

In vitro evaluation of shape changes in curved artificial root canals prepared with two rotary systems

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ABSTRACT

The aim of this *in vitro* experimental analysis was to compare the changes in canal shape after the use of ProTaper Universal NiTi rotary system, ProDesign system, and a hybrid technique using both systems. A total of seventy-five simulated root canals were prepared and divided into five groups ($n = 15$). For Group 1, the ProTaper Universal System with apical preparation file F3 was used. For Group 2, ProDesign System with apical preparation using file 30/0.2 was used. For Group 3, ProTaper Universal System with apical preparation with file F2 was applied. For Group 4, ProDesign System and ProTaper Universal System with apical preparation with file F2 were applied. For Group 5, ProDesign System and ProTaper Universal System with apical preparation F1 and F2 were used. All instrumentation was performed with

the help of Gates-Glidden drills #5, #4, #3, #2 and #1 according to crow-down preparation. The difference and the quotient the amount of removed resin were analyzed within six millimeters of the canal curvature, measured for both inner and outer walls. The amount of zip and elbow apical formation and mean final shape for each type tested were analyzed. Data were analyzed using parametric tests (ANOVA $p < 0.05$), non-parametric test Kruskal-Wallis ($p < 0.05$) and Chi-square test ($p < 0.05$). When difference, quotient and final mean shape were analyzed, the best preparations were observed in groups 2 and 3. Through qualitative and quantitative analysis, the best preparations were obtained with ProDesign System and ProTaper Universal System with apical preparation file F2.

Keywords: Rotary nickel-titanium instruments. Root canal preparation. Curved artificial root canals.

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Introduction

The main goal of preparing root canals is to provide cleanliness and shape, resulting in a surgically prepared canal with tapered shape, seeking to preserve its original anatomy.¹ This task is considerably difficult to be achieved in curved and narrow root canals, because the stainless steel files tend to straighten the canal curvature, causing aberrations which were described by Weine et al,² as zip, elbow and danger zones.

The nickel-titanium (NiTi) rotary systems were designed to prepare root canals with marked curvatures. The ProDesign (Easy®, Belo Horizonte, Brazil) system is composed of rigid preparation files with high-cutting efficiency to work in the straight part of the canal (0.7 taper #20 and 0.10 taper #35). The apical files have triple helix and good flexibility (0.3 taper #20, 0.5 taper #15, 0.4 taper #22, 0.4 taper #25 and 0.6 taper #20).

ProTaper instruments (Dentsply Maillefer®, Ballaigues, Switzerland) present innovative files concerning taper variation (multitaper) of 3.5% to 19%. The technique which is used for the system is the crow-down technique, and the system has three root canal shaping files (shaping SX, S1 and S2), of greater taper, and three apical preparation files (finishing files) with different diameters: #20 (F1), #25 (F2) and #30 (F3).³ Recently, Dentsply Maillefer® (Ballaigues, Switzerland) made modifications to the system and named it ProTaper Universal.⁴ Therefore, it was the goal of this study to assess the shape modifications of the simulated curved canals after using ProTaper Universal, ProDesign and a hybrid technique combining both rotary systems, as well as the final mean shape for each case was also assessed.

Materials and Methods

A total of 75 Endo-training resin blocks (Dentsply Maillefer®, Ballaigues, Switzerland) with gradual curvatures of about 40 degrees, according to the Schneider⁵ method were used in this study.

Working length

In order to establish the working length (WL), a K-File #10 (Dentsply Maillefer®, Ballaigues, Switzerland) was placed up to the apical end of each simulated root canal to determine patency (P). This was established by using the transparency of the resin blocks. For instrumentation sequence, 1 mm of this measure was reduced to determine the WL.

Photographic Procedures

A total of two references were determined in the resin blocks for image superimposed before and after the preparation of the simulated root canals. India ink (Acrilex®) was inserted in the artificial root canals in order to photograph them before and after preparation. The blocks were placed always in the same position, and photographed using a Nikon D70S camera with 60 mm macro lenses, 0.23 focal length, under fluorescent lighting attached to an LPL light stand, following the same subject-to-camera distance. In order to quantify the transportations produced by the instruments, a measured section was placed along with the resin blocks. After preparation, the blocks were photographed one more time, using the initial position direction and the previously established subject-to-camera distances. The photos were digitalized and edited using (Photoshop 6.0; Adobe, San, Jose) and superimposed in order to analyze possible modifications.

