

IN VITRO EVALUATION OF ROOT CANAL PREPARATION WITH TWO ROTARY INSTRUMENT SYSTEMS – PRO TAPER AND HERO SHAPER

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Abstract

Background and aims. The purpose of this study was to compare several parameters of root canal preparation using two different rotary Nickel-Titanium instruments: Pro-Taper (Dentsply Maillefer; Ballagigues, Switzerland) and Hero-Shaper (Micro Mega, Besancon, France).

Methods. Twelve extracted maxillary premolars were randomly divided into two groups and embedded into a muffle system. All root canals were prepared to size 25 using Pro-Taper or Hero-Shaper rotary instruments. The following parameters were evaluated: root canal form, centering capacity of the instrument, the presence of residual dentinal debris and smear layer on the root canal walls, working time and the occurrence of intraoperative accidents. Statistical analysis was performed using the χ^2 test ($p=0.05$).

Results. The majority of the root canals prepared with Hero Shaper (88.89%) and ProTaper (77.78%) showed a round or oval cross-section postoperatively. Superposition of pre- and postoperative photographs of the cross-sections showed that for the coronal third of the root canals the Hero Shaper performed in a superior manner, while for the apical third better results were obtained with the Pro Taper system. Cleanliness of the root canal walls was investigated under the SEM, in the middle third of the canal, using a five-score system for debris and smear layer. For debris Hero Shaper and Pro Taper rotary systems achieved 66.67% and 50% scores of 1 or 2, respectively. The results for the smear layer were similar: cleaner root canal walls were found after preparation with Hero Shaper (66.67% scores 1, 2), followed by Pro Taper (50%). Mean working time was shorter for Hero Shaper (124s) than for Pro Taper (184s); the difference was not significant.

Conclusions. Within the limits of this study, both systems had almost the same cleaning ability and excellent centering capacity.

Keywords: root canal preparation, rotary systems, scanning electron-microscopy

Background and aims

The most important phase during endodontic treatment is the cleaning and shaping of the root canals. The goal of this phase is to remove the content, disinfect the

root canals and prepare a three-dimensional space for the root canal filling. The mechanical and biological objectives of root canal preparation prompted the necessity of nickel-titanium rotary instruments. The two main characteristics of this alloy are superior elasticity and memory shape [1]. These properties allowed the design of instruments with a taper greater than 2%, which is the ISO standard

Manuscript received: 05.12.2014

Received in revised form: 17.04.2015

Accepted: 05.05.2015

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for stainless steel instruments [1]. Using nickel-titanium rotary instrument systems is currently an important step in modern endodontics, making possible the treatment of more complex cases with fewer procedural errors [2]. A large number of systems are now available on the market. These show similar features but differ in taper, cutting angle, tip design, number of blades and cross section, all directly influencing the flexibility, cutting efficacy and torsion resistance of the instrument [3]. They allow a quicker preparation with less transportation of dentinal debris beyond the apex, a considerable reduction of risks for the apical periodontium, an increased capacity to negotiate curved root canals, and reliable and reproducible results even when used by less experienced practitioners [1,4]. They are also leading to less reduction in working length during root canal flaring compared to stainless steel instruments [5]. Among their properties, such as flexibility, cutting efficacy, torsional resistance [3], the centering ability and maintenance of initial root canal anatomy are the most important [2].

A large number of Ni-Ti instruments are now available on the market. They all show different designs with specific taper, cutting blades direction, tips and specific motions.

Hero Shaper (Micro Mega, Becacon, France) is designed, as the manufacturer claims, with a variable helical angle and an adapted pitch that increases with the taper of the instrument. This design has the purpose to avoid the screwing effect of the instrument.

The Pro Taper system (Dentsply, Switzerland) is designed with a progressive taper, a progressive changing helical angle and balanced pitch thus reducing the threading and improving the debris removal [6].

