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Analysis of preparation time, wear, transportation and centering ability of Flexofile and Prodesign® M manual instruments in curved root canals preparation

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ABSTRACT

OBJECTIVE: This *in vitro* study aimed to evaluate preparation time, wear, transportation, and centering ability of two manual instruments, namely Flexofile and Prodesign® M, in curved root canal preparation.

METHODS: Forty mesiobuccal and mesiolingual canals of the first or second lower molars were used, with standard length, degree, and radius of curvature among all samples. The canals were randomly divided into two experimental groups (n=20) according to the preparation instrument analyzed. The preparations were performed by a single operator. The preparation time was controlled, and the values obtained were analyzed. To verify the wear, transportation, and centering ability of the instruments, tomography images were taken before and after instrumentation. The analysis was performed using axial sections previously identified at 2 mm below the tooth apex with the aid of the OnDemand3D™ Dental program. For statistical analysis, Student's *t*-test was used, with a significance level of 5%.

RESULTS: The time required to prepare root canals was lesser using Prodesign® M instruments than using Flexofile instruments. Regarding tooth wear, no statistical difference was observed. However, Flexofile instruments had a low centralization capacity in root canal preparation, and there is a trend of transport in the mesial direction of the root canal.

CONCLUSION: Although no statistical difference was observed between the two instruments, the Prodesign® M instruments had a better cantering ability in the preparation. As well as, the time required to prepare the root canals was inferior when Prodesign® M was used.

Keywords: endodontics; dental instruments; root canal preparation; cone-beam computed tomography.

Análise do tempo de execução, desgaste e centralização no preparo de canais radiculares curvos realizados com instrumentos manuais Flexofile e Prodesign® M

RESUMO

OBJETIVO: Este estudo tem como objetivo avaliar, *in vitro*, o tempo de execução, desgaste, transporte e a centricidade no preparo de canais radiculares curvos com dois tipos de instrumentos manuais: Flexofile e Prodesign® M.

METODOLOGIA: Foram utilizados quarenta canais mésio-vestibulares e mésio-linguais de primeiros ou segundos molares inferiores, com comprimento, grau e raio de curvatura padronizados entre todas as amostras. Os canais foram divididos aleatoriamente em dois grupos experimentais (n=20), conforme o instrumento de preparo a ser testado. Os preparos foram feitos por um único operador. O tempo para execução do preparo foi cronometrado e os valores obtidos foram analisados. Para verificação do desgaste, centricidade e ocorrência de transporte no preparo, foram realizadas imagens tomográficas, antes e após a realização das instrumentações. A análise foi feita em cortes axiais previamente identificados a 2 mm aquém do ápice dentário, com auxílio do programa OsiriX® Imaging. Para análise estatística, foi utilizado o Teste *t* de Student, com nível de significância de 5%.

RESULTADOS: O tempo para execução do preparo dos canais radiculares com instrumentos Prodesign® M foi menor do que em relação aos instrumentos Flexofile. Com relação ao desgaste dentinário, não foi observada diferença estatística. Entretanto, os instrumentos Flexofile apresentaram menor capacidade de centralização durante o preparo, havendo uma tendência de transporte no sentido mesial do canal radicular.

CONCLUSÃO: Apesar de não haver diferença estatística entre os instrumentos avaliados, o Prodesign® M apresentou uma melhor capacidade de centralização durante o peparo. Além disso, o tempo de preparo durante o seu uso foi inferior.

Palavras-chave: endodontia; instrumentos odontológicos; preparo de canal radicular; tomografia computadorizada de feixe cônico.

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INTRODUCTION

An objective of endodontic preparation is to maintain a root canal in a progressive conical shape by preserving the original anatomical curvature and the position of the apical foramen [1].

Accidents such as deviations, zips, and root perforations can occur in root canal preparation [2]. The apical third is the region of root canal that presents with a greater difficulty in being maintained with respect to its original trajectory and conformation. Therefore, technical knowledge and good command over endodontic instruments are fundamental for reducing accidents, providing greater precision in treatment, and reducing working time [3].

Many endodontic instruments such as stainless steel hand instruments have been commercialized for root canal preparation and are increasingly used by dentists since 1963 [4].

