic instruments, samples are rigidly secured in both endings (the teeth and the instrument), not allowing any other movement than the vertical in-and-out advancement of the instrument. In a clinical situation, the hand of the practitioner can change the direction of the instrument following the natural anatomy of the root canal system.

TABLE 1. Mean (±standard deviation) of Peak Torque and Maximum Force (n = 6 per Group)

System	Instrument	Large canals Torque (Ncm)	Large canals Force (N)	Small canals Torque (Ncm)	Small canals Force (N)
PT Next	X1	2.5 ± 0.8	6 ± 2.8	2.6 ± 0.3	17.1 ± 3.6
	X2	3.5 ± 0.8	7.3 ± 1.7	3.7 ± 0.5	19.6 ± 3.4
	X3	2.5 ± 0.5	6 ± 1.4	2.9 ± 0.4	16.4 ± 2.4
	X4	2.8 ± 0.4	6.2 ± 1.1		
	X5	2.9 ± 0.2	6.1 ± 0.9		
PTU	S1	6.1 ± 0.8	7.9 ± 0.8	2.5 ± 0.2	16.5 ± 2.8
	S2	1.1 ± 0.2	4.5 ± 1.05	2.2 ± 0.4	13.6 ± 2.4
	F1	1 ± 0.3	4.4 ± 0.8	2 ± 0.1	10.1 ± 1.5
	F2	2 ± 0.4	7 ± 0.7	3.2 ± 0.1	15.4 ± 1.9
	F3	2.6 ± 0.5	5.9 ± 0.4	3.8 ± 0.2	16.8 ± 3.1
	F4	1.7 ± 0.3	6.4 ± 0.9		
	F5	2.6 ± 0.5	9.4 ± 1.7		

In vitro studies of the torsional profiles of instruments with innovative characteristics are recommended to suggest more accurate directions for use. Within the limitations of this *in vitro* study, the results suggest that the different instruments in PTN sequence showed greater regularity in peak torque than those in PTU shaping protocol in large and small root canals.

