UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

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AVALIAÇÃO DA RESISTÊNCIA À FRATURA DE PRÉ-MOLARES, COM PREPARO MOD E MANIPULADOS ENDODONTICAMENTE, RESTAURADOS E TRANSFIXADOS POR UM PINO DE FIBRA DE VIDRO

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Trabalho de Conclusão de Curso apresentado ao Curso de Graduação em Odontologia da Universidade Federal do Rio Grande do Sul, como requisito básico para obtenção do título de Cirurgiã-dentista.

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Porto Alegre, 13 de maio de 2021.

Prof. Dr. Tiago André Fontoura de Melo
Universidade Federal do Rio Grande do Sul

Prof. Dr. Francisco Montagner
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Prof. Dr. Jefferson Tomio Sanada
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O sucesso nasce do querer, da determinação e persistência em se chegar a um objetivo. Mesmo não atingindo o alvo, quem busca e vence obstáculos, no mínimo fará coisas admiráveis.

José de Alencar

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Encerro meus agradecimentos com a frase de George Herbert para a vida: "Senhor, deste-me tanto. Dá-me uma coisa a mais: um coração agradecido."

RESUMO

Objetivo: Avaliar se o preparo endodôntico cervical e a posição de transfixação do pino de fibra de vidro na coroa dentária influenciam na resistência à fratura de um dente com preparo MOD e manipulado endodonticamente. **Método:** Setenta e dois primeiros pré-molares superiores humanos com duas raízes foram selecionados e preparados seguindo os objetivos e protocolos descritos em cada um dos artigos apresentados ao longo do TCC. Após o preparo dos dentes e suas reabilitações, as amostras foram submetidas ao ensaio de resistência à fratura por compressão em uma máquina de ensaio universal. Os dentes foram inspecionados quanto ao tipo de fratura e classificados em: fratura em assoalho pulpar (não recuperável) ou em cúspide (recuperável). Para análise estatística nos dois estudos foi utilizada ANOVA, seguido do teste de comparações múltiplas de Tukey, quando necessário. O nível de significância adotado foi de 5%. **Conclusões:** De acordo com os resultados obtidos nos dois artigos, pode-se concluir que o preparo endodôntico cervical está associado a uma menor resistência à fratura em dentes restaurados sem pino de fibra. Os dentes restaurados com pino de fibra transfixados apresentam uma maior resistência à fratura. Entretanto, a posição de transfixação do pino de fibra parece influenciar na localização da fratura.

Palavras-chave: Endodontia, Dentística operatória, Análise do estresse dentário.

ABSTRACT

Objectives: To evaluate whether the cervical endodontic preparation and the transfixation position of the fiberglass post in the dental crown influence the resistance to fracture of a tooth with MOD preparation and endodontically manipulated. **Method:** Seventy-two human upper first premolars with two roots were selected and prepared following the objectives and protocols described in each of the manuscripts provided throughout the TCC. After the preparation of the teeth and their rehabilitation, the samples were submitted to the compression fracture resistance test in a universal testing machine. The teeth were inspected for the type of fracture and classified as: fracture in the pulp floor (non-recoverable) or cusp (recoverable). For statistical analysis in both studies, ANOVA was used, followed by Tukey's multiple comparison test, when necessary. The level of significance adopted was 5%. **Conclusions:** According to the results obtained in the two manuscripts, it can be concluded that cervical endodontic preparation is associated with less resistance to fracture in restored teeth without a fiber post. Teeth restored with transfixed fiber posts have greater fracture resistance. However, the transfix position of the fiber post seems to influence the fracture location.

Keywords: Endodontics, Operative dentistry, Analysis of dental stress.

LISTA DE ABREVIATURAS E SIGLAS

CAAE = Certificado de Apresentação de Apreciação Ética

cm = centímetro

Dr. = doutor

Dr^{a}. = doutora

E = endodontics

et al. = e colaboradores

kN = quilograma força

M = one root

ml = mililitro

mm = milímetro

mm/min = milímetros por minuto

MOD = mésio-ocluso-distal

RCT = preparo cervical

R = restauração

HP = Pino de fibra de vidro transfixado horizontalmente

n = número

N = newtons

Prof. = professor

Prof^{a}. = professora

UFRGS = Universidade Federal do Rio Grande do Sul

SUMÁRIO

1. INTRODUÇÃO

A obtenção de uma maior longevidade no tratamento restaurador direto em dentes fragilizados e tratados endodonticamente é um dos grandes desafios clínicos na Odontologia Conservadora. Elementos dentários, desprovidos de vascularização pulpar, tendem a apresentar uma maior fragilidade estrutural devido à desidratação dentinária com consequente perda de humidade e flexibilidade (Dikbas *et al.*, 2007; Soares *et al.*, 2007). Muitas vezes, associada a esta carência de suprimento sanguíneo, os dentes tratados endodonticamente apresentam-se com grandes destruições coronárias.

Segundo Santos-Filho *et al.* (2014), a resistência à fratura de dentes tratados endodonticamente está diretamente relacionada à quantidade e qualidade da estrutura dental remanescente, sendo assim um fator determinante para longevidade do procedimento restaurador.

Normalmente, quando ocorre a fratura dentária, ela está associada à fratura das cúspides. Fato esse que merece uma atenção especial, pois existe o risco de a linha de fratura estender-se abaixo da crista óssea, podendo acarretar a perda da peça dentária ou dificultar a sua restauração (Lagouvardos *et al.*, 1989).

Dentre os preparos cavitários, aquele que mais enfraquece o remanescente dentário é o tipo Classe II MOD (mésio-ocluso-distal), pois há a perda de estruturas importantes de reforço, tais como: ponte de esmalte e cristas marginais (Mondelli *et al*., 1980; Eakle, 1986). No entanto, quando o elemento dentário com preparo MOD é submetido ao tratamento endodôntico a tendência é de ainda haver uma maior fragilidade da peça dentária, pois ocorre a perda de uma outra estrutura de reforço, que é o teto da câmara pulpar. O teto da câmara pulpar, num preparo MOD, passa a ser o "elo" de ligação mais próximo entre as cúspides, absorvendo e auxiliando na distribuição das tensões mastigatórias e funcionais sobre toda a superfície dentária (Khera *et al*., 1991; Burke, 1992).

