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Natércia Rezende da Silva

Cimentação de pinos de fibra de vidro – efeito do método de verificação do preparo do conduto e da mistura e inserção de cimento resinoso

Tese apresentada à Faculdade de Odontologia da Universidade Federal de Uberlândia, como requisito parcial para obtenção do Título de Doutor em Odontologia na Área de Concentração de Clínica Odontológica Integrada.

Uberlândia, Julho de 2017

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Integrada.

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Ata da defesa de TESE DE DOUTORADO junto ao Programa de Pós-graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia.

Defesa de: Tese de Doutorado nº 020- COPOD
Data: 18/08/2017
Discente: Natércia Rezende da Silva - (11313ODO010)
Título do Trabalho: **Cimentação de pinos de fibra de vidro – efeito do método de preparo do conduto e da manipulação e inserção de cimento resinoso Análise por Micro CT, ensaio de adesão e análise de elementos finitos**
Área de concentração: Clínica Odontológica Integrada.
Linha de pesquisa: Biomecânica Aplicada à Odontologia
Projeto de Pesquisa de vinculação: Biomecânica Aplicada à Odontologia
As **oito horas** dia **dezoito de agosto de 2017** no Anfiteatro Bloco 4L Anexo A, sala 23 Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em junho de 2017, assim composta: Professores Doutores: Murilo de Sousa Menezes (UFU); Paulo César Freitas Santos Filho (UFU); Hugo Lemes Carlo (UFJF); Rodrigo Borges Fonseca (UFG); Carlos José Soares (UFU) orientador(a) do(a) candidato(a) **Natércia Rezende da Silva.**

Iniciando os trabalhos o(a) presidente da mesa Dr. Carlos José Soares apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de argüição e resposta foram conforme as normas do Programa.

A seguir o senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos (às) examinadores (as), que passaram a argüir o(a) candidato(a). Finalizada a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Em face do resultado obtido, a Banca Examinadora considerou o(a) candidato(a) Aprovado(a).

Esta defesa de Tese de Doutorado é parte dos requisitos necessários à obtenção do título de Doutor. O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos às 14 horas e 05 minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Prof. Dr. Hugo Lemes Carlo - UFJF

Prof. Dr. Rodrigo Borges Fonseca - UFG

Prof . Dr. Murilo de Sousa Menezes – UFU

Prof. Dr. Paulo César Freitas Santos Filho– UFU

Prof. Dr. Carlos José Soares – UFU
Orientador(a)

DEDICATÓRIA

Ao Divino Pai Eterno, á Jesus Cristo e à Nossa Senhora Aparecida

Agradeço pela minha vida e por todas as bênçãos a mim concedidas. Muito obrigada por ter certeza de que apesar das tribulações em alguns momentos posso sentir a proteção e as infinitas bênçãos do céu na minha vida. Obrigada Senhor, a ti toda honra, louvor e glórias!

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“Aquele que habita no esconderijo do Altíssimo, à sombra do Onipotente descansará. Direi do Senhor: Ele é o meu Deus, o meu refúgio, a minha fortaleza, e nele confiarei”

Salmo 91.

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Cimentação de pinos de fibra de vidro – efeito do método de verificação do preparo do conduto e da mistura e inserção de cimento resinoso. – Faculdade de Odontologia – Universidade Federal de Uberlândia

