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Evaluation of Cutting Efficiency and Defects Influencing Surface Topography of Two Ni-Ti Rotary Instruments (An in Vitro Study)

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Abstract **Original Research Article**

This study was designed to evaluate the cutting efficiency and defects influencing surface topography of HeroShaper and Revo-S NiTi rotary files.90mesiobuccal root canals of extracted permanent mandibular first molar, with fully developed apices and curvature ranging between 25-35 degree. Samples were divided into two groups according to the instrument used for canal preparation where *group A* prepared with *HeroShaper* and *group B* was prepared with *Revo-S* instruments. The cutting efficiency of both tested systems was evaluated by randomly selecting 10 samples from each group. The selected samples were weighted by a highly sensitive 5 digits scale, then each sample in both groups were instrumented according to the manufacturer's recommendation, after preparation, each sample was re-weighted. The weight loss of each sample was being calculated. The data analysis showed statistically insignificant. Before preparation, each group of the files were subdivided into 3 groups, unused, after a single use, and after 9 uses. Both files showed no visible defect, and with SEM there was no statistically significant difference in unused and after single-use, while the Revo-S rotary instrument demonstrated the incidence of fracture after 9 uses. It could be concluded that the rotary Ni-Ti instruments should be examined prior to instrumentation using any type of magnification to check if there is a sign of deterioration.
Keywords: Cutting Efficiency; Surface topography; HeroShaper; and Revo-s.

INTRODUCTION

Successful endodontic therapy is dependent upon practitioner's ability to safely and effectively clean and shape the root canal [1].

The aim of root canal shaping is to form a tapered funnel preparation with increasing diameters from the end point to the orifice in order to allow effective irrigation and obturation [2].

NiTi endodontic instruments were introduced to facilitate the instrumentation of curved canals with few or no procedural errors, NiTi instruments are 2 or 3 times more flexible than stainless steel instruments [3].

Cutting efficiency of endodontic instruments depends on a number of factors such as metallurgical properties, cross-sectional configuration of shafts, sharpness of the flutes, flute design, tip design, lubrication during cutting, wear resistance, chip removal capability, and mode of use [4-6].

Increasing numbers of NiTi rotary instruments of various designs are now marketed; new instruments and materials seem to appear faster than clinicians could learn about the preceding versions. This has created an educational challenge for practitioners, universities, and manufacturers requiring a greater degree of cooperation among these groups than ever before [7].

So, there is an increasing concern about instrument surface changes and fracture of NiTi files.

New generations are introduced to the market with specific design feature such as variable taper, absence of helical angles and flutes and changes in cross section design.

Therefore we have to shed a light on the cutting efficiency and surface changes of two systems of nickel-titanium instruments. The aim of this study was to compare the cutting efficiency of the two rotary Ni-Ti files HeroShaper and Revo-S systems and to Study the surface topography of both systems.

METHODS

A total of (90) mesial roots of freshly extracted human mandibular first molars, with fully developed apices and root curvature, ranges between 25-35º according to Schneider technique and have the same length ±1mm was selected to be used in this study. Any tooth with root canal abnormality was excluded from the study. Teeth were thoroughly washed under running water. The root surfaces were planned and any soft tissue, remnant or calculus was removed from the root surfaces using the ultrasonic scaler. The teeth were then stored in saline at room temperature till the time of use. The crown of the selected teeth were sectioned and decapitated at the level of CEJ using, safe sided diamond disc mounted on conventional speed under coolant water. The mesial root was separated from the distal one and the orifice of the mesiobuccal canal was located and scouted with K-file #10 until the tip of the file is visible at the apical foramen and subtracting 1.0 mm from that length and the working length was adjusted. The 90 mesiobuccal roots were divided into two main groups forty-five roots for each: *Group A: 45canals will be prepared by HERO* shaper system (MicroMega Besancon-France) according to manufacturer recommendation. *Group B:* 45canals will be prepared by Revo-s system (MicroMega Besancon-France) according to manufactures recommendation. *Ten* roots randomly selected of each group were pre-weighted before instrumentation and after final instrumentation for evaluating the cutting efficiency. Five sets of each instruments type were examined *before use, after single use, and after 9 usages, usage,* using *Stereomicroscope* and *SEM* to evaluate surface topography.

