Effect of Endodontic Instrumentation Technique on Root Canal Geometry

Miranda Stavileci[1], Veton Hoxha[1], Mehmet Ömer Görduysus[2], Kjell Laperre[3], Ilkan Tatar[4], Rina Hoxha[5]*

1. University of Prishtina, Faculty of Medicine, Department of Dental Pathology and Endodontics, Prishtina, Kosovo.
2. University of Sharjah, College of Dental Medicine, Department of Preventive and Restorative Dentistry, Sharjah, UAE.
3. Bruker microCT, Kontich, Belgium.
4. Hacettepe University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey.
5. University of Prishtina, Faculty of Medicine, Department of Social Medicine at the National Institute of Public Health of Kosova, Prishtina, Kosovo.

Abstract

Root canal morphology can be changed after root canal preparation depending on the technique used. Therefore, the object of this study was to use micro-CT to investigate the shaping ability of the ProTaper rotary system and stainless steel manual files in permanent premolars.

Material and methods

Sixty extracted upper premolars were used for this study. They were divided into 2 groups of 30 teeth each. Before preparation, all samples were scanned by micro-computed tomography. Thirty teeth were prepared with the ProTaper system and the other 30 with stainless steel files. The root canal models before and after preparation were reconstructed and superimposed, and the volume, surface area and diameter changes were quantitatively measured in 3D analysis with SkyScan according to preparation techniques.

F test and t test showed a statistically significant difference in the root canal diameter increase between the ProTaper group and the manual instrumentation group ($P < 0.000001$).

The ProTaper system produced a greater volume change than the manual instrumentation technique ($P < 0.001$).

The ProTaper system produced a greater change in surface area than the manual instrumentation technique ($P < 0.00001$).

ProTaper system produced significantly increased root canal diameter, volume and surface area when compared with the manual instrumentation technique.

Experimental article (J Int Dent Med Res 2017; 10(3): pp. 952-957)

Keywords: Root canal geometry, ProTaper, stainless steel, micro CT.

Received date: 30 August 2017 **Accept date:** 04 October 2017

Introduction

Mechanical instrumentation of the root canal system is a key factor in endodontic therapy.[1,2] The anatomy of the root canal system is the main variable that should be considered as a factor for achieving successful root canal therapy. The desirable shape is achieved by gradually decreasing the cross-sectional diameter of the root canal towards the apex of the root.[3] Root canal instrumentation involves mechanical debridement, creating space for medicaments, and optimizing the root canal geometry for quality obturation.[4] Many rotary instruments have been developed for use in endodontics. Root canal preparation is influenced by the complex anatomy of root canals,[5,6] which may be oval, flat, or curved.[7-9]

A variety of methodologies have been used to determine the shaping ability of endodontic instruments, including decalcification techniques, sectioning techniques, and radiographic examination. The limitations of these methodologies have influenced researchers to look for new methods that can realize better results. Micro-computed tomography (micro-CT) techniques are now widely used in many fields of research. Micro-CT imaging was initially used for evaluating tooth morphology, surface area and volume changes,[10,11] but more recently it has been used

***Corresponding author:**
Miranda Stavileci
University of Prishtina, Faculty of Medicine,
Department of Dental Pathology and Endodontics,
Prishtina, Kosovo.
E-mail: mirandastavileci@gmail.com

to study canal curvature,[12] the percentage of instrumented canal wall,[6,13,14] and volume changes within the tooth.[15] Although micro-CT is not available for clinical dental use, it is an important technique in 3D dental research.[16] From 3D color coded images, researchers can determine morphological changes in the root canal system after instrumentation.[17]

Therefore, the object of this study was to use micro-CT to investigate the shaping ability of the ProTaper rotary system and stainless steel manual files in permanent premolars.

Materials and methods

This study used 60 upper premolars which had been extracted for periodontal and orthodontic reasons. Tissue fragments and calcified debris were removed by scaling, and the teeth were stored in 10% formalin. At the time of the study, the teeth were washed with distilled water to remove residual formalin. All teeth were placed in a sample holder before micro-CT scanning to allow reproducible orientation in the pre- and post-preparation scans.

