Available online at www.giornaleitalianoendodonzia.it

ORIGINAL ARTICLE

Influence of operator's experience in three different instrumentation techniques: an *in vitro* study

ABSTRACT

Aim: *To evaluate the influence of operator's experience comparing rotary and reciprocating shaping systems on simulated root canals.*
Methodology: *Ninety resin blocks with simulated root canals were distributed to six groups (15 for each group); three groups of instrumentation were assigned to undergraduate students and three to specialists in endodontics. For each category of experience, the shaping was performed with Protaper Gold™, WaveOne Gold™ and Stainless-steel K-File (Control). Resin blocks were inked, then pre- and post-instrumentation photographic images were taken to be superimposed by an imaging software (GIMP 2.10.10) and analyzed by ImageJ software. After the use of each instrument, a rinse with NaOCl 2,5% was made. The outcomes evaluated were the presence of apical zip, ledges, perforation, the centering ability and the amount of resin removed.*
Results: *The photographic analysis of the resin blocks showed a prevalence of apical zips within the undergraduate groups; the expert groups realized a higher number of ledges, while the number of perforations resulted to be higher in the inexpert Stainless-steel control group. The amount of resin removed was significantly higher in the undergraduate WOG group, as well as the centering ability.*
Conclusions: *The rotary and reciprocating systems provide valid operative standards; by the way, inexpert operators showed major difficulties managing the reciprocating system. More studies are required to assess this parameter.*

Ilaria La Prova[1,2*]
Isabella Perondi[1,2]
Stefano Corbella[1,2,3]
Roberto Fornara[1,2]
Silvio Taschieri[1,2,3]

[1]*Department of Biomedical, Surgical and Dental Sciences, University of Milan, Milan, Italy*

[2]*IRCCS Galeazzi Orthopedic Institute, Milan, Italy*

[3]*Department of Oral Surgery, Institute of Dentistry, I. M. Sechenov First Moscow state medical University, Moscow, Russia*

Received 2020, September 24
Accepted 2020, November 25

KEYWORDS *apical zip, in vitro study, Protaper Gold, reciprocating, WaveOne Gold*

Corresponding author
Ilaria La Prova | Department of Biomedical, Surgical and Dental Sciences, University of Milan, Milan | Italy
Email: ilaria.laprova@gmail.com

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2021.35.01.11

Introduction

The shaping of the root canal is one of the most important steps of an endodontic treatment; its aim is to remove the necrotic tissues, pulpal debris and remnants, and to shape the canals in order to obtain a tridimensional obturation by preserving the integrity of the canal system (9). The introduction of the Ni-Ti alloy took to many evolutions and to an improvement both of techniques and instruments used in endodontics; nowadays, in fact, we can distinguish instruments for different materials, morphologies, taper and apical diameters. Anyway, they're all referable to two different cinematics: continuous and reciprocating.

The use of rotary instruments, introduced by McSpadden in 1992, has always been the best technique to obtain a predictable and repeatable shaping of the root canal, compared to the use of stainless-steel manual instruments (4). The occurrence of cyclic fatigue fractures (3), caused by the "taper lock" phenomenon, brought to the development of a new generation of instruments; they work through a reciprocating motion, in order to overtake the risk of this adverse event (18). The reciprocating motion allows to invert the direction of rotation of the instrument before the first cycle of rotation gets complete, reducing the engagement of the instrument in the root canal and, consequently, the stress it's exposed to. Protaper Gold™ and WaveOne Gold™ (Dentsply Maillefer-Chemin du Verger 3, 1338 Ballaigues, Switzerland) had a remarkably good response due to their innovative cutting sections and the increasing flexibility of the Gold alloy (16).

The Protaper Gold™ category includes seven flexible instruments, with a triangular convex section and different tapers along the working part: three shaping files SX (019.04), S1 (018.02) e S2 (020.04) for the coronal shaping and five finishing files F1 (020.07)- F2 (025.08)- F3 (030.09)- F4 (040.06)- F5 (050.05) for the apical shaping. WaveOne Gold™ includes a sequence of four instruments with different diameters and a progressive cross section: Small (020.07), Primary (025.07), Medium (035.06) e Large (045.05). The real advantage of using those instruments is to shape canals potentially with one file, reducing the working time; anyway, they are disposable and can't be sterilized.

Many reviews (5, 1, 11) compared the two different systematics, particularly in terms of cyclic fatigue resistance, shaping features, apical debris extrusion and dentinal cracks. The results were controversial and showed how, at the moment, there's no a significant difference in the centering ability, the apical debris transportation and the number of dentinal cracks. The main differences were found in the analysis the resistance to fractures, which was higher in the reciprocating categories; some studies (13), moreover, showed how the reciprocating endodontic treatment caused a worsening of patients *QoL* (quality of life) with a stronger post-operative pain due to the non-controlled apical debris extrusion.

The aim of this in vitro study is to compare three different shaping systems (stainless-steel K-File, Protaper Gold™ and WaveOne Gold™) and to evaluate the differences between the shaping made by undergraduate students and specialists in Endodontic.

Materials and Methods

The study presents three main groups of shaping: shaping with Protaper Gold™, with WaveOne Gold™ and with stainless-steel K-File. The influence of operator's experience will be evaluated for each category (6) and the shaping of the three groups above will be performed on simulation resin blocks (Endo Training Bloc, Maillefer).

The number of resin blocks was established in 15 blocks for each group of instruments, for both experience groups, for a total of 90 blocks (15) by *sample size calculation.* Every operator shaped three resin blocks, one for each category of instruments (Table 1).

The shaping with K-File (control) followed the steps below: WL detection and scouting with K-File 8-10 and, enlargement of the coronal third with Gates drills from #1 to

Table 1
Group division

Group 0 (Control)	K-File (inexpert)
Group 1 (Control)	K-File (expert)
Group 2	Protaper Gold™ (inexpert)
Group 3	Protaper Gold™ (expert)
Group 4	WaveOne Gold™ (inexpert)
Group 5	WaveOne Gold™ (expert)

#6, manual *preflaring* and *glide path* with stainless-steel K-File from 10 to 20; check of the patency with K-File 10, shaping of the root canal with K-File in sequence of sizes from 25 to 80, following an apical to coronal approach.
The shaping with Protaper Gold™ (group 2 and 3) was realized through the following steps: WL detection and scouting with K-File 8-10, manual *preflaring* and *glide path* with K-File 15-20, instrumentation of the root canal with Shaping Protaper Gold™ S1-S2, check of the patency with K-File 10, sequence of Finishing Protaper Gold™ F1-F2.
The shaping with WaveOne Gold™ (group 4 and 5) was realized through the following sequence: WL detection and scouting with K-File 8-10, manual *preflaring* and *glide path* with K-File 15-20, shaping with WaveOne Gold™ Primary 3 mm to the end of the canal system, check of the patency with K-File 10, shaping with WaveOne Gold™ Primary at the working length (WL).

A dedicated shaping program with parameters suggested by manufacturers has been selected for the utilization of each file (X-Smart; Dentsply Maillefer). Before use, each instrument was lubricated with Glyde (Dentsply Maillefer), whilst a rinse with 2,5% NaOCl was made after the use of each instrument (15).

Data recording
The endo training blocks were inked before the use, to enhance the canal. Pre and post- shaping photographic images were taken (Nikon D7200), at stable reference points and magnification. The camera was set on a tripod to guarantee the stability of the camera.
Then, resin blocks were positioned on a graph paper to obtain calibrated points and to ease the superimposition of images (Figure 1). The latter was realized through the utilization of GIMP 2.10.10; after that, the superimpositions were uploaded on ImageJ software to obtain the analysis of the shaping.

Outcomes
This study has the aim to evaluate two main outcomes: the centering ability and the amount of removed resin. The centering ability was evaluated by dividing the canal into nine parts of 1mm and subtracting at each point the amount of resin removed from the inner part to that removed from the outer aspect of the canal. The amount of resin removed was evaluated by adding the amount of resin removed from the inner and the outer part of the

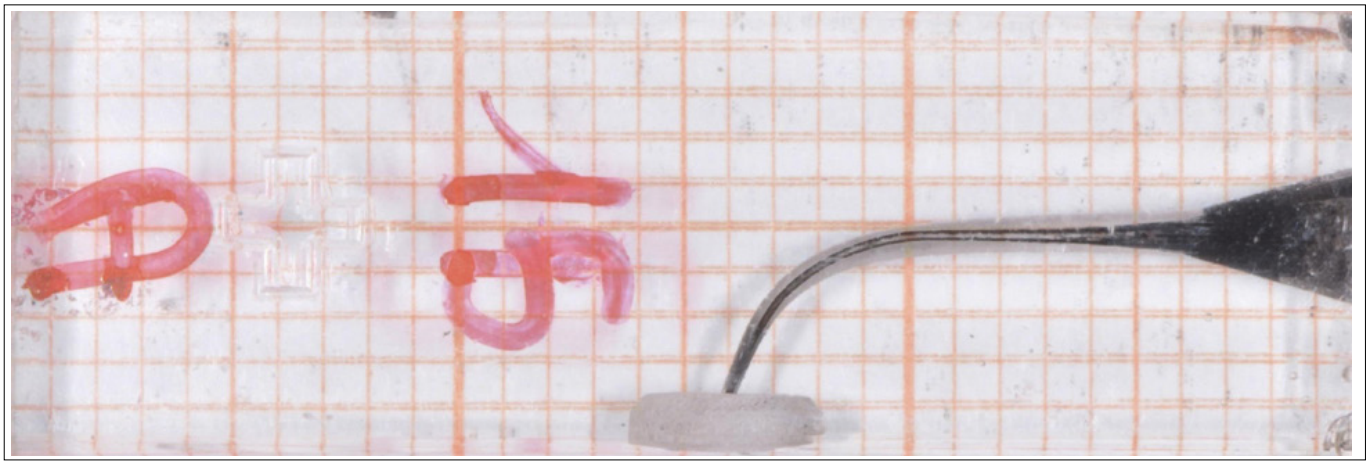

Figure 1
Example of superimposition of the pre and post- instrumentation images.

Table 2
Distribution of apical zip within the six groups

Apical zip	No	Yes	Total
Group 0	4	1	5
Group 1	3	0	3
Group 2	10	2	12
Group 3	14	0	14
Group 4	10	3	13
Group 5	9	0	9
Total	**50**	**6**	**56**

Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: WaveOne Gold™ (inexpert); Group 5: WaveOne Gold™ (expert).

Table 3
Distribution of ledges within the six groups

Ledges	No	Yes	Total
Group 0	11	3	14
Group 1	9	6	15
Group 2	13	0	13
Group 3	15	0	15
Group 4	13	1	14
Group 5	11	4	15
Total	**72**	**14**	**86**

Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: WaveOne Gold™ (inexpert); Group 5: WaveOne Gold™ (expert).

Table 4
Distribution of perforations within the six groups

Perforations	No	Yes	Total
Group 0	8	6	14
Group 1	11	4	15
Group 2	12	1	13
Group 3	15	0	15
Group 4	14	0	14
Group 5	15	0	15
Total	**75**	**11**	**86**

Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: Wave One Gold™ (inexpert); Group 5: WaveOne.

canal, for each of the nine millimeters (17). The study assessed three secondary outcomes: the presence of ledges, perforations and apical zips. For those parameters the measurements were made by dichotomous indexes (0=absent, 1=present).

Statistical analysis
The statistical analysis was performed by an operator who was unaware of group allocation. Descriptive statistics was provided, for continuous normally-distributed variables (centering and dentin removal), by means of mean values and relative standard deviations. Categorical variables were presented by frequency distributions. The comparison between groups was performed using Student's t-test. The level of significance was p=0.05.

Results

A total of 86 resin blocks were analyzed, while 4 were excluded due to problems during the superimposition of the images.

Presence of apical zip
The number of apical zips is summarized up in Table 2. Apical zips occurred 6 times of 56 considered, all in the undergraduate groups. Resin blocks in which ledges or perforations prevented a correct evaluation of the apex were excluded from the analysis.

Presence of ledges and perforations
Stainless-steel K-File showed a higher tendency to produce perforations compared to other groups (Table 3).
The distribution of ledges was uniform along the groups, except for the Protaper Gold™ groups in which none occurred (Table 4).

Amount of resin removed
The measurements of the amount of resin removed are shown in Table 5. The undergraduate control group removed a significantly higher amount of resin compared to the expert control group, as confirmed in literature (14).

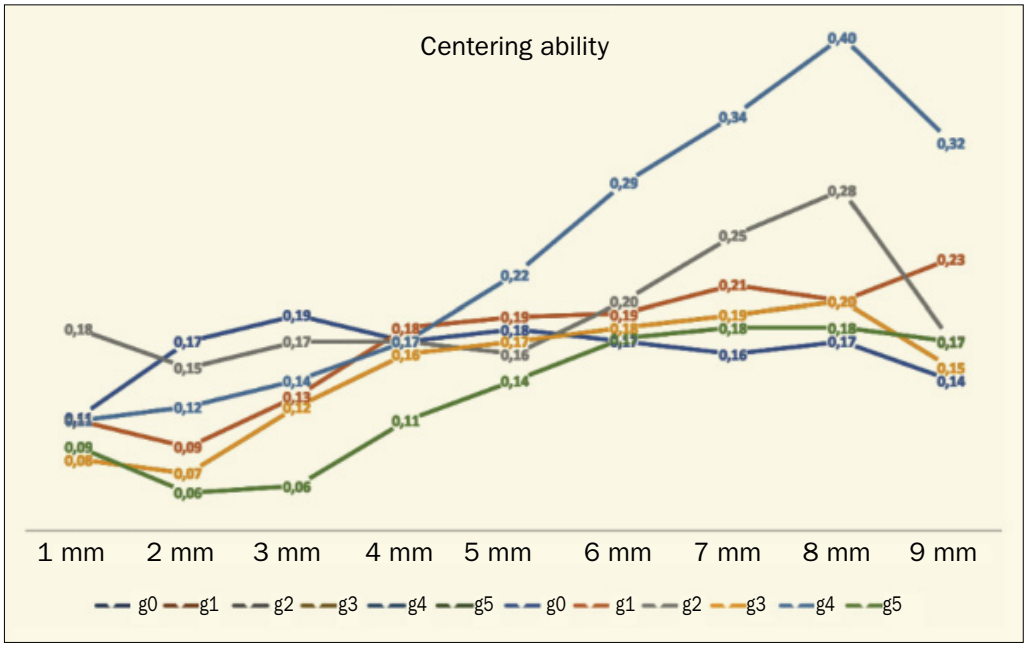

Figure 2
Centering ability within the six groups. Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: WaveOne Gold™ (inexpert); Group 5: Wave One Gold™ (expert).

The most significant data concerns the difference within the WaveOne Gold Groups™; a significantly higher amount of resin was, in fact, removed by inexpert operators. No statistically significant differences were found in the other groups.

Centering ability
The results are shown in Table 6. The most significant difference was found within the WaveOne Gold™ groups, in which inexpert operators removed more material than others; on the contrary, in the Protaper Gold™ expert group a higher amount of resin was removed, especially in the apical third. No differences were found in the other groups (Figure 2).

Discussion

Nowadays there's a lively debate over the best shaping system to use, in particular regarding the choice between continuous and reciprocating motions. The ideal shaping technique should guarantee an equally distributed dentine removal along the canals, anyway the presence of curvatures often compromises the result (8).
The introduction of the Ni-Ti alloy certainly contributed to the improvement of the

Table 5
Dentine removal

	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm	7 mm	8 mm	9 mm
Group 0	0.28	0.3	0.36	0.35	0.35	0.37	0.4	0.45	0.46
Group 1	0.191	0.223	0.212	0.192	0.189	0.19	0.212	0.211	0.253
Group 2	0.36	0.33	0.37	0.42	0.42	0.43	0.47	0.515	0.437
Group 3	0.31	0.33	0.32	0.37	0.39	0.4	0.42	0.45	0.4
Group 4	0.42	0.36	0.39	0.44	0.44	0.46	0.51	0.53	0.45
Group 5	0.249	0.259	0.265	0.316	0.338	0.37	0.386	0.422	0.394

Amount of resin removed within the six groups. Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: Wave One Gold™ (inexpert); Group 5: Wave One Gold™ (expert).

Table 6
Centering ability

	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm	7 mm	8 mm	9 mm
Group 0	0.11	0.17	0.19	0.17	0.18	0.17	0.16	0.17	0.14
Group 1	0.11	0.09	0.13	0.18	0.19	0.19	0.21	0.20	0.23
Group 2	0.18	0.15	0.17	0.17	0.16	0.20	0.25	0.28	0.17
Group 3	0.08	0.07	0.12	0.16	0.17	0.18	0.19	0.20	0.15
Group 4	0.11	0.12	0.14	0.17	0.22	0,.29	0.34	0.40	0.32
Group 5	0.09	0.06	0.06	0.11	0.14	0.17	0.18	0.18	0.17

Centering ability within the six groups. Group 0: Control (inexpert); Group 1: Control (expert); Group 2: Protaper Gold™ (inexpert); Group 3: Protaper Gold™ (expert); Group 4: Wave One Gold™ (inexpert); Group 5: WaveOne Gold™ (expert).

shaping method thanks to its properties: the shape memory and the superelastic effect. These features allow the material to have a better spring back and a higher self-centering ability in the root canal (2). Moreover, the development of new alloys contributed to enhance the performances of the instruments considered.
In this study the rotary and reciprocating systems were compared on the basis of the operator's experience, and shaping was performed on resin blocks (Endo Training Bloc, Maillefer). It was demonstrated that, although they're biologically different from teeth, resin blocks represent a valid tool for in vitro evaluations, allowing standardization and the comparison of different shaping methods (12).

The analysis of the *perforations* shown a prevalence within the control groups, in particular distributed in the undergraduate category. This result confirms the tendency of the stainless-steel instrument to straighten the canal curvatures because of their intrinsic rigidity, as already assessed in literature (20). For the same reasons the number of *ledges* was higher in the Control groups, with 9 cases on a total of 14.
The *apical zip* is defined by the American Association of Endodontics as "an elliptical shape that may be formed in the apical foramen during preparation of a curved canal when a file extends through the apical foramen and subsequently transports that outer wall" (19); the totality of them occurred in the undergraduate groups, highlighting the difficulty an inexpert operator finds in respecting the working length.
The evaluation of the *amount of resin removed* showed no significant differences either between the Protaper Gold™ groups or in the comparison between different techniques in the same groups of experience, even though the undergraduate operators realized less conservative shapings (15). The only significant difference was found within the inexpert WaveOne Gold™ group, with a relevant higher amount of material removed; this can be justified by the particularity of the reciprocating movement, as well as the parameter of the centering ability. We can hypothesize that reciprocating instruments, in fact, work more while entering the canal, in the most coronal portion, in contrast to the rotary instruments which work more during their comeback. This leads to a higher difficulty to control the pressure to apply during the shaping, resulting in an over instrumentation by a non-expert operator.
Finally, the *centering ability* was more respected by experts in particular in the apical third. Moreover, the WaveOne Gold™ group gained the highest results in the last millimeters of the canal system (10, 7), probably due to its apical taper (=7), smaller than the one of Protaper Gold (=8); this feature influences the amount of material removed, determining the ability of the instrument of "self-centering" inside

the canal. The scientific literature only offers few studies and only about the previous generation of the instruments considered, among which the most similar is the one written by Troiano G. et al. (15); our results are in contrast with some of those, and we can assume this is probably due to the differences of the alloy. Anyway, the results of this study can only give partial information about the parameters considered; an enlargement of the sample size and to the evaluation of other studies could lead to a better and more complete comprehension of those events.

Conclusions

This study easily allows to determine how the operator's experience influences, in particular, the manual shaping. Regarding the comparison between continuous and reciprocating systems, there were no significant differences in terms of quality of shaping, except for the parameter of the *centering ability* which resulted more respected by expert operators, especially in the apical third. As expected, undergraduate students realized fewer conservative preparations, but the difference results significant only in a few millimeters of the canal.
Among the secondary outcomes the influence of the experience wasn't significant, even though some differences were found between categories. Anyway, the present study was realized to analyze the primary outcomes; it would be appropriate to elaborate an *ad hoc* protocol for the evaluation of the secondary outcomes to reach more accurate results.

Clinical Relevance

Both rotary and reciprocating systems provide a valid instrumentation standard, with no significant differences resulting from the operator's experience.

Conflict of Interest

None.

Acknowledgements

None.

References

1. *Ahn SY, Kim HC, Kim E. Kinematic Effects of Nickel-Titanium Instruments with Reciprocating or Continuous Rotation Motion: A Systematic Review of In Vitro Studies. J Endod. 2016 Jul;42(7):1009-17. doi: 10.1016/j.joen.2016.04.002. Epub 2016 May 13.*
2. *Buehler WJ, Wiley RC, Gilfrich JV. Effect of low-temperature phase changes on mechanical properties of alloys near composition. J Applied Phys. 1963;34:1475-7.*
3. *Cheung GSP. Instrument fracture: mechanisms, removal of fragments, and clinical outcomes. Endod Topics 2009;16:1-26.*
4. *Esposito PT, Cunningham CJ (1195). A comparison of canal preparation with nichel-titanium and stainless Steel instruments. Journal of Endodontics 21, 173-6.*
5. *Ferreira F, Adeodato C, Barbosa I, Aboud L, Scelza P, Zaccaro Scelza M. Movement kinematics and cyclic fatigue of NiTi rotary instruments: a systematic review. Int Endod J. 2017 Feb;50(2):143-152. doi: 10.1111/iej.12613. Epub 2016 Feb 26.*
6. *Mandel E, Adib-Yazdi M, Benhamou LM, Lachkar T, Mesgouez C, Sobel M. Rotary Ni-Ti profile systems for preparing curved canals in resin blocks: influence of operator on instrument breakage. Int Endod J 1999; 32(6): 436-43. [http://dx.doi.org/10.1046/j.1365-2591.1999.00239.x] [PMID: 10709491].*
7. *Goldberg M, Dahan S, Machtou P. Centering ability and influence of experience when using WaveOne® single-file technique in simulated canals. Int J Dent. 2012;2012:206321.*
8. *Grossman LI. Endodontic practice. 10th ed. Lea and Febigger; 1982. p. 297.*
9. *Hulsmann, M., Peters, O.A., and Dummer, P.M.H. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Top. 2005; 10: 30-76.*
10. *Javaheri HH, Javaheri GH. A comparison of three Ni-Ti rotary instruments in apical transportation. J Endod. 2007;33:284-6.*
11. *Laurindo F, Poli de Figueiredo JA. Reciprocating versus Rotary instruments: a review. Rev Odonto Cienc 2016;31(3):135-139.*
12. *Lim KC, Webber J. The validity of simulated root canals for the investigation of the prepared root canal shape. Int Endod J 1985; 18(4): 240-6.*
13. *Pasqualini D, Corbella S, Alovisi M, Taschieri S et al. Postoperative quality of life following single-visit root canal treatment performed by rotary or reciprocating instrumentation: a randomized clinical trial. Int Endod J. 2016 Nov;49(11):1030-1039. doi: 10.1111/iej.12563. Epub 2015 Nov 5.*
14. *Sonntag D, Guntermann A, Kim SK, Stachniss V. Root canal shaping with manual stainless steel files and rotary Ni^Ti files performed by students. International Endodontic Journal, 36, 246-255, 2003.*

15. Troiano G. et al. Influence of Operator's Experience on the Shaping Ability of Protaper Universal and Waveone Systems: A Comparative Study on Simulated Root Canals. Open Dent J. 2016; 10: 546–552.
16. Wan J, Rasimick BJ, Musikant BL, Deutsch AS (2011) A comparison of cyclic fatigue resistance in reciprocating and rotary nickel-titanium instruments. Australian Endodontic Journal 37, 122–7.
17. Yang GB, Zhou XD, Zhang H, Wu HK. Shaping ability of progressive versus constant taper instruments in simulated root canals. Int Endod J 2006; 39(10): 791-9. [http://dx.doi.org/10.1111 /j.1365-2591.2006.01151.x] [PMID: 16948665].
18. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. Int Endod J 2008;41:339-44.
19. Glossary of Endodontics terms. American Association of Endodontists (AAE) - 2020.
20. Weine F, Kelly R, Lio P. The effect of preparation procedures on the original canal shape and on apical foramen shape. J Endodon 1975;1:255-62.