The root canals were prepared using either the HERO-Shaper system or the Revo-S system mounted on SAESHINE-cube motor (ENDODONTIC MICROMOTER-DAEGUE, KOREA), with speed and torque adjusted according to the limit of each rotary files in a crown-down manner according to manufacturer's instructions.

Evaluation of the Cutting efficiency

The cutting efficiency of both tested systems was evaluated by selecting 10 samples randomly from each group. The preoperative weighting of each sample of both groups was carried out before mechanical preparation and after drying it in the open air for 24-hours by using a highly sensitive 5 digital scale (Kern 770 KERN, Germany). Each sample was labeled with a serial number to represent each group (HERO Shaper and Revo-S), and each measurement was repeated three times and the mean was calculated.

After final preparation, the root canals were dried by the corresponding paper point and left to dry in the open air for 24-hrs. Each sample was re-weighted and repeated three times and the mean will be calculated [8-10].

Evaluation of the Instrument surface topography

The surface topography of each instrument of both groups were examined by Stereomicroscope with magnification X16 for any defects and the selected samples were assisted by SEM using the scoring system modified from *Al-Khawas* [11] (Table 1).

Table 1: The scoring system used to evaluate the instruments

Score	Type of Surface Defect
1	Milling marks
2	Metal rollover
3	Any changes affecting the edge of the flutes: pits, groups, notches, denting, blunting and/or metal flash or stripping
4	Unwinding of the flutes or permanent deformation of the instrument
5	Instrument Fracture

Each instrument was examined as follows:
1) Control files (unused).
2) After single use.
3) After 9 uses.

Control files (unused)

All files of both systems were cleaned in an ultrasonic bath and the selected files were examined before usage, firstly the files were examined with stereomicroscope using x16 magnification, then Scanning electron microscope (SEM) examination of the files was done using X150 and X500 magnification. Files were examined for design, uniformity, tip, shape of the cutting edges of the flutes, absence of metal tears, quality of grinding process, and the file surface.

After single use:

Before an examination, the files of both systems were cleaned in an ultrasonic cleaner using ethyl alcohol to remove any dentin debris, then examined with SEM atX150 and X 500 for the presence of microfracture without complete separation, metal strips, pitting distribution of the cutting edge, complete fracture, and observable corrosion from the irrigating solutions used and debris adhering to the files surfaces even after ultrasonic cleaning.

After 9 uses

Before examination, the files of both systems were cleaned in an ultrasonic cleaner using ethyl alcohol to remove any dentin debris followed by SEM examination for the same scores mentioned before.

Statistical Analysis of the Data

Weight loss data were presented as mean and standard deviation (SD) values. Mann-Whitney U test was used to compare between the two systems. This test is the non-parametric alternative to Student's t-test and it was used due to the non-parametric distribution of weight loss data. Instrument evaluation scores were presented as frequencies and percentages. Chi-square (x^2) test was used to compare between the two systems.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with PASW Statistics 18.0® (Predictive Analytics Software) for Windows

RESULTS

Evaluation of the Instrument Cutting Efficiency

The data was statistically analyzed using the Mann-Whitney U test.

The mean and standard deviation values of weight loss for HeroShaper and Revo-S were (0.0096 ± 0.0047 gm) and (0.0096 ± 0.0040 gm) respectively (Figure 1).

There was no statistically significant difference in cutting efficiency between the two systems (P-value = 0.849).