The aim of this study was to assess the mechanical preparation of root canals in vitro with two rotary instrument systems: Pro Taper (Dentsply Maillefer, Ballagigues, Switzerland) and HeroShaper (Miro Mega, Becanson, France). We analyzed the following parameters: root canal form, centering capacity of the instrument, the presence of residual dentinal debris and smear layer on the root canal walls, working time and the occurrence of intraoperative accidents (loss of working length, fracture of instruments, occurrence of perforations).

Method

The quality of root canal preparation was assessed by the modified Bramante method [7]. This technique allows simultaneous assessment of the amount of debris and smear layer remaining on the root canal walls in longitudinal section, as well as the shape of the root canal in cross-section.

Selection and preparation of teeth

The study was carried out on a total of 12 teeth, maxillary first premolars with fully formed root and closed apex, without apical resorption. Extracted teeth

were kept in 3% paraformaldehyde solution. The selected teeth showing the same mean curvature, were randomly divided into 2 groups of 6 teeth. Preoperatively all teeth were embedded in acrylic resin by using a conformer. The conformer consisted of a metallic cylinder with a base of 3.6 x1.8 cm and 2 pairs of holes with a diameter of 5 and 2 mm respectively. Two pairs of cylindrical pins were inserted into these holes. The pair of pins with a diameter of 5 mm had the role of orientation and the other pair of pins had the role of stabilization. In the center of the base was a metallic support where teeth were fixed with wax in a firm position. The entire inner surface was lubricated, and then the teeth were embedded in acrylic resin 1 mm below the cement-enamel junction. The tip of the orientation pin was placed at the cement-enamel junction. After the setting of the resin the pins were removed by tapping. All teeth were shortened before preparation at the length of 19 mm.

Root canal preparation

First, the cleaning and shaping of the buccal root canals was performed using the rotary instrument systems Hero Shaper and Pro Taper respectively. Working length was set at 18.5 mm. Preparation of root canals was made by crown-down technique at a constant working speed of 300 rev/min.

For the Hero Shaper system the preflaring of the root canal entry was performed with the Endoflare instrument that was active in the coronal 2 mm of the root canal. The coronal 2/3 were prepared with the 6% taper and 0.20 mm diameter instrument. The apical third was prepared with a sequence of two instruments of 4% taper and diameters 0.20 and 0.25 mm respectively.

The Pro Taper system consists of six instruments, three shaping files, used for the preparation of the coronal 2/3 of the root canal and three finishing-files for the preparation of the apical third of the root canal. Enlargement of the root canal orifice was performed with the SX instrument (0.19 mm diameter and 19% taper) that worked on the coronal 1-2 mm from the working length. Subsequently, the root canals were prepared with the S1 instrument (0.17 mm diameter and 11% taper) in 2/3 of the length of the work and later on the entire working length. The following instrument was the S2 (0.20 mm diameter and 11.5% taper) which was used over the whole length in order to prepare the middle third of the root canal. Finishing of the preparation was carried out in the apical third by the use of instruments F1 (diameter 0.20 mm and 7%) and F2 (0.25 mm diameter and 8%) on the entire working length. The irrigating solution used for both groups of teeth was 2.5% sodium hypochlorite in combination with EDTA 15% solution. Irrigation was performed with 2 ml sodium hypochlorite after each instrument used. At the end, the root canals were irrigated with 3 ml of EDTA solution, which was allowed to act for 3 minutes, followed by a lavage with 4 ml saline solution and dried with paper points.