Nestas condições, a opção mais indicada de tratamento é o recobrimento das cúspides por meio de restaurações indiretas, pois dessa forma estaremos recuperando a resistência à fratura da coroa dentária praticamente no nível de um dente íntegro (Assif *et al*., 2003). Tal opção, entretanto, envolve a realização de um preparo cavitário expulsivo, com desgaste de estrutura dental sadia, tempo clínico maior e custo mais elevado em relação aos procedimentos restauradores diretos com resina composta.

Restaurações diretas com resina composta, quando bem executadas, podem ser uma forma de tratamento viável, pois, além do baixo custo operacional, não necessita a realização de um desgaste adicional em tecido dentário sadio. Plotino *et al*. (2007) demonstraram que não há diferença estatística na resistência à fratura de molares, com extensa perda de estrutura dentária e tratados com restaurações de resina composta pela técnica direta ou indireta.

Um fato já conhecido e consagrado na literatura científica, é que o uso de pinos intrarradiculares para restauração de dentes tratados endodonticamente não aumenta a resistência do remanescente dentário. O pino intrarradicular apenas tem a função de promover a retenção e adesão do material restaurador (Glazer, 2000).

Atualmente, uma alternativa que está sendo testada a fim de aumentar a resistência à fratura de dentes fragilizados e tratados endodonticamente é a utilização de pinos flexíveis de fibra de vidro transfixados horizontalmente nas paredes vestibular e palatino/lingual. Esses pinos estéticos pré-fabricados apresentam módulo de elasticidade muito próximo ao da dentina (Pergoretti *et al*., 2002). Conforme estudos de Beltrão *et al*. (2009) e Fávero *et al*. (2015), os grupos que receberam a transfixação de pinos e restauração com resina composta apresentaram um aumento significativo da resistência à fratura quando comparado com aos grupos restaurados apenas com resina. Além disso, houve um menor grau de comprometimento da estrutura dentária frente à fratura.

2. OBJETIVOS

2.1. Objetivo geral

Avaliar, *in vitro*, a resistência à fratura do elemento dentário, com preparo MOD e manipulado endodonticamente, restaurado e transfixado por um pino de fibra de vidro.

2.2. Objetivos específicos

* Artigo Científico n°1:

- Avaliar a influência do preparo endodôntico cervical na resistência à fratura;

- Avaliar se a utilização do pino de fibra de vidro transfixado à coroa dentária interfere na resistência à fratura;

- Avaliar e comparar os grupos quanto ao padrão de fratura das peças dentárias; e,

- Analisar, pelo método visual, o desfecho em relação à fratura do remanescente dentário.

* Artigo Científico n°2:

- Avaliar a influência da posição de transfixação do pino na resistência à fratura do elemento dentário;

- Avaliar e comparar os grupos quanto ao padrão de fratura das peças dentárias; e,

- Analisar, pelo método visual, o desfecho em relação à fratura do remanescente dentário.

3. ARTIGO CIENTÍFICO N°1

O artigo foi traduzido para o idioma inglês (Anexo A) e submetido à publicação no periódico *Brazilian Journal of Oral Sciences,* eISSN 1677-3225.

Evaluation of the influence of cervical endodontic preparation on fracture strength of premolars with MOD preparation subjected to different restorative protocols

Abstract

Aim: To evaluate *in vitro* the influence of cervical preparation performed in endodontic treatment on fracture strength of upper premolars subjected to different restorative procedures. Methods: Fifty-six extracted human double-rooted maxillary first premolars were selected and randomly divided into seven groups (n = 8): S: Healthy teeth; C: endodontic treatment with MOD cavity preparation; CC: C cervical preparation; CR: C restoration with composite resin (R); HPCR: CR horizontal fiberglass post (HP); CCR: CC R; and HPCCR: CCR HP. After allocation to the groups, the samples were thermocycled and subjected to the fracture strength test on a universal testing machine. The teeth were then inspected for 1) pulp floor fracture or 2) no pulp floor involvement. Results: Means followed by the same letter do not show statistical difference in Tukey's test ($p > 0.05$): S: $2.451^{A} \pm 552.9$; C: $95.13^{B} \pm 7.93$; CC: $32.63^{B} \pm 4.89$; CR: $816.8^{C} \pm 84.34$; HPCR: $1.501^{D} \pm 130$; CCR: $398.7^{E} \pm 73.8$; and HPCCR: $1.253^{D} \pm 82.15$. Conclusions: The HPCR group presented over 25% of fractures at the pulp chamber level. The presence of cervical wear increased by 62.5% (HPCCR). The use of the transfixed post in the horizontal position increases the fracture strength of upper premolars with or without cervical wear, but it does not prevent fractures at the pulp floor level.

Keywords: Cervical endodontic preparation. Composite resin. Endodontically treated teeth. Fiberglass post. Fracture resistance.

Introduction

Achieving a higher survival rate for the restoration of endodontically treated teeth is not only related to the remaining tooth structure[1] and to the type of preparation and restorative material employed[2], but also to procedures performed in endodontic treatment[3].

Studies show that the type of cavity access and root canal instrumentation[4], the type of irrigating solution used in endodontic treatment[5], and the duration of intracanal medicament application[6] can influence crown fracture strength.

Preservation of the tooth structure and maintenance of good quality of the tooth substrate directly influence the survival of endodontically treated teeth. Cusp deflection and consequent crown fracture are greater when access and the endodontic approach are performed[7].

Thus, the present study aimed to measure the fracture strength of premolars with or without cervical preparation performed in endodontic treatment when subjected to different restorative procedures.

The initial null hypothesis was that there would be no influence of the cervical preparation performed in endodontic treatment on fracture strength when compared to teeth without cervical preparation and restored with composite resin.

Methods

The methodological procedures performed in this research study were approved by the local research ethics committee (process CAAE 68708217.2.0000.5347; Anexo B).

Sample selection and preparation

Fifty-six human upper first premolars with two root canals, free of carious lesions, restorations, or cracks were used in the study.

The selected teeth had crowns with buccopalatal (9 mm ± 0.5 mm) and mesiodistal (7 mm ± 0.5 mm) dimensions, measured with a digital caliper (Mitutoyo, Suzano, SP, Brazil) in the most prominent part of the respective surfaces.