Table 2: Mean weight loss, Standard Deviations (SD) and P-values, when comparing the Hero shaper system vs. the Revo-S system

Hero Shaper		Revo-S		*P*-value
Mean	SD	Mean	SD	
0.0096	0.0047	0.0096	0.0040	0.849

**: Significant at $P \leq 0.05$*

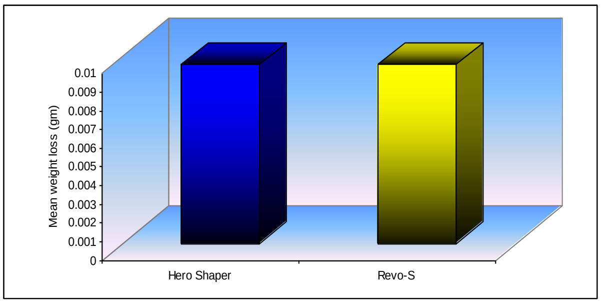

Figure 1: Bar chart representing mean weight loss after using the two systems

Evaluation of the Instrument surface topography

The surface topography of each instruments of both groups were examined by Stereomicroscope for any defects and selected samples examined by SEM using the scoring system modified as mentioned in the material and methods, and the data in this section was statistically analyzed using the Chi-square (x^2) test.

I: HeroShaper Files

Unused Files

No visible defects were detected in new HeroShaper files. *Stereomicroscope and SEM* examination showed milling marks, debris in 4 files (80%), and 1 files (20%) showed metal flashes and pits (Figure 2, & 3).

Figure 2: A photograph showing; A stereomicroscope of apical segment of size30 unused HeroShaper

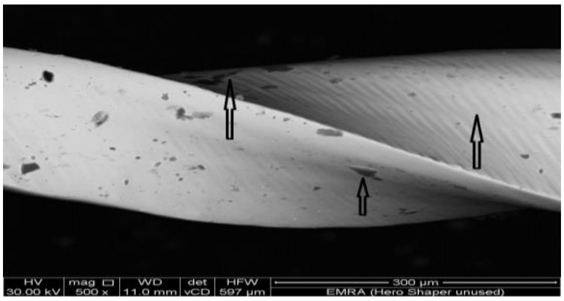

Figure 3: A photograph showing: A SEM of middle segment of size #30 of unused HeroShaper file showing milling marks and debris

After single use

File size 30 Taper 0.04 was selected to be examined under SEM. As this file reaches the full working length of the root. SEM examination showed that two files (40%) had milling marks, dentin deposits. While one file (20%) showed metal rollover, pitting, and smoothness of the cutting surface, blunting of cutting edge and/or metal flashes. No unwinding, surface cracks or fracture were seen (Figure 4).

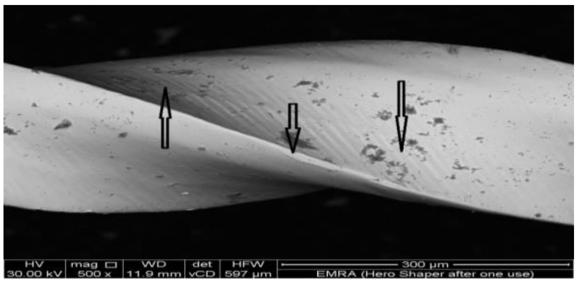

Figure 4: A photograph showing: A SEM of middle segment of size 30 HeroShaper file after single use showing milling marks, dentin debris, metal flashes and blunting of cutting edge

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After 9 uses

File size 30 Taper 0.04 was selected to be examined under Stereo and SEM. SEM examination, after 9 uses showed one file (20%) with milling marks, dentin deposits, onefile (20%) showed metal rollover and 3 files (60%) showed pits, metal flashes and blunting of the cutting edge. No file fractured or cracks were showed (Figure 5).

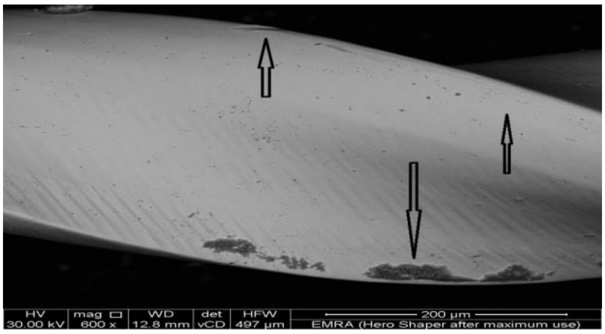

Figure 5: A photograph showing: A SEM of middle segment of size #30 HeroShaper file after 9 uses showing milling marks, dentin debris, metal flashes and pits

II: Revo-S Files
Unused Files

No visible defects were detected in new Revo-S files. *Stereomicroscope and SEM* examination showed milling marks, debris in 5 files (100%), and no microfracture or cracks were showed (Figure 6).