Preparation of cross-sections for SEM examination

In order to assess the shape of the cross sections and the degree of overlapping of pre- and postoperative cross sections, preoperatively the roots were marked for subsequent repositioning and were sectioned horizontally at 3, 6 and 9 mm from the apex with a microtome (Isomet, Plus, Buheler, Lake Bluff, IL) whose disc had a thickness of 0.3 mm. The resulted slices were photographed under standard conditions and examined in the scanning electron microscope (SEM). The segments were then placed back into their original position with the help of the marks and pair of pins. After that, the palatal root canals were prepared as described previously. At the end of the preparation, palatal cross sections were photographed again and the images were superimposed over the original. In this manner, the area of the root canal which remained un-instrumented in the coronal, middle and apical thirds respectively, was evaluated. The form of the preparation was determined after superimposing pre- and postoperative root canal outlines. According to Loushine et al. [8] cross sections were classified into round, oval and irregular. The round and oval are considered clinically acceptable, and the irregular clinically unacceptable.

Sample preparation for the SEM evaluation of dentinal debris and smear layer

In the next stage, the buccal roots were sectioned longitudinally and prepared for the SEM evaluation. Initially the central beam of the SEM had been directed to the center of the object by the SEM operator at 10X magnification. The magnification was then increased to 200X and subsequently to 1000X and the canal wall region appearing on the screen was photographed.

Debris and smear layer were evaluated separately and scored from 1 to 5 using the scoring system introduced by Hülsmann et al. [9,10].

The presence of debris was evaluated from the images at 200X magnification using a scale of 5 scores, as follows:

1. clean root canal wall and only a few small debris particles;
2. a few small agglomerations of debris;
3. many agglomerations of debris covering less than 50% of the root canal wall;
4. more than 50% of the root canal walls were covered with debris;
5. complete or nearly complete root canal wall coverage with debris.

The smear layer was evaluated from the images at 1000X magnification on a scale of the following five scores: [9,10]

1. no smear layer, and all dentinal tubules open;
2. a small amount of smear layer, and some dentinal tubules open;
3. homogenous smear layer covering the root canal wall, and only a few dentinal tubules open;
4. complete root canal wall covered by a homogeneous smear layer, and no open dentinal tubules observed;
5. heavy, homogeneous smear layer covering the complete root canal wall.

The scoring was performed by an independent, trained examinee that could not identify the samples or the instruments used for their preparation.

Statistical analysis

Statistical analysis of results was performed using IBM SPSS 20.0 software (SPSS, Inc., Chicago, IL, USA). All data regarding the followed parameter were analyzed using the χ^2 test and the limit of statistical significance was set at $p < 0.05$.

Results

Evaluation of the root canal form on cross section

The quality of the preparation on the cross section was assessed according to the classification of Loushine [8] that considers round and oval sections as clinically acceptable and the irregular as clinically unacceptable.

In the coronal third the Hero Shaper system recorded a greater number of round and oval sections than the Pro Taper system, the difference being statistically significant ($p = 0.010$) (Table I). In the middle and apical third no statistically significant differences between the two rotary systems were found (Table I). Evaluation of the samples prepared with the Hero Shaper system showed that there were highly statistically significant differences in terms of shape ($p = 0.003$), the number of regular sections being 16 while the number of irregular sections being 2; 14 sections prepared with Pro Taper system presented regular shape, the differences between acceptable and unacceptable sections being only close to the limit of statistical significance ($p = 0.01$).

Evaluation of the centering capacity

The quality of the root canal preparation was also evaluated by assessing the degree of contact between

Table I. Evaluation of palatal root canal form on cross section.

	Coronal 1/3		Middle 1/3		Apical 1/3	
Rotary system	acceptable	unacceptable	acceptable	unacceptable	acceptable	Unacceptable
Pro Taper	4	2	6	0	4	2
Hero Shaper	6	0	6	0	4	2

Table II. Evaluation of the contact area between the pre- and postoperative cross sections of the palatal root canal.

Contact area	Teeth prepared with Pro Taper				Teeth prepared with Hero Shaper			
	Coronal 1/3	Middle 1/3	Apical 1/3	Total	Coronal 1/3	Middle 1/3	Apical 1/3	Total
0-25%	2	2		4	2	2		4
25-50%	2	2	2	6			4	4
50-75%		2	2	4		2	2	4
75-100%	2		2	4	4	2		6

the instruments and the surface of the root canal. The contact surface between the instruments and root canal walls was calculated by overlaying the images of pre- and postoperative cross sections and expressed as a percentage. An overlap of 100% means complete contact between the instrument and the circumference of the canal and a very good centering ability of the instrument.

