UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE ODONTOLOGIA

GABIANA RODRIGUES FREITAS

INFLUÊNCIA DA CAVIDADE DE ACESSO ENDODÔNTICO NA INSTRUMENTAÇÃO ROTATÓRIA EM MOLARES SUPERIORES

Porto Alegre
2019

GABIANA RODRIGUES FREITAS

INFLUÊNCIA DA CAVIDADE DE ACESSO ENDODÔNTICO NA INSTRUMENTAÇÃO ROTATÓRIA EM MOLARES SUPERIORES

Trabalho de Conclusão de Curso apresentado ao Curso de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal do Rio Grande do Sul, como requisito parcial para obtenção do título de Especialista em Endodontia.

Orientador: Prof. Dr. Tiago André Fontoura de Melo

Porto Alegre

2019

AGRADECIMENTOS

Primeiramente, agradeço as pessoas mais importantes da minha vida, meus pais,Arilton e Carmem, minha tia Maura e com um carinho especial, minha avó Enid. Por estarem sempre ao meu lado, me incentivando, dando todo suporte e atenção possível e por me apoiarem em todos os momentos.

Agradeço imensamente minha família de Porto Alegre, os quais sempre me receberam com muito carinho, deixando cada módulo mais leve e agradável. Incluo aqui também, minha amiga, irmã de coração,BibianaZappe, a qual esteve sempre comigo, me confortando incentivando e me apoiando incondicionalmente. Vocês fizeram cada quilômetro valer ainda mais a pena.

Aos colegas agradeço que companheirismo e amizade, vocês tornaram meus dias mais leves e divertidos.

A aluna de iniciação científica, ThaisMarchand Ribeiro, que de forma responsável e correta, contribuiu lindamente na execução da minha pesquisa.

A meu orientador,Tiago André Fontoura de Melo, agradeço pela confiança que depositou em mim para executar esse trabalho. Por sempre estar disposto a ajudar, sanar dúvidas, ensinar e também corrigir. Quero expressar minha admiração pelo profissional que és. Um exemplo para mim.

Aos demais professores, agradeço os ensinamentos, apoio e confiança. Vocês foram fundamentais para minha formação como Especialista em Endodontia.

Aos pacientes, agradeço a compreensão por eu ter que me ausentar do consultório com freqüência, assim comoa todos que atendi no Hospital de Ensino Odontológico, os quais muito contribuíram com minha formação.

A todos que de alguma forma contribuíram nesses 2 anos, o meu muito obrigada.

Concluo mais essa etapa extremamente grata por cada experiência e aprendizado.

SUMÁRIO

Introdução

A preservação e manutenção da estrutura dentinária, durante a realização do tratamento endodôntico, influencia diretamente na sobrevida dentária. Segundo Sabetiet al. (2018), o tipo de acesso cavitário e a instrumentação do canal radicular podem influenciar a resistência à fratura nos dentes tratados endodonticamente.

A cavidade de acesso endodôntico convencional recomenda a remoção completa do teto da câmara, tentando a penetração mais retilínea do instrumento endodôntico no canal radicular, a fim de melhorar a eficiência da instrumentação e minimizar o risco de acidentes (Schroeder et al. 2002; Patel, Rhodes, 2007). No entanto, isso geralmente resulta em maior remoção de tecido da coroa dentária. Quanto maior a perda de estrutura, menor a resistência à fratura do dente (Tang et al., 2010).

Uma abordagem alternativa para o acesso endodôntico tradicional é a cavidade minimamente invasiva (Gluskinet al., 2014; Bürklein; Shäfer, 2015), que enfatiza uma maior preservação do tecido dental saudável durante a abertura coronariana do estágio. Krishanet al. (2014) observaram que o desempenho de uma menor cavidade de acesso diminui a força de fratura necessária nos pré-molares e molares quando comparada à abertura coronária convencional.

Por outro lado, o design de um acesso endodôntico mais conservador pode influenciar os princípios desejados no estágio de preparo químico mecânico. O acesso minimamente invasivo pode levar os instrumentos endodônticos a trabalhar principalmente na superfície interna do canal radicular, resultando na ocorrência de transporte apical. Estudos recentes mostraram que o transporte do canal radicular afeta negativamente o prognóstico a longo prazo devido à remoção excessiva da dentina e à retificação da curvatura do canal original (Bürklein, Schäfer, 2013, Elnaghy, Elsaka, 2014). Assim, o presente estudo tem como objetivo avaliar se a conformação da cavidade de acesso endodôntico realizada em molares superiores influencia na eficácia da instrumentação, na área preparada, na ocorrência de transporte e na centralização.