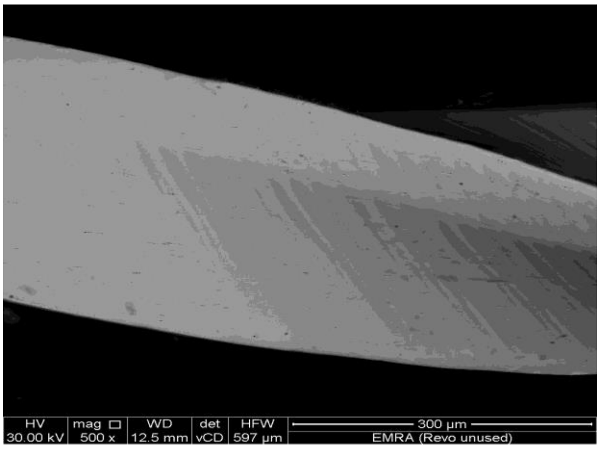

Figure 6: A photograph showing: A SEM of middle segment of unused Revo-S file SU showing milling marks

After single use

File *SU* Taper 0.06 was selected to be examined under stereo and SEM. As this file reaches the full working length of the root. SEM examination showed 3 files (60%) with milling marks, dentin deposits. And one files (20%) showed, pitting, and smooth surface in few area of the file, remnant dentin and metal flashes. No unwinding, surface cracks or fracture were seen (Figure 7).

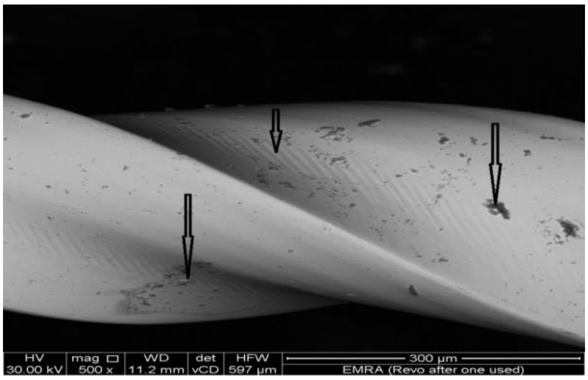

Figure 7: A photograph showing: A SEM of middle segment of SU Revo-S file after single used showing milling marks, dentin debris, smooth surface, and metal flashes

After 9 uses

The file was used for scanning file SU taper .006. It was selected because it reaches the full working length of the root. After SEM examination showed one files (20%) with milling marks, dentin deposits. two files (40%) showed, remnant dentin, pitting, and smooth surface in few area of the file, blunting of the cutting edges, and crack propagation along the surface of the file (Figure 8). Fracture was showed in SC1 file and SC2 file (Figure 9).

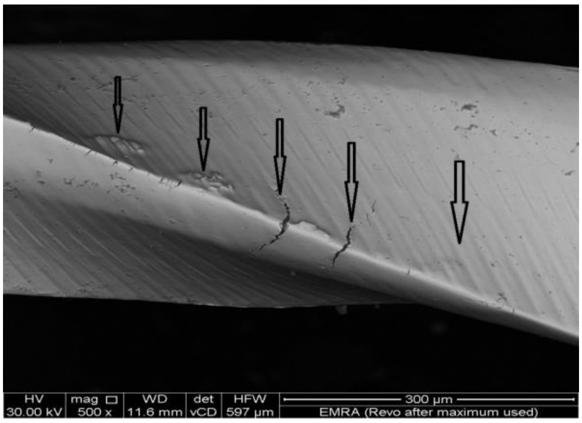

Figure 8: A photograph showing: A SEM of middle segment of Revo-S file SU after 9 uses showing milling marks, dentin debris, smooth surface, metal flashes and crack propagation