Preparation of simulated root canals

The 75 blocks were randomly divided into five groups with 15 samples each and handled by a single operator, who had previous experience performing both systems. Gates-Glidden drills (Dentsply Maillefer®, Ballaigues, Switzerland) #5, #4, #3, #2, and #1 were used for all groups in the straight segment of the root canal. Endo Easy SI (Easy®, Belo Horizonte, Brazil) electric engine, started the files of both systems. For Protaper Universal Sx, S1, S2 and F3 instruments a speed of 300 rpm and a 3 N.cm torque were applied. Protaper Universal instruments F1 and F2 required 300 rpm speed and 2 N.cm torque. For ProDesign files a chip inside the device was responsible for programming files sequence, speed and torque. At each instrument change canals were abundantly irrigated with 2 ml of distilled water (Pharmakon® Uberaba, Brazil), along with 0.25 ml of bi-distilled glycerin (Farmax®, Brazil), in order to lubricate the canal and make the instrumentation easier in each block. A #10 instrument was taken up to the patency to prevent resin residues from accumulating. The blocks with artificial root canals were fixed into a mini vice (Western®) for easier handling. A dark-colored adhesive tape was placed to cover the preparation, simulating the clinical condition.

Group 1 (n=15) — preparation with (NiTi) ProTaper Universal:

- » File SX, working before curvature.
- » Gates-Glidden: 5, 4, 3, 2 and 1.
- » Files S1, S2, F1, F2 and F3 up to WL.

Group 2 (n=15) — preparation with NiTi ProDesign:

- » Black (20/07) and green (35/10) files before curvature.
- » Gates-Glidden: 5, 4, 3, 2 and 1.
- » Files #1 20/0.3 (white), #2 15/0.5 (yellow), #3 22/04 (red), #4 25/0.4 (blue), #5 20/0.6 (green) and #6 20/0.7 (black) in the WL.
- » Apical preparation #30/02 (blue).

Group 3 (n=15) — preparation with NiTi ProTaper Universal:

- » File SX, working before curvature.
- » Gates-Glidden: 5, 4, 3, 2 and 1.
- » Files S1, S2, F1 and F2 up to WL.

Group 4 (n=15) — preparation with NiTi ProTaper Universal and ProDesign hybrid technique 1:

- » ProDesign Black (20/07) and Green (35/10) files before curvature.
- » Gates-Glidden: 5, 4, 3, 2 and 1.
- » ProDesign files #1 20/0.3 (white), #2 15/0.5 (yellow), #3 22/04 (red), #4 25/0.4 (blue), #5 20/0.6 (green) in the WL.
- » F2 ProTaper Universal in the WL.

Group 5 (n=15) — preparation with (NiTi) ProTaper Universal and ProDesign hybrid technique 2:

- » ProDesign (Easy®) black (20/07) and green (35/10) files before curvature.
- » Gates-Glidden: 5, 4, 3, 2 and 1.
- » ProDesign (Easy®) files #1 20/0.3 (white), #2 15/0.5 (yellow), #3 22/04 (red), #4 25/0.4 (blue), #5 20/0.6 (green) in the WL.
- » F1 and F2 ProTaper Universal (Dentsply-Maillefer®) in the WL.

Evaluation methods

The superimposed images were increased and evaluated with Image Tool 3.0, which measures distances, angles and areas of the images. It was initially calibrated

in millimeters, as a measure unit, with the measured sections placed in the blocks as reference point. In the distance icon, each millimeter was marked until it reached a total of 6 millimeters before the apical end of the simulated root canal, coinciding with the end of the curvature (Fig 1). The amount of material removed was measured in each millimeter of the curved segment (6 mm) both inside and outside, according to Uzun et al⁶ (Fig 2). To calculate the difference, the following was defined:

$$D (\text{difference}) = D_o (\text{outer resin removed}) - D_i (\text{inner resin removed})$$