After cleaning procedures, the teeth were disinfected with 0.5% chloramine solution (Seachem Laboratories, Madison, GA, USA) for 48 hours. The teeth were then randomly divided into seven experimental groups (Table 1).

Table 1 - Experimental groups.

Groups	**n**	**Group Description**
S	8	Healthy tooth
C	8	MOD preparation (MOD) + endodontic treatment (RCT) (without cervical preparation)
CC	8	MOD + RCT (with cervical preparation)
CR	8	MOD + RCT (without cervical preparation) + composite resin restoration (R)
HPCR	8	MOD + RCT (without cervical preparation) + horizontal fiberglass post (HP) + R
CCR	8	MOD + RCT (with cervical preparation) + R
HPCCR	8	MOD + RCT (with cervical preparation) + HP + R

Preparation of specimens

For individual inclusion of the teeth, PVC cylinders measuring 2 cm in height and 3 cm in diameter were used. The teeth were inserted in self-curing acrylic resin and centered inside the PVC cylinder, exposing the anatomical neck of the tooth 2 mm above the edge of the acrylic. Afterwards, the specimens were stored in distilled water at 37°C.

MOD cavity preparation

For MOD cavity preparations, the inclination and movements performed by diamond bur #2143 (KG Sorensen, São Paulo, SP, Brazil) during the procedure were standardized.

Cavity preparations followed the methodology described by Cötert et al. [8] (2001) and Beltrão et al. [9] (2009), in which a line was drawn from the central groove to allow the buccal and palatal preparation walls to be equidistant two groove was extended to the mesial surface, passing over the marginal ridge, going towards thirds of the intercuspal distance. This line over the central the dental neck up to a height of 4 mm. This was the depth established for the preparation. The predetermined buccopalatal width in the occlusal area was extended to the mesial surface and equally determined for the proximal boxes. Diamond bur #2143 was initially positioned on the mesial surface over the central line along the predetermined length. Next, a mesiodistal box with the same width as the tip was prepared. The buccal and palatal walls were prepared to the predetermined limits so that the gingival floor could be connected to the pulp floor of the occlusal box, forming a single mesiodistal corridor. Therefore, MOD preparation presented only the buccal and palatal walls, a common mesiodistal floor, and the pulpobuccal and pulpopalatal angles, naturally rounded by the shape of bur #2143. The bur was replaced every five cavity preparations. The superficial cavity angle received manual finishing with margin cutter #28 and #29 (SSWhite Art. Dentários Ltda., Rio de Janeiro, RJ, Brazil).

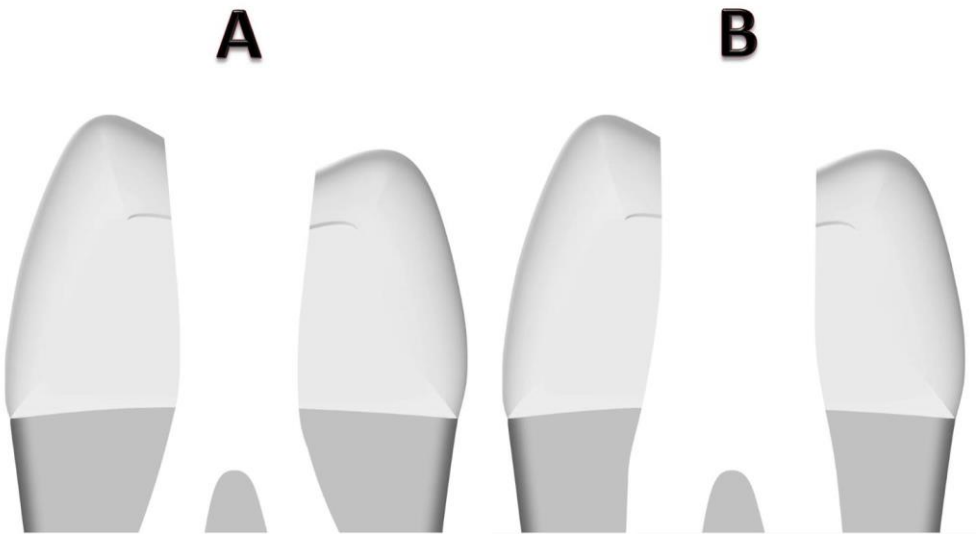
After MOD preparation, the specimens were once again stored in distilled water at 37°C.

Endodontic treatment

Carbide burs #02 and #04 (KG Sorensen Ind. E Com Ltda., Barueri, SP, Brazil) were used to access the pulp chamber at high speed, under water cooling. Convenience form was obtained using the Endo Z tip (Dentsply Ind. E Com Ltda., Petrópolis, RJ, Brazil).

The working length for preparation of the canals was 1 mm below the outlet of the foramen, following the serial technique using K-files #15, #20, #25, #30, and #35 instruments (Dentsply/Maillefer, Ballaigues, Switzerland). Irrigation was carried out with a 2.5% sodium hypochlorite solution administered with a 10-mL plastic syringe and Navitip® needle with an external diameter of 0.30 mm (Ultradent Products, Inc South Jordan, Utah, USA). Cervical preparation was performed only in teeth from groups CC, CCR, and HPCCR prior to the preparation of the canal. This was done with an La Axxess® bur (SybronEndo, Glendora, USA), #35, taper 0.6 mm, at a depth of 5 mm site of access to the canal, under irrigation with hypochlorite, for five seconds. The La Axxess® bur was changed every five cervical preparations (Figure 1).

Figure 1 - Schematic drawing of the MOD cavity preparation performed in premolars without (A) and with cervical preparation of the root canal (B).



After chemomechanical preparation, the canals were rinsed with 17% EDTA solution for 3 minutes with agitation of file #35 prior to filling. The canals were filled with gutta-percha cones and epoxy resin-based cement - AH Plus® (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland) and by the Tagger hybrid technique using McSpadden® #60 compactor (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland).

Demarcation and perforation for post transfixation

Perforations for horizontal transfixation of the posts were performed in the central portion of the coronal middle third of the buccal and palatal walls with a diamond bur #3145 (KG Sorensen, São Paulo, SP, Brazil) at high speed under water cooling. Bur #3145 has a diameter equal to 1.2 mm, slightly larger than that of the post, which favored its better fit in the transfixation hole. Perforation of both sides, buccal and palatal, was performed simultaneously on the same axis of insertion of the bur. The bur was changed every five cavity preparations. Reforpost® fiberglass posts with 1.1 mm in diameter (Angelus, Londrina, PR, Brazil) were used according to the technique described by Favero et al. [10] (2015).