Resumo

Introdução: O formato do acesso coronário do tratamento endodôntico pode influenciar a longevidade clínica da fratura do dente a ser tratado, principalmente por estar correlacionada com maior desgaste e fragilidade de sua estrutura. **Objetivos:** Avaliar se a conformação da cavidade de acesso endodôntico em molares afeta a eficácia da instrumentação na ação dos instrumentos no interior do canal radicular durante a realização do preparo químico-mecânico. **Método:** Foram utilizados 20 canais mesiovestibulares dos molares superiores, com comprimento, grau e raio de curvatura padrão em todas as amostras. Os canais foram divididos aleatoriamente em dois grupos experimentais (n = 10), de acordo com o tipo de acesso endodôntico analisado (abertura convencional e minimamente invasiva). Os preparativos foram feitos por um único operador. Os canais foram preparados com o sistema Logic, e o instrumento apical final, no comprimento de trabalho (PA), foi padronizado no Logic nº 25 tapper .04. Para verificar a área de dentina removida, o transporte e a centralização no canal, foram realizadas imagens de tomografia computadorizada, antes e após a instrumentação. A análise foi realizada em cortes axiais previamente identificados em duas posições pré-determinadas no canal radicular: 3 mm da entrada do canal e 3 mm do ápice dentário, com o auxílio do programa OnDemand3DTM Dental. Para análise estatística, foi utilizado o Teste T de Student, com nível de significância de 5%. **Resultados e Conclusões:** Independentemente da posição dos canais analisados, não houve diferença na área preparada, na ocorrência de transporte e centralização do instrumento endodôntico entre os dois tipos de acessos coronarianos realizados. Embora, na posição mais próxima ao terço cervical do canal, tenha sido observada uma maior tendência ao desgaste da dentina em dentes cujo acesso endodôntico era convencional.

Palavras-chave: acesso endodôntico, instrumentos minimamente invasivos, níquel-titânio, preparo de canais radiculares, tomografia computadorizada.

Article

Title: Influence of endodontic cavity access on rotatory instrumentation in upper molars.

Authornamesandaffiliations:

Gabiana Rodrigues Freitas[a]

Thais Marchand Ribeiro[b]

Fabiana Soares Grecca Vilella[c]

Tiago André Fontoura de Melo [d]

[a]GraduateStudent, DentistryCollege,FederalUniversityof Rio Grande do Sul – Porto Alegre, RS, Brazil.

[b]UndergraduateStudent, DentistryCollege, Federal Universityof Rio Grande do Sul – Porto Alegre, RS, Brazil.

[c] DDS, MSc, PhD, Associate Professor, EndodonticDivision, DepartmentofConservative-Dentistry, Federal Universityof Rio Grande do Sul – Porto Alegre, RS, Brazil.

[d] DDS, MSc, PhD, Assistant Professor, EndodonticDivision, DepartmentofConservativeDentistry, Federal Universityof Rio Grande do Sul – Porto Alegre, RS, Brazil.

CorrespondingAuthor:

Tiago André Fontoura de Melo

Universidade Federal do Rio Grande do Sul

Faculdade de Odontologia

Departamento de Odontologia Conservadora

Rua Ramiro Barcelos, 2492 – Bairro Santana

CEP 90035-003

Porto Alegre, RS - Brazil

E-mail: tiago.melo@ufrgs.br

Phone: +55 (51) 3308-5430

Abstract

Introducion: The form of coronary access and endodontic treatment may influence the clinical longevity of the fracture of the tooth to be treated, mainly because it is correlated with a greater wear and fragility of its structure. **Objectives:** To evaluate if the conformation of the endodontic access cavity in molars the impact of on instrumentation efficacy the action of the instruments inside the root canal during the accomplishment of the mechanical chemical preparation. **Method:** Twenty mesiobuccal canals of maxillary molars were used, with standard length, degree and radius of curvature among all the samples. The canals were randomly divided into two experimental groups (n = 10), according to the type of endodontic accessanalyzed (conventional and minimally invasive opening). The preparations were made by a single operator. The canals were prepared with Logic system, and the final apical instrument, in the working length (WL), was standardized in Logic nº 25 taper .04. To verify the area of dentin removed, transport and centralization in the canal, micro-computed tomography images were taken, before and after instrumentation. The analysis was performed on axial sections previously identified in two predetermined positions in the root canal: 3 mm from the canal entrance and 3 mm from the dental apex, with the aid of the OnDemand3D^{TM} Dental program. For statistical analysis, Student's T-Test was used, with a significance level of 5%. **Results and Conclusions:** Regardless of the position of the analyzed canals, there was no difference in the prepared area, in the occurrence of transport and centralization of the endodontic instrument between the two types of coronary accesses performed. Although, in the position closest to the cervical third of the canal, a greater tendency was observed for dentin wear in teeth whose endodontic access was conventional.

Keywords: endodontic access, minimally invasive, nickel-titanium instruments, root canal preparation, micro-computed tomography.

Introduction

The preservation and maintenance of the dentin structure, during the accomplishment of the endodontic treatment, directly influences the dental survival. According Sabeti et al. (2018), the type of cavitary access and instrumentation of the root canal can influence the fracture resistanceendodontically treated teeth.

The conventional endodontic access cavity recommends the complete removal of the chamber roof, attempting the most rectilinear penetration of the endodontic instrument into the root canal in order to improve the efficiency of the instrumentation and to minimize the risk of accidents (Schroeder et al. 2002; Patel, Rhodes, 2007). However, this usually results in further removal of tissue from the dental crown. The greater the loss of structure, the lower the fracture resistance of the tooth (Tang et al., 2010), as there will be a weakening of tissue stiffness (Lang et al., 2006).

An alternative approach for traditional endodontic access is the minimally invasive cavity (Gluskin et al., 2014; Bürklein; Shäfer, 2015), which emphasizes a greater preservation of healthy dental tissue during the stage coronary opening. Krishan et al. (2014) observed that the performed of a smaller access cavity increases the necessary fracture force in premolars and molars when compared to the conventional coronary opening.

On the other hand, the design of a more conservative endodontic access can influence the principles desired in the stage of mechanical chemical preparation. The minimally invasive access may cause the endodontic instruments to work mainly on the inner surface of the root canal, resulting in the occurrence of apical transport. Recent studies have shown that transport of the root canal adversely affects the long-term prognosis because of excessive dentin removal and rectification of the original canal curvature (Bürklein, Schäfer, 2013, Elnaghy, Elsaka, 2014). Thus, the present study aims to evaluate if the conformation of the endodontic access cavity performed in upper molars influences in the instrumentation efficacy, in the prepared area, in the occurrence of transport and in the centralization.

Methods

This study was approved by the Research Committee of the Faculty of Dentistry of UFRGS and by the Research Ethics Committee of the same institution (Protocol CAAE 89366618.0.0000.5347).

Samples selection

Twenty third human permanent upper molarswere used in the study. The teeth presented crown similar dimensions and degree and radius of curvature of the root canals among all the samples. The buccal-palatal (BP) and mesio-distal (MD) dimensions of each tooth were recorded using a digital caliper (Mitutoyo, Suzano, São Paulo, Brazil). Only teeth with the following dimensions were selected: BP width (11 mm ± 1 mm) and MD width (9.5 mm ± 1 mm).

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

The sample size was estimated based on the study by Moore et al. (2016) with α = 0.05 and 80% power in which at least 10 teeth were allocated in each of the two experimental groups: conventional access and minimally invasive access.

Endodontic Access Cavity

In the teeth of the conventional access group, coronary opening followed the basic principles by Torabinejad and Walton (2010); in which the roof of the pulp chamber is completely removed. For this, a spherical diamond tip no. 1012 (KG Sorensen, Barueri, São Paulo, Brazil)and Endo Z tip (Dentsply / Maillefer, Ballaigues, Switzerland) were used.

On the other hand, in the minimally invasiveaccess group, endodontic access was minimally invasive. With the help of a clinical microscope (D.F. Vasconcellos, Valença, Rio de Janeiro, Brazil), access to a pulp chamber was made in the central fossa main per occlusal, perpendicular to the long axis of the tooth, with a spherical diamond tip no. 1016 (KG Sorensen, Barueri, São Paulo, Brazil).