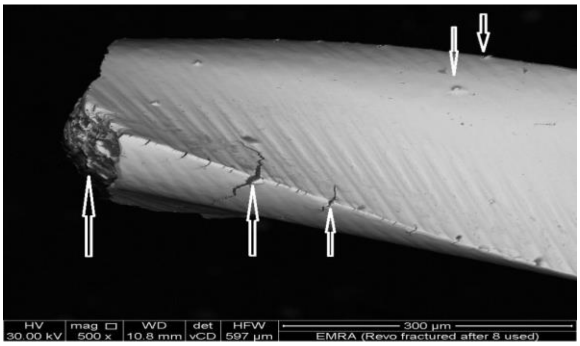

Figure 9: A photograph showing: A SEM of fractured of SC1 Revo-S file after 8 uses

By comparing both systems statistically and using the Chi-square (x^2) test the results showed the following

- ***Unused files***

There was no statistically significant difference between the two systems (P-value = 0.292) (Table 3) (Figure 10).

Table 3: The frequencies, percentages and P-values, when comparing the Hero shaper system vs. the Revo-S system before file usage

System / Score	Hero Shaper		Revo-S		*P*-value
	Frequency	%	Frequency	%	
1	4	80	5	100	0.292
3	1	20	0	0	

*: *Significant at P ≤ 0.05*

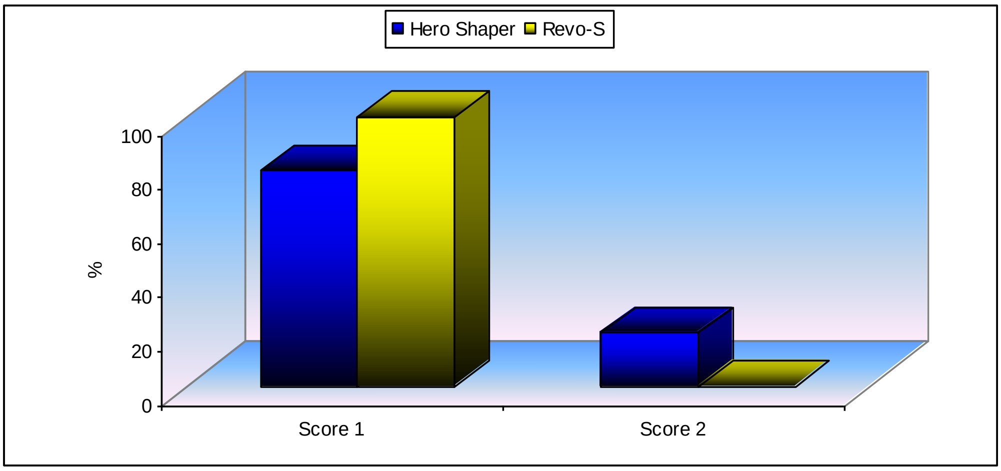

Figure 10: Bar chart representing instrument evaluation before file usage

After single use

There was no statistically significant difference between the two *systems (P-value = 0.766)* (Table 4) (Figure 11).

Table 4: The frequencies, percentages and P-values, when comparing the Hero shaper system vs. the Revo-S system after single use

System / Score	Hero Shaper		Revo-S		*P*-value
	Frequency	%	Frequency	%	
1	2	40	3	60	0.766
2	1	20	1	20	
3	2	40	1	20	