The positive result meant the prevalence of outer and the negative result meant prevalence of inner resin removed. The closer has come to zero, the more balanced

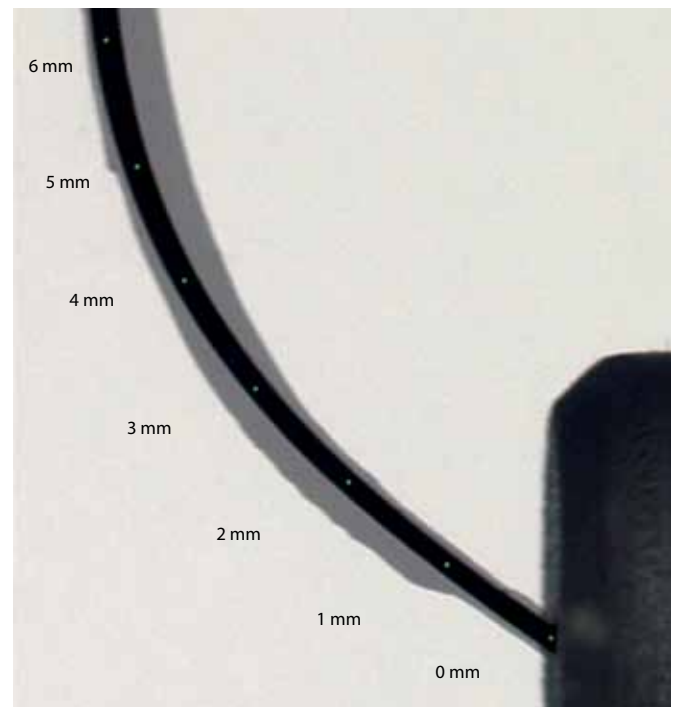


Figure 1. Values evaluated in this study.

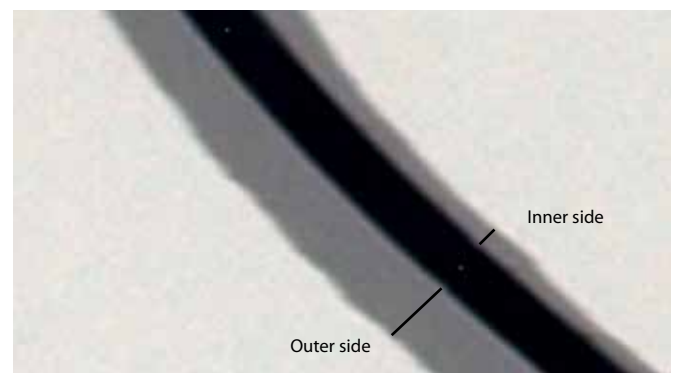


Figure 2. Measuring of removed material, inner and outer sides, at each level.

the preparation was, the further, positive or negative, the greater transportation, according to Hata et al.⁷

The quotient between inner and outer resin removed was calculated. The highest value was placed in the numerator and the lowest in the denominator. The most balanced preparation was that which was closer to 1. Aydin et al⁸ indicate this systematic evaluation, however they place the lowest number in the numerator and the highest in the denominator. The superimposed were analyzed by two experienced raters, Endodontics Masters, who did not know to which group the preparation belonged. A “masking” technique was used to verify the occurrence of zip and elbow apical formation. The reference figures were revealed by Thompson and Dummer.⁹ The removed resin means were used to generate a final mean of preparation for each group.

Results

Normality tests were carried to determine differences. The adoption of non-parametric Kruskal-Wallis test was applied for levels 1, 2, 4, 5 and 6 mm, whereas the

ANOVA parametric test with Tukey's test (Table 1) was applied for level 3 mm.

We can observe through the mean values that outer removed resin prevailed for all groups up to the third millimeter. The remaining millimeters had greater inner curvature.

Significant differences were observed for group 1 in levels 3, 4 and 5. At levels 5 and 6, a significant inner material removed was observed for group 1 and 5.

Normality tests were carried for quotients. Kruskal-Wallis non-parametric test was adopted for levels 1, 2, 4, 5 and 6 mm and ANOVA parametric test with Tukey's test was applied for level 3 mm (Table 2). Comparisons were made at each level.