By evaluating pre- and post-operative overlapping of the cross sections of the palatal root canal, 10 for Hero Shaper and 8 sections for Pro Taper respectively, we found a contact area of more than 50% (Table II). In the coronal third the Pro Taper instruments gave a larger un-instrumented area than the HeroShaper systems (Table II). In the apical third of the root canal the preparation was more uniform with the Pro Taper system, two sections for

Hero Shaper system (Figure 1) and 4 for the Pro Taper (Figure 2) showing values exceeding 50% overlap. Hero Shaper system recorded better results in the coronal third while the Pro Taper system in the apical third of the root canal (Table II).

Evaluation of dentinal debris and smear layer

Regarding the dentinal debris, the data showed a majority of scores 2 and 3 evenly distributed among the two rotary systems. No statistically significant differences were found. (Table III, Figures 3,4).

By evaluating the smear-layer, only two samples showed scores of 1, both samples belonging to the Hero Shaper (16.67%) group (Table III). At this level a large number of open dentinal tubes were present (Figure 5). Otherwise a large number of scores 2 (33.33%) (Figures 5,6)

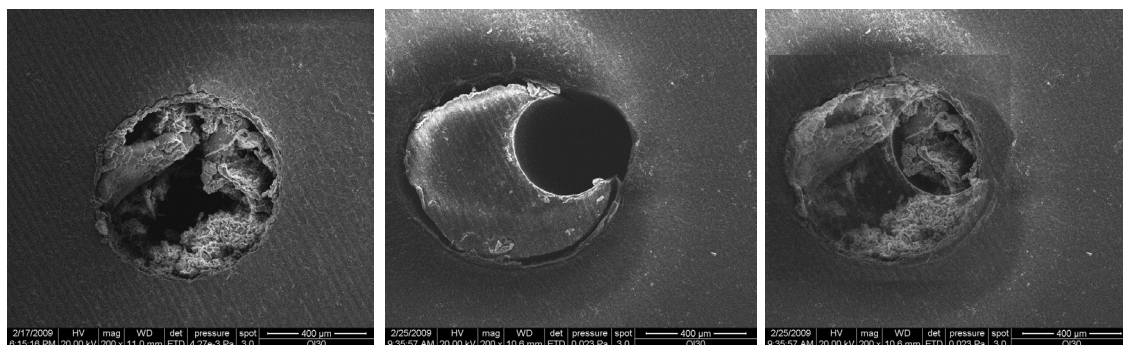


Figure 1. Horizontal section of a tooth prepared with the Hero Shaper system. The left picture shows the preoperative cross section, the middle picture the postoperative cross section and the right picture shows the two overlapped images. The images show how the postoperative circumference includes completely the preoperative circumference, demonstrating a complete instrumentation of the root canal and a high centering ability of the instrument.