RESUMO

A restauração de dentes tratados endodonticamente frequentemente requer o uso de retentores intraradiculares para viabilizar a reconstituição coronária, promovendo retenção à restauração. No entanto, o sucesso desse tratamento pode ser influenciado por diversos fatores biológicos, mecânicos e estéticos. Este estudo tem como objetivo geral avaliar diversas etapas que interferem no desempenho da cimentação de pinos de fibra de vidro em dentes tratados endodonticamente. O mesmo foi dividido em quatro objetivos específicos; **objetivo específico 1:** avaliar o efeito da porosidade de cimentos resinosos autoadesivos na distribuição de tensões, retenção do pino e padrão de falha de pinos de fibra de vidro cimentados em dentina radicular humana. O**bjetivo específico 2:** avaliar o efeito do método de visualização durante o preparo do espaço do pino sobre o remanescente de material obturador endodôntico e sobre a resistência adesiva do pino de fibra de vidro. Análise por microCT e micropushout. O**bjetivo específico 3:** avaliar o efeito do método de mistura e inserção de cimentos resinosos no canal radicular sobre a porosidade do cimento e resistência adesiva do pino de fibra de vidro. Análise por microCT e micropushout. O**bjetivo específico 4:** apresentar aos clínicos protocolo de cimentação de pinos de fibra de vidro, estabelecendo guia prático de técnicas de mistura e inserção de cimentos resinosos auto-adesivos. A análise dos resultados dos diferentes objetivos conclui se que: a presença de bolhas afetou negativamente a distribuição de tensão e a resistência de união de pinos de fibra de vidro à dentina radicular. Recomenda-se o uso de microscopia confocal para análise de padrão de falha. O uso de dispositivo de aumento da visão como a lupa e o microscópio no momento do preparo do espaço do pino não melhorou a resistência adesiva e não interferiu na quantidade de material obturador endodôntico remanescente no preparo de dentes

anteriores. O uso de dispositivo de ampliação da visão como lupa e microscópio não são primordiais no processo de preparo do conduto para cimentação de pino de fibra de vidro. A resistência adesiva e a porosidade são negativamente influenciados pela manipulação manual e inserção do cimento com lima endodôntica na cimentação de pinos de fibra de vidro, pois resulta em maior geração de bolhas. O método de auto-manipulação e inserção dos cimentos resinosos auto-adesivos com pontas que geram acesso à porção mais apical do conduto radicular (endo tips) produzem melhor resultado na cimentação de pino de fibra de vidro. A adequada seleção do sistema de pino somente deve ser indicada na ausência de retenção para reconstrução coronária e o mínimo desgaste da estrutura dental deve ser preconizado; o diâmetro do pino deve ser limitado ao diâmetro do canal radicular. Cimentos resinosos auto-adesivos reduzem os passos clínicos e possíveis erros técnicos na cimentação de pinos de fibra de vidro e devem ser misturados e inseridos usando pontas com acesso ao terço mais apical do canal radicular (centrix para cimentos misturados manualmente e endo tips para cimentos automix).

ABSTRACT

Cimentação de pinos de fibra de vidro – efeito do método de verificação do preparo do conduto e da mistura e inserção de cimento resinoso. – Faculdade de Odontologia – Universidade Federal de Uberlândia

ABSTRACT

Restoration of endodontically treated teeth frequently requires the use of fiberglass post to enable coronary reconstitution, promoting retention to the restoration. The success of the treatment may be influenced by several biological, mechanical and aesthetic factors. This study aimed to evaluate several steps that interfere in the performance of fiberglass post cementation in endodontically treated teeth. This study was divided into four specific objectives; **specific objective 1:** to evaluate the effect of porosity of self-adhesive resin on the stress distribution, post retention and failure mode of fiber post cemented to human root dentin; **specific objective 2:** to evaluate the effect of visualization method for post space preparation on root cleanness and on fibre post bond strength. MicroCT and micopushout analysis. **Specific objective 3:** to evaluate the effect of the resin cement mixing and insertion method into the root canal on resin cement porosity and fiber post push-out bond strength. MicroCT and micopushout analysis. **Specific objective 4:** to present the clinical protocol of fiberglass post cementation, establishing clinical guidelines for mixing and insertion of self-adhesive resin cements. After analysing the results, it can be concluded that the bubbles generated during resin cement insertion into the root canal negatively affect the stress distribution and the bond strength. The use of confocal microscopy is recommended for failure analysis. The use of magnification devices as loupes and microscopes while performing post space preparation did not improve the bond strength and did not affect in the sealer remain of anterior teeth. Bond strength and porosities is influenced by the mixing process and insertion with endodontic file for luting glass fiber posts. The automix associated to delivery system (endo tip) produced better results for cementing fibreglass posts. The adequate selection of the post system which should only be indicated in the absence of retention for coronary reconstruction and the minimum wear of the tooth structure should be prioritized; the post diameter should be limited to the root canal diameter. Self-adhesive resin cements reduce clinical steps and possible technical errors in glass fiber post cementation and should be mixed and inserted using tips with access to the most apical third of the root canal (centrix for manual mixing cements and endo