We can observe values which are far from 1 for group 1 in the three apical millimeters, except for the third millimeters. In the three remaining millimeters, we can observe more discrepant values for groups 1, 4 and 5.

Based on inner and outer material removal at all levels, a final mean shape outline was made along with an example of the transference of means to Image Tool (Fig 3).

Table 1. Statistical Inference, for compared differences at each level.

Levels/ Groups	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
Group 1	0.0880 ^A	0.1887 ^A	0.1053 ^{Ab}	-0.1213 ^A	-0.2813 ^A	-0.2540 ^{Ab}
Group 2	0.0853 ^A	0.0840 ^B	0.0020 ^C	-0.1393 ^A	-0.1913 ^B	-0.1347 ^{Cb}
Group 3	0.0120 ^B	0.0713 ^{Cb}	0.0687 ^B	-0.0387 ^B	-0.1887 ^B	-0.1933 ^B
Group 4	0.0007 ^B	0.1313 ^{Ab}	0.1220 ^A	-0.0200 ^B	-0.2080 ^B	-0.2640 ^A
Group 5	0.0767 ^A	0.1253 ^{Ab}	0.0760 ^B	-0.0760 ^A	-0.2433 ^A	-0.3127 ^A

Capital letters different in columns indicate significant differences.

Table 2. Statistical Inference, for quotients, compared at each level.

Levels/Groups	1 mm	2 mm	3 mm	4 mm	5 mm	6 mm
Group 1	5.5647 ^A	4.1117 ^A	2.1205 ^{Ab}	5.3540 ^A	5.3539 ^A	4.0819 ^{Bc}
Group 2	2.5853 ^B	2.4453 ^B	1.3703 ^C	2.7449 ^{Ab}	3.7659 ^B	2.4744 ^C
Group 3	1.9021 ^B	2.4570 ^B	1.9229 ^{Ac}	1.5195 ^{Cd}	3.8589 ^B	3.3282 ^C
Group 4	1.9317 ^B	2.9786 ^{Ba}	2.4726 ^A	1.2185 ^{Dc}	4.7617 ^{Ab}	7.2291 ^A
Group 5	2.0114 ^B	2.3212 ^B	1.6606 ^{Bc}	1.6145 ^{Bd}	4.8421 ^{Ab}	8.5153 ^A

Capital letters different in columns indicate significant differences.

