A comparative study on the shaping ability of three endodontic rotary Nickel-Titanium systems and stainless- steel hand K-flexofile in simulated curved canals

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ABSTRACT

Background: The purpose of this study is to compare the Shaping ability of three rotary endodontic nickel-titanium systems (ProFile, CT and Protaper) with stainless steel hand K-flexofile in simulated curved canals at different levels, this include total canal diameter, outer and inner transportations and centering ratio (the ability of the instruments to remain centered in the shaped canals).

Materials and method: Eighty simulated curved canals made of clear polyester resin were used to assess instrumentation.The acrylic blocks were divided into four groups, 20 simulated canals for each group were enlarged from #10 to # 25. In the first three groups all NiTi rotary instruments were set into a permanent rotation with a 16:1 reduction handpiece powered by a torque-limited electric motor set at 300 rpm. All the instruments were used in a crown down manner using a gentle in-and-out (pecking) motion. In the fourth group the simulated canals were instrumented with stainless steel K-flexo-files by using balanced force technique. Each simulated canal was filled with a drawing ink using to increase the color contrast for photographic documentation. Photographs of the unprepared canals were taken by the aid of stereomicroscope and digital camera at magnification of 40 times. When instrumentation of the canals was completed, the canals were injected again with the drawing ink and the image procedure is repeated. Pre- and postoperative digital photographs of the resin blocks were accomplished using Adobe Photoshop CS2 software program. At this stage the amount of resin removed i.e. the difference between the canal configuration before and after instrumentation was determined for both the inner and the outer side of the curvature at five reference points.

Results: For total canal diameter there was highly significant difference among the four groups at all levels. For outer canal transportation there was highly significant difference among the four systems at all levels except at the second level where the differences were not significant. For inner transportation there was highly significant difference among the four groups at all levels. For centering ratio there was highly significant difference among the tested groups at all level.

Conclusion: K-flexofile scored the maximum canal diameter at the apical two levels. ProTaper prepared the largest canal diameter at all levels. In comparison with ProTaper, canals prepared by GT and ProFile maintained original curvature was better with less straightening. The ability of instruments to remain centered in prepared canals was significantly better in NiTi systems than K-flexofiles. ProTaper files have lower centering ability than GT and ProFile.

INTRODUCTION

The ideal preparation for the root canal is a funnel shaped form with the smallest diameter at the apex and the widest width at the orifice. This shaped form can be achieved either by hand or mechanical preparation. Various instrumentation techniques and endodontic instruments have been introduced in an attempt to reduce these problems aiming to provide the most favorable shaped preparation [1].The unique properties of nickel-titanium (NiTi) alloy, such as flexibility, have allowed the development of NiTi endodontic instruments in order to overcome the limitations imposed by stainless steel alloy [1]. The innovation of rotary NiTi instruments has totally changed the way of endodontics. Comparing these changes with K-files is truly dramatic. These changes are bringing the especially of endodontic practice into the twenty-first century with greater precision, fewer procedural errors, less discomfort to the patient, and faster case completions. Although there are many pitfalls on the road to consistent results, with proper use of the NiTi systems, endodontists will be able to improve the quality and esthetics of their endodontic obturations quickly [2].

The purpose of this study is to compare the shaping ability of three rotary endodontic nickel-titanium systems (ProFile, CT and Protaper) with stainless steel hand K-flexofile in simulated curved canals at different levels, this include:

a.Total canal diameter.

b.Outer and inner transportations.

c.Centering ratio (the ability of the instruments to remain centered in the shaped canals).

MATERIALS AND METHODS

Simulated curved canals made of clear polyester resin were used to assess instrumentation. The diameter and the taper of all simulated canals were equivalent to an ISO standard size 10 root canal instrument. The canals were 16 mm long, the straight part being 11 mm and the curved part 5 mm with angle of 40° [3]. (Fig.1).