*: *Significant at P ≤ 0.05*

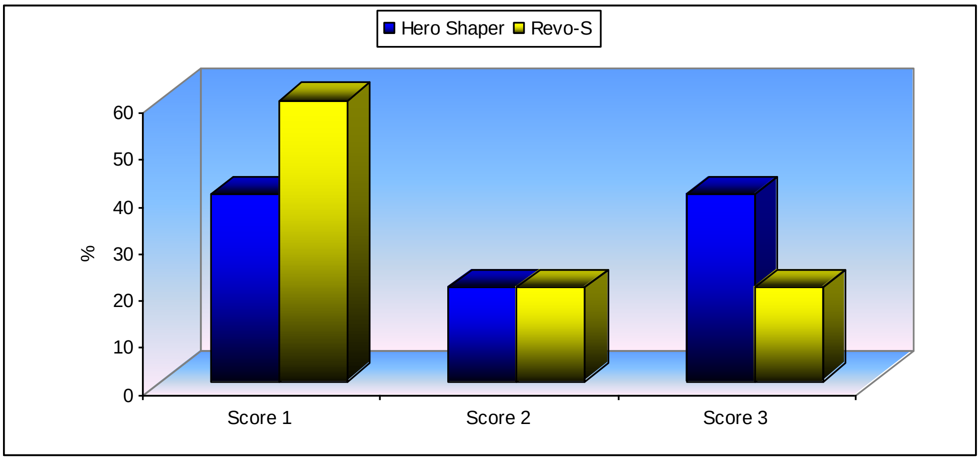

Figure 11: Bar chart representing instrument evaluation after single use

After 9 use

There was no statistically significant difference between the two systems (P-value = 0.572) (Table 5) (Figure 12).

Table 5: The frequencies, percentages and P-values, when comparing the Hero shaper system vs. the Revo-S system after 9 uses

System / Score	Hero Shaper		Revo-S		*P*-value
	Frequency	%	Frequency	%	
1	1	20	0	0	0.572
2	1	20	1	20	
3	3	60	3	60	
5	0	0	1	20	

**: Significant at P ≤ 0.05*

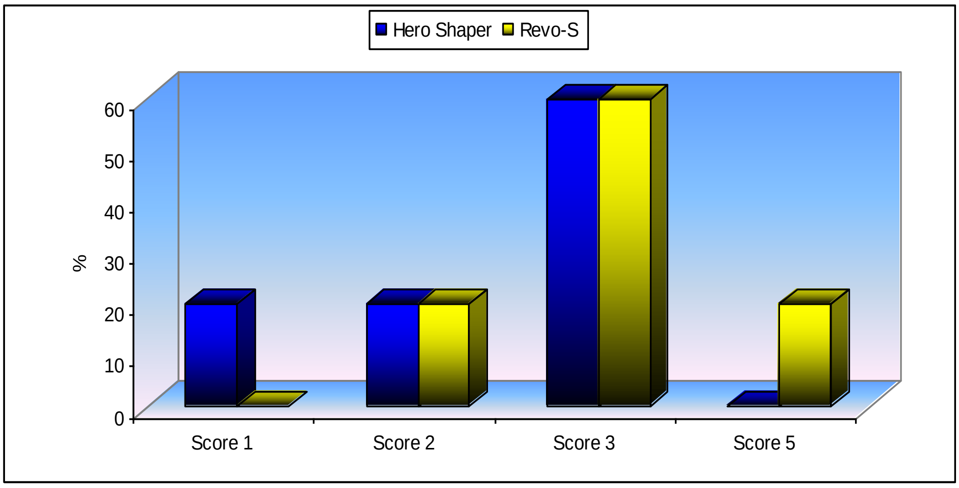

Figure 12: Bar chart representing instrument evaluation after 9 uses

DISCUSSION

It is essential for the endodontic clinician not only to understand the clinical aspect of the root canal therapy, but also to understand the range of usefulness and limitations of the instruments involved to produce optimal results consistently. The appropriate selection of endodontic instruments to correlate with various situations that may arise in root canal therapy is an important factor in achieving quality results. One selection criterion is the effect of the working environment on the stainless-steel and NiTi instruments. Reactivity of the metal in its working environment includes properties such as chemical corrosion resistance and effect of repeated clinical instrumentation and various cleaning, disinfection and sterilization procedures on the cutting efficiency [12, 13].

On the other hand, one of the main purposes of the root canal instrumentation is cutting of the root canal dentine, shape and form distinct configuration of the canal space capable of receiving a three dimensional filling material [9]**.**

The HeroShaper instruments used in the present study are characterized by having adapted pitch which vary according to the taper (i.e., the larger the taper, the longer the pitch), the helix angle increases from the tip to the shank and it is claimed to reduce threading. It has a triple helix cross-sectional design and rounded non-cutting tip, a positive rake angle for excellent debris removal and improves cutting efficiency, and their handle has been shortened to improve the access to posterior teeth [14-16].

