Evaluation of the lengths and angles of the tips of rotatory files in root canal preparations

Avaliação do comprimento e do ângulo das pontas de instrumentos rotatórios no preparo de canais radiculares

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Abstract

Purpose: To detect changes in the angles and lengths of the tips of rotary nickel-titanium files after use.

Methods: Forty human teeth were prepared with eight sets of rotary ProTaper® Universal nickel-titanium files with a length of 25 mm and rotation of 350 rpm. The files were evaluated in a scanning electron microscope (SEM) at three different times: Group A – before use; Group B – after using each file in the preparation of three molars; and Group C – after using each file in the preparation of five molars. The length of the tip was determined by measuring the length of a straight line drawn parallel to the file axis, from the apex of the tip to its posterior border. The SEM software provided the angle measurements. Data were analyzed by using paired t-tests and Wilcoxon tests.

Results: There were no differences between the groups for the S1 file. There was a decrease in length when the F2 file was used to prepare three and five molars, whereas decreases in length were seen when F5 files were used to prepare three or five molars.

Conclusion: The results suggest that the tips of the rotary instruments showed significant changes in length and angle even with relatively low use.

Key words: Dental files; Endodontics; molar

Resumo

Objetivo: Comparar as alterações no ângulo e comprimento da ponta dos alargadores rotatórios após sua utilização em relação à sua configuração original.

Metodologia: Quarenta dentes humanos foram preparados com instrumentos rotatórios de níquel-titânio ProTaper® Universal, 25 mm e rotação de 350 rpm. Os alargadores foram avaliados em um microscópio eletrônico de varredura (SEM) em três grupos: Grupo A – antes do uso dos instrumentos; Grupo B – após o uso de cada instrumento na preparação de três molares; e Grupo C – após o uso de cada instrumento na preparação de cinco molares. O comprimento da ponta foi determinado medindo o comprimento de uma linha reta traçado paralelamente ao eixo do instrumento, desde o vértice da ponta até seu limite posterior. O software do SEM forneceu a medição do ângulo delimitado por dois segmentos de retas. Os dados foram analisados estatisticamente por teste t pareado teste de Wilcoxon.

Resultados: Para o instrumento S1 não houve diferença entre os grupos. Para o alargador F2 houve uma diminuição no comprimento entre os grupos B e C e uma diferença entre os grupos A com B e C foi observada no alargador F5.

Conclusão: Os resultados sugerem que a ponta dos instrumentos rotatórios sofreu alterações significativas de comprimento e ângulo com relativo pouco uso.

Palavras chaves: Limas endodônticas; Endodontia; molar

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Introduction

Nickel-titanium alloys have been introduced for the manufacture of endodontic instruments with the aim of replacing the stiffness, *i.e.*, the modulus of elasticity, of stainless steel materials (1-3). These instruments are two to three times more flexible than stainless steel files (4). The alloy used for manufacturing endodontic instruments consists of approximately 55% nickel and 45% titanium, and it is generically called 55-Nitinol (5).

Several instrument systems were introduced because of the growing popularity of hand files and nickel titanium rotatory files in endodontic practice, with various features such as design, tip sizing, pitch, cross-sectional helix angle and taper (6,7). In 2006, Dentsply Maillefer introduced the ProTaper® Universal System with modified characteristics of the original ProTaper®. The changes included the new rounded tip and removal of the angle of transition to reduce canal transportation and provide greater security. Minor changes were made in the S2 instrument to improve the balance between S1, S2, and F1. The cross-sectional blades of the F2 and F3 instruments were changed to a triangular concave shape with a shallow U-shaped groove at the sides to make them more flexible and homogeneous. The cross-section of the F3 instrument also became lighter with grooves to reduce the abrasion of the metal section (8-10). New files, F4 and F5, were introduced to accomplish a non-brushing action inside the root canals (10,11).

However, these endodontic instruments may present defects on their surface such as slots, microcavities and a pronounced variation between the actual and nominal dimensions originating in the manufacturing process. Due to this lack of manufacturing precision in the shape and size of these instruments, iatrogenic problems may occur in the final configuration of the endodontic treatment of root canals (3,10). Therefore, standardization has become increasingly important due to demands for safety, quality and uniformity in the production of materials (10). The aim of this study was to detect possible changes in the angle and in the lengths of the tips of the files resulting from their use in preparing root canals.