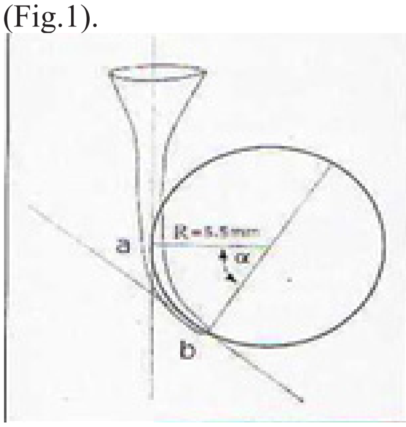

Fig.1: Angle and radius of canal curvature.

Preparation of artificial canals

Eighty acrylic blocks were divided into four groups, 20 simulated canals for each group were enlarged from #10 to # 25. The first penetration in the simulated Canal was performed with #10 K-file hand instrument to the full working length (16 mm). Patency of the resin blocks was checked with the same size after each sequence. Prior to use., each instrument was coated with glycerin to act as a lubricant and copious irrigation with tap Water was performed repeatedly before and after the use of each instrument using disposable syringes and 27 gauge tips.

Rotary NiTi instruments

In the first three groups all NiTi rotary instruments were set into a permanent rotation with a 16:1 reduction handpiece powered by a torque-limited electric motor set at 300 rpm and the torque at 1.2 Ncm. All the instruments were used in a crown down manner using a gentle in-and-out (pecking) motion until resistance was felt and changed for the next instrument.

Manual technique

In the fourth group the simulated canals were instrumented with stainless steel K-flexo-files by using balanced force technique described by Roan et al in 1985 [4] which continue until an apical stop of size 25 was achieved. Then stepping backs the preparation with ti 30, # 35 and # 40 files and used also in balanced force motion.

Assessment of canal preparation

Postoperative canal shape

Prior to their preparation, each simulated canal was filled with a drawing ink using a 27 gauge needle to increase the color contrast for photographic documentation. In order to achieve a standardized position of the resin blocks against the lens of the microscope, a holder was constructed from stone for this purpose with a hole. in the center in which the resin blocks could be placed and repositioned in exactly the same position. The central hole was covered with a transparent paper on which the five chosen levels were drawn and the artificial canal could be measured easily. Photographs of the unprepared canals were taken by the aid of stereomicroscope and digital camera at magnification of 40 times. One image on screen corresponded to 2 mm of the real canal length. Therefore eight images were needed to assemble the entire canal. Both X and Y coordinates on the microscope's nonius scale were recorded for each image, allowing repositioning and reproduction of the pictures at any given moment (i.e. pre- and postoperative). The images were standardized by securing the camera at a fixed distance from a microscope lens. After that the simulated, canals were cleaned using tap water with irrigating syringe. When instrumentation of the canals was completed, the canals were injected again with the drawing ink and the image procedure is repeated.

Pre- and postoperative digital photographs of the resin blocks were stored in a Pentium 4 computer and measurements were accomplished using Adobe Photoshop CS2 software program. At this stage the amount of resin removed. i.e. the difference between the canal configuration before and after instrumentation was determined for both the inner and the outer side of the curvature at five reference points, using a method described by Calberson et al in 2002 [5]. Al[measurements were made at right angles to the surface of the canal (Fig.-2).

- Point 1 (O): the canal orifice.
- Point 2 (HO): the point half-way from the beginning of the curve to the orifice.
- Point 3 (BC): the point where the canal deviates from the long axis of its coronal portion and is called the beginning of the curvature.
- Point 4 (AC): the point where the long axes of the coronal and the apical pen ions of the canal intersect and are called the apex of the curve.
- Point 5 (EP): the end point of preparation

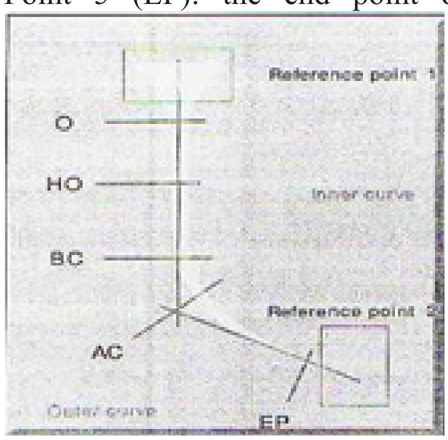

Fig.-2: The five levels of measurement

The mean centering ratio is a measure of the ability of the instrument to stay centered in the canal: the smaller the ratio, the better the instrument remained centered in the canal. This ratio was calculated at each of the five points using the following formula [(6)]:

X1-X2/Y

`X1: The maximum extent of canal movement in one direction.