On the other hand, the Revo-S instruments were used to be compared with HeroShaper. Revo-S is a recent generation of MicroMega characterized by having asymmetrical cross-section which provides less stress on the instruments and increases the available volume for upward debris elimination, the canal axis has 3 cutting edges located on 3 different radiuses, inactive tip, the SC2 instrument has symmetrical cross-section, with a 0.04 taper allowing better penetration, and both SC1and SU have asymmetrical cross-section for upward elimination [44].

A wide variety of materials with different hardness have been used as substrate to measure the cutting efficiency of various endodontic instruments. These materials include bovine bone which was used by Villalobos *et al.*, [4], Gohn *et al.*, [5], Miserendino *et al.*, [7], Henry *et al.*, [17], Ibrahim *et al.*, [18], epoxy resin was used by Tepel *et al.*, (19), Schaifer [20], clear polyester resin, special plastic samples with abrasive properties were used by Ametrano *et al.*, [21], polymethyl methacrylate (Plexiglas) used by Craig *et al*., [3], Anderson *et al*., [6]. However variations in hardness between specimens and variations due to storage and handling make them less suitable for quantitative comparison.

Extracted teeth were used in current study, which gave the study greater reliability being more similar to clinical conditions than artificial canals made of acrylic resin. This was previously recommended by Bertrend *et al*., [22], Kuttler *et al*., [23], Schefer and Vlassis [24]. Mesio-buccal canals of fully formed roots of permanent mandibular first molar were selected rather than both mesio-buccal and mesio-lingual canals, as usually the apical foramen and the height of curvature of the two canals were not usually at same level. Therefore, the marking levels would not be identical in both canals [25]. The difficulty in creating homogeneous sample in human teeth can be considered a drawback, therefore the selection of the teeth in two groups were balanced with respect to the angle of curvature according to *Schneider,s* [1] technique.

All samples in the current work were prepared using the crown down technique as instructed by the manufacturer at the speed and torque recommended. It has many advantages as, it reduces intra-canal frictions thus minimizes the risk of instruments separation, significantly better shape and terminus, also less debris extruded from the apical foramen, this was approved by Cunningham and Senia [25] Morgan and Montgomery [26], Kucukay *et al*., [27] and Kataia [9].

Sodium hypochlorite in dilutions of 2.6% was used in the present study as it is the most commonly used root canal irrigant. It is an antiseptic and inexpensive lubricant that has been used. Advantages of NaOCl include its ability to dissolve organic substances present in the root canal system and its affordability [28, 29]. Yet, it was approved that the most effective irrigation regimen is 5.25% at 40 minutes, whereas irrigation with 1.3% and 2.5% NaOCl for the same time interval is ineffective in removing infected tissue [30].

The method used to assess cutting efficiency of the two instruments used in current study was done by measuring the amount of weight loss; this was in agreement with the work of Miserendino *et al.*, [7]. This method is still a valid method in evaluating the cutting efficiency of the instrument [10].

On the other hand, the method used to examine the surface changes of the instruments was the Stereomicroscope for general examination to all files and Scanning Electron Microscope for the selected files which is still one of the most commonly used tools for analysis and the literature is replete with research using it for evaluation of different instruments. The instrument surface topography was evaluated using a scoring system similar to other surface analysis research [31, 32, 35, 36].

Results of the present study regarding cutting efficiency showed that

The mean and standard deviation values of weight loss for HeroShaper and Revo-S were (0.0096 ± 0.0047 gm) and (0.0096 ± 0.0040 gm) respectively, that was no statistically difference between both groups. This may be attributed to the similarity in the design characteristics of the instruments such as variable progressive pitch, non cutting tip, large metal core, positive rack angle and similarity in cross section.

Both instruments characterized by debris elimination and cleaning cycle which optimize the root canal cleaning, that determines the efficiency of rotary instruments because the removal of cut dentin chips is important to the reduce clogging of the cutting blades [33].