After access to the pulp chamber, the entrance of themesiobuccal, distobuccal and palatal root canals was located with the aid of a Rhein catheter no. 3 (GolgranIndústria e Comércio de Instrumental Odontológico Ltda., São Paulo, São Paulo, Brazil).

Endodontic instrumentation

Initially, canals were negotiated with an endodontic instrument type K no. 10(Dentsply/Maillefer Instruments S.A., Ballaigues, Switzerland), until the tip of the instrument was juxtaposed with the foraminal outlet. From the length measured on the instrument in this condition, 1 mm was reduced, determining the WL.

The mechanical chemical preparation of the root canals was performed using instruments from the ProDesign Logic system (Easy Odontological Equipment, Belo Horizonte, Minas Gerais, Brazil). After the exploration of the root canal with the typeKendodontic instrument no. 15, the Logic rotary instrument no. 25 taper .01 was used in the electric motor (Easy Dental Equipment, Belo Horizonte, Minas Gerais, Brazil) with a speed of 350 rpm and torque of 1N, to effect patency. Then, for sequence of the preparation of the canals, the Logic instruments were used successively no. 15 taper 03 (350 rpm speed and 2N torque) and Logic no. 25 taper .04 (950 rpm speed and 4N torque) in the WL.

The intraradicular irrigation process during instrumentation was performed with 2.5% sodium hypochlorite solution (Iodontosul - Industrial Odontológica do Sul LTDA, Porto Alegre, Brazil).

The endodontic preparation was performed by a single operator trained to use this rotational system. Each set of instruments was used for the preparation of five molars from the same experimental group.

After completion of the preparation, the canal was filled with 17% trisodium EDTA (IodontecIndústria e Comércio de ProdutosOdontológicosLtda., Porto Alegre, Rio Grande do Sul, Brazil) and the solution was activated for two minutes with endodontic instrument type Kno. 15. Then, the EDTA was removed with 2 mL of distilled water and dried the canals using absorvent paper points no. 25 (TanariIndústria Ltda., Manaus, Amazonas, Brazil) in the WL.

Micro-computed tomography (micro-CT)

The SMX-90CT Plus (Shimadzu®) microtomograph was operated with 70 kV, 100 uA, FOV (XY) 13.3 mm, FOV (Z) 7.0 mm and Voxel size 0.013 mm/Pix.

The teeth were submitted to scanning in the microtomograph in two moments: pré and post instrumentation. A support model made using ExpressTM XT Putty Soft (3M ESPE, St. Paul, MN - USA) addition silicone was used in order to standardize the individual positioning of the teeth in the microtomograph.

The analysis of the wear area, transportation and centering ability with the preparation was made in the mesiobuccal root of all teeth.With the slices obtained from the dental root, the analyzes were performed in two predetermined positions in the root canal: 3 mm from the canal entrance (Position A) and 3 mm from the dentalApex (Position B).

Analysis of the wear area in root canal preparation/ volume dentin removed

The wear area was calculated using axial cutting of micro-CT, which were manipulated by the Image J program (Fiji, Madison, EUA).

To calculate the canal area value, the tool area of the 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.

Analysis of transportation and centering ability

The analysis of transportation and centering ability of the preparation was performed in a linear mesiodistal direction of root canal.

For this, the formula described by Gambill et al. (1996) 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.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.

Statistical analysis

The Shapiro-Wilk test was used to evaluate the normality of the data. For the comparison of the groups, for the dentin wear due to mechanical chemical preparation, Student's t-test was used. The level of significance was 5% ($P \leq 0.05$) with the GraphPadPrism 7 (GraphPad Software Inc., San Diego, CA, EUA) program.

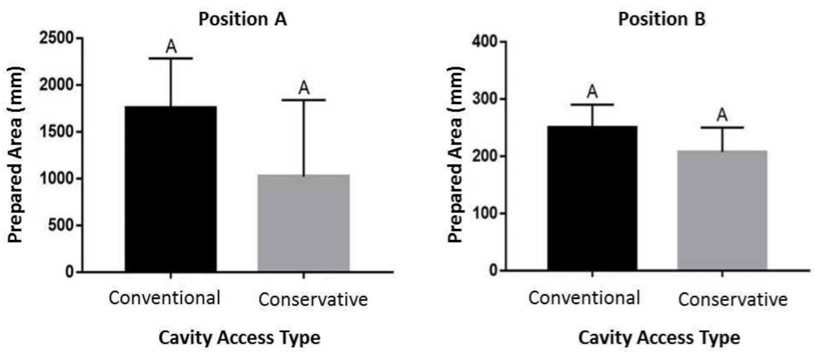
Transportation and centralization of the preparation were analyzed using the mean and standard deviation of the samples and application of the formulas described above to observe these factors.