X2: is the movement in the opposite direction.

Y: Is the diameter of the final canal preparation.

RESULTS

Postoperative canal shape

Total canal diameter

The mean values and the standard deviations of the total canal diameters after instrumentation at the five different levels examined for the four groups are presented in Table -1.

Table-1: Mean and standard deviation of post instrumentation total canals diameter (mm) for the four groups at the five levels.

System		O	HO	BC	AC	EP
PF	Mean	0.818	0.616	0.542	0.527	0.329
	SD±	0.012	0.006	0.048	0.034	0.027
GT	Mean	0.899	0.643	0.573	0.472	0.328
	GT	0.022	0.028	0.025	0.030	0.032
PT	Mean	0.974	0.969	0.784	0.631	0.351
		0.071	0.097	0.050	0.029	0.021
KO	Mean	0.829	0.777	0.731	0.750	0.368
	SD±	0.042	0.047	0.041	0.042	0.037
F-test		54.77	182.6	154.6	250.7	292.4
P-value		0.000 HS	0.000 HS	0.000 HS	0.000 HS	0.000 HS

ProTaper showed the largest canal diameter (0.974) at the first level and the smallest canal diameter (0.351) at the end point of preparation. GT showed the largest canal diameter (0.899) at the first level and the smallest canal diameter (0.328) at the end point of preparation. ProFile showed the largest canal diameter (0.818) at the first level and the smallest canal diameter (0.329) at the end point of preparation. K-flexofile showed the largest canal diameter (0.829) at the first level and the smallest canal diameter (0.368) at the end point of preparation. In general, the data confirm that; the NiTi files were flared the canals uniformly, being narrowest at their end point and widest at the orifice. The increase in width of the canals between each position varied from file to file.

Furthermore it became obvious that a proportion of canals which have been prepared by K-flexofile did not have a continuously tapering form often there were a relatively wider regions at the apex of the curve than the beginning of the curve, followed by a narrow regions towards the orifice.

The Student t-test (Table -2) revealed a highly significant difference between ProFile and GT at the first and fourth levels; while a significant difference was found at the second and third levels and not significant difference was found at the apex. By comparing ProFile and ProTaper, a highly significant difference was found at all levels except at the last one where the difference was significant. The difference between ProFile and K-flexofile was highly significant at all levels excluding the first one where the difference was not significant

Table -2 shown a significant difference between GT and ProTaper at the orifice and apex of the prepared canals and a highly significant difference at the other measuring points; While the difference between GT and K-flexofile was highly significant also there was a highly significant difference between ProTaper and K-flexofile along the canals, but not at the third level where the difference was significant.

Table -2: t-test of the post instrumentation total canals diameter for the four groups at the five levels

Groups	O		HO		BC		AC		EP	
	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig
PF&GT	0.000	HS	0.005	S	0.017	S	0.000	HS	0.960	NS
PF&PT	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.008	S
PF&KO	0.280	NS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
GT&PT	0.002	S	0.000	HS	0.000	HS	0.000	HS	0.015	S
GT&KO	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
PT&KO	0.000	HS	0.000	HS	0.009	S	0.000	HS	0.000	HS

Outer transportation

The mean values and the standard deviations of outer canal transportation after instrumentation at the five measuring points are given in Table -3.

Table-3: Mean and standard deviation of outer transportation (mm) for the four groups at the five levels.