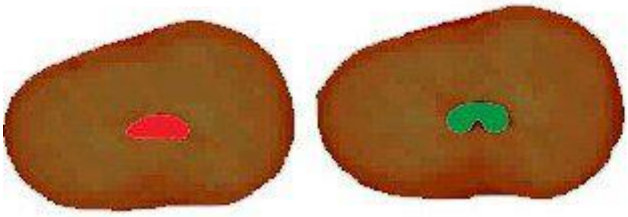

Figure 1. False-colored cross-section of a tooth showing root canal before (left, red) and after (right, green) preparation.

All teeth were scanned using the SkyScan 1173 micro-CT system (Bruker-microCT, Kontich, Belgium) with an isotropic voxel size of 22.86 μm at 70 kV/114 microA using a 1-mm aluminum filter, and the SkyScan 1174 micro-CT system (Bruker-microCT) with an isotropic voxel size of 24 μm at 50 kV/800 microA. Two-dimensional lateral projections of the samples were created over 360°, with a rotation step of 0.4°. An algorithm allowed co-registration, visualization and quantification of the analyzed variables. Root canals were three-dimensionally reconstructed using SkyScan NRecon with graphics processing unit recon server version 1.6.8.0 (SkyScan, Kontich, Belgium) and evaluated root canal diameter, surface area and volume before and after shaping (figure 1, 2 and 3). The root canal models before and after preparation were reconstructed and superimposed, and instrumentation techniques were quantitatively measured in 3D analysis in SkyScan CTAn software version 1.12.10.3 (SkyScan, Kontich, Belgium).

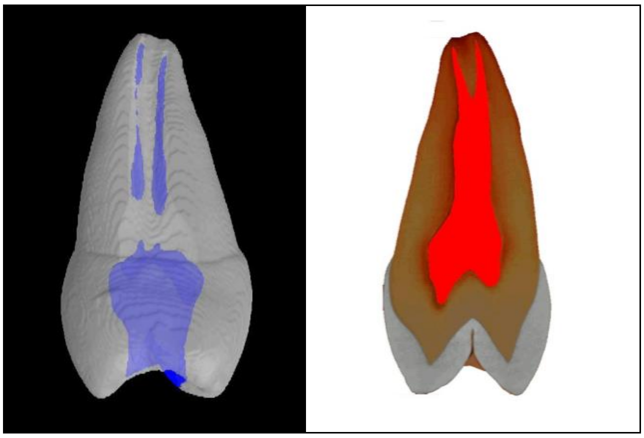

Figure 2. Surface rendered 3D model of a premolar showing the root canal in blue (left). The image on the right shows a false-colored volume rendered 3D model of the tooth which the front part virtually removed to show the root canal in red.

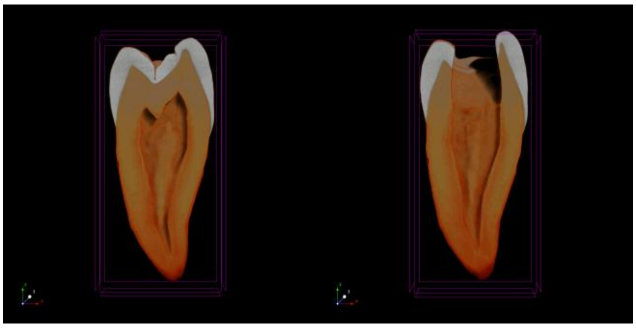

Figure 3. False-colored volume rendered 3D models of a premolar before (left) and after (right) root canal preparation. Half of the tooth is virtually removed to show the inner root canal.

Endodontic access was obtained in all the samples, and the root canals were localized and explored with size 15 K-files (Diadent, France) until their tips were visible at the apical foramen. Working length was set at 1 mm from the apical foramen. The samples were divided into two groups of 30 teeth each. The root canals of the first group were prepared with the ProTaper rotary system (Dentsply, Maillefer, Ballaigues, Switzerland) using a crown-down technique. An X Smart Plus motor (Dentsply) was used in accordance with the manufacturer's instructions and the canals were instrumented with an in-and-out motion in an apical direction. An SX instrument was used to shape the coronal part of the canal. S1 and S2 files were then used to prepare the middle and apical sectors of the canal up to the working length, followed by F1, F2, and F3 files for finishing of the canal.