The null hypothesis was that there is no statistical difference in the design of the endodontic access cavity in relation to the rotatoryinstrumentationof the root canals, in the prepared area, in the occurrence of transport and in the centralization.

Results

The mean and standard deviation of the root canal preparation area at the two positions analyzed is shown in figure 1. Regardless of the analyzed position, there was no difference in the area prepared by the instrument between the two experimental groups. Only in the position closest to the cervical third of the canal (position A) there is a trend towards greater dentinal wear in teeth whose endodontic access was conventional.

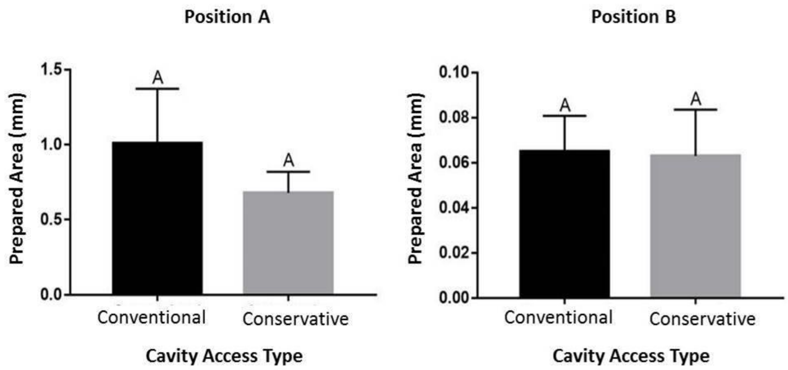
Figure 1 -Analysis of the two types of endodontic access in relation to the preparation area of the root canal.



Means followed by distinct capital letters in the column differ significantly by means of the Student's t-test, at the significance level of 5%.

Figure 2 shows the results referring to wear on the vestibular face of the root canal according to the type of endodontic access performed. Regardless of the position analyzed, there was no difference in wear on the vestibular face of the root canal during instrumentation between the two experimental groups. Only in the position closest to the cervical third of the canal (position A) there is a tendency for greater vestibular wear in teeth whose endodontic access was conventional.

Figure 2-Analysis of the two types of endodontic access in relation to the wear of the vestibular face of the root canal.



Means followed by distinct capital letters in the column differ significantly by means of the Student's t-test, at the significance level of 5%.

The occurrence of transport and centralization of the preparation in the two types of endodontic accesses are expressed in tables 1 (Position A) and 2 (Position B). Regardless of the type of endodontic access performed, the instruments presented a capacity of centralization in the preparation, without occurrence of transportation.

Table 1 - Analysis of the two types of endodontic access with regard to centralization and transportation in the preparation in position A.

Typeofendodonticaccess	Positionsanalyzed in axial section				Transportation (X1-X2) - (Y1-Y2) Mean	Centralization (X1-X2) / (Y1-Y2) Mean
	(X1-X2) MeanSD		(Y1-Y2) Mean	SD		
Conventional Access	0.120	0.012	0.128	0.012	- 0.008	0.93
Conservative Access	0.118	0.020	0.122	0.024	- 0.004	0.96

Table 2 - Analysis of the two types of endodontic access with regard to centralization and transportation in the preparation in position B.

Typeofendodonticaccess	Positionsanalyzed in axial section				Transportation (X1-X2) - (Y1-Y2) Mean	Centralization (X1-X2) / (Y1-Y2) Mean
	(X1-X2) Mean	SD	(Y1-Y2) Mean	SD		
Conventional Access	0.053	0.024	0.056	0.024	- 0.003	0.94
Conservative Access	0.077	0.009	0.079	0.012	- 0.002	0.97

Discussion

The purpose of minimally invasive endodontic access is to preserve a greater amount of healthy dental structure, resulting in a better prognosis of the tooth when subjected to cyclic occlusal loads(Pereira *et al.*, 2013; Plotino*et al.*, 2017).On the other hand, this type of access should not hamper the performance of mechanical chemical preparation.