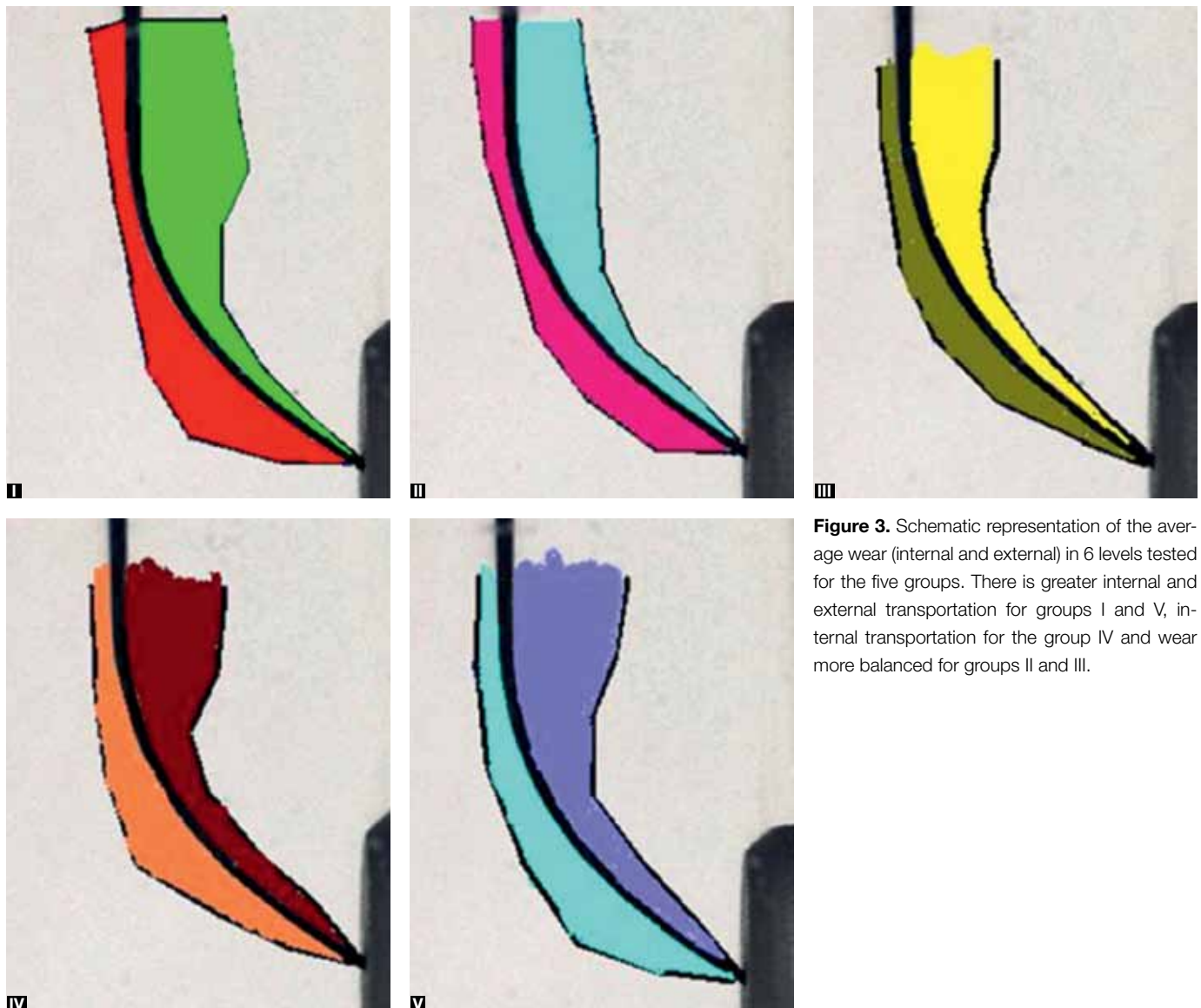


Figure 3. Schematic representation of the average wear (internal and external) in 6 levels tested for the five groups. There is greater internal and external transportation for groups I and V, internal transportation for the group IV and wear more balanced for groups II and III.

In order to obtain inter-rater agreement, Kappa test was applied results value = 1 with very good inter-rated agreement.

The occurrence of zip and elbow apical formation was also observed according to Table 3. Chi-square test was applied in order to verify the significance between comparisons. No significant differences were observed, but the amount of deformations in the ProTaper Universal, group 1, was much higher than those of the other analyzed groups.

It was observed that, when there was zip formation, mostly for group 1, the values for the difference between inner and outer resin removal, at 2 mm, were 0.25 and the quotient was 4. For group 2, the

difference was 0.15 and the quotient was 4. For group 3, the difference was 0.21 and the quotient was 6. For group 4, the difference was 0.23 and the quotients were 5 and 6. For group 5, the difference was 0.16 and the quotient was 3.

Discussion

Just as observed in previous studies, the artificial root canal methodology was introduced by Weine et al.² in order to analyze the preparation procedures of root canals. The use of simulated curved root canals offers a standardized condition of curvature angle and length, as well as the analysis of the previous and final shapes of preparation.⁷⁻¹⁰

Table 3. Formation of zip and elbow.

Formation	ProTaper F3	ProDesign	ProTaper F 2	ProDesign+F2	ProDesign F1+F2
Zip	5	1	1	1	1
Elbow	5	1	1	1	1

Observed more aberration for group 1.

We can observe in this *in vitro* study that, through the values of the material removal means and of the difference between inner and outer, there was greater outer removal in the three apical millimeters of the curvature and, there was greater inner material removal to all groups in the three cervical millimeters of the curvature (Table 1). These results were supported by other studies.^{11,12,13} For the 2 mm level, greater transportations are observed for groups 1, 4 and 5, significant in comparison with the other tested groups. At this level, we observed that greater outer material removal and values distant from zero induced the occurrence of zip formation. For the 5 mm level, the greatest material removals were for groups 1 and 5, which were significant in comparison with the other tested groups, showing a strong tendency for perforation in inner curvature. For the 6 mm level, groups 1, 4 and 5 presented significant material removals, in comparison with the other groups, confirming the tendency of perforation. Better preparations are observed for groups 2 and 3 in the prevention of zip and perforation in inner curvature. Preparations with greater potential for aberrations formation are found in groups 1, 4 and 5 (Fig 3).