Each instrument was passively introduced into the canal at a rotation rate of 250 rpm. The root canals of the second group were prepared with stainless steel K-files (Diadent, France) using a step-back technique. The root canals of both groups were irrigated with 2 ml of 3% sodium hypochlorite (Ultradent Products Inc., South Jordan, USA) after each file use. When the preparation was completed, each sample was inserted into the micro-CT scanner and the teeth were re-scanned (using the same parameters as for the initial scan) for comparison with the pre-preparation images. Typically, 500–750 slices were scanned per tooth. All CT scans were recorded on a computer in bitmap image format.

The volume, surface area and diameter changes were analyzed statistically using SPSS for Windows (SPSS® Statistics 15.0). The differences between samples to determine any statistically significant differences between the groups have been tested with (ANOVA) test. A 0.05 level of confidence was used for all analyses.

Results

The root canal diameter of all tested teeth was determined before and after preparation. In all teeth, the root canal diameter increased substantially after root canal preparation.

Group	Coronal sector Mean ±SD		Middle sector Mean ± SD		Apical sector Mean ±SD	
	before	after	before	After	Before	After
ProTaper	0.80 ± 0.13	0.99 ± 0.13	0.51 ± 0.09	0.79 ± 0.08	0.36 ± 0.06	0.51 ± 0.06
Stainless steel	0.65 ± 0.10	0.75 ± 0.10	0.43 ± 0.08	0.60 ± 0.09	0.33 ± 0.07	0.42 ± 0.07
P-value*	0.000001	0.000000	0.000890	0.000007	0.033396	0.000001

*ANOVA

Table 1. Mean of root canal diameter before and after shaping.

Table 1 shows the means and standard deviations of the root canal diameters of the three sections of the teeth (coronal, middle and apical) before and after preparation. Statistically significant differences in the diameter of the root canals were observed after root canal preparation in both techniques ($P < 0.000001$).

There was a statistically significant difference in the root canal diameter increase between the ProTaper group and the manual instrumentation group ($P < 0.000001$).

Table 2 shows the root canal volume change before and after instrumentation in both groups.

The ProTaper system produced a greater volume change than the manual instrumentation technique. The F test value of the ProTaper group was 12.2 ($P < 0.001$), while the F test value of the manual instrumentation group was19.56 ($P < 0.00001$).

There was a statistically significant difference in the t test values between the ProTaper group and the manual instrumentation group ($t = -16.3$, $P < 0.00001$).

Differences in the surface area (ΔA in mm^2) and volume (ΔV in mm^3) of each canal before and after preparation were calculated using custom-made software. The mean ΔV for the ProTaper group was 2.4 mm^3, but only 1.1 mm^3 for the manual instrumentation group.

Group	n	Mean± SD before	Mean± SD after	p-value
ProTaper	30	22.1 ± 6.2	24.5 ± 6.4	p<0.001
Stainless steel	30	17.8 ± 2.6	18.9 ± 2.7	p<0.000
Total	60	20.0 ± 5.1	21.7 ± 5.6	p<0.00001

Table 2. Root canal volume change before and after instrumentation.

Group	n	Mean± SD before	Mean± SD after	p-value
ProTaper	30	60.1± 15.2	63.5± 15.2	p<0.00001
Stainless steel	30	75.6±10.5	76.8± 10.5	p<0.00001
Total	60	67.9±15.1	70.2 ± 14.6	p<0.00001

Table 3. Mean of root canal surface area change before and after preparation.

Table 3 shows the change in root canal surface area before and after instrumentation in the two groups. The ProTaper system produced a greater change in surface area than the manual instrumentation technique. The F test values were 21.5 (P < 0.00001) for the ProTaper group and 15.59 (P < 0.00001) for the manual instrumentation group.

There was a statistically significant difference in the t test between the ProTaper group and the manual instrumentation group (t = -13.6, P < 0.00001).

The mean ΔA was 3.4 mm^2 for the ProTaper group and 1.2 mm^2 for the manual instrumentation group.

Discussion

This study investigated how root canal morphology can be changed after root canal preparation depending on the technique used. We also determined quantitative changes in the volume, surface area and diameter after root canal preparation with two different techniques.

The geometrical root canal shape produced by the correct mechanical action of endodontic instruments against the canal walls allows the tapered master cone of gutta-percha to be fitted. By adapting the shaping of the root canal to its anatomy, procedural errors can be overcome to achieve correct mechanical cleaning and disinfection.[18-21] The clinical importance of a correctly-shaped root canal is well described in the guideline published by the European Society of Endodontics, which states that instrumentation should extend to the entire wall of the canal, so that it is completely cleaned and shaped.[22]

Investigators have demonstrated that the dentin in the root canal wall is infected with microorganisms and their endotoxins, extending to a depth of 1–2 mm.[23,24]

The results of the current study showed significant differences in the diameter, surface area and volume after root canal preparation with the ProTaper technique. Similar results were reported by Al Jabbari et al.,who observed significant differences in the geometrical characteristics between endodontic files with different ISO sizes.[25]

A gradual increase in the diameter along the length of the canal was noted by Li et al., who showed that canal volume and surface area of all teeth increased by 5–146% after instrumentation, depending on the root canal type.[17]

The instrumentation of root canals to retain their anatomy and ensure the least amount of dentin removal is a challenge, depending on the system used.[26]

As reported by Yang et al., root canal instrumentation with ProTaper universal and Mtwo, both Ni-Ti instrument systems, resulted in significantly increased root canal volume and surfaces area.[27] Uýanik et al. reported that the ProTaper system removed more dentin than the Hero Shaper and RaCe systems.[28]

The effect of root canal instrumentation is also related to the preoperative canal geometry. In the study of Peters et al., after manual instrumentation, the mean increase in canal volume was 1.28 ± 0.57 and the mean increase in surface area was 2.58 ± 1.83.[29]

In contrast, Moura-Netto et al. reported a significantly greater increase in surface area after instrumentation with the EndoEZE/AET system when compared with the ProTaper system.[30]

The increase in volume was found to be lower with the ProTaper system in wide root canals. This can be explained by the different manipulation characteristics of the system that was used.[31]Although the ProTaper system shaped simulated canals without any significant error, the Reciproc system produced increased apical volume changes compared with the ProTaper system.[32]

The variable taper of the files allows optimal root canal shapes to be achieved quickly and safely.[33] It has been reported that instruments with a progressive taper can shape canals more quickly than those with a constant taper.[34] In the progressive ProTaper system, the taper of the shaping files increases from the tip to the coronal area, whereas the finishing files have a decreasing taper.[35]

Rotary instruments with a taper greater than 4% have been shown to be more efficient than hand files in preparing root canals.[36]

Gomes et al. concluded that the mechanical action of instruments eliminated more than 47% of oral bacterial endotoxins against the dentin wall.[37]

However, the manual techniques have less cleaning effect than sonic irrigation technique.[38] But, with a greater volumetric change, the irrigating needle can be placed into deeper apical areas, producing a better irrigating effect,[39,40] also confirmed by Margono et al. who reported that EDTA 17 % has the most excellent cleaning ability in cases when irrigation needle diameter was adjusted to the size of the apex preparation.[41] Additionally, the final preparation with the F3 instrument increases the root canal volume and reduces the un-instrumented area.[42]

The results of the present study reveal that the use of the ProTaper system resulted in significantly greater changes in the root canal diameter, volume and surface area than instrumentation with hand files. The superior performance of the ProTaper system may have resulted from continuing the apical preparation up until the use of the F3 file, which may be associated with better root canal cleaning.

In the present study, the use of micro-CT images at a resolution of 22.86 μm provided an excellent method for evaluating the shaping properties of Ni-Ti rotary instruments and manual files. However, further studies are required to improve the evaluation of root canal preparation to achieve better outcomes for endodontic therapy.

Conclusions

The findings of this study suggest that root canal preparation with the ProTaper system and manual files significantly increased the root canal diameter, volume and surface area. The ProTaper system produced significantly increased root canal diameter, volume and surface area when compared with the manual instrumentation technique.

Acknowledgments

This research was completed in Hacettepe University, Faculty of Dentistry, Department of Endodontics and Hacettepe University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey.

The authors thank the Bruker microCT company for helping in data reconstruction.

We thank Helen Jeays, BDSc AE, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Declaration of Interest

The authors deny any conflict of interest related to this study.

References

1. Hülsmann M, Peters O, Dummer M. Mechanical preparation of root canals: Shaping goals, techniques and means. Endodontic Topics. 2005; 10:30-76.
2. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. Scand J Dent Res. 1981; 89:321-8.
3. Ruddle CJ. Cleaning and shaping the root canal system, in Pathway of the pulp, S.Cohen Ed. 2002; 241-245.
4. Mahran AH, Abo El-Fotouh MM. Comparison of effects of ProTaper, Hero Shaper and Gates Glidden Burs on cervical dentin thickness and root canal volume by using multi slice computed tomography. J Endod. 2008; 34:1219-22.
5. Metzger Z, Teperovich E, Zary R, Cohen R, Hof R. The self –adjusting file (SAF): part 1-respecting the root canal anatomy: a new concept of endodontic files and its implementation. J Endod. 2010; 36:679-90.
6. Paqué F, Ganahl D, Peters OA. Effects of root canal preparation on apical geometry assessed by micro-computed tomography. J Endod. 2009; 35:1056-59.
7. Fornari VJ, Silva –Sousa YT, Vanni JR, Pecora JD, Versiani MA, Sousa-Neto MD. Histological evaluation of the effectiveness of increased apical enlargement for cleaning the apical third of curved canals. Int Endod J. 2010; 43:988-94.
8. Nadalin MR, Perez DE, Vansan IP, Paschoala C, Sousa-Neto MD, Saquy PC. Effectiveness of different final irrigation protocols in removing debris in flattened root canals. Braz Dent J. 2009; 20:211-4.
9. Taha NA, Ozawa T, Messer HH. Comparison of three techniques for preparing oval shaped root canals. J Endod. 2010; 36:532-5.
10. Bergmans L, Van Cleynenbreugel J, Wevers M, Lambrechts P. A methodology for quantitative evaluation of root canal instrumentation using micro CT. Int Endod J. 2001; 34:390-8.
11. Peters OA, Laib A, Rüegsegger P, Barbakov F. Three dimensional analysis of root canal geometry by high resolution computed tomography. J Dent Res. 2000; 79:1405-9.
12. Lee J, Ha B, Choi J, Heo S, Perinpanayagam H. Quantitative three dimensional analysis of root canal curvature in maxillary first molars using micro-computed tomography. J Endod. 2006; 32:941-5.
13. Peters OA, Boessler C, Paqué F. Root canal preparation with a novel nickel-titanium instrument evaluated with micro-computed tomography: Canal surface preparation over time. J Endod. 2010; 36:1068-72.
14. Markvart M, Darvann TA, Larson P, Dalstra M, Kreiborg S, Bjorndal L. Micro-CT analysis of apical enlargement and molar root canal complexity. Int Endod J. 2012; 45:273-81.
15. Gantt DG, Kappleman J, Ketcham RA, Alder ME, Deahl TH. Three dimensional reconstruction of enamel thickness and volume in humans and hominoids. Eur J Oral Sci. 2006; 114 (suppl.1): 360-4.
16. Maret D, Molinier F, Braga J, Peters OA, Telmon N, Treil J. et al. Accuracy of 3D reconstruction based on cone beam computed tomography. J Dent Res. 2010; 89:1465-9.
17. Li KZ, Gao Y, Zhang R, Hu T, Guo B. The effect of a manual instrumentation technique on five types of premolar root canal geometry assessed by micro CT and 3D reconstruction. BMC Medical Imaging. 2011; 11:14.
18. Salzgeber RM, Brilliant JD. An in vivo evaluation of the penetration of an irrigating solution in root canals. Journal of Endodontics. 1977;3(10):394–8.
19. Ram Z. Effectiveness of root canal irrigation. Oral Surgery, Oral Medicine, Oral Pathology. 1977; 44(2):306–12.
20. Shuping GB, Ørstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. Journal of Endodontics. 2000; 26(12):751–5.
21. Siqueira JF, Jr., Lima KC, Magalhäes FAC, Lopes HP, de Uzeda M. Mechanical reduction of the bacterial population in the root canal by three instrumentation techniques. Journal of Endodontics. 1999; 25(5):332–5.
22. Undergraduate curriculum guidelines for endodontology. European Society of Endodontology. Int Endod J. 1992; 25:169-72.
23. Saunders WP, Saunders E. Root canal instrumantation. In: Bergenholz G, Horsted-Bindslev P, Reit C, editors. Textbook of Endodontics. 1 st ed. Oxford, England: Blackwell Publishing Ltd. 2003; 231-61.

24. Horiba N, Maekawa Y, Matsumoto T, Nakamura H. A study of the distribution of endotoxin in the dentinal wall of infected root canals. J Endod. 1990; 16:331-4.
25. Youssef S. Al Jabbari,Y Peter Tsakiridis P, Eliades G, Al-Hadlaq S, Zinelis S. Assessment of geometrical characteristics of dental endodontic micro-instruments utilizing X-ray micro computed tomography. J. Appl. Oral Sci. 2012; 6: 655-60.
26. Zmener O, Pameijer CH and Banegas G. Effectiveness of cleaning of oval-shaped root canals using Anatomic Endodontic Technology (AET), ProFile and manual instrumentation: a scanning electron microscopic study. Int Endod J. 2005;38:356-63.
27. Yang G, Yuan G, Yun X, Zhou X, Liu B, Wu H. Effects of Two nickel-titanium instrument systems, Mtwo versus ProTaper universal, on root canal geometry assessed by micro–computed tomography. J Endod. 2011; 37:1412-6.
28. Uýanik OM, Cehreli ZC, Mocan OB, Dagli TF. Comparative evaluation of three nickel-titanium instrumentation systems in human teeth using computed tomography. J Endod. 2006;32:668-71.
29. Peters OA, Laib A, Göhring T, Barbakow F. Changes in root canal geometry after preparation assessed by high-resolution computed tomography. J Endod. 2001; 27:1-4.
30. Moura-Netto C, Palo RM, Camargo CH, Pameijer CH, Bardauil MR. Micro-CT assessment of two different endodontic preparation systems. Braz Oral Res. 2013; 27:26-30.
31. Sillelioglu H, Ölmez A, Atabek D. Micro-computed tomography evaluation of root canal preparation using rotary system and hand instrument in young permanent molars. J Pediatr Dent. 2015; 3:61-6.
32. Wei Zh, Cui Zh, Yan P, Jiang H. A comparison of the shaping ability of three nickel-titanium rotary instruments: a micro-computed tomography study via a contrast radiopaque technique in vitro. BMC Oral Health. 2017;17:39.
33. Buchanan LS. The standardized taper root canal preparation-Part 1. Concepts for variably tapered shaping instruments. Int End J. 2000; 33:516-29.
34. Veltri M, Mollo A, Mantovani L, Pini P, Balleri P, Grandini S.A comparative study of Endoflare-Hero Shaper and Mtwo NiTi instruments in the preparation of curved root canals. International Endodontic Journal. 2005; 38, 610–6.
35. Bergmans L, Van Cleynenbreugel J, Beullens M, Wevers M, Van Meerbeek B, Lambrechts P. Progressive versus constant tapered shaft design using NiTi rotary instruments. International Endodontic Journal. 2003; 36, 288–95.
36. El Ayouti A, Chu AL, Kimionis I, Klein C, Weiger R, Löst C. Efficacy of rotary instruments with greater taper in preparing oval root canals. Int Endod J. 2008;41:1088–92.
37. Gomes BP, Martinho FC, Vianna ME. Comparison of 2.5% sodium hypochlorite and 2% chlorhexidine gel on oral bacterial lipopolysaccharide reduction from primarily infected root canals. J Endod. 2009;35:1350–3.
38. Kamizar, Ricardo SH, Nursasongko B. Comparison of apical third cleanliness of smear layer using Endoactivator and Vibringe. J Int Dent Med Res. 2016; 9 (3): 211-14.
39. Sedgley CM, Nagel AC, Hall D, Applegate B. Influence of irrigant needle depth in removing bioluminescent bacteria inoculated into instrumented root canals using real-time imaging in vitro. Int Endod J. 2005; 38:97–104.
40. Shen Y, Gao Y, Qian W, Ruse ND, Zhou X, Wu H, et al. Three-dimensional numeric simulation of root canal irrigant flow with different irrigation needles. J Endod. 2010; 36:884–9.
41. Margono A, Angellina A, Suprastiwi E. The Effect of Grape Seed Extraction Irrigation Solution towards Cleanliness the Smear Layer on Apical Third of the Root Canal Wall. J Int Dent Med Res. 2017; 10(2): 244-47.
42. Duque JA, Vivani RC, Cavenago BC, Amoroso-Silva PA, Bernardes RA, De Vasconcelos BC, Hungaro MA. Influence of NiTi alloy on the root canal shaping capabilities of the ProTaper Universal and ProTaper Gold rotary instrument systems. J Appl Oral Sci. 2017;25(1):27-33.