Groups	O		HO		BC		AC		EP	
	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig
PF&GT	0.000	HS	0.005	S	0.430	NS	0.001	S	0.069	NS
PF&PT	0.000	HS	0.280	NS	0.019	S	0.000	HS	0.000	HS
PF&KO	0.032	S	0.910	NS	0.000	HS	0.000	HS	0.000	HS
GT&PT	0.000	HS	0.110	NS	0.003	S	0.000	HS	0.000	HS
GT&KO	0.000	HS	0.102	NS	0.000	HS	0.000	HS	0.000	HS
PT&KO	0.001	S	0.320	NS	0.001	S	0.000	HS	0.000	HS

GT showed the highest mean of outer transportation (0.260) at the first level and the smallest mean of outer transportation (0.119) at the end point of preparation while ProTaper showed the reverse, the highest mean of outer transportation (0.380) at the fourth level and the smallest mean of outer transportation (0.134) at the first level. ProFile showed the highest mean of outer transportation values (0.215) at the first and third levels and the smallest mean of outer transportation (0.128) at the end point of preparation. K¬flexofile showed the highest mean of outer transportation (0.484) at the fourth level and the smallest mean of outer transportation (0.127) at the third level.

By using the Student t-test (Table -4), a highly significant difference was found between ProFile and GT at the orifice and a significant difference at second and fourth levels; while no significant difference was found at the third and fifth levels. The relation between ProFile and ProTaper show a highly significant difference at the orifice, after curvature and end point; while it was not significant by the side of second measuring site and significant at the beginning of curvature. The variance between ProFile and K--flexofile was significant at the orifice and not significant next to the second level; while it was a highly significant at the other measuring points.

The Student t-test showed a highly significant difference between GT and ProTaper at the first, fourth and last part of preparation. At the second level there was no significant difference; while there was a significant difference at the third point of measurement. The difference between GT and K-flexofile was a highly significant at all measuring sites, but not at second level where the difference was not significant

Table-4: t-test of the outer transportation for the four groups at the five levels.

System		O	HO	BC	AC	EP
PF	Mean	0.215	0.206	0.215	0.205	0.128
	SD±	0.011	0.004	0.036	0.017	0.014
GT	Mean	0.260	0.218	0.222	0.188	0.119
	SD±	0.015	0.016	0.013	0.013	0.015
PT	Mean	0.134	0.184	0.178	0.380	0.200
	SD±	0.054	0.089	0.056	0.030	0.021
KO	Mean	0.198	0.205	0.127	0.484	0.465
	SD±	0.032	0.030	0.023	0.039	0.036
F-test		52.31	1.72	28.86	547.2	923.8
P-value		0.000 HS	0.000 HS	0.000 HS	0.000 HS	0.000 HS

Table -4 shown a significant difference between ProTaper and K-flexofile at the orifice and beginning of the curve; while there was no significant difference next to the second place; the relation was a highly significant difference after the curve and end point of instrumentation

Independent of the files used, all instruments removed material on the whole length of the outer side of canal. Canal shaped by the NiTi systems showed an almost regular removal of resin material on the outer side of the canals and remained more centered in the canals; while K-flexofile produced uneven pattern of resin removal along the outer aspect of the canals (Fig.3).

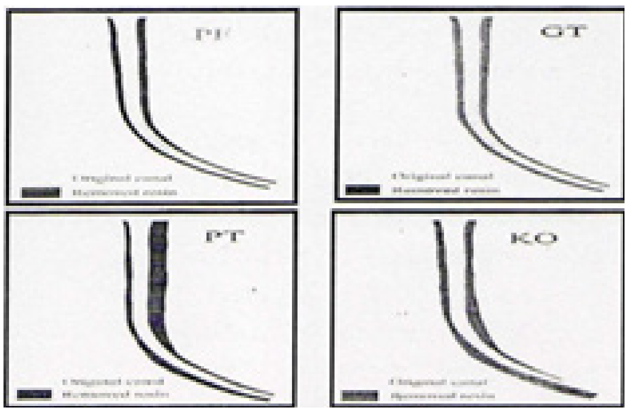

Fig.3: A plot of the mean changes in the canals as the results of preparation with different systems

Inner transportation

The mean values and the standard deviations of inner transportation after instrumentation at the five different levels examined for the four groups are listed in Table-5.