Bonding of the fiberglass post in a horizontal position and restorative procedure

The procedures for horizontal bonding of the fiberglass posts were performed according to the following protocol:

- cleaning of the posts with 70% alcohol and drying with air jets.
- application of a silane layer (FGM Produtos Odontológicas, Joinville, SC, Brazil). Drying at room temperature, followed by the application of air jets at a distance of 15 cm for one minute.
- application of a thin layer of Singlebond Universal adhesive (3M ESPE, St. Paul, MN, USA), photoactivation with LED light unit (Bluephase, Ivoclar) for 20 seconds.

- etching of enamel and dentin with 35% phosphoric acid (Dentsply Ind e Com. Ltda, Petrópolis, RJ, Brazil) in the transfixation holes for 15 seconds, washing for 20 seconds, and drying with air jets for 5 seconds.
- etching of the enamel surface cavity with 35% phosphoric acid for 30 seconds, followed by washing for 30 seconds and drying with air jets for 5 seconds.
- application of the Singlebond Universal adhesive in the transfixation holes, and cavity preparation including pulp chamber, drying for 5 seconds, and photoactivation for 20 seconds per surface.
- insertion of Bulkfill flow resin (3M ESPE, St. Paul, MN, USA) in the pulp chamber up to the middle portion of the cavity preparation below the transfixation holes, followed by photoactivation for 40 seconds. All teeth, with or without transfixed posts, were filled from the pulp chamber to the middle portion of the preparation with Bulkfill flow resin, with a thickness of approximately 4 mm.
- insertion of Bulkfill flow resin in the transfixation holes, insertion of the fiberglass post horizontally in the transfixation holes, removal of excess resin with microbrush, and photoactivation for 40 seconds.
- application of Z250 resin (3M ESPE, St. Paul, MN, USA) by the incremental technique (4 increments of 2 mm each) in the MOD cavity preparation and photoactivation for 40 seconds per increment.

After the restorative procedure, the specimens were placed back in distilled water and kept therein for 48 hours at 37°C.

Mechanical compression test

The specimens were initially thermocycled between 5°C and 55°C in 500 cycles. The fracture strength test was then carried out on an EMIC DL - 2000 universal testing machine

(São José dos Pinhais, PR, Brazil). A 10-kN load cell was selected and the speed was 0.5 mm/min. A 6.0-mm metallic sphere was used for contact only with the inclined planes of the intercuspid surface of the occlusal surface of the specimen, without contact with the restorative material. Compressive stress was applied parallel to the long axis of the tooth until its fracture. The maximum fracture strength (rupture) of each specimen was recorded in Newtons.

Analysis of the type of dental fracture

After the fracture strength test, the teeth were visually examined for dental fracture with the aid of a magnifying glass (4X magnification). Two types of fractures were considered: 1) pulp chamber floor fracture associated or not with the cusp and 2) cusp fracture only. Floor fracture was considered when the fracture line divided the tooth into two parts at the pulp chamber floor level, regardless of whether it was buccal/palatal or mesial/distal. Cusp fracture was identified when the fracture line totally or partially involved one or more cusps, regardless of the presence or absence of displacement.

Statistical analysis

The Shapiro-Wilk test was used to assess the normality of the results, followed by one-way ANOVA and Tukey's test ($\alpha = 5\%$). Two-way ANOVA was used to assess the influence of the variables post, restoration, and cervical wear. Statistical analysis was performed using Statistix for Windows v.8.0.

Results

Two-way ANOVA indicated a significant influence of cervical wear ($p = 0.0001$), post ($p = 0.001$), and resin ($p = 0.001$). Considering all variables, the averages were: 599 N

for the group with cervical wear and 842 N for the group without it; 1,105 N for the group with post transfixation and 335 N for the group without it; and 992 N for restorations with composite resin and 449 N for those without it. The mean and standard deviation of fracture strength in Newtons (N) for the different experimental groups are shown in Table 2.

Table 2 - Fracture strength (Newtons (N)), coefficient of variation (CV), strength recovery in relation to group S, and pulp and cusp floor fracture in different experimental groups.

Groups	Mean ± SD (N)	CV	Strength recovery	Pulp floor fracture	Cusp fracture
S	2451 ^{A} ± 552.9	23%	--------	12.5% (1)	87.5%(7)
C	95.13 ^{B} ± 7.93	8%	-96%	100% (8)	----
CR	816.8 ^{C} ± 84.34	10%	-66.7%	50% (4)	50% (4)
HPCR	1,501 ^{D} ± 130	9%	-38.8%	25% (2)	75% (6)
CC	32.63 ^{B} ± 4.89	15%	-98.7%	100% (8)	----
CCR	398.7 ^{E} ± 73.8	19%	-83.7%	87.5% (7)	12.5% (1)
HPCCR	1,253 ^{D} ± 82.15	7%	-48.9%	62.5% (5)	37.5% (3)

Means followed by different uppercase letters differ significantly in one-way ANOVA and Tukey's test ($p < 0.05$)

Discussion

Cervical preparation prior to chemomechanical preparation allows greater control over cleaning, instrumentation, and disinfection of the root canal system[11]. The operative technique can be performed with Gates Glidden drills, wide orifice openers, and La Axxess burs. La Axxess burs provide better technical quality[12]. This was decisive for the selection of this system in the present study.

The null hypothesis that there would be no statistical difference in fracture strength in upper premolars treated endodontically with or without cervical preparation was rejected. Those teeth subjected to cervical preparation and restored without a post showed less fracture

strength (Table 2). Although the negative controls, without restoration, with or without cervical preparation did not show statistical difference in fracture strength ($p = 0.5743$), 100% of crown fractures in both negative controls occurred at the pulp floor level.

Dental fracture has been reported as the third leading cause of loss of restored teeth[13]. It is believed that greater dilation of the cervical third of the root canal tends to induce the extension of dental fractures to the more cervical region, as with greater tissue loss in the region, associated with dental arch constriction, there will consequently be greater stress there, which will favor the occurrence of fractures at or below the pulp chamber floor. This leads us to reflect on the importance of preserving the structure of the pericervical dentin as much as possible, which can be defined as the area approximately 4 mm above and 6 mm below the bone crest[14].

The loss of the pericervical dentin structure is responsible for the transfer of occlusal forces to the root region. This somewhat justifies the finding of our study that dental fracture in teeth subjected to dilation of the cervical third of the root canals was greater at the pulp floor level.

The use of upper premolars was based on the study by Salameh et al. [15] (2007), in which the incidence of fractures was higher in those teeth, mainly due to the morphological configuration of the teeth. Taha et al. [16] (2015), Kalay et al. [17] (2016), and Hshad et al.[18] (2018) also used premolars in their studies.

MOD cavity preparation was performed in order to simulate a routine situation in the clinical setting. According to Reeh et al. [19] (1989), MOD cavity preparation reduces the structural stability of teeth by approximately 63%.

In teeth whose restorative protocol was associated with the transfixation of fiberglass posts, a significant increase in fracture strength can be seen in teeth with or without cervical preparation (Table 2). In other words, the use of a transfixed post influenced the final fracture

strength (p = 0.0001). These findings are in line with studies by Karzoun et al. [20] (2015), Aslan et al. [21] (2018), and Dhingra et al. [22] (2018), who presented positive results with the use of fiber posts horizontally transfixed in the dental crown.

Achieving greater fracture strength with this restorative technique is due not only to the position of fixation of the posts closest to the occlusal surface of the teeth, reinforcing them, but also to the replacement, to some extent, of the lost anatomical structures that lead to lesser or greater deflection of cusps without supports[23].

In cases without cervical preparation and with the use of transfixed posts in the restorative treatment, most fractures were at the cusp level, which is in accordance with the study by Dhingra et al. [22] (2018), who observed a lower rate of catastrophic fractures in teeth subjected to horizontal post placement. On the other hand, in teeth subjected to greater cervical wear resulting from cervical endodontic preparation, there was an increase in pulp floor fractures, even after restoration with post transfixation.

According to Soares et al. [24] (2008) and Skupien et al. [3] (2016), the preservation of a good cervical tooth structure considerably increases fracture strength. In the positive control group, fracture strength was significantly greater than in all other groups. These results can be explained by the fact that the preservation of the tooth structure increases fracture strength in the presence of occlusal loads[25].

It can be concluded that cervical preparation is associated with lower fracture strength in restored teeth without fiber posts. Teeth restored with transfixed fiber posts, regardless of cervical preparation, have greater fracture strength. However, the use of fiberglass posts does not prevent the occurrence of fractures at the pulp floor level, either in the presence or absence of cervical wear.

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4. ARTIGO CIENTÍFICO N°2

O artigo foi traduzido para o idioma inglês (Anexo C) e submetido à publicação no periódico *Giornale Italiano di Endodonzia*, eISSN 1121-4171.

Effect of horizontal position of fiber post placement on fracture resistance and location in endodontically treated premolars with a MOD preparation

Abstract

Aim: To evaluate the effect of the position of fiber post placement on fracture resistance and location in endodontically treated teeth. **Methodology:** Forty double-rooted human first premolars were divided into five groups: S: healthy teeth; C: endodontic treatment with MOD cavity preparation; CR: restoration with composite resin; CMP: fiber post placed horizontally in the center of the middle third of the crown; CAP: fiber post placed horizontally 2 mm below the center of the middle third of the crown. After thermocycling and fracture strength tests using a universal test machine, pulp floor involvement was evaluated. The Tukey test was used for statistical analysis. **Results:** Means and standard deviations of fracture strength (N) were: S: $2451^{A} \pm 552.9$; C: $32.63^{B} \pm 4.89$; CR: $398.7^{C} \pm 73.8$; CRMFP: $1253^{D} \pm 82.15$; and CRAFP: $1156^{D} \pm 88.23$ (different letters indicate statistical differences - $P > 0.05$). Posts placed 2 mm below the center of the middle third of the crown were associated with catastrophic fractures of the pulp chamber floor. **Conclusions:** The position of a fiber post seems to affect fracture location. The use of fiber posts, regardless of position, increases fracture resistance of endodontically treated teeth.

Keywords: Endodontically treated teeth, horizontal fiber post, position of the post, fracture resistance.

Introduction

Endodontically treated teeth have a higher risk of biomechanical failure than vital teeth, despite advances in restorative materials and procedures (1). The loss of structural integrity of cusps and ridges and the complete removal of the pulp chamber roof during endodontic access affect tooth function because of cusp deflection, which may lead to a higher occurrence of fractures (2).

Restorative treatments using posts placed horizontally across the dental crown seem to be an excellent method to increase the resistance to fracture of the crown in weakened teeth, although catastrophic fractures may still occur (3-6).

According to Mangold et al (7), unfortunately, most tooth fractures occur 2 to 3 mm below the coronal margin, which may complicate restoration and make prognosis unclear. Dentists should be aware of the interaction between loads applied to the tooth, the distribution of areas of greatest stress and the types of potential fractures, so that they may plan a restorative treatment that eliminates or reduces the effect of these factors to preserve any remaining tooth structure as much as possible. This study evaluated the effect of horizontally placed fiber posts on fracture strength and location in endodontically treated premolars restored with a MOD preparation.

The initial null hypothesis was that there would be no influence of the horizontally placed fiber posts on fracture strength and location in the restored teeth.

Methods

This study was approved by the local Research Ethics Committee (CAAE 68708217.2.0000.5347; Anexo B).

Sample selection and preparation

Forty double-rooted human maxillary first premolars, free of carious lesions, restorations, or cracks were selected.

Buccolingual (9 mm ± 0.5 mm) and mesiodistal (7 mm ± 0.5 mm) dimensions of the crowns were measured at the most prominent part of their surfaces using a digital caliper (Mitutoyo, Suzano, SP, Brazil).

After cleaning, the teeth were placed in 0.5% chloramine (Seachem Laboratories, Madison, GA) for 48 hours for disinfection. After that, they were randomly divided into five experimental groups (Table 1).

Table 1 - Experimental groups.

Groups	**n**	**Group Description**
S	8	Healthy tooth
C	8	MOD preparation (MOD) + endodontic treatment (RCT)
CR	8	MOD + RCT + composite resin restoration (R)
CMP	8	MOD + RCT + horizontal fiberglass post transfixed in the middle third of dental crown center + R
CAP	8	MOD + RCT + horizontal fiberglass post transfixed 2 mm below the center of middle third dental crown + R

Preparation of specimens

Each tooth was individually included in PVC cylinder measuring 2 cm in height and 3 cm in diameter using a self-curing acrylic resin. The specimens were centered inside the PVC cylinder and the anatomic neck of the tooth was kept 2 mm above the edge of the acrylic material. After that, the specimens were stored in distilled water at 37° C.

MOD cavity preparation

The inclination and movements of a #2143 diamond bur (KG Sorensen, São Paulo, Brazil) were standardized for the preparation of MOD cavities.

Cavity preparations followed the method described by Cötert et al. (8) and Beltrão et al. (9). A line from the central groove was drawn to ensure that the buccal and palatal walls of the prepared area were at a distance that corresponded to two-thirds of the intercuspal distance. This line ran over the central groove, to the mesial surface, over the marginal ridge and towards the tooth neck to define a height of 4 mm for the preparation. The same buccolingual width previously determined on the occlusal surface was defined for the mesial surface, and the same width was defined for the proximal boxes. A #2143 diamond bur initially positioned on the mesial surface over the central line was used along a predetermined length. Next, a mesiodistal box as wide as the tip was prepared. The buccal and palatal walls followed the predetermined limits, so that the gingival floor was connected to the pulp floor of the occlusal box, forming a single mesiodistal corridor. Therefore, the MOD preparation had only buccal and palatal walls and a common mesiodistal floor; the buccal and palatal angles of the pulp chamber floor were rounded using a #2143 bur, replaced after each five cavity preparations. The superficial cavity angle was finished manually using #28 and #29 margin cutters (SSWhite Art. Dentários Ltda., Rio de Janeiro, Brazil). In group S, no MOD cavity was prepared.

After MOD preparation, the specimens were again stored in distilled water at 37°C.

Endodontic treatment

The pulp chamber was accessed using #02 and #04 Carbide burs (KG Sorensen Ind. E Com Ltda., Barueri, SP, Brazil) at high speed, under water cooling. Convenience form was established using the Endo Z tip (Dentsply Ind. E Com Ltda., Petrópolis, Brazil).

The working length was set at 1 mm short of the foramen, and canals were prepared following a serial technique using #15, #20, #25, #30, and #35 K-files (Dentsply/Maillefer, Ballaigues, Switzerland). Canals were irrigated with 2.5% sodium hypochlorite applied with a 10-mL plastic syringe and a 30-ga Navitip® (Ultradent Products, Inc. South Jordan, UT). The cervical area was prepared before canal preparation using a #35 La Axxess® bur (SybronEndo, Glendora, CA), 0.6 mm taper, to a depth of 5 mm of canal access, under irrigation with hypochlorite.

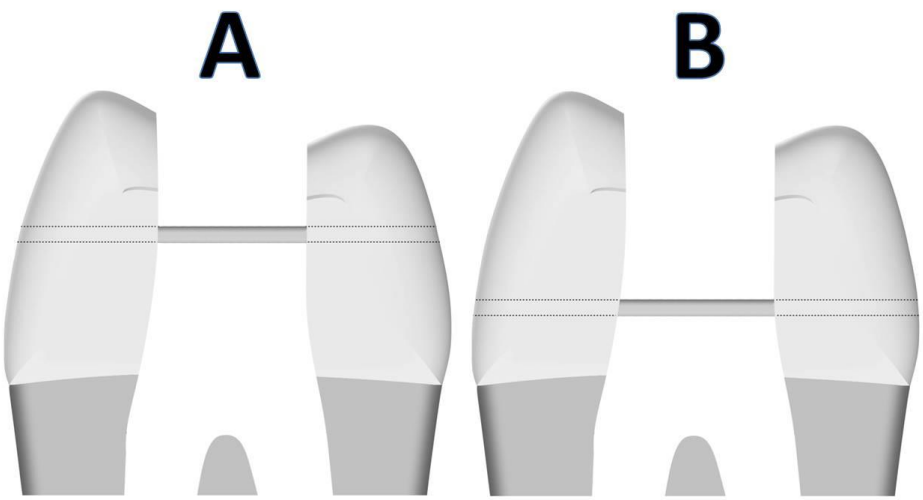
After cleaning and before filling, the canals were rinsed with 17% EDTA under agitation with a #35 file for 3 minutes. The canals were filled with a resin-based sealer (AH Plus®, Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland) using the Tagger hybrid technique and a #60 McSpadden® compactor (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland).

Perforation for post placement

The fiber posts used were Reforpost® (Angelus, Londrina, Brazil) measuring 1.1 mm in diameter. They were perforated on the buccal and palatal walls using a #3145 diamond tip (KG Sorensen, São Paulo, Brazil) at high rotation and under refrigeration. As the #3145 tip has a diameter of 1.2 mm, slightly larger than that of the post, the posts fit the perforated holes. The perforation of both buccal and palatal walls was simultaneous and along the axis of tip insertion. The tip was changed after perforation of each five teeth.

The teeth of the CMP group were perforated in the central area of the middle third of the crown on the two tooth surfaces. In the CAP group, the perforations were made 2 mm below the most prominent point of the middle third of the crown (Figure 1).

Figure 1 - Schematic drawing of the transfix position of the fiberglass post in the dental crown (A - middle third of dental crown; B - 2 mm below the middle third of dental crown).