The method chosen for analysis of root canal instrumentation was micro CT. This method provides greater precision, validity and reproducibility of the generated data (Saberi et al., 2017; Silva et al., 2017).

As regions analyzed in the study were defined the axial cuts located in the cervical and apical thirds of the canals. Excessive instrumentation of the cervical third of the canals may cause root weakening or even cause some type of accident in the region (Peterset al., 2014). Therefore, for analysis of the cutting action caused only by the endodontic instrument, no type of drill was used for cervical pre-dilatation. The choice of the apical third for analysis has been made, since the correct cleaning and shaping area are directly related to the success of the endodontic treatment (Antunes et al., 2015).The apical transport favors the maintenance of microorganisms and organic tissue remnants in the dentin walls, compromising the disinfection as well as the sealing of the root canal system (Wu et al., 2000).

The null hypothesis that there would be no statistical difference in the type of endodontic access in relation to the rotatory preparation of the root canals was accepted. Theoretically that with the accomplishment of the minimally invasive access there would be a greater difficulty of the endodontic instrument to work in all extension of the canal, mainly due to the difficulty of access and coronary interferences on the act of instrumentation.In the study it can be observed that, independently of the region analyzed in the root canal, there was no difference in the prepared area, in the occurrence of transport and centralization of the endodontic instrument between the two types of coronary accesses tested. Moore et al. (2016) also did not observe any difference in mechanical chemical preparation between the two types of endodontic accesses.In addition, the authors verified that the instrumentation modified 49% -59% of buccal canal walls of upper molars, corroborating the limited efficacy of enginedriven instruments previously shown in all tooth types.

On the other hand, Alovisi et al. (2018) observed a greater displacement of the instrument in the central region of the root canal in the teeth submitted to minimally invasive endodontic access.According to the researchers, with the presence of occlusal interferences present in the more conservative access, there is a greater number of pecking motions for the instrument to reach the WL, thus, a greater probability of the instrument to correct the curvature of the root canal and to cause the apical transport.

The final apical instrument of the study was standardized Logic nº 25 taper .04, differently from Moore et al. (2016) that defined the last instrument in the WL being the V-Taper2H rotary instruments (SSWhite Dental) no. 20 taper .06. According to Harris et al. (2013), the use of endodontic instruments of smaller caliber and conicity in the preparation of the root canal reduces the occurrence of deviations and apical accidents.

Pinheiro et al. (2018) analyzed the occurrence of transport and centralization in lower molar mesial canals performed with the following rotary systems: Protaper Gold®, Prodesign S®, Hyflex CM®, Hyflex EDM® and Logic®.The authors verified that the Logic® system presented the lowest value of apical transport, but without significant difference in relation to the other systems tested ($P > 0.05$).This, in a way, corroborates the data obtained in our study with this same type of rotating instrument. Studies such as that of Bürklein et al. (2014) and Marceliano-Alves et al. (2005), demonstrated that heat-treated NiTi instruments promoted lower values of transport at the apical level.

Another fact that although not presented statistical difference and that was observed in the study is a greater tendency to wear of the dentin in the cervical third of the canal in the teeth submitted to the conventional endodontic access in relation to the minimally invasive.This finding can be justified by the kinematics of brushing motions against the canal walls during instrumentation, since there was no occlusal dentin interference that made this preparation movement difficult.

Conclusions

According to the proposed objectives, regardless of root canal analysis, there was no difference in the prepared area, in the occurrence of transport and centralization of the endodontic instrument between the two types of coronary accesses. Conventional endodontic access showed a greater tendency for dentin wear in the cervical third of the canal in relation to minimally invasive access.

References

1. Alovisi M, Pasqualini D, Musso E, Bobbio E, Giuliano C, Mancino D, Scotti N, Berutti E. Influenceofcontractedendodonticaccesson root canal geometry: na in vitro study. J Endod. 2018;44(4):614-20.

2. Antunes HS, Rôças IN, Alves FR, Siqueira JF Jr. Total and specific bacterial levels in the apical root canal system of teeth with post-treatment apical periodontitis. J Endod. 2015;41(7):1037-42.

3. Bürklein S, Börjes L, Schäfer E. Comparison of preparation of curved root canals with Hyflex CM and Revo-S rotary nickel-titanium instruments. IntEndodJ. 2014;47(5):470-6.

4. Bürklein S, Schäfer E. Critical evaluation of root canal transportation by instrumentation.Endod Topics. 2013;29:110-24.

5. Bürklein S, Shäfer E. Minimally invasive endodontics. Quintessence Int. 2015;46(2):119-24.

6. Elnaghy AM, Elsaka SE. Evaluation of root canal transportation, centering ratio, and remaining dentin thickness associated with ProTaper Next instruments with and without glide path. J Endod. 2014;40(12):2053-6.

7. Gambill JM, Alder M, del Rio CE. Comparison of nickel-titanium and stainless steel hand-file instrumentation using computed tomography. J Endod 1996;22(7):369-75.

8. Gluskin AH, Peters CI, Peters OA. Minimally invasive endodontics: challenging prevailing paradigms. Br Dent J. 2014;216(6):347-53.

9. Harris SP, Bowles WR, Fok A, McClanahan SB. An anatomic investigation of the mandibular first molar using micro-computed tomography. J Endod.2013;39(11):1374-8.

10. Krishan R, Paque F, Ossareh A, Kishen A, Dao T, Friedman S. Impacts of conservative endodontic cavity on root canal instrumentation efficacy and resistance to fracture assessed in incisors, premolars, and molars. J Endod. 2014;40(8):1160-6.

11. Lang H, Korkmaz Y, Schneider K, Raab WH. Impact of endodontic treatments on the rigidity of the root. J Dent Res. 2006;85(4):364-368.

12. Marceliano-Alves MF, Sousa-Neto MD, Fidel SR, Steier L, Robinson JP, Pécora JD, Versiani MA. Shaping ability of single-file reciprocating and heat-treated multifile rotary systems: a micro-CT study.IntEndod J. 2015;48(12):1129-36.

13. Moore B, Verdelis K, Kishen A, Dao T, Friedman S. Impacts of contracted endodontic cavities on instrumentation efficacy and biomechanical responses in maxillary molars.J Endod. 2016;42(12):1779-83.

14. Patel S, Rhodes J. A practical guide to endodontic access cavity preparation in molar teeth. Br Dent J. 2007;203(3):133-40.

15. Pereira JR, McDonald A, Petrie A, Knowles JC. Effect of cavity design on tooth surface strain. J Prosthet Dent.2013;110(5):369-75.

16. Peters OA, Morgental RD, Schulze KA, Paqué F, Kopper PM, Vier-Pelisser FV. Determining cutting efficiency of nickel-titanium coronal flaring instruments used in lateral action.IntEndod J. 2014;47(6):505-13.

17. Pinheiro SR, Alcalde MP, Vivacqua-Gomes N, Bramante CM, Vivan RR, Duarte MAH, Vasconcelos BC. Evaluation of apical transportation and centring ability of five thermally treated NiTi rotary systems. IntEndod J. 2018;51(6):705-13.

18. Plotino G, Grande NM, Isufi A, Ioppolo P, Pedullà E, Bedini R, Gambarini G, Testarelli L. Fracture strength of endodontically treated teethwith different access cavity designs. J Endod.2017;43(6):995-1000.

19. Sabeti M, Kazem M, Dianat O, Bahrololumi N, Beglou A, Rahimipour K, Dehnavi F. Impacto f access cavity design and root canal taper on fracture resistance of endodontically treated teeth: an ex vivo investigation. J Endod. 2018;44(9):1402-1406.

20. Saberi N, Patel S, Mannocci F. Comparison of centring ability and transportation between four nickel titanium instrumentation techniques by micro-computed tomography. IntEndod J. 2017;50(6):595-603.

21. Schroeder KP, Walton RE, Rivera EM. Straight line access and coronal flaring: effect on canal length. J Endod. 2002;28(6):474-6.

22. Silva EJNL, Pacheco PT, Pires F, Belladonna FG, De-Deus G. Microcomputed tomographic evaluation of canal transportation and centring ability of ProTaper Next and Twisted File Adaptive systems. IntEndod J. 2017;50(7):694-9.

23. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod. 2010; 36(4):609-617.

24. Torabinejad M, Walton RE. Endodontia: princípios e práticas. In: Johnson WT, Williamson AE. Isolamento, Abertura Coronária e Determinação do comprimento. Rio de Janeiro: Elsevier Editora Ltda.; 2010. p. 236-9.

25. Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved canals. Part I. Effects of apical transportation on seal of root fillings. J Endod. 2000;26(4):210-6.