tips for automix cements). The use of vision magnifying devices such as lupes and surgical microscope are not primordial in the process of clearing the root canal for fiberglass post cementation. Adhesive strength and porosity are negatively influenced by the manual manipulation and insertion of the cement with endodontic file in the fiberglass post cementation, as it results in a greater generation of bubbles. The method of self-manipulation and insertion of self-adhesive resin cements with tips that generate access to the most apical portion of the root canal (endo tips) produces a better result in fiberglass post cementation. The adequate selection of the post system should only be indicated in the absence of retention for coronary reconstruction and the minimum wear of the dental structure should be recommended; the diameter of the post should be limited to the diameter of the root canal. Self-adhesive resin cements reduce clinical steps and possible technical errors in fiberglass post cementation and should be mixed and inserted using tips with access to the most apical third of the root canal (centrix for manually mixed cements and endo tips for automix cements).

INTRODUÇÃO E REFERENCIAL TEÓRICO

INTRODUÇÃO E REFERENCIAL TEÓRICO

Inúmeros fatores biológicos, mecânicos e estéticos estão envolvidos no sucesso dos procedimentos restauradores em dentes tratados endodonticamente (Soares *et al.,* 2012). Estes dentes requerem frequentemente o uso de sistema de pino para promover retenção à restauração, devido à extensa perda de estrutura dental coronária decorrente de cárie, das sucessivas trocas de restaurações, fraturas dentais ou do preparo cavitário (Heydecke & Peters, 2002; Rezende *et al*., 2016; Rodrigues *et al*., 2017).

A adequada seleção do sistema de pino a ser utilizado, associado à priorização de desgaste mínimo de estrutura dentária, deve ser destacada (Soares *et al.,* 2012). Tem sido preconizado que a presença da férula garante melhora na previsibilidade de pinos de fibra de vidro (Soares *et al.,* 2012). Estes pinos têm demonstrado bom desempenho clínico, de forma semelhante aos núcleos moldados e fundidos. Os núcleos metálicos fundidos apresentam boa longevidade clínica. No entanto, as falhas são em sua maioria catastróficas e irreversíveis, ao contrário do que acontece com os pinos de fibra de vidro, que são na sua maioria reparáveis (Soares *et al.,* 2012; Novais *et al*., 2016).

As interações químicas entre os cimentos resinosos e a hidroxiapatita podem ser mais impactantes ao processo de adesão á dentina radicular do que a capacidade do mesmo material hibridizar a dentina (Bitter *et al.,* 2009). Os cimentos auto-adesivos, compostos por monômeros acídicos polimerizáveis a base de metacrilato, na presença de água, devem desmineralizar a camada de smear layer da dentina subjacente e simultaneamente infiltrar a superfície dentinária porosa devido às suas propriedades hidrofílicas. Contudo, por meio da microscopia eletrônica de transmissão (TEM) e de microscopia eletrônica de varredura (SEM) foi observado que não há formação de camada híbrida na interface adesiva cimento-dentina e a incapacidade do cimento autoadesivo penetrar na dentina desmineralizada (Yang *et al.,* 2006). Além disso, a habilidade desses cimentos se difundirem e descalcificarem a dentina subjacente está relacionada à viscosidade do produto devido à reação ácido-base que ocorre após a mistura das pastas (Monticelli *et al.,* 2008). Reagir efetivamente com a dentina é particularmente importante para os cimentos auto-adesivos porque os mesmos dependem do maior contato com os tecidos dentários para reagir com a hidroxiapatita, permitindo uma interação melhor dos monômeros com a dentina e garantindo o potencial de selamento (Di Hipólito *et al.,* 2012; Pereira *et al*., 2015). Esses cimentos autoadesivos apresentam maiores valores de resistência de união quando tendem a aumentar o pH por um período de 24 horas a fim de não provocar efeito adverso na adesão decorrente da manutenção de um ph baixo (Pedreira *et al*., 2009).

Além disso, o fator de configuração cavitário (Fator C) desfavorável encontrado no interior do canal, em adição à elevada contração de polimerização observada quando da cimentação de pinos, representam ainda grande obstáculo à efetiva adesão às paredes do canal radicular (Bouillaguet *et al.,* 2003). A distribuição do cimento ao longo do espaço preparado para o pino desempenha papel significante na resistência adesiva entre cimento resinoso e parede interna do canal radicular (Gomes *et al.,* 2011; Silva *et al*., 2015). Assim como a adequada polimerização desse cimento, que deve ser suficiente e capaz de alcançar propriedades mecânicas satisfatórias do cimento resinoso e boa adesão à dentina radicular (Gomes *et al.,* 2011). A redução da intensidade de luz por consequência da distância da fonte de luz e pelo bloqueio natural das estruturas presentes torna-se desafio a ser vencido na obtenção de homogênea adesão ao longo da extensão do pino no interior do canal preparado (Rueggeberg & Caughman, 1993). Assim, quando a interação entre dentina-cimento-pino de fibra de vidro falha, não forma complexo mecânico homogêneo e a distribuição de tensão é comprometida (Soares *et al.,* 2012). Além da efetiva polimerização, a homogeneidade de penetração e ausência de descontinuidade da camada de cimento, resultando em perfeita interface com as superfícies do pino e da dentina radicular são fundamentais para a estabilidade retentiva do complexo restaurador. A presença de bolhas no interior do canal, geradas pela forma de inserção inadequada do cimento no momento de cimentação, pode comprometer a distribuição de tensões e influenciar na estabilidade retentiva do pino. O uso de métodos não destrutivos de análises, como a microtomografia computadorizada (MicroCT), pode facilitar a análise da integridade estrutural (Silva *et al.,* 2015). Este método pode ser associado à quantificação da resistência adesiva por meio de ensaios de push-out, e ainda servir de fonte para geração de modelos de elementos finitos específicos que possibilite análise individualizada dos efeitos dessas imperfeições.

Outro fator a ser considerado é a remoção da camada de smear layer criada durante o preparo do conduto radicular e de resíduos de cimento obturador para receber o retentor radicular. Os cimentos endodônticos residuais deixados acidentalmente nas paredes do canal radicular podem provocar defeitos no processo de polimerização do cimento resinoso, afetando a resistência adesiva do pino à dentina intrarradicular (Grassi *et al.,* 2012). A ampliação da visão por meio do uso de microscópio clínico permite maior precisão, potencializando as habilidades motoras finas, possibilitando posicionamento mais preciso dos instrumentos endodônticos dentro do campo operacional (Bowers *et al.,* 2010). Tem sido demonstrado que o uso de magnificação resulta em maior precisão nos testes com o uso do microscópio comparado ao teste de visão sem ajuda de aparelho de amplificação da visão e ao uso de lupa de aumento de 2,5 vezes (Perrin *et al.,* 2014). Os benefícios adicionais de maior iluminação e ampliação na prática odontológica incluem vantagens como visão mais detalhada de ampla extensão do canal radicular, permitindo ao operador examinar de forma mais eficiente, limpar e até realizar procedimentos reabilitadores, mesmo em casos de anatomia complexa (Saunders & Saunders, 1997). O microscópio tem sido considerado o único meio de visualizar estruturas no interior do conduto radicular independente da idade do operador (Perrin *et al.,* 2014), além de possibilitar melhorar a resistência de união de pinos de fibra de vidro à dentina radicular quando é usado na preparação do espaço do canal radicular (Ferreira *et al.,* 2015).

Todos esses fatores fazem com que a etapa de cimentação adesiva intrarradicular ainda represente um desafio significativo para os clínicos devido às variáveis técnicas envolvidas e ao pouco conhecimento sobre a previsibilidade clínica desses materiais em longo prazo (Ramos et al., 2012; Goracci & Ferrari, 2011). Dessa forma, a associação de tratamento endodôntico de alta qualidade com uso de protocolo restaurador adequado é decisiva para elevar o índice de longevidade e reduzir complicações em dentes tratados endodonticamente (Salvi *et al.,* 2007).

OBJETIVOS

2. OBJETIVOS

Objetivo Geral

Este estudo visa avaliar de forma sequencial e integrada a cimentação de pinos de fibra de vidro por meio da avaliação do efeito do método de verificação do preparo do conduto e da mistura e inserção de cimento resinoso. Análise por Micro CT, ensaio de adesão, análise de elementos finitos e relato de caso clínico.

Objetivos específicos

Objetivo específico 1

Capitulo 1 - Effect of Resin Cement Porosity on Retention of Glass-Fiber Posts to Root Dentin: An Experimental and Finite Element Analysis

O objetivo deste estudo foi avaliar a influência da porosidade de cimentos resinosos autoadesivos na distribuição de tensões, retenção do pino e padrão de falha de pinos de fibra de vidro cimentados em dentina radicular humana.

Objetivo específico 2

Capítulo 2 – Effect of the visualization method for post space preparation on root cleanness and fibreglass post bond strength

O objetivo deste estudo foi avaliar o efeito do método de visualização durante o preparo do espaço do pino sobre a quantidade de remanescente de material obturador endodôntico e sobre a resistência adesiva do pino de fibra de vidro.

Objetivo específico 3

Capítulo 3 – Effect of the resin cement mixing and insertion method into the root canal on resin cement porosity and fiber post bond strength

O objetivo deste estudo foi avaliar o efeito do método de mistura e inserção de cimentos resinosos autoadesivos no canal radicular sobre a porosidade do cimento e resistência adesiva do pino de fibra de vidro.

Objetivo específico 4

Capítulo 4 - Cimentação pinos de fibra de vidro – preparo radicular, mistura e inserção de cimento

O objetivo deste estudo foi por meio de um relato de caso clínico, abordar a técnica de mistura e inserção do cimento resinoso autoadesivo no interior do conduto radicular para permitir interação efetiva do cimento com a dentina radicular e pino de fibra de vidro. A descrição de caso clínico proporciona ao clínico suporte para executar técnica mais adequada visando desempenho biomecânico satisfatório dos procedimentos de reabilitação de dentes tratados endodonticamente.

Capítulos

Cimentação de pinos de fibra de vidro – efeito do método de verificação do preparo do conduto e da mistura e inserção de cimento resinoso. Faculdade de Odontologia – Universidade Federal de Uberlândia

3. CAPÍTULOS

Capítulo 1

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Effect of Resin Cement Porosity on Retention of Glass-Fiber Posts to Root Dentin: An Experimental and Finite Element Analysis

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Effect of Resin Cement Porosity on Retention of Glass-Fiber Posts to Root Dentin: An Experimental and Finite Element Analysis

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The aim of this study was to evaluate the effect of porosity of self-adhesive resin on the stress distribution, post retention and failure mode of fiber post cemented to human root dentin. Ten human central upper incisors with circular root canal were selected. They were sectioned with 15 mm and were endodontically filled. The roots were scanned using micro-CT after post space preparation for root filling remaining evaluation. Fiber posts were cemented using self-adhesive resin cement (Rely X U200, 3M-ESPE). Two 1-mm-thick slices from the cervical, medium and apical thirds were scanned for resin cement bubbles volume measurements and submitted to a push-out test (PBS). Three operators using stereomicroscopy and confocal laser microscopy classified the failure mode. Stress distributions during the push-out test were analyzed using 3D finite element analysis. PBS values (MPa) were submitted to one-way ANOVA and Tukey's post hoc tests and the failure modes using the Kappa coefficient to assess inter-operator agreement. Chi-square test was used to determine significant differences between the methods ($\alpha = 0.05$). Push-out bond strength was significantly affected by the bubbles presence in all root depth ($p<0.05$). The stress concentration was higher when the bubbles were present. Adhesive dentin/resin cement interface failure was the most frequent type of failure. Confocal microscopy was better than stereomicroscopy for failure analysis. Bubbles generated during resin cement insertion into the root canal negatively affect the stress distribution and the bond strength. The use of confocal microscopy is recommended for failure analysis.

Key Words: fiber post, resin cement, push-out bond testing, micro-CT, confocal laser microscopy.

Introduction

The bond strength of resin cement and fiber post is a critical factor for the success of endodontic procedures. The dentin/resin and cement/fiber post interactions are influenced by several factors, like root canal contamination (1,2), effective polymerization of resin cement (3,4) and the integrity of the bonding interface (5). Post-dentin interface bond failure can increase the risk of failure of endodontic treated teeth (6).

The use of self-adhesive resin cement has been recommended to fix the fiber post achieving better bond strength to the root dentin (7,8). Due to the restrict root-canal geometry, any controlled application of resin cement is difficult (9). Remnants of post space preparation may negatively influence the post retention (10). As a consequence of cement application voids and bubbles are observed within the resin cement caused air entrapment (11). The bubbles and voids may reduce the resin cement contact area with the post surface and ultimately to retention the endodontic post. Micro-CT has been recently used in the endodontic field to analyze several factors linked to root canal preparation and filling procedures (12,13); however few studies have used it to analyze the restorative procedure in the root canal. The bond strength values are important for the studies involved with restorative procedures, however the failure mode classification is essential to qualify the factors that may interfere on the failure process. Push-out bond test failure analysis has been performed using stereomicroscopy (14), scanning electron microscopy (5) and confocal laser microscopy (10,14,15). Nevertheless, few studies have analyzed the efficiency of these methodologies and also the effect of bubbles on stress distributions.

Hence, the aim of this *in vitro* study was to evaluate the effect of porosity generated by resin cement application used for fiber post cementation on its retention to the root dentin and to test the efficiency of the method used to analyze the failure mode after push-out test. Two null hypotheses were: the bubbles volume would not affect the stress distribution on resin/cement interface and the post retention to root dentin irrespective of root region, and the method used to classify the failure mode after push-out test would not reflect on the efficiency of the analysis.

Material and Methods

Sample Selection and Root Canal Preparation

This study was approved by the local Ethics Committee (Protocol 227/09). Ten single-rooted human maxillary central incisors with similar root morphology were obtained from a pool of extracted teeth and stored in distilled water. The specimens were decoronated by transversally sectioning the roots at 15 mm from the apex with a double-faced diamond disc (KG Sorensen, Barueri, SP, Brazil) at a low speed with air/water spray coolant.

One trained operator prepared root canals. The root canals were enlarged using Gates-Glidden drills 2, 3 and 4, with diameters of 0.7, 0.9, 1.1 mm, respectively (Dentsply Malleifer, Petrópolis, RJ, Brazil). The apical end (1 mm) was left unprepared to prevent the apical extrusion of solutions and luting cement. The root canal was irrigated with 2.5% sodium hypochlorite solution (2.5% Chlorine Rio, São José do Rio Preto, SP, Brazil) and 17% EDTA (Biodynamics, Ibiporã, PR, Brazil) for 3 min. Roots were rinsed with 5 mL physiologic saline solution (NaCl) to remove the remaining debris. All root canals were filled with gutta-percha and a calcium hydroxide sealer (Sealer 26; Dentsply, Sao Paulo, SP, Brazil). Root canal openings were filled with resin modified glass ionomer cement (Vitremer; 3M-ESPE, St Paul, MN, USA), and the samples were stored at 37 °C in distilled water for 1 week. After this period, the canal relief was performed immediately after filling, using a heated instrument (GP heater; Dentsply Maillefer) to remove the gutta-percha to a depth of 10 mm (16). The post spaces were prepared to a depth of 10 mm with special preparation drills supplied by the manufacturer of the fiber posts (Exacto #3; Angelus, Londrina, PR, Brazil). Post used is tapered with a coronal diameter of 2.0 mm and an apical diameter of 1.1 mm. All procedures were performed by using an operating microscope (DF Vasconcelos, Rio de Janeiro, RJ, Brazil), with 10 × magnification.

Micro-CT Analysis

After post space preparation, the roots were mounted on a custom attachment, and scanned in a micro-CT scanner (SkyScan 1272; Bruker-microCT, Kontich, Belgium). The scanner operated at 100 kV and 111 mA (0.5-mm Al/0.038-mm Cu filter). The resolution used was 1632/1092 pixels - 10 µm. The scanning was performed by 360° rotation around the vertical axis with a rotation step of 0.6. Images of each specimen were reconstructed (NRecon v., Bruker-microCT) providing axial cross-sections of their inner structure. CTAn v. software (Bruker-microCT) was used for the 3-dimensional (3D) (volume, surface area and structure model index) evaluation of the root canal (Fig. 1). CTVol v. software (Bruker-microCT) was used for visualization and qualