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Centering ability of variety of instruments and techniques used to over-instrument simulated tiny curved canals.

Dr. Sargon Youel Eliya B.D.S, M.Sc.
Dr. Raid Fahim Salman B.D.S., M.Sc., Ph.D.

Abstract

Aim: To determine centering ability of variety of instruments and techniques used to over-instrument simulated tiny curved canals.

Method: Standardized eighty blocks of clear resin, each had a canal of 20 mm in length, the straight portion was 17 mm in length, while the length of the curved apical portion was 3 mm, with a curvature of 20˚ and a radius of 4 mm, its size was equal to no.8 .02 ISO K-file, the resin blocks were divided into 8 groups, six of them were over instrumented by 1mm using hand SS K-files and Ni-Ti K-files in step back technique, Gates-Glidden drills and hand SS K-files and Ni-Ti K-files in hybrid technique, ProTaper and ProFile rotary file system in crown down technique, while two groups were under instrumented by 1 mm using hand SS K-files in step back technique and ProTaper rotary file system in crown down technique.

Preoperative and postoperative images were recorded using a digital camera, fixed on a wooden platform .the pre- and postoperative images were superimposed and Microsoft office Visio program version 11 was used to measure the centering ability.

Results: Regarding Centering ability for Over-instrumentation techniques, there was a significant difference at $p < 0.05$ in favor of crown down technique, in favor of Ni-Ti over the SS, and in favor of rotary instruments over the hand instruments. For under-instrumentation groups, there was a significant difference at $p < 0.05$ with in favor of hand SS instruments in step back technique over the rotary Ni-Ti instruments in crown down technique. Also there was a significant difference between the over and under instrumentation techniques at $p < 0.05$, with in favor of under instrumentation techniques.

Conclusion: Within the limitations of this in vitro study, crown down technique gave better results than step back and hybrid technique, as well Ni-Ti instruments performed better than SS instruments. Rotary instruments had less deviation than the hand instruments when used inside simulated tiny curved resin canals.

Keywords; Over instrumentation, ProTaper, Ni-Ti, simulated resin canal, rotary instruments.

Introduction

The aim of root canal preparation is to clean and shape the root canal while maintaining its special relationship within the root. This is especially difficult in curved canals, where procedural errors such as transportation, zipping, elbow formation, ledging, perforation, stripping perforation, and instrument fracture can occur [1,2].

Various techniques, modification to instrument tip design, and flute alteration have been used to avoid or minimize these errors, though none had provided a solution to the management of the apical section of the curved root canal [1].

In 1988, nickel titanium was first introduced in endodontics to overcome the limitations of stainless steel ISO instruments and make the preparation of curved canals much easier because of its superior elasticity and shape memory effect. Scientific evidence had clearly shown that rotary Ni-Ti instruments used in a crown-down fashion produced consistent canal shape, less debris extrusion and stayed well centered inside the root canal [3].

Unfortunately over-instrumentation can occur as a procedural accident during root canal instrumentation leading to distortion of canal morphology resulting in for example, failure to produce an apical seat. Recently, it has been reported that, while disruptive changes in root canal morphology occurred when a canal was over-instrumented with a stainless steel file, over instrumentation with nickel-titanium files resulted in acceptable canal morphology [1].

The aim of the present study was to investigate which endodontic instrument &/or technique is more likely to prepare the canal in an acceptable manner when over instrumentation is taking place.

Materials and Methods

Description of the simulated root canals and equipments

Standardized eighty blocks of clear resin were prepared by the manufacture (Dental store, Italy) **(Fig 1.A)**, the block dimensions were 2×2×2 cm, in the center of the block a simulated canal was prepared so that it was parallel to one side of the block, and the canal communicates with external surface at the top & bottom of the block. The total length of the canal was 20 mm, the straight portion was 17 mm in length, while the length of the curved apical portion was 3 mm, with a curvature of 20º and a radius of 4 mm, its size was equal to no.8 .02 ISO K-file.

In order to take standardized and reproducible pictures for the resin blocks, a platform was made of wood on which the camera (Sony, DSC-W70, 7.2 Mega pixels, Japan) and the resin blocks were placed in a fixed position [4] **(Fig 1.B)**.

A wooden stand was made to standardize the instrumentation techniques, simulate the clinical conditions as much as possible, to act as a base and hold the resin block during instrumentation in a stable posture **(Fig 1.C)**.

Pre-operative preparation

A high-speed air turbine hand piece (pana air, Hatakeyama, Japan) and a carbide fissure bur size 557 (Caulk super bur, size 557, Switzerland) with water cooling were used to enlarge the first 3 mm of the coronal orifice of each simulated canal to facilitate the injection of ink and irrigating water, also were used to make three indicating holes in each resin block to facilitate superimposition of pre and post-operative images later on. The patency of each canal was checked using hand stainless steel K-file, .02, size 8(Dentsply, Maillefer, Switzerland). The length of each canal was confirmed to be 20 mm by measuring the length of pre-curved no. 8 stainless steel k-file that was introduced into the canal till the tip was evident with naked eye at the simulated apex; however the length of the file after re-straightening was 21 mm. The resin blocks were divided randomly into 8 groups each had 10 blocks and the blocks were numbered.

Then using the digital camera, a pre-operative image with a resolution of 7 mega pixel was taken for each canal that was filled, using a disposable syringe with 22-gauge needle, with black ink to enhance the image outline of the simulated canal, the images were transferred to the computer later on. Then the canal was irrigated with tap water using a disposable syringe with 22-gauge needle to remove the ink to prevent its dryness and blocking the canal. With the aid of Microsoft office Visio program version 11, all pre-operative images of all resin blocks that were used in this study and stored in the computer were confirmed to have 20º curvatures in the apical third of the canal, and this was done to ensure the standardization. Then each resin block was rapped with a black adhesive tape to obscure the vision and simulate the clinical conditions thus ensuring that the process was carried out with purely tactile sensation without bias to certain technique or instrument [4].

Sample grouping

Each group of the resin blocks was prepared using one of the following techniques, groups (A to F) were over instrumented by 1 mm using hand stainless steel K-files (Mani, INC, Japan), in step back technique (group A), hand Ni-Ti K-files (Handelsbolag, Sweden), in step back technique (group B), Gates-Glidden drills (Antaeos, Germany) and hand stainless steel K-files in hybrid technique (group C), Gates-Glidden drills and hand Ni-Ti K-files in hybrid technique (group D), ProTaper rotary file system (Dentsply, Maillefer, Switzerland), in crown down technique (group E), and ProFile rotary file system (Dentsply, Tulsa, OK, USA), in crown down technique (group F). While groups (G and H) were under instrumented by 1 mm using hand stainless steel K-files in step back technique (group G) and ProTaper rotary file system in crown down technique (group H).

Instrumentation techniques

1: Group A and B

The instrumentation was started with stainless steel K-file no. 8, the length of the file was measured with endodontic ruler to be 22 mm (i.e over instrumented), and secured with a rubber stopper, without pre-curving to standardize the method of instrumentation, then instrumentation was started with watch winding movement [5], circumferential filing with push and pull motion was done till the file was loose confirmed by tactile sensation, followed by no. 10, 15 and 20 SS K-files which were all used in a similar method, and the last file no. 20 was considered as a master apical file. Then K-file no. 25, 30, 35 and 40 were used sequentially reducing working length 1 mm for each succeeding file, recapitulation was done using master apical file no. 20 to prevent blockage of the canal and confirm patency. A new set of instruments was used for each resin block in addition to the discarded files due to fatigue [6].

The following steps were done in all 8 groups of instrumentation:

1: Irrigation of the simulated canal before engaging any file was regularly done with disposable syringe with 22-gauge needle and the instrument was lubricated with liquid soap before instrumentation and cleaned directly after use with cotton roll dampened with tap water to remove resin chips adhered to it. During instrumentation the instruments were regularly checked with naked eye for signs of deformation, distortion, plastic deformation and wear, so that to be discarded and replaced by a new one to prevent fracture and to optimize cutting efficiency [(4)].

2:The total time required for the preparation was measured with a hand watch including time of irrigation, changing the files and measuring the working length.

3: No dryness of the canal was done since there was no need for that.

4: After completion of canal preparation, the canal was filled with red ink using a disposable syringe with 22-gauge needle, to enhance the canal image outline, to differentiate easily between the pre and post-operative images and making the measurement steps more accurate and easier, then a digital a post-operative image was captured and stored in the computer.

For group (B), the same steps used for preparation in group (A) were followed exactly with one exception which is Ni-Ti hand K-files (sizes 15 to 40) were used instead of SS hand K-files (sizes 15 to 40).

2: Group C and D

The instrumentation was started with Gates-Glidden drills (GG) in a slow-speed contra angled conventional hand-piece (super, Hatakeyama, Japan), that were used to prepare the straight portion of the canal in a crown down technique using speed between 450 to 800 RPM. It was started with GG drill no. 5 (matching ISO no. 120) to prepare the first 6 mm of the canal. Then no. 4 GG drill (matching ISO no. 100) was used to prepare the first 9 mm of the canal, followed by no. 3 GG drill (matching ISO no. 80) that was used to prepare the first 12 mm of the canal, followed by no. 2 GG drill (matching ISO no. 60) that was used to prepare the first 14 mm of the canal, and lastly no.1 GG drill (matching ISO no. 40) was used to prepare the first 16 mm of the canal [(5)]. Later on SS hand K-files (size 8 to 40) were used exactly as in group (A).

For group (D), same steps of Group (C) were exactly followed using Ni-Ti hand K-files (sizes 15 to 40) instead of SS hand K-files (sizes 15 to 40).

3: Group E

The instrumentation was started following the manufacturer instructions, using 1:8 reduction electrical hand-piece (Anthogyr, France) powered by an electrical motor (AEU, 20, Aseptico, Dentsply, Tulsa, USA) in a constant and stable speed of 150 rpm and torque of 3 N/cm. First, SX file (matching ISO no. 19) was used in a brushing action to prepare the coronal third of the canal (the first 7 mm), then S1 (matching ISO no. 17) followed by S2 (matching ISO no. 20) files were used to the full working length (22 mm) [(5)], in a brushing action. Finally F1 (matching ISO no. 20) was used in a non-brushing motion to the working length (22 mm) since it’s important to standardize the sizes of the all files in all techniques that were used to prepare the apex. The files were withdrawn once the working length was reached by observing the position of the rubber stop on the file. A new set of instruments was used for every 5 resin blocks [(7)].

4: Group F

The instrumentation was started with .06 ProFile rotary file system following manufacturer instructions and rotated in a constant speed of 150 rpm and torque of 3 N/cm using 1:8 reduction electrical hand-piece powered by an electrical motor.

The .06 ProFile rotary systems were used with a pecking motion, with distinct forward and backward movements. The backward movement took place as soon as resistance was felt whilst moving the rotating instrument forwards. The force applied with ProFile instruments, irrespective of their size, was no more than that required to snap a sharp lead pencil point. Because ignoring this simple yet basic rule will unnecessarily increase the risk of instrument fracture. The pecking motion was continued until the desired penetration into the canal for that particular instrument was attained [8].

ProFile orifice shaper file size 50 .07 was used to prepare the first 12 mm of the canal. Followed by ProFile no. 40 .06 that was inserted to 17 mm to prepare the first straight 17 mm of the canal, then ProFile no. 35 .06 was inserted to 19 mm to prepare the first 18 mm of the canal, then ProFile no. 30 .06 was inserted to 20 mm to prepare the first 19 mm of the canal, then ProFile no. 25 .06 was inserted to 21 mm to prepare the whole 20 mm of the canal, finally ProFile no. 20 .06 was inserted to 22 mm to over prepare the canal by 1 mm, thus the size of all files in all techniques that were used to prepare the apex was standardized. The files were withdrawn once the working length was reached. A new set of instruments was used for every 5 resin blocks [7].

5: Group G and H

The same steps applied in group (A) and (E) were followed during preparation of group (G) and (H) respectively, with one exception that is the working length was measured to be shorter than the simulated apical foramen by 1 mm (i.e. the working length was 20 mm without pre-curving)**.**

Canal morphology changes measurements

Microsoft office Visio program version 11 was used to measure the changes produced by instrumentation in the simulated canals. In this study, Visio program was used to magnify each millimeter of the canal to 1000 times, thus the measurements would be more accurate and the changes produced by instrumentation would be easier to notice. A centre line was drawn along the midline of the pre-operative image of the canal. The pre and post-operative images of each simulated canal were super imposed with the aid of indicating holes. With the aid of Visio program, the distance between the centre line and the edge of the pre-operative canal was measured on the inner curve (concave side) X1, and on the outer curve (convex side) Y1 **(Fig 2)**. Also the distance between the centre line and the edge of the post-operative canal was measured on the inner curve (concave side) X2, and on the outer curve (convex side) Y2. As well the final width of the canal (X2 + Y2) was calculated. These measurements were done at 6 apical levels of each simulated canals (0 mm, 1st mm, 2nd mm, 3rd mm, 4th mm, and 5th mm), except the last two groups (under instrumented groups by 1 mm) in which the measurements were done at 5 apical levels of each simulated canals (1st mm, 2nd mm, 3rd mm, 4th mm, and 5th mm).

The ratio of the differences of the measurements of the concave and the convex parts of post-operative canal were compared with the width of the filed canal (X2+Y2). The following mathematical formula was used to obtain a parameter ß= [(D1–D2)/D] ×

100, where; parameter ß represents centering propensity of the filed canal (deviation of the of the center line of the post-operative canal from the center line of pre-operative canal) [9].

D1 (X2-X1) being the distance between the edge of the original (pre-operative) canal and the edge of the filed (post-operative) canal on the concave side, D2 (Y2-Y1), being the distance between the edge of the original (pre-operative) canal and the edge of the filed (post-operative) canal on the convex side, and D (X2+Y2), being the width of the filed canal **(Fig 2)**. A value thus obtained for the parameter ß, expressed in percentage terms, can be negative or positive, the negative value indicates a deviation of the long axis of the original canal towards the concave side of the filed canal (i.e. there is transportation toward convex side), while the positive value showing its shift towards the convex side of the filed canal (i.e. there is transportation toward concave side). The ideal result should be '0 %' presenting no shift of the long axis of the filed canal, indicating an optimum centering ability and no transportation or zipping.

Results

Regarding Centering ability for Over-instrumentation techniques by using One-Way Analysis of Variance, there was a significant difference among the three instrumentation techniques (step back, hybrid, crown down) at $p < 0.05$, with in favor of crown down technique over the other techniques.

Centering ability for materials of hand instruments in over instrumentation groups, by using t-test, there was a significant difference between the stainless steel compared with Ni-Ti at $p < 0.05$, with in favor of Ni-Ti over the stainless steel.

Centering ability for hand instruments and rotary instruments (over instrumentation), using t- test, there was a significant difference between the hand instruments compared with rotary instruments at $p < 0.05$, with in favor of rotary instruments over the hand instruments.

Centering ability for under-instrumentation groups, by using t-test, there was a significant difference between the rotary Ni-Ti instruments in crown down technique compared with hand stainless steel instruments in step back technique at $p < 0.05$, with in favor of hand stainless steel instruments in step back technique over the rotary Ni-Ti instruments in crown down technique.

Centering ability regarding over and under instrumentation techniques, by using t- test, there was a significant difference between the over and under instrumentation techniques at $p < 0.05$, with in favor of under instrumentation techniques over the over instrumentation techniques.

Incidences of mishaps

The mishaps which occurred in the study are showed in **(Table 1).** Concerning blockage, there were only 2 cases of blockage which occurred in group (G) (20%), the first blockage occurred when SS file size 25 ISO was used and the blockage was at the apical 2 nd millimeter of the canal, while the second blockage occurred when SS file size 40 ISO was used and the blockage was at the apical 5 th millimeter of the canal. As well ledges occurred in 2 cases, the first in group (B) (10%) when Ni-Ti file size 25 ISO was used; the ledge was between 0 and 1 st mm apically, while the second ledge occurred in group (D) (10%) when Ni-Ti file size 25 ISO was used, the ledge was at 1st mm.

Discussion

Instrumentation techniques

The results of the study revealed that crown down technique gave the best results in comparison with hybrid or step back techniques and that during crown down technique the instruments were more centered in the canal than the other two techniques. For step back technique, the instruments were more deviated from the canal centerline in comparison with the other techniques. This result agreed with the findings of [10, 11, 12].

The surpass of the crown down technique might be explained by the effect of what is known as coronal pre-enlargement which gives the clinician better tactile control when directing small negotiating files into the delicate apical third microanatomy since there is less constraint to the files and better control of the file tip as their shank ends were freed up by the early coronal pre-enlargement. Early coronal two-thirds enlargement removes restrictive dentin and reduces significant pressure from the more coronal cutting flutes of any file type. Further pre-enlarging the coronal two thirds of a canal allows a pre-curved file to be more easily inserted, freely passed through areas once occupied by canyons of restrictive dentin, and gently finessed around pathways of curvature common to the apical third, so that instruments do not bind short of the working length**,** all these advantages lead to decrease the deviation of instruments in canal curvatures since root wall contact was reduced [13, 14, 15, 16].

Also the cause of good performance of crown down technique in comparison with others could be due to the design of instruments being used in this technique, as we know that ProTaper rotary system has a unique feature that is their progressive tapered design, which clinically serves to significantly improve flexibility and cutting efficiency thus reducing the number of recapitulations needed to achieve length, especially in tight or more curved canals. Also progressive tapered design allow only a limited part of the instruments' cutting surface to make contact with the root canal wall during instrumentation which allow the instruments to follow the canal curvature more easily. ProTaper rotary system has negative rake angles plus their greater cutting efficiency has been safely improved by balancing the pitch and helical angle in addition to a modified guiding instrument tip which in combination prevent the instruments from inadvertently screwing into the canal and most important is that following manufacturer instruction by taking these instruments to length not more than one time, and not more than 1 sec. [3, 4, 7, 13, 17].

Considering ProFile rotary system design, it is known that they have three radial lands which keep the instrument centered in the canal, minimizing transportation and zipping [7], plus they have 90º cutting angle which scrape rather than actively engage and screw into dentin, their flexibility is enhanced first: with flutes being deeply cut and second: with a parallel inner core of metal. Their non-cutting tips with a 60-degree bullet nose that smoothly joins the flat radial lands play an important role in guiding the instrument through the canal during preparation procedures and following a pilot hole [5, 13,17].

Instrument materials

This study had showed that Ni-Ti was better than SS when centering ability was considered and that there was a significant difference between them.

This result is attributed to the fact that Ni-Ti has two to three times more flexibility i.e. super elasticity and shape memory behaviour compared to SS instruments, also to the low modulus of elasticity of Ni-Ti instruments that permits maintenance of the original canal shape and minimizes iatrogenic errors such as ledging, zipping and canal transportation [5,18, 19, 20, 21].

Hand versus rotary instruments

It was clear from the study results that rotary instruments performed significantly better than hand instruments and were more able to conserve the original shape of the canal as they had greater centering ability.

The reasonable explanation for rotary instruments being better than hand instruments is through following manufacturer instruction plus the effect of the design of the rotary systems used in this study which allowed better maintenance of the canal outline in comparison to hand instruments.

Over versus under instrumentation

The study results showed that under instrumentation was significantly better than over instrumentation regarding centering ability. Unfortunately, there are no previous studies comparing between over and under instrumentation. However, when any non pre-curved file gets out through & beyond the apex, it will become more free from the enclosed space & touching walls so as expected it will tend to straighten and work more toward the outer outline of the canal leading consequently to zipping & deviation & this phenomenon is exaggerated in case of tiny curved canal [5]**.**

Incidences of mishaps

Regarding canal blockage, the study revealed that only 2 canals were blocked in group (G), and this may be due to resin chips being accumulated in the canal, since **Hülsmann *et al,* at 2005** [16] showed that the size of resin chips and natural dentine chips may be not identical, leading to difficulties in removing the debris in resin canals, specially that group (G) was under instrumented, so the apical end of the canal was not patent as other groups of over instrumentation, and group (G) was manually instrumented while group (H) was instrumented with ProTaper rotary system which is more able to remove the canal debris [13]**.**

Concerning ledge, groups (B and D) had just one case of ledge each. This may be attributed to using Ni-Ti instruments in these two groups and because of flexibility of Ni-Ti instruments; the instruments were unable to bypass the ledge [22]**.**

Greater number of perforation occurred in group (F) (80%), while (0%) in group (H), this may be due to using ProFile rotary system with .06 taper in such tiny canals (equal to size no. 8 .02 ISO K-file) [5], and may be due to the fact that ProFile rotary Ni-Ti files remove more material from the outside of the canal having a greater angle of curve and more on the inner side of the canal having a smaller angle [23]**.** While ProTaper substantially is designed to simplify root canal preparation, particularly in curved and restricted canals [5]. However, the result of this study disagree with [18, 24, 25]**,** who used ProFile .06 alone and successfully in preparation of curved canals with curvature of 20º and even more.

Regarding elbow formation, group (A) showed the highest percentage of elbow formation (100%) while group (F) showed the lowest percentage (50%). This may be due to using SS hand K-file in group (A) which has low flexibility and high hardness that was shown to be three to four times more than Nickel Titanium., thus has more tendency to straight the canal apically producing elbow [5, 10]. However, the low percentage of elbow in group (F) may be in part due to the high percentage of perforation in this group, thus obscuring the elbow.

Under the conditions of this in vitro study, the instruments in crown down technique were more centered inside simulated tiny curved resin canals than did the instruments using other techniques, and Ni-Ti instruments performed better than SS counterparts in respect the centering ability, also rotary instruments showed less deviation than the hand instruments inside simulated tiny curved resin canals, similarly under instrumentation techniques kept the instruments more centered than did the over instrumentation techniques. However, there was a high incidence of perforation and elbow for all the groups while there was low incidence of blockage and ledging.

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A B C

Fig 1: A. The resin block. B. Platform with wooden screen covered with white blank paper C. Wooden stand holding resin block

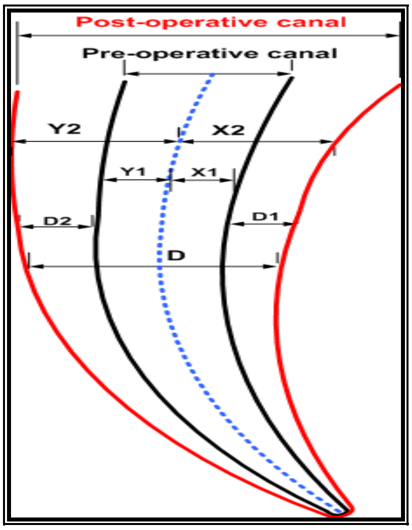

Fig 2: Diagram representing optimum centering ability without transportation.

Table 1: Showing incidence of mishaps

Mishaps	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
Blockage							2	
Ledge		1		1				
Perforation	1	2	2	2	1	8	1	0

Elbow	10	9	9	9	8	5	6	6