Material and methods

The study protocol was approved by the Federal University of Espiríto Santo (UFES) Ethical Committee and all the procedures followed were in accordance with Resolution 196/96 of Health State Department, Brazil. Forty human maxillary and mandibular molars, extracted with completely formed apices, were obtained from the Human Teeth Bank in the School of Dentistry of the University of São Paulo (FOUSP), São Paulo, Brazil. The teeth were prepared with the aid of eight sets of the rotary nickel-titanium ProTaper® Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland) that were 25 mm in length, and were driven by an electric motor with a constant rotation of 350 rpm. The following ProTaper® Universal files were tested: SX, S1, S2, F1, F2, F3, F4 and F5. According to the manufacturer's recommendations, the "crown-down" technique was used. Sixty-four instruments were evaluated in a scanning electron microscope (SEM, Superscan SS-550, Shimadzu, Japan) before and after their use to measure the lengths and the angles of their tips. Observations were made during three different times and grouped as follows: Group A – before the use of the instruments; Group B – after using each instrument in the preparation of three molar teeth, making a total of twenty four molars, and Group C – after using each instrument in the preparation of five molars each, for a total of 16 molar teeth.

All canals were prepared by the same operator who had been previously calibrated. The time taken for the preparation of root canals by each instrument was recorded. The use of a nickel-titanium ProTaper® Universal rotary system kit (Dentsply Maillefer, Ballaigues, Switzerland) (SX, S1, S2, F1, F2, F3, F4 and F5) has been reported to be safe in preventing the fracture of these instruments when used to prepare up to five molar teeth.

The analysis of these surfaces was performed using scanning electron microscopy (SEM, Superscan SS-550, Shimadzu, Japan) by measuring the angles and the lengths of the tips at the Laboratory of Carbonaceous Materials and Ceramic of the Department of Physics, Federal University of Espirito Santo (CCE-UFES), according to Specification No. 101 of ANSI/ADA (12).

All files of the ProTaper® Universal System (Dentsply Maillefer, Ballaigues, Switzerland) were disinfected to remove the surface residues originating from the manufacturing process and instrumentation by brushing with enzymatic detergent, and sterilized in an autoclave in 200 mL of distilled water in a complete cycle for 30 minutes at 121 °C and 15 psi.

The instruments were attached to the SEM specimen holder with carbon double-sided tape, and the instrument cable slot was positioned upward to standardize the measurements. The long axis of each file was placed parallel to a horizontal reference. To measure the tip length and angle, the image of the tip of the instrument was positioned in the center of the screen at a magnification of 300X to 400X. The tip length was determined by measuring the length of a straight line drawn parallel to the axis of the instrument, from the apex to the posterior border of the tip, according to ISO 3630-1 (Fig. 1) (12,13). The value was recorded in nanometers (nm) and then converted into millimeters (mm). The posterior limit of the tip of the instrument was delimited by a line perpendicular to the long axis of the instrument, which was tangential to the initial limit of the first helical channel of the active part. The SEM software provided the measurements of the angle enclosed by the two line segments (Fig. 2) (12).

Data analyses included descriptive statistics, Wilcoxon tests for comparison of the length measures, and paired t-test for the comparison of angle measures. The dimensional values were compared with references from the literature and Specification no. 101 ANSI/ADA (12) at a significance level of 5%.

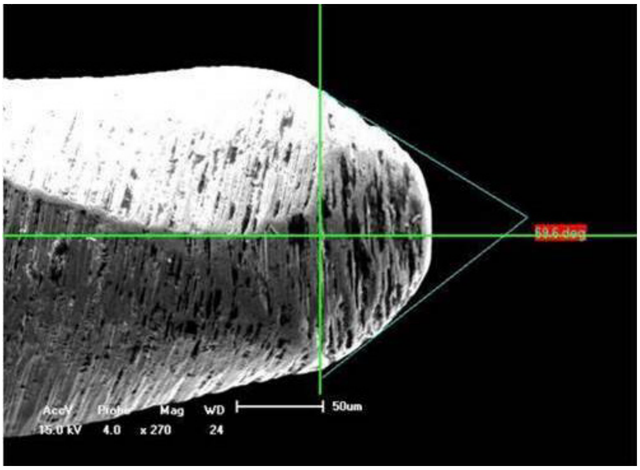

Fig. 1. SEM image of the tip angle geometry of an F2 ProTaper Universal instrument.