This was found to be in agreement with the Bergmans *et al*., [12], who stated in his observation that cutting efficiency and cleaning effectiveness of rotary NiTi instruments are closely related.

Result related to surfaces changes of the instruments showed that; examination of the two groups with scanning (HeroShaper and Revo-S) *before usage* revealed that there were no visible defects, any microfractureor cracks. Some manufacturing landmarks as milling marks, debris were showed. These were in agreement with Rapisarda *et al*., [31], Koch and Brave [34] and Bonaccoroso *et al*., [35] revealing that the electropolishing of NiTi files would decrease the incidence of microfracture and subsequent file separation. Also, these results were in agreement with Herold *et al*., [36] who stated that developers of the files claimed with electropolishing should eliminate surface imperfections. And Thompson [37] stated that the presence of surface irregularities on the cutting edges of the unused instruments may compromise their cutting ability and potentially cause problems with corrosion. In contrast Eggert *et al*., [38] reported that these surface irregularities are probably insignificant.

Examination after one usage of both groups showed milling marks, dentin deposits, metal flashes, smooth area of cutting surface and blunting of cutting edge. No unwinding, cracks or fracture were seen in both groups. Metal flashes and deposits, seen were in agreement with Arens *et al.*, [39] stating that pitting or fretting occurred when oxides were worn off the surface exposing fresh metal. Pitting corrosion is probably caused by debris accumulation, irrigation and frequent use. The presence of these defects suggested an increased potential for failure with further use because the defects could act as focal stress raiser and a potential origin of cracks. However, there is a controversy as to whether NiTi rotary files should be treated as single-use disposable instruments.

Examination of the HeroShaper files size 30 after 9 uses with SEM showed pits, milling marks, dentin debris and blunting of cutting edge. No fractured files were seen. Debris particles that adhered on the instrument surface could be seen in many cases despite the ultrasonic cleaning process before SEM examination. . It is possible that they could either be of metal origin from the manufacturing process or dentine particles from preparation of the root canal [38].

Examination of SU Revo-S files after 9 uses with SEM showed milling marks, deposits pit, smooth area, blunting of cutting edge, and crack propagation along the surface of the file. Two files SC1 were fractured after 8 uses, while SC2 file fractured after 9 uses. It has been suggested that instrument fracture is a complex multi-factorial clinical problem with variables due to operator and root canal anatomy being more influential than the instrument itself [40]. Furthermore, this is may be due to the fact that posterior teeth often have smaller or more variable canal anatomy than anterior teeth which might partly explain these findings. Also, material fatigue affects instruments that are rotating in the confines of a curved root canal. Such rotational bending will lead to the formation of microcracks on the surface, which will coalesce to become fatigue cracks. The crack then propagates transgranularly with little to no discernible macroscopic plastic deformation of the adjacent material [37, 41]. To prevent fatigue failure, instruments should be discarded after a certain number of uses, regardless of whether any defects are visible. Pruett *et al*., [42], Alpati *et al*., [43] and Arens *et al*., [39] however, stated that there has been no consensus concerning the number of times which NiTi rotary files may be reused safely.

The results of our present study, revealed that two Revo-S files were fractured (Sc1, Sc2) after 8, 9 times respectively, this may be attributed to that Revo-S were less resistant to cyclic flexural fatigue than HeroShaper files with tip diameter and taper**.**

Contradicting our result, regarding the speed, fracture occurred in Revo-S(300) comparing to HeroShaper (600), as was approved by many investigators. Dietz *et al*., [45], Yard *et al*., [46] and Martin *et al.*, [47] stated that NiTi files are less likely to fracture when used in lower speeds

CONCLUSION

Within the limits of this study the following conditions were drawn:

1. It is recommended not to use HeroShaper and Revo-S more than nine times.
2. Rotary nickel-titanium instruments should be examined prior to instrumentation using any type of magnification to check if there is a sign of deterioration.
3. Regarding the cutting efficiency behavior both systems showed statistically insignificant differences.

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