Table-5: Mean and standard deviation of inner transportation (mm) for the four groups at the five levels.

System		O	HO	BC	AC	EP
PF	Mean	0.202	0.239	0.213	0.195	0.100
	SD±	0.007	0.005	0.027	0.018	0.014
GT	Mean	0.240	0.255	0.229	0.174	0.106
	SD±	0.023	0.015	0.013	0.020	0.018
PT	Mean	0.441	0.613	0.486	0.141	0.050
	SD±	0.044	0.032	0.038	0.010	0.007
KO	Mean	0.230	0.396	0.478	0.152	0.000
	SD±	0.024	0.038	0.035	0.009	0.000
F-test		302.8	848.7	595.2	488.0	324.5
P-value		0.000 HS	0.000 HS	0.000 HS	0.000 HS	0.000 HS

At the second level, ProTaper showed the highest mean of inner transportation (0.613) and the smallest mean of inner transportation (0.050) at the end point of preparation but GT showed the highest mean of inner transportation (0.255) at the second level and the smallest mean of inner transportation (0.106) at the end point of preparation. Also ProFile showed the highest mean of inner transportation (0.239) at the second level and the smallest mean of inner transportation (0.100) at the end point of preparation while K-flexofile showed the highest mean of inner transportation (0.478) at the third level and did not touch the inner sides at the end point of preparation.
By using Student t-test (Table-6), a highly significant difference was found between ProFile and GT at the orifice and a significant difference at the second, third and fourth levels; while no significant difference was found at the last measuring point. The relation between ProFile and ProTaper was a highly significant difference at all levels. The variance between ProFile and K-flexofile was significant next to the orifice and a highly significant at the other measuring sites.
As well Student t-test showed a highly significant difference between GT and ProTaper at all levels. The difference between GT and K-flexofile was not significant at the first plane. The variation between these two instruments next to the second, third and last measuring points were highly significant; while there was significant difference at the forth level.
Also, Table-6 shown a highly significant difference between ProTaper and K-flexofile at the first, second and fifth tested points; while there was no significant difference next to the third level. After the curve the difference between these two groups was significant.

Table-6: t-test of the inner transportation for the four groups at different levels.

Groups	O		HO		BC		AC		EP	
	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig
PF&GT	0.000	HS	0.002	S	0.023	S	0.001	S	0.240	NS
PF&PT	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
PF&KO	0.001	S	0.000	HS	0.000	HS	0.000	HS	0.000	HS
GT&PT	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
GT&KO	0.210	NS	0.000	HS	0.000	HS	0.020	S	0.000	HS
PT&KO	0.000	HS	0.000	HS	0.510	NS	0.006	S	0.000	HS

Centering ratio

Table -7 has shown the mean values and the standard deviation of canal centering ratio after instrumentation with the four systems at the five measuring points

Table-7: Mean and standard deviation of canal centering ratio for the four groups at the five levels

System		O	HO	BC	AC	EP
PF	Mean	0.017	0.055	0.018	0.018	0.048
	SD±	0.015	0.012	0.030	0.011	0.016
GT	Mean	0.031	0.057	0.016	0.033	0.034
	SD±	0.003	0.010	0.014	0.015	0.038
PT	Mean	0.329	0.454	0.395	0.377	0.424
	SD±	0.091	0.134	0.117	0.042	0.054
KO	Mean	0.044	0.241	0.476	0.440	0.818
	SD±	0.042	0.068	0.062	0.030	0.037
F-test		163.7	132.1	232.9	103.5	200.0
P-value		0.000 HS	0.000 HS	0.000 HS	0.000 HS	0.000 HS

The lower the score of the centering ratio the better the instruments centered in the canal [6].

At the first level ProFile showed the best centering ability among the other three systems (0.017) and exhibited the worst ability to center in the canal (0.084) at the end point of preparation.GT showed the best centering ability (0.016) at the third level and exhibited the worst ability to center in the canal (0.057) at the second level.ProTaper showed the best centering ability (0.329) at the first level and exhibited the worst ability to center in the canal (0.454) at the second level.K-flexofile showed the best centering ability (0.044) at the first level and exhibited the worst ability to center in the canal (0.818) at the end point of preparation..