Bonding of fiber posts place horizontally and restorative procedures

Bonding of the posts placed horizontally followed the protocol below:

- cleaning of the posts with 70% alcohol and drying with air spray;

- application of a silane layer (FGM Produtos Odontológicas, Joinville, Brazil); drying at room temperature, followed by application of air spray from a distance of 15 cm for one minute;

- application of a thin layer of Singlebond Universal adhesive (3M ESPE, St. Paul, MN), and photoactivation using a LED light unit (Bluephase, Ivoclar) for 20 seconds;

- enamel and dentin etching with 35% phosphoric acid (Dentsply Ind. e Com. Ltda, Petrópolis, Brazil) applied to the holes for 15 seconds, then rinsing for 20 seconds and air drying for 5 seconds;

- etching of enamel on the cavity surface with 35% phosphoric acid for 30 seconds, rinsing for 30 seconds and air drying for 5 seconds;

- application of the Singlebond Universal adhesive to the holes, cavity and pulp chamber preparation, drying for 5 seconds, and photoactivation for 20 seconds on each surface;
- insertion of Bulkfill flow resin (3M ESPE, St. Paul, MN) into the pulp chamber up to the middle of the cavity below the site of the holes, and photoactivation for 40 seconds; all teeth, with or without posts were filled from the pulp chamber to the middle of the area prepared using the Bulkfill flow resin, applied to a thickness of about 4 mm;
- insertion of Bulkfill flow resin into the holes, placement of the fiber posts horizontally in the holes, removal of excess resin with a microbrush, and photoactivation for 40 seconds.
- application of Z250 resin (3M ESPE, St. Paul, MN) to the MOD cavity in four increments of 2 mm each, and photoactivation for 40 seconds for each incremental application.

After restorations, the specimens were placed back in distilled water and stored for 48 h at 37° C.

Mechanical compression test

Specimens were thermocycled between 5° C and 55° C for 500 cycles. Fracture strength was determined using an EMIC DL - 2000 universal testing machine (São José dos Pinhais, Brazil) with a 10-kN load cell at a crosshead speed of 0.5 mm/min. A 6.0-mm metal sphere was used for contact only with the inclined planes of the intercuspal surface of the occlusal surface of the specimen, without any contact with the restorative material. Compressive stress was applied parallel to the long axis of the tooth until fracture. The maximum fracture strength (rupture) was recorded in Newton for each specimen.

Analysis of type of tooth fracture

A magnifying glass (4X magnification) was used to examine specimens visually for fractures, which were classified either as a pulp chamber floor fracture associated or not with

the cusp, or as a cusp fracture only. Floor fractures separated the tooth into two parts at the pulp chamber floor, in a buccolingual or mesiodistal direction. Cusp fractures involved one or more cusps totally or partially, with or without displacement.

Statistical analysis

The Shapiro-Wilk test was used to evaluate normality of the results, and data were analyzed using one-way ANOVA and the Tukey test (α = 5%). The GraphPad Prism 7 software (GraphPad Software Inc., San Diego, CA) was used for all statistical analyses.

Results

Means and standard deviations of fracture strength in Newton (N) according to study group are shown in Table 2.

Table 2 - Fracture strength (Newtons (N)), coefficient of variation (CV), strength recovery in relation to group S, and pulp and cusp floor fracture in different experimental groups.

Groups	**Mean ± SD (N)**	**CV**	**Strength recovery**	**Pulp floor fracture**	**Cusp fracture**
S	2451 ^{A} ± 552.9	23%	--------	12.5% (1)	87.5%(7)
C	32.63 ^{B} ± 4.89	15%	-98.6%	100% (8)	----
CR	398.7 ^{C} ± 73.8	18%	-83.7%	87.5% (7)	12.5% (1)
CMP	1253 ^{D} ± 82.15	7%	-48.8%	62.5% (5)	37.5% (3)
CAP	1156 ^{D} ± 88.23	8%	-52.8%	87.5% (7)	12.5% (1)

Means followed by different uppercase letters differ significantly in one-way ANOVA and Tukey's test ($p < 0.05$)

Discussion

Fractures of endodontically treated teeth are common in clinical practice, and numerous studies have reported a high incidence of fractures of maxillary premolars (10-12). Ibrahim et al (13), Taha et al (14), and Aslan et al (4) also used premolars in their experimental studies.

This study simulated an unfavorable clinical scenario, in which the cusps lose tissue support and tend to undergo greater deflection, and used class II MOD preparations for restorations, as in the studies by Salameh et al (15), Soares et al (16), and Taha et al (14). Lopes et al (17) showed that MOD preparations in premolars reduce cusp stiffness to a third of that of a healthy tooth, which makes them more susceptible to fracture.

Horizontally placed posts associated with the material used for restorations in endodontically treated teeth, regardless of placement position, had greater fracture resistance than teeth restored without posts. These findings are in agreement with the studies by Karzoun et al (3), Aslan et al (4), and Dhingra et al (5), who also worked with horizontal post placement in premolars with MOD cavities.

The horizontal placement of posts in the center of the middle third of the crown is associated with a greater chance of fractures at the cusp level, without involvement of the pulp floor. These fractures have a better prognosis and result in better tooth survival and restoration. In specimens that received other treatments in this study, including horizontal post placement 2 mm below the center of the middle third of the crown, most fractures occurred catastrophically at or below the floor of the pulp chamber. All fractures were above the horizontal post, which is in agreement with the study conducted by Kao (18), who found that less catastrophic tooth fractures are largely associated with post placement position, that is, posts placed closer to the occlusal surface have better outcomes.

The cervical constriction of premolars may play an important role in the extension of tooth fractures to the most cervical region, at or below the floor of the pulp chamber. Restorations should be carefully planned to predict the site of a possible future fracture. Dentists may, thus, induce and direct the fracture to a position that, should it happen, ensures good conditions for a better restoration.

Almost all fractures in this study were in the palatal area of the teeth, in agreement with findings by Mangold and Kern (7). According to Panahandeh et al (19), the stress area on the palatal cusp is greater than on the buccal cusp.

Conclusions

The use of fiber posts for restorations, regardless of their position, increases fracture resistance of endodontically treated teeth. However, their placement position seems to affect fracture location.

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5. CONCLUSÃO

De acordo com os resultados encontrados, pode-se concluir que dependendo do procedimento restaurador realizado o preparo cervical influência na resistência à fratura de dentes tratados endodonticamente, inclusive com maior porcentagem de fraturas ao nível do assoalho da câmara pulpar.

Também, pode-se concluir que o uso transfixado de pinos de fibra de vidro horizontalmente no procedimento restaurador aumentou a resistência à fratura dos dentes tratados endodonticamente, porém a sua posição de transfixação não interferiu. Os pinos transfixados no meio da coroa dentária induziram que uma maior porcentagem das fraturas ocorresse ao nível de cúspide.

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ANEXOS

ANEXO A - Certificado da tradução do artigo científico n°1 para o idioma inglês

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CERTIFICATE

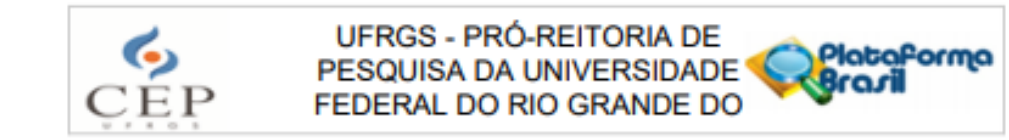
This is to certify that Gilson André França de Mattos, technical translator with extensive expertise in the translation/revision of scientific articles, has been involved in the revision of the English language in the manuscript entitled "EVALUATION OF THE INFLUENCE OF CERVICAL ENDODONTIC PREPARATION ON FRACTURE STRENGTH OF PREMOLARS WITH MOD PREPARATION SUBJECTED TO DIFFERENT RESTORATIVE PROTOCOLS."

I do not take any responsibility for changes in the manuscript made by the authors and co-authors after my final revision without my knowledge and approval.

Gilson Mattos

Porto Alegre, March 19, 2020.

ANEXO B - Carta de aprovação do Comitê de Ética em Pesquisa



PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliação da resistência à fratura de pré-molares, com preparo MOD e manipulados endodonticamente, restaurados e transfixados por um pino de fibra de vidro

Pesquisador: Tiago André Fontoura de Melo
Área Temática:
Versão: 2
CAAE: 68708217.2.0000.5347
Instituição Proponente: Faculdade de Odontologia
Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.180.017

Apresentação do Projeto:
Trata-se de um projeto de pesquisa da Faculdade de Odontologia da UFRGS

Objetivo da Pesquisa:
Objetivo Primário:
Avaliar, in vitro, a resistência à fratura do elemento dentário, com preparo MOD e manipulado endodonticamente, restaurado e transfixado por um pino de fibra de vidro. Também será avaliado se a posição de transfixação do pino de fibra de vidro no elemento dentário interfere na sua resistência à fratura.
Objetivo Secundário:
- Avaliar a influência do preparo endodôntico cervical na resistência à fratura;
- Avaliar se a utilização do pino de fibra de vidro transfixado à coroa dentária interfere na resistência à fratura;
- Avaliar a influência da posição de transfixação do pino na resistência à fratura do elemento dentário;
- Avaliar e comparar os grupos quanto ao padrão de fratura das peças dentárias; e,

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Bairro: Farroupilha **CEP:** 90.040-060
UF: RS **Município:** PORTO ALEGRE
Telefone: (51)3308-3738 **Fax:** (51)3308-4085 **E-mail:** etica@propesq.ufrgs.br

- Analisar, pelo método visual, o prognóstico do remanescente dentário após a ocorrência da fratura.

Avaliação dos Riscos e Benefícios:

Os pesquisadores fizeram as mudanças solicitadas pelo CEP e as considerações em relação aos riscos estão em condições de aprovação. (PENDÊNCIA ATENDIDA)

Comentários e Considerações sobre a Pesquisa:

Serão utilizados setenta primeiros pré-molares superiores humanos hígidos, obtidos em consultórios odontológicos particulares, os quais serão extraídos por motivos diversos. Os dentes selecionados serão divididos aleatoriamente em sete grupos experimentais. A realização dos procedimentos experimentais basear-se-á em estudos prévios e serão testadas variações técnicas nos procedimentos de realização do tratamento endodôntico e restaurador com vistas a redução do risco de fratura.

Dois tipos de fraturas serão consideradas: fratura de assoalho pulpar ou fratura de cúspide. Será considerada fratura de assoalho quando a linha de fratura dividir o dente em duas partes no nível do assoalho pulpar da cavidade, independente do sentido ser vestibular/palatino ou mesial/distal.

Os pesquisadores esclareceram que as amostras serão provenientes dos ambulatórios de atendimento da Faculdade de Odontologia e anexaram uma carta de anuência da professora responsável pelos atendimentos. (PENDÊNCIA ATENDIDA)

Considerações sobre os Termos de apresentação obrigatória:

- Folha de rosto: adequada
- Cálculo amostral: apresentado
- Orçamento: a pedido do CEP, os custos gerados pela execução do projeto foram atribuídos apenas ao pesquisador responsável pelo mesmo. (PENDÊNCIA ATENDIDA)
- Cronograma: apresentado e em condições de aprovação.
- Termo de doação de dentes: apresentado e em condições de aprovação.
- TCLE: a linguagem foi adequada. (PENDÊNCIA ATENDIDA)

Conclusões ou Pendências e Lista de Inadequações:

O parecer é favorável à aprovação do projeto.

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Considerações Finais a critério do CEP:

Aprovado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_923592.pdf	23/06/2017 13:56:04		Aceito
Outros	PARECER_tiago_melo.pdf	23/06/2017 13:54:30	Tiago André Fontoura de Melo	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TERMO_DE_CONSENTIMENTO_LIVRE_E_ESCLARECIDO_PARA_PESQUISA.pdf	23/06/2017 13:52:22	Tiago André Fontoura de Melo	Aceito
Outros	Carta_de_Anuencia_da_Cirurgia.pdf	23/06/2017 13:51:57	Tiago André Fontoura de Melo	Aceito
Outros	Carta_resposta_ao_CEP.pdf	23/06/2017 13:50:41	Tiago André Fontoura de Melo	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_de_Pesquisa.docx	23/06/2017 13:45:49	Tiago André Fontoura de Melo	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_doacao_dentes.pdf	19/05/2017 09:03:36	Tiago André Fontoura de Melo	Aceito
Folha de Rosto	Folha_de_Rosto_Tiago.pdf	19/05/2017 08:57:45	Tiago André Fontoura de Melo	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

PORTO ALEGRE, 20 de Julho de 2017

Assinado por:
MARIA DA GRAÇA CORSO DA MOTTA
(Coordenador)

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ANEXO C - Certificado da tradução do artigo científico n°2 para o idioma inglês

Anelise**T**eixeira **B**urmeister
Tradutora Pública e Intérprete Comercial – Português – Inglês
Public Translator and Commercial Interpreter – Portuguese – English

Statement

I hereby certify that I reviewed the manuscript *Effect of position of fiber post placement on fracture resistance and location in endodontically treated premolars with a MOD preparation* on December 3, 2020, as requested by one of its authors, Tiago André Fontoura de Melo.

Anelise Burmeister

Translator