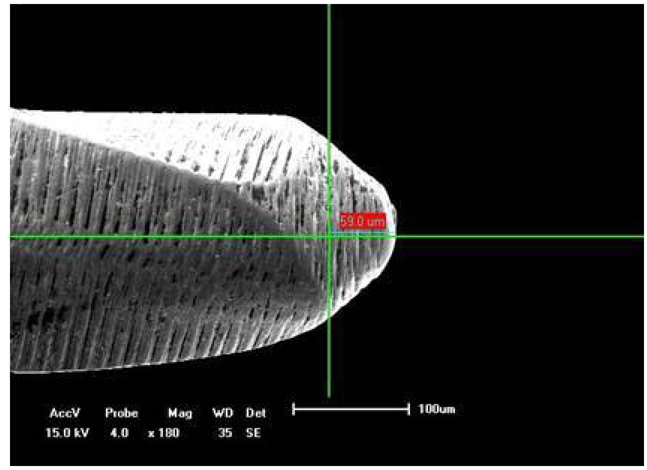

Fig. 2. SEM image of the length of the tip of an F2 ProTaper Universal instrument.

Results

Table 1 shows the descriptive statistical analysis of the angles of the tips measured with the help of the instruments. Table 2 presents the comparisons of tip angle measures between groups (Group A × Group B; Group B × Group C; Group A × Group C). There was an increase in the tip angles at all times ($P<0.05$).

Table 3 shows the descriptive statistical analysis of the lengths of the tips (in mm) measured with the help of the instruments. The data were asymmetric, as shown by differences between the mean and median values. Table 4 shows the results of the Wilcoxon tests for the comparisons of the tip lengths between groups (Group A × Group B; Group B × Group C; Group A × Group C). Some groups showed significant differences in tip angles ($P<0.05$).

Table 1. Descriptive statistics of the angle (in degrees) of the tips from different experimental groups (n=8).

Files	Groups	Minimum	Maximum	Median	Mean	Standard deviation
SX	A	41.000	56.000	46.000	47.125	4.853
	B	42.000	57.000	48.000	48.813	4.735
	C	43.000	58.500	49.000	49.813	5.000
S1	A	40.000	47.000	41.500	42.250	2.605
	B	41.000	48.000	43.500	43.813	2.419
	C	42.500	49.500	44.750	45.125	2.446
S2	A	42.000	50.000	45.000	45.375	3.068
	B	42.000	52.000	46.000	46.688	3.535
	C	43.000	53.000	47.250	47.938	3.438
F1	A	93.000	124.000	110.000	109.750	9.377
	B	95.000	125.000	112.500	111.500	9.040
	C	97.000	127.000	113.750	112.813	9.134
F2	A	87.000	105.000	98.500	97.500	6.234
	B	89.000	107.000	99.500	99.250	6.065
	C	90.000	109.000	101.000	100.500	6.425
F3	A	51.000	97.000	84.500	79.375	14.918
	B	52.000	97.800	86.500	80.550	15.054
	C	53.500	99.000	86.750	81.688	14.856
F4	A	100.000	109.000	103.000	103.625	2.774
	B	102.000	110.000	105.000	105.375	2.774
	C	102.500	111.000	105.750	106.500	2.752
F5	A	91.000	105.000	99.000	99.000	4.870
	B	92.000	105.000	99.500	99.750	4.773
	C	93.500	107.000	100.750	100.937	4.686

Table 2. Results of the paired t-test for comparisons of angle measures between groups.

Files	*P*-value*		
	Group A × Group B	Group B × Group C	Group A × Group C
SX	0.000	0.000	0.000
S1	0.000	0.000	0.000
S2	0.015	0.000	0.001
F1	0.000	0.002	0.000
F2	0.000	0.001	0.000
F3	0.000	0.001	0.000
F4	0.001	0.000	0.000
F5	0.048	0.002	0.000

* all comparisons are statistically significant at the significance level of 0.05

Table 3. Descriptive statistics of the length (in mm) of the tips from different experimental groups (n=8).

Files	Groups	Minimum	Maximum	Median	Mean	Standard deviation
SX	A	0.060	0.107	0.087	0.086	0.015
	B	0.054	0.105	0.078	0.077	0.016
	C	0.053	0.102	0.075	0.075	0.015
S1	A	0.071	0.128	0.114	0.103	0.024
	B	0.064	0.119	0.107	0.098	0.023
	C	0.061	0.116	0.108	0.096	0.024
S2	A	0.079	0.128	0.108	0.108	0.018
	B	0.069	0.120	0.097	0.094	0.019
	C	0.064	0.118	0.096	0.090	0.019
F1	A	0.030	0.057	0.039	0.039	0.008
	B	0.027	0.052	0.030	0.033	0.009
	C	0.025	0.050	0.028	0.031	0.009
F2	A	0.055	0.092	0.075	0.072	0.013
	B	0.050	0.090	0.070	0.069	0.012
	C	0.048	0.087	0.066	0.066	0.012
F3	A	0.060	0.120	0.079	0.085	0.022
	B	0.011	0.099	0.061	0.056	0.029
	C	0.014	0.740	0.082	0.207	0.269
F4	A	0.063	0.080	0.069	0.070	0.006
	B	0.058	0.068	0.066	0.064	0.003
	C	0.055	0.067	0.064	0.063	0.004
F5	A	0.065	0.102	0.085	0.087	0.012
	B	0.060	0.092	0.079	0.079	0.011
	C	0.057	0.090	0.079	0.078	0.010

Table 4. Results of the Wilcoxon test for comparisons of tip length measures between groups.