By using the Student t-test (Table -8) a significant difference was found between ProFile and GT at the orifice and not significant at the second, third and fourth levels; while a highly significant difference was found at the last plane. The relation between ProFile and ProTaper was a highly significant difference at all measuring sites; while the variance between ProFile and K-flexofile was significant at the orifice and a highly significant at the other levels.

Also the Student t-test showed a highly significant difference between GT and ProTaper at all levels. The difference between GT and K-flexofile was not significant at the first measuring point; while there was a highly significant difference at the other tested sites. Additionally there was a highly significant difference between ProTaper and K¬flexofile at the first, second and fifth tested points; while there was no significant difference next to the beginning of the curvature (BC). After the curve (AC) the difference between these two groups was significant.

Table-8: t-test of canal centering ratio for the four groups at different levels.

Groups	O		HO		BC		AC		EP	
	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig
PF&GT	0.024	S	0.680	NS	0.740	NS	0.062	NS	0.000	HS
PF&PT	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
PF&KO	0.014	S	0.000	HS	0.000	HS	0.000	HS	0.000	HS
GT&PT	0.000	HS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
GT&KO	0.220	NS	0.000	HS	0.000	HS	0.000	HS	0.000	HS
PT&KO	0.000	HS	0.000	HS	0.011	S	0.000	HS	0.000	HS

DISCUSSION

Total Canal Diameter

The given results of Table -1 shown that, K-flexofile scored the maximum canal diameter at the apical two levels. This was perhaps as a result of the relatively high rigidity of K-flexofiles if compared with flexible NiTi systems. Stainless-steel instruments tend to straighten when rotating in a curved canal, thus remove more material from the outer walls of the canal. These findings have already noted by Schafer and Schlingemann, 2003b [7]; Perez et al, 2005 [8].

Furthermore, it became obvious that some samples which have been prepared by K-flexofile did not have a continuously tapering form. There were relatively wider regions apical to the beginning of the curve followed by narrow areas towards the orifice. These wider parts near the curve would appear to correspond to the danger zone described by Abou-Rass et al in 1980 [9] where strip perforations occur in vivo.

Comparing NiTi systems, ProTaper prepared the largest canal diameter at all levels and this aggressive behavior of these files has been confirmed by other investigations (Al-Omari et al, 2003 [10]; Bergmans et al, 2003 [11]). This is may be due to three reasons:(a) ProTaper is an active design which has more cutting efficiency if compared with passive instruments like ProFile and GT, (b) the increased taper of ProTaper shaping files of up to 0.19 whereas other instruments were used only with tapers of maximum 0.12 for GT and 0.06 for ProFile, (c) a brushing action that is recommended with this system before further advancing the instruments which may caused, oving more resin coronally.

GT exhibited more dentine removal at the coronal three levels of the canals than ProFile. This finding is coinciding with other studies (Calberson et al, 2002 [5]; Al- Omani et al, 2003 [10]; Bergmans et al, 2003 [11]).This may attribute to the increased taper of the GT up to 0.12 , whereas ProFile is restricted to a 0.06 taper. In contrast, at the apical part of the canals GT performed significantly less canal diameter than Pro-

File. Similar results have been also established by several studies (Garip and Gencoglu [12], 2006; Rodig et al, 2007 [13]). This probably is due to the length of the cutting part of GT is shorter than that of ProFile.

Transportation (outer and inner)

The distance of transportation was determined by measuring the greatest length between the edge of each instrumented canal and the corresponding edge of the un instrumented canal.

Transportation of the canal is determined by the flexibility of the preparation instruments, the movement of the instruments in the canal, as well as the length of time the instrument is in contact with the canal wall during preparation [14].