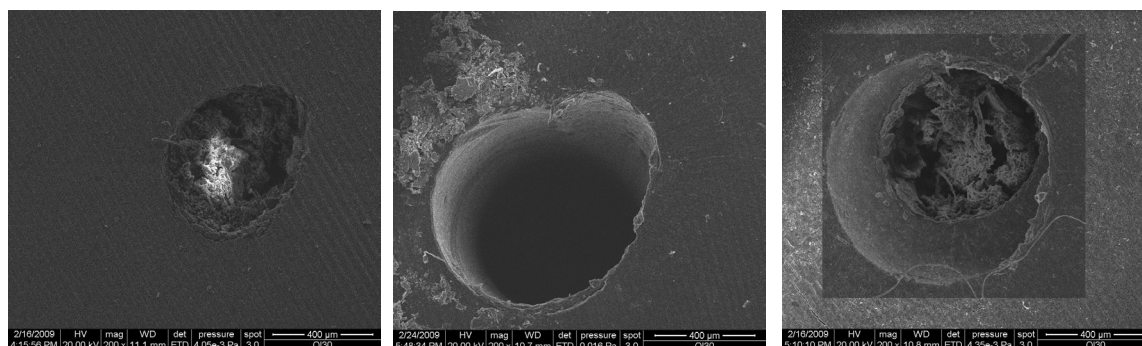


Figure 2. Horizontal section of a tooth prepared with the Pro Taper system. The left picture shows the preoperative cross section, the middle picture the postoperative cross section and the right picture shows the two overlapped images. The images show how the postoperative circumference includes completely the preoperative circumference, demonstrating a complete instrumentation of the root canal and a high centering ability of the instrument.

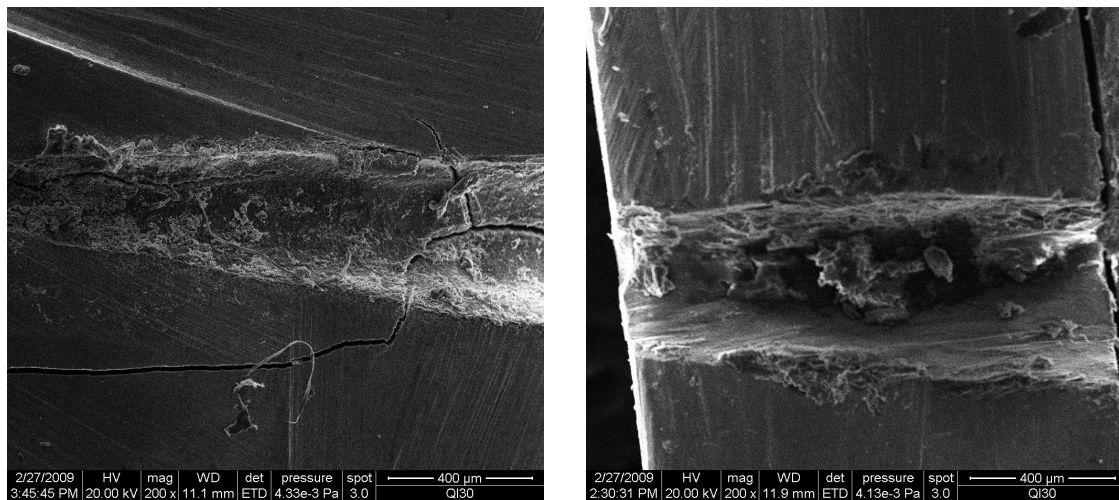


Figure 3. Longitudinal section of the buccal root of a tooth prepared with Hero Shaper. At this magnification the debris remaining on the walls of root canal can be seen. The left picture corresponds to a score 3 while the right picture is assigned a score 2.

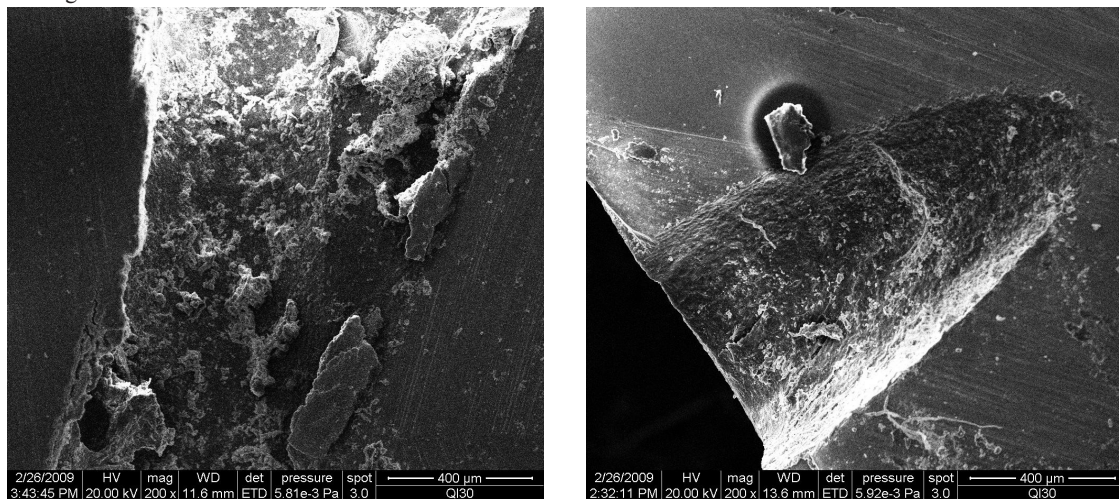


Figure 4. Longitudinal section of the buccal root of a tooth prepared with Pro Taper. At this magnification the debris remaining on the walls of root canal can be seen. The left picture corresponds to a score 3 while the right picture is assigned a score 2.

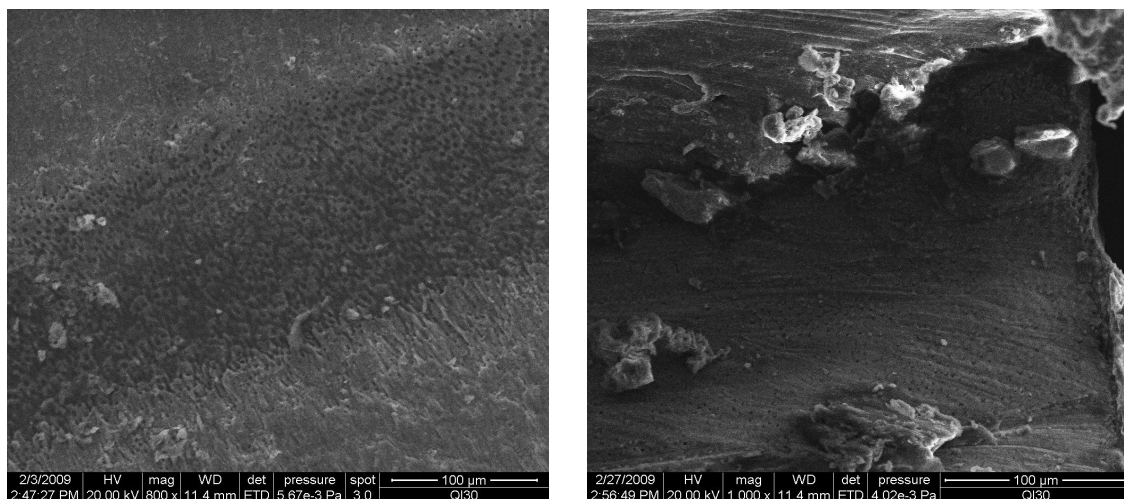


Figure 5. Longitudinal section of the buccal root of a tooth prepared with Hero Shaper. At this magnification the smear layer remaining on the walls of root canal can be seen. The left picture corresponds to a score 1 while the right picture is assigned a score 2.

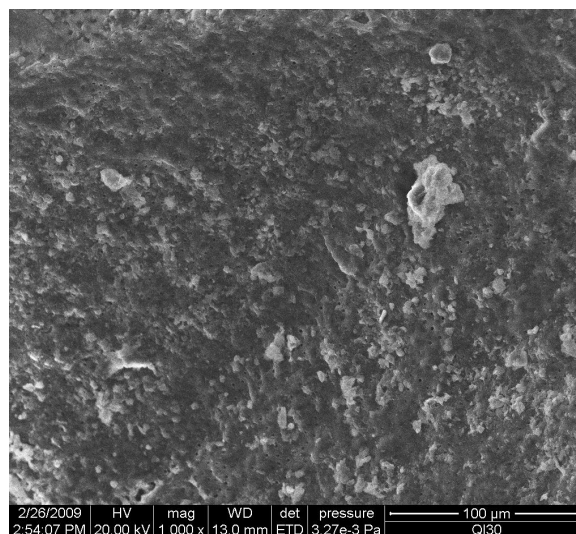
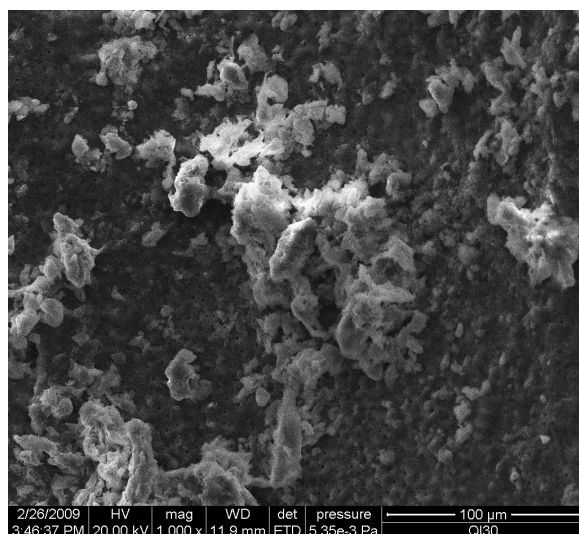


Figure 6. Longitudinal section of the buccal root of a tooth prepared with Pro Taper. At this magnification the smear layer remaining on the walls of root canal can be seen. The left picture corresponds to a score 3 while the right picture is assigned a score 2.

and 3 (33.33%) (Figure 6) were found, evenly distributed between the two systems and two scores 4 (16.67%) in the Pro Taper group (Table III). From a statistical point of view the two rotary systems showed no significant differences.

Table III. Evaluation of the dentinal debris and smear layer in the root canal walls.

Score	Dentinal debris		Smear layer	
	Pro Taper	Hero Shaper	Pro Taper	Hero Shaper
1				2
2	3	4	2	2
3	3	2	2	2
4			2	
5				

Evaluation of intraoperative accidents

During root canal preparation the fracture of one instrument was recorded (Table IV). It was the No. 25 instrument of the Hero Shaper system. Also the loss of working length at one of the prepared sample was observed (Table IV), due to a ledge that occurred through an exaggerated pressure applied with the instrument on the outer wall of the root canal. No perforations were created during the instrumentation of the teeth.

Table IV. Accidents that occurred during root canal preparation.

Accidents	Pro Taper	Hero Shaper
Loss of working length (dentinal plug, ledge)	0	1
Perforation	0	0
Instrument fracture	0	1

Evaluation of preparation time

Regarding the time designated to the preparation of the root canals, no statistically significant differences between the two rotary systems were observed ($p=0.0019$). The Hero Shaper system due to a 4 instruments working

sequence, recorded a shorter working time when compared to the Pro Taper system with a 6 instruments working sequence (Table V).

Table V. Mean time used for root canal preparation.

System	Mean (seconds)
Pro Taper	184
Hero Shaper	124

Discussion

Evaluation of the root canal form on cross section

Assessment of the root canal form was performed by SEM analysis of postoperative cross sections. Regular cross sections evidenced a good centering ability of the instruments. Both systems showed a large number of round and oval sections. The Hero Shaper obtained a higher number of regular cross sections than the Pro Taper system at all three levels. Hero Shaper recorded only two irregular sections in the apical third, while Pro Taper had two irregular sections at the coronal and two in the apical third. These results are supported by other studies that showed a better compliance with the original shape of the root canal cross section for the Hero Shaper system [11,12].