Stainless steel instruments are widely accepted and used by endodontists in clinical practice. However, at the same time, departments with root dilations, the use of instruments with this alloy tends to rectify the anatomical conformation. However, when faced with accentuated curvature in root canals, the use of instruments with this alloy tends to rectify the anatomical conformation. Pettiette et al. [5] and Leonardi et al. [2] verified that the rigidity of stainless steel instruments directly influenced the occurrence of accidents.

The nickel–titanium (NiTi) alloy was first introduced around 1988 and since then has been used on a large scale for manufacturing endodontic instruments. According to Pettiette et al. [5,6], NiTi provides superelasticity, a term that describes the ability of the material to return to its original state after discharge of force that produces substantial deformation. Deformations of up to 10% can be recovered for NiTi instruments, whereas those of 1% can be recovered for stainless steel instruments. Moreover, some studies [7-9] found that the use of NiTi instruments tended to maintain the original shape of the canal in instrumentation.

This study aimed to analyze preparation time, wear, transportation, and centering ability of stainless steel (Flexofile) and NiTi (Prodesign® M) instruments in curved root canal preparation.

METHODS

This study was approved by the Research Ethics Committee of UFRGS (CAAE: 71681717.1.0000.5347).

Selection and preparation of samples

Forty mesiobuccal and mesiolingual canals of the first or second mandibular molars with moderate curvature between 10° and 20° were used, according to the classification proposed by Schneider [10].

In addition, teeth with an average length of 22.8 mm (±0.5 mm) were selected and presented the two mesial canals with distinct trajectories throughout the mesial root extension, with independent foraminal exits.

Teeth with previous endodontic manipulation, presence of dental resorptions, incomplete rhizogenesis, intraradicular pins, calcified root canals, lacerations, and root fractures were excluded from the sample.

After opening the pulp chamber and locating the mesial canals, the working length (WL) was determined as 1 mm below the actual length of the canal.

For each experimental stage, the teeth were stored in a pot that contained distilled water (Iodontosul, Industrial Odontológica do Sul Ltda, Porto Alegre, Brazil).

Division of root canals between preparation instruments

The two endodontic instruments used for mechanical and chemical root canal preparation were stainless steel Flexofile instruments of the first and second series (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland) and NiTi Prodesign® M (Easy Equipment Odontológicos, Belo Horizonte, Minas Gerais, Brazil).

Using the Excel simple random sample technique (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA), mesiobuccal and mesiolingual root canals of the molars were randomly distributed between the two instruments analyzed.

Obtaining cone beam computed tomography images

To standardize and identify the dental region to be analyzed using tomography images, a cavity was made at 2 mm from the tooth apex (±1 mm short of WL).

Using the LN bur (Dentsply/Maillefer Instruments S.A., Ballaigues, Switzerland), the cavity was made mesially on the external radicular surface, without contact with the interior canals, and was filled with the temporary restorative material Cimpat® (Septodont Brasil Ltda, São Paulo, Brazil) (**Figure 1**).

Figure 1. Reference cavity at the root surface for tomographic analysis.

Figure 2. Positioning of the teeth in the silicone for tomographic analysis. Tomography images were obtained using the Orthopantomograph® OP300.

The root portion of the teeth was inserted into a ZetaPlus® condensation silicone model (Zhermack, Ro, Italy). The teeth were inserted into the silicone until it reached the cervical region, side by side, with a 2 mm space between the crowns, keeping the alignment of the mesial roots to the operator's right in an occlusal view of the teeth. Two silicone models, with 10 dental samples each, were prepared with standard dimensions of 160 × 28 × 28 mm (**Figure 2**).

Maxio (Instrumentarium Dental, Tuusula, Finland)

The protocol used for obtaining images was 8 cm in diameter × 8 cm in height; 0.2 voxel for 8.9 s, creating tomographic cuts of 0.2 mm in the axial plane, according to the manufacturer's instructions.

Root canal preparation

All mesial canals were initially exploited with #10 and #15 Flexofile instruments in all extensions.

The canals were prepared in sequence following the method described below for both types of instruments.