Concerning the original root curvatures, Tables 3 and 5 reveal that, NiTi systems obtained better canal geometry, demonstrated less canal transportation and straightening at the apical portion of the simulated canals and better maintained the original shape of the curved canals compared with stainless-steel instruments (Fig.3). The direction of transportation observed in this study was generally toward the inner aspect at the coronal and middle parts of the canal and toward the outer aspect of the canal apically. Other studies have confirmed this trend of endodontic instruments (Schafer and Schlingemann, 2003 b [7]; Guelzow et al, 2005[15]).The explanation for this is due to the restoring forces of the instrument in a curved canal which attempt to return the file to its original shape and act on the outer side of the canal wall during preparation and thus lessens its cutting along the inner wall .If this effect is pronounced a significant portion of canal wall remains untouched [16].

In comparison with ProTaper, canals prepared by GT and ProFile maintained original curvature was better with less straightening. ProTaper removed more resin from the outer side at the apical portion of the canal; while it was more efficient on the inner wall at the coronal and middle thirds. These observations are in accordance with recently published studies (Yang et al, 2006 [17]). This fact may be as a results of: (**a**) the sharp cutting edges of ProTaper because of their convex triangular cross- section design [15], (**b**) ProTaper finishing files have progressively tapers resulted in a thicker instrument especially at the apical third of the file cause less flexibility of the instruments when compared with other NiTi systems with the same apical size [18].

In term of outer transportation, Table -3 reveals more cutting effectiveness of GT at the first three levels than ProFile. This may come in agreement with the findings of other studies (Garip and Gencoglu, 2006 [12]; Rodig et al, 2007 [13]). This was as a result of excessive tapering of GT up to 0.12; while it was just 0.06 for ProFile, but this efficiency of GT was decreased by the side of apical two planes .These results were in accordance to a previous reports (Garip and Gencoglu, 2006 [12]; Rodig et al, 2007 [13]). This possibly due to the short cutting part of GT compared with ProFile, which may increase the flexibility of this system.

In regard to inner transportation (Table -5), there were no differences from the results of outer transportation except at the end of preparation where more material has been removed when the canals were instrumented by GT in comparison to ProFile, but the difference was not significant. This may come in agreement with the findings of similar studies (Garip and Gencoglu; 2006 [2]; Rodig et al, 2007 [13]).

Centering ratio

The centering ratio can defined the ability of instruments to remain centered in shaped canals. According to the formula, the centering ratio approaches zero as X1 and X2 become closer .The lower the score, the better the instruments centered in the canal. The flexibility of instruments may be the main factor that allows the instruments to plane the canal walls rather than engaging and screwing into them and to cut of dentin evenly along the canal wall [6].

Table -7 indicated that, the ability of instruments to remain centered in prepared canals was significantly better in NiTi systems than K-flexofiles. Because of the inherent stiffness of stainless-steel instruments there is a tendency to straighten the curved portion of the canal, and consequently this may result in more uneven and excessive dentin removal. By comparing NiTi systems, ProTaper files have excessive tapering this may increase the rigidity of instrument consequently more resin will removed from one side of the canal than the other. Additionally the brushing action which is recommended with this system may cause unevenly resin removal, these factors may explain relatively low centering ability of this system compared with other tested NiTi instruments [19].

Furthermore ProFile were centered in the coronal portion of the canals better than GT, this is related to the increased taper of the GT up to 0.12, whereas ProFile is limited to a 0.06 taper. Excessive tapering may increase the rigidity of instrument consequently more resin will removed from one side of the canal than the other. Conversely GT was better at the end point of preparation. This probably is due to the smooth shank of the GT that may increase the flexibility of this system. These findings confirmed the results previously reported by Park, 2001 [20].

CONCLUSION

K-flexofile scored the maximum canal diameter at the apical two levels. ProTaper prepared the largest canal diameter at all levels. GT exhibited more dentine removal at the coronal three levels of the canals than ProFile. At the apical part of the canals GT performed significantly less canal diameter than ProFile. In comparison with ProTaper, canals prepared by GT and ProFile maintained original curvature was better with less straightening. The ability of instruments to remain centered in prepared canals was significantly better in NiTi systems than K-flexofiles. ProTaper files have low centering ability. ProFile was centered in the coronal portion of the canals better than GT while GT was better at the end point of preparation.

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