Evaluation of the centering capacity of the two rotary systems

The ability of the two rotary systems to instrument root canals can be appreciated by overlapping pre- and postoperative cross sections. It is considered that a root canal is fully instrumented when the postoperative circumference of the root canal includes completely the original root canal perimeter [7]. After overlapping the pre- and postoperative cross sections of the palatal root, we found that both rotary systems left un-instrumented root canal areas. Although most sections had regular shapes, only a few had a degree

of overlap of 75-100%. Only the Pro Taper system recorded that degree of overlapping in the apical third. This fact can be explained by the variable taper of these instruments along their active portion, having a more pronounced taper in the apical third than the Hero Shaper system instruments. A total of 8 of 18 cross sections for the Pro Taper system and 10 of 18 cross sections for the Hero Shaper system had a contact perimeter greater than 50%. There were no statistically significant differences between the two systems at all three levels, coronal, middle and apical. Hülsmann et al. [13] also found a good centering ability of the Hero 642 system, while other studies reported a good centering capacity of the Hero Shaper system being more evident in the middle third [4,11].

Evaluation of the capacity of the two rotary systems to remove dentinal debris and smear layer

Only the middle third of the buccal root canal was evaluated regarding the removal of debris and smear layer, because this area is the most easily reproduced and analyzed under SEM. Both systems failed to completely remove the debris and smear layer. Regarding the removal of dentinal debris both systems achieved a great number of scores 2, which indicates a good cleaning capacity. Regarding the smear layer, the Hero Shaper system obtained two scores of 1, showing a large number of open dentinal tubules. Otherwise the results showed a large number of scores 2 almost equally distributed to the two systems. The differences were not statistically significant. This is consistent with the results of other studies. Yang et al. [14] assessing the amount of debris and smear layer removed by the same two rotary systems found no statistically significant differences, except in the apical third, where Pro Taper system gave better results. These data confirm our study, which refers only to the middle third where both systems performed similarly. The parameter of surface preparation is not completely clarified clinically as yet; however, taking into account that viable microbes penetrate deep into the dentinal tubules and can persist during root canal preparation, the use of an irrigant is essential. In this study EDTA was used only as irrigating solution at the end of the preparation and not as a gel during preparation. This fact might have decreased the ability of the two systems to remove debris and smear layer. Another factor that influences the capacity of the instruments to remove the dentinal debris and the smear layer is the depth reached by the irrigating solution during root canal irrigation. A larger diameter and a greater taper of the preparation are improving the irrigation. Since the Pro Taper system implies a larger number of instruments, it also increases the amount of irrigation. The deeper diffusion of the irrigating solution is favored also by the greater taper of the Pro Taper system, which is the only system that has a variable taper throughout the length of the active part combined with a negative cutting angle of the helix. These factors explain the better performance of the Pro Taper system in the apical portion and the lack of differences in other regions of the root canal.

Evaluation of preparation time

Some studies calculate the working time as the actual instrumentation time, summing the necessary time for the instruments to work in the canal [15]. In this study we found a statistically significant difference between the time needed by each rotary system for the preparation of the root canals. Hero Shaper showed a shorter working time, probably due to the lower number of instruments belonging to this system.

Evaluation of intraoperative accidents

Procedural errors depend on many factors such as instrument design, the manufacturing process, root canal morphology, pressure applied on the instrument, preparation technique, operator's experience and the number of uses in the root canal [16]. In the process of comparing the Hero Shaper and Pro Taper a single incident was recorded, namely the intraoperative fracture of a single instrument at the end of sample preparation, which belonged to the Hero Shaper system. It should be noted that the number of teeth included in this study was relatively small, thus not being representative for the assessment of procedural errors.

Conclusions

The study shows a good centering ability of both systems, but a lower efficiency in terms of removing the dentinal debris and smear layer. Working time was lower for the Hero Shaper system, but an intraoperative incident occurred with this system.

Nickel-titanium instruments ensure a nearly ideal tapered preparation, allowing the treatment of the most difficult canals; the effectiveness of these instruments reduces the time required for endodontic treatment, providing more comfort for both practitioner and patient.

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