Preparation with stainless steel instruments

With the canals filled with 2.5% sodium hypochlorite solution (Iodontec Indústria e Comércio de Produtos Odontológicos Ltda., Porto Alegre, Rio Grande do Sul, Brazil), instrumentation was initiated using the #45 Flexofile instrument according to the anatomical diameter obtained at the entrance of the canal. This instrument was introduced into the canal until it encountered resistance.

Oscillatory movements were then made with a quarter turn to the right and left, with apical pressure and traction. These movements were repeated until the instrument was loose in the canal. This step was successively repeated with instruments of smaller caliber until WL was reached. Instrument #25 prepared the apical stop. Scaling was then performed using instruments #30 (1 mm short of WL), #35 (2 mm short of WL), and #40 (3 mm short of WL).

Instrument #15 was inserted between instruments in the cervical-apical stage and the memory (#25) during the programed recoil.

The instruments were pre-curved to the last millimeters using the Flexobend® device (Flexobend, Aronson, São Paulo, Brazil) to act in conditions in the apical third of the root canal.

Preparation with NiTi instruments

After exploring the canal with instrument #15, the Prodesign® M #25/.06 instrument preenlarged the cervical and middle third of the canal via rotational movements. Next, the Prodesign® M #25/.01 instrument was used with rotational movement until the patency of the canal was reached. Attaining patency with instrument #25/.01, Prodesign® M #15/.05 and #25/.06 were used, all in WL and with the same instrumentation kinematics previously performed. The rotational movement was performed clockwise after penetration and apprehension of the tip of the instrument into the canal apically.

The maximum apical surgical dilation was standardized according to the instrument gage #25 for both instruments.

For both groups, before and after each instrument used, the canals were irrigated with 2 ml of 2.5% sodium hypochlorite solution using a 10 ml disposable plastic syringe and a 0.30-mm NaviTip® needle, followed by suction with vacuum tips attached to 40- to 20-gauge cannula (Ibrás CBO Indústria e Cirúrgica e Óptica S.A, Campinas, São Paulo, Brazil).

After using the last instrument of each group, the canal was filled with 17% trisodium EDTA (Iodontec Indústria e Comércio de Produtos Odontológicos Ltda., Porto Alegre, Rio Grande do Sul, Brazil). The solution was agitated with sn endodontic instrument #15 for 2 min. Final irrigation was then performed with 2 ml of distilled water, followed by aspiration and drying with tips of absorbent paper #25 (Tanari Indústria Ltda., Manaus, Amazonas, Brazil) in the WL.

Analysis of the preparation time

A digital timer (Herweg®, Timbó, Santa Catarina, Brazil) was used to measure the time needed to perform the preparation.

Timing started when the first instrument of each system was introduced inside the canal. The preparation time was finalized when the canal was properly prepared. The timer was paused during every instrument change and during irrigation and aspiration of the irrigating solution.

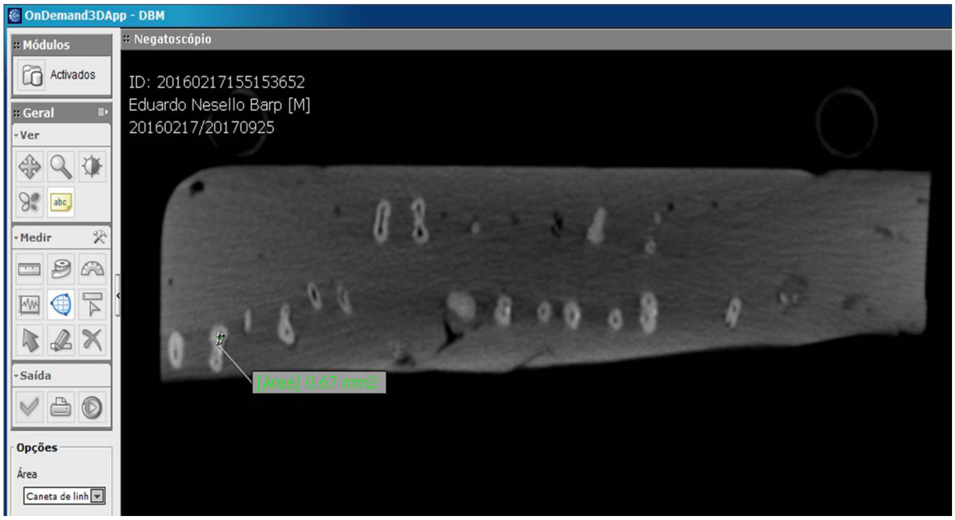

Figure 3. Demarcation of the root canal wear area in the OnDemand3D^{TM} Dental program.

Analysis of the wear area in root canal preparation

The wear area was calculated using tomographic images, which were manipulated using the OnDemand3D^{TM} Dental program (Cybermed Inc., Tustin, CA, USA).

To calculate the canal area value, the tool area of the OnDemand3D^{TM} Dental program was selected; its primary function was to highlight the contour of the region to be measured. The wear area was calculated based on the difference of the canal area before and after instrumentation at 2 mm from the root apex (**Figure 3**).

Analysis of transportation and centering ability

The analysis of transportation and centering ability of the preparation was performed using the final 2 mm of the canals in a linear mesiodistal direction.

For this, the formula described by Gambill et al. [11] was used. The transport was calculated as follows: (X1-X2)−(Y1-Y2). X1 represents the shortest distance from the distal portion of the root to the periphery of the unprepared canal; X2 represents the shortest distance from the distal portion of the root to the periphery of the prepared canal; Y1 represents the shortest distance from the mesial portion of the root to the periphery of the unprepared canal; and Y2 represents the shortest distance from the mesial portion of the root to the periphery of the prepared canal (**Figure 4**). A result of zero indicated no canal transport; a positive result indicated the transport toward the distal region of the root; and a negative result indicated transport toward the mesial region of the root. The centering capacity was calculated using the following formula: (X1-X2)/(Y1-Y2) or (Y1-Y2)/(X1-X2). The numerator of the formula was the lowest number found when the values were unequal. The resulting values closer to 1 indicated a better centralization capacity and the values closer to 0 indicated a lower centralization capacity.

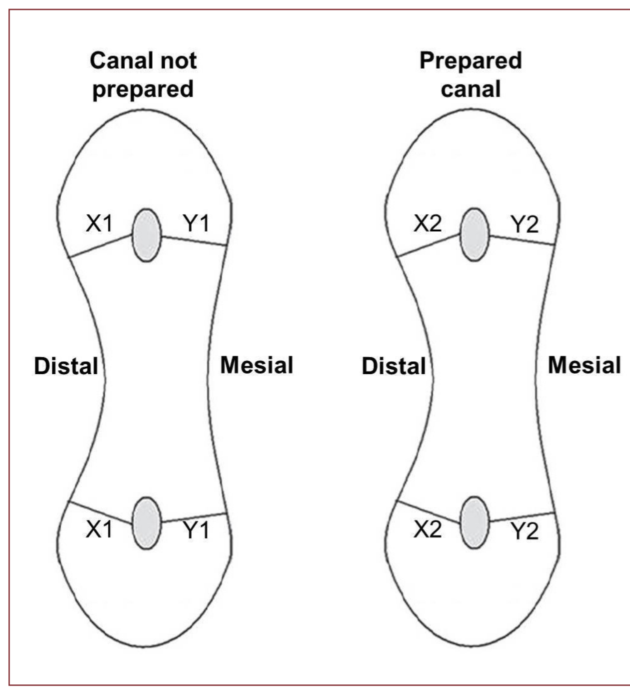

Figure 4. Schematic drawing of the positions for analyzing the centralization and transportation of the root canal.

Statistical analysis

The data obtained were analyzed using the Statistical Package for the Social Sciences, SPSS version 22.0 (SPSS Inc, Chicago, IL, USA).

For analyzing the preparation time and wear, Student's *t*-test was used, with a significance level of 5%.

Transportation and centralization of the preparation were analyzed using the mean and standard deviation of the samples and application of the formulas described above to observe these factors.

RESULTS

Table 1 shows the mean and standard deviation of the preparation time and wear produced in root canal preparation with two types of instruments. The time required to perform the preparation was lesser using Prodesign® M instruments than using Flexofile instruments (P<0.0001). In the wear analysis, no significant difference was observed between the two instruments.

Table 1. Mean and standard deviation of the preparation time and wear produced in root canal preparation with the two instruments

Analyzed Items	Endodontic instrument				P
	Flexofile		Prodesign® M		
	Mean	SD	Mean	SD	
Time (s)	237.65^{A}	38.65	102.45^{B}	32.23	< 0.0001
Wear	0.21^{A}	0.003	0.23^{A}	0.02	0.1436

Means followed by distinct capital letters in the line differ significantly differ by Student's *t*-test, with the significance level of 5%.

Table 2. Analysis of the two instruments with regard to centralization and transportation in the preparation

Endodontic instrument	Positions analyzed in axial section				Transportation (X1-X2) – (Y1-Y2) Mean	Centralization (X1-X2) / (Y1-Y2) Mean
	(X1-X2)		(Y1-Y2)			
	Mean	SD	Mean	SD		
Flexofile	0.069	0.038	0.118	0.040	-0.049	0.58
Prodesign® M	0.069	0.026	0.070	0.028	-0.001	0.98

Table 2 shows the occurrence of transportation and centralization of the preparation using the two instruments. The Flexofile instruments had a lower centralization capacity, with a tendency to transport in the mesial direction of the root canal. The Prodesign® M instruments had a better ability to centralize the preparation.

DISCUSSION

The ability of an instrument or technique to remain centered within the root canal during preparation is an objective in endodontic treatment [12].

Despite the varying morphology of human teeth, several attempts were made in this study to ensure comparability of the two experimental groups. Therefore, the canals were balanced with regard to the final apical diameter, length, and angle of curvature. McRay et al. [13] and Coelho et al. [14] also used mesial canals of lower molars in preparation analysis studies.

To analyze canal preparation (wear, transportation, and centering ability), cone beam computed tomography was used in this study and in those by Shah et al. [15], Shenoi et al. [16], and Mamede-Neto et al. [17], who all analyzed the same factors.

The study results show that the preparation time of root canals was lesser using Prodesign® M than using Flexofile instruments. This can be mainly attributed to the operative sequence and the number of instruments for each of the instrument used to perform the endodontic preparation. Glosson et al. [18] also observed lesser time for preparation using NiTi manual instruments (Mity files) witthan using K-flex stainless steel instruments; however, in 1996, Gambill et al. [11] did not identify differences in preparation time between the instruments.

The wear analysis of the two types of instruments showed similar results regarding area size prepared at 1 mm below WL. Prodesign® M instrument #25/.06 has a diameter in the D1 position of the active part (D1=0.31), very close to the Flexofile #30 instrument (D1=0.30), which is used during the step of same region of the canal.

A fact that drew attention in the analysis of the transport and in the capacity of centralization of the instrument in the preparation. Although the Prodesign® M instruments had centralizing capability without the occurrence of transport inside the canal, Flexofile instruments performed differently. Glosson et al. [18], Gambill et al. [11], Short et al. [19], Elliot et al. [20], and Schäfer and Florek [21] revealed a better centering ability in the preparation using NiTi instruments than using stainless steel instruments. According to Stavileci et al. [22], the centralization capacity of NiTi instruments is in part determined by their characteristic flexibility.

The stainless steel instruments have a difficult centralization capacity, with a tendency of transport toward the mesial direction of the canal. This can be attributed to the difference between the metal alloys and the kinematics of each instrument.

According to Wildey et al. [23] and Glosson et al. [18], the stainless steel instruments tend to rectify the anatomical condition of curved root canals.

The NiTi Prodesign® M instruments were used in the clockwise rotational direction and long-axis traction. The Flexofile stainless steel instruments were used in an anticurvature direction by following the principles of Abou-Rass et al. [24]. This, in a way, can explain the trend of greater transport and wear toward the mesial aspect of the canal, where in a lower molar, the safety zone is located.

For Flexofile instruments, a mean transport of 0.049 mm was observed, which according to Peters [25] values of up to 0.15 mm and is considered acceptable. For Wu et al. [26], values of >0.30 mm have a negative impact on apical sealing.

CONCLUSIONS

Our study results concluded that the time required to prepare the root canals with Prodesign® M instruments was less than that with Flexofile instruments. Although no statistical difference was observed between the two instruments regarding the area of canal wear at 2 mm from the tooth apex, the Flexofile instruments had a lower centralization capacity in the preparation, with the tendency of transport in the mesial direction of the canal root. The Prodesign® M instruments had a better cantering ability in the preparation.

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