Files	*P*-value*		
	Group A × Group B	Group B × Group C	Group A × Group C
SX	0.012	0.011	0.012
S1	0.159	0.156	0.161
S2	0.018	0.017	0.012
F1	0.012	0.010	0.011
F2	0.122	0.011	0.123
F3	0.011	0.671	0.674
F4	0.012	0.017	0.012
F5	0.012	0.157	0.012

* *P*-value in bold is statistically significant at the significance level of 0.05.

Table 5. Descriptive statistics of the instrumentation time (in seconds).

Files	Median	Mean	Standard deviation
Sx	72.00	72.50	6.63
S1	72.50	73.10	8.93
S2	75.00	75.55	8.67
F1	73.00	72.35	7.51
F2	74.00	73.40	8.11
F3	73.00	74.30	5.91
F4	75.00	75.15	8.27
F5	76.00	74.20	8.82

Differences were observed among the instruments, Sx, S2, F1 and F4, but there was always a decrease in length. There were no differences between the groups for the S1 instrument. There was a decrease in length between B and C groups for the F2 file and between A and B groups for the F3 file. For the F5 file, there was a decrease in length from A to B groups, but not between B and C groups. Table 5 shows the instrumentation time for all groups.

Discussion

Specific design parameters of the tip, such as the angle, length, cross-section and geometry can significantly influence the clinical efficacy of endodontic instruments (11). The tip angle is formed by the contour of the instrument tip and its vertex. The tip length is the distance between the vertex and the base. The tip angle is related to its length, *i.e.*, the lower the angle of the tip of the file, the greater is its length (14). According to the manufacturer, all ProTaper Universal instruments recently underwent a modification of their tip orientation and geometry.

The results of the present study show that the mean values of the lengths of the tips ranged from 0.075 to 0.108 mm for Sx, S1 and S2 shaping instruments, and from 0.031 to 0.027 mm for F1, F2, F3, F4, and F5 finishing instruments. The comparison of A, B, and C groups reveals a decrease in the tip length for all groups of the shaping (Sx and S2) and finishing instruments (F1 and F4).

Miserendino et al. (15) studied the dimensional aspects of seven types of instrument tips as they influence the cutting efficiency. Tip length and angle were two of the dimensional variables analyzed according to Specification #28 ANSI/ADA (12). Tips of files with lengths lower than 0.5 mm and 1.0 to 1.5 mm had better cutting efficiency. Tip angles with values between 60° and 69° showed better performance in atresic root canals than the angles between 40° and 49°. In root canals with a wider diameter, the tips having smaller angles were the most efficient.

A previous comparison of dimensional and geometric tip changes was reported by Câmara et al. for ProTaper and ProTaper® Universal instruments (17); their mean values for initial tip lengths were greater than the ones reported in the present study. The use of files from different lots in this study may have accounted for some of the confounding effects on the outcome values. The angles of the tips for S1 and S2 ProTaper® Universal files decreased when compared with the ProTaper system, but they increased for the finishing instruments, F1, F2 and F3. The mean values for the tip lengths ranged from 0.094 to 0.117 mm for the S1 and S2 shaping files, and from 0.082 to 0.130 mm for the F1, F2, and F3 finishing files.

Some studies (11,17) reported that specific features such as the design of the tip, tip angle, length, cross-section and tip geometry may significantly affect the penetration, cutting and shaping by endodontic instruments inside the root canal. For ProTaper® Universal instruments, the reduction of the tip angle from 66° to 39° is said to favor the centralization of the files inside the root canal walls, thus reducing the risk of transportation. However, in the case of new finishing files, the increase in tip angle from 66° to 95° would lead to an opposite effect.

In the present study, the tip angle values in all groups of ProTaper® Universal shaping files ranged from 40° to 50°, and from 87° to 124° in group A of the finishing files. There was an increase in tip angle of all groups of ProTaper® Universal instruments with use, which may provide a safer cutting at the apical third, possibly reducing the risk of fracture and deviation of these files inside the root canal.

Conclusions

Within the limitations of this study, the results suggest that the tips of rotary instruments showed significant changes in length and angle, even with relatively low use. There was no fracture of shaping and finishing ProTaper® Universal files during this experiment.

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