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References

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14:346–51.
2. Bird DC, Chambers D, Peters OA. Usage parameters of nickel-titanium rotary instruments: a survey of endodontists in the United States. J Endod 2009;35:1193–7.
3. Glossen CR, Haller RH, Dove SB, del Rio CE. A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. J Endod 1995;21:146–51.
4. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centering ability of four instrumentation techniques. J Endod 1997;23:503–7.
5. Sattapan B, Nervo G, Palamara J, Messer H. Defects in rotary nickel-titanium files after clinical use. J Endod 2000;26:161–5.
6. Oh S-R, Chang S-W, Lee Y, et al. A comparison of nickel-titanium rotary instruments manufactured using different methods and cross-sectional areas: ability to resist cyclic fatigue. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:622–8.
7. Ye J, Gao Y. Metallurgical characterization of M-Wire nickel-titanium shape memory alloy used for endodontic rotary instruments during low-cycle fatigue. J Endod 2012;38:105–7.
8. Plotino G, Costanzo A, Grande NM, et al. Experimental evaluation on the influence of autoclave sterilization on the cyclic fatigue of new nickel-titanium rotary instruments. J Endod 2012;38:222–5.
9. Arias A, Perez-Higueras JJ, la Macorra de JC. Influence of clinical usage of GT and GTX files on cyclic fatigue resistance. Int Endod J 2013 May 23. doi: 10.1111/iej.12141. [Epub ahead of print].
10. Shen Y, Zhou H-M, Zheng Y-F, et al. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013;39:163–72.
11. Shen Y, Qian W, Abtin H, et al. Effect of environment on fatigue failure of controlled memory wire nickel-titanium rotary instruments. J Endod 2012;38:376–80.
12. Gambarini G, Grande NM, Plotino G, et al. Fatigue resistance of engine-driven rotary nickel-titanium instruments produced by new manufacturing methods. J Endod 2008;34:1003–5.
13. Johnson E, Lloyd A, Kuttler S, Namerow K. Comparison between a novel nickel-titanium alloy and 508 Nitinol on the cyclic fatigue life of ProFile 25/.04 rotary instruments. J Endod 2008;34:1406–9.
14. Alapati SB, Brantley WA, Iijima M, et al. Metallurgical characterization of a new nickel-titanium wire for rotary endodontic instruments. J Endod 2009;35:1589–93.
15. Kramkowski TR, Bahcall J. An *in vitro* comparison of torsional stress and cyclic fatigue resistance of ProFile GT and ProFile GT Series X rotary nickel-titanium files. J Endod 2009;35:404–7.
16. da Cunha Peixoto IF, Pereira ES, da Silva JG, et al. Flexural fatigue and torsional resistance of ProFile GT and ProFile GT Series X instruments. J Endod 2010;36:741–4.
17. Kell T, Azarpazhooh A, Peters OA, et al. Torsional profiles of new and used 20/.06 GT Series X and GT rotary endodontic instruments. J Endod 2009;35:1278–81.
18. Ha J-H, Kim SK, Cohenca N, Kim H- C. Effect of R-phase heat treatment on torsional resistance and cyclic fatigue fracture. J Endod 2013;39:389–93.
19. Park S-Y, Cheung GSP, Yum J, et al. Dynamic torsional resistance of nickel-titanium rotary instruments. J Endod 2010;36:1200–4.
20. Wycoff RC, Berzins DW. An *in vitro* comparison of torsional stress properties of three different rotary nickel-titanium files with a similar cross-sectional design. J Endod 2012;38:1118–20.
21. 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.
22. Schrader C, Peters OA. Analysis of torque and force with differently tapered rotary endodontic instruments *in vitro*. J Endod 2005;31:120–3.
23. Bahia MGA, Melo MCC, Buono VTL. Influence of simulated clinical use on the torsional behavior of nickel-titanium rotary endodontic instruments. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:675–80.
24. Bardsley S, Peters CI, Peters OA. The effect of three rotational speed settings on torque and apical force with vortex rotary instruments *in vitro*. J Endod 2011;37:860–4.
25. Basrani B, Roth K, Sas G, et al. Torsional profiles of new and used Revo-S rotary instruments: an *in vitro* study. J Endod 2011;37:989–92.
26. Boessler C, Paqué F, Peters OA. The effect of electropolishing on torque and force during simulated root canal preparation with ProTaper Shaping files. J Endod 2009;35:102–6.
27. ProTaper Next rotary files: directions for use. Available at: http://www.tulsadentalspecialties.com/default/endodontics_brands/ProTaperNEXT.aspx. Accessed August 8, 2013.
28. ProTaper Universal rotary files: directions for use. Available at: http://www.tulsadentalspecialties.com/default/endodontics_brands/ProTaperUniversal.aspx. Accessed August 8, 2013.
29. Turpin YL, Chagneau F, Vulcain JM. Impact of two theoretical cross-sections on torsional and bending stresses of nickel-titanium root canal instrument models. J Endod 2000;26:414–7.
30. Melo MCC, Pereira ESJ, Viana ACD, et al. Dimensional characterization and mechanical behaviour of K3 rotary instruments. Int Endod J 2008;41:329–38.
31. Pereira ESJ, Singh R, Arias A, Peters OA. *In vitro* assessment of torque and force generated by novel ProTaper Next instruments during simulated canal preparation. J Endod 2013;39:1615–9.
32. Peters OA, Barbakow F. Dynamic torque and apical forces of ProFile.04 rotary instruments during preparation of curved canals. Int Endod J 2002;35:379–89.
33. Peters OA, Gluskin AK, Weiss RA, Han JT. An *in vitro* assessment of the physical properties of novel Hyflex nickel-titanium rotary instruments. Int Endod J 2012;45:1027–34.
34. Blum JY, Machtou P, Micallef JP. Location of contact areas on rotary Profile instruments in relationship to the forces developed during mechanical preparation on extracted teeth. Int Endod J 1999;32:108–14.