Centering ability was quantified by obtaining the quotient between the highest and the lowest value. Results closer to 1 mean that the system is better at balancing inner and outer material removal. Except for the 6 mm level, we observed a longer distance from 1 for the ProTaper Universal system up to F3 apical file (group 1). At this level, there was a greater distance for groups 4 and 5. For the 1 mm level, there was a significant difference for groups 1 and 2. It is possible to observe that the value for group 1 is twice the value of group 2, showing reduced balance. For the 2 mm level, we can see the significance of group 1 in comparison with the other groups. At 3 mm level, the significant preparations with longer distance from 1 were for groups 1 and 4. For 4 mm level, the least centered group was group 1. For 5 mm level,

there was also a significant unbalanced material removal for group 1. At 6 mm level, there was greater significant level for groups 4 and 5. Therefore, ProTaper Universal system up to F3 instrument was that which provided more irregular and less centered preparations. We can observe values closer to 1 for the other groups, except for 5 mm and 6 mm levels for groups 4 and 5, which were maintaining preparation regularity (Table 2). ProTaper systems up to F2 instrument and ProDesign showed more centered preparations at all levels.

Peters et al¹⁴ (through the use of human teeth and CT scan), Iqbal et al¹⁵ and Veltri et al¹⁶ (through radiographic method), and Guelow et al¹⁷ (through Bramante et al¹⁸ methodology) showed preparations with low incidence of apical transportation for ProTaper system up to F3 file. A similar result was obtained by Yun and Kim¹⁹ in simulated root canals and by Ankrum et al²⁰ in extracted molars, showing inner removed resin for the furcation area whereas Schäfer and Vlassis;¹¹ Yoshimine et al;¹² Uzun et al²¹ conducted research using simulated root canals showing that ProTaper system provides a high occurrence of zips when taken up to F3 file. Schäfer and Vlassis²² in a similar study, but using human teeth and radiographic method before and after preparations, verified similar results for ProTaper system.

Loizides et al;²³ Zhang et al;¹⁰ recommend a hybrid technique using ProTaper and Hero (Micro-Mega®) and show better results in “S”-shaped simulated root canals. They also observed better taper of preparations, due to the taper of ProTaper files F1 (#20 diameter tip and 0.07 taper initially) and F2 (#25 diameter tip and 0.08 taper initially). Setzer et al.²⁴ observed no differences in the combination of different systems in increasing the level of apical transport. It was proved that group 4, with hybrid technique, presented regular shapes in the apical region and greater taper than group 2 ProDesign using the apical preparation #30/0.2. These conditions favor cleanliness

and filling quality. Special attention must be paid to displacement, at levels 5 and 6 mm, inner wall, to groups 1, 4 and 5, with tendency to form perforation in inner curved.

Visual analysis showed high incidence of zip and elbow formation for ProTaper Universal when using F3 file (group 1). This result is similar to those observed in other studies^{8,11,12,17,22,25,26}. Contrarily, Guelso et al¹⁷ showed a low incidence of irregularities for ProTaper.

It is important to be careful when transferring these results to patient preparation. Despite the countless advantages of artificial root canals, they do not simulate their complicated internal anatomy, mainly the flattening of roots in curved root canals. Cleanness is

one of the factors which should be considered, since it cannot be observed in artificial root canals because they are made of resin, whereas human teeth root canals present such a complex anatomy.

Conclusion

In conclusion, based on the adopted methodology used and on the obtained results, we can conclude that: through the results of difference and quotient, a greater distance of reference values (0 to 1) was observed for groups 1, 4 and 5. A larger number of zip and elbow formation was present in group 1. The removal resin means showed more regular mean configurations for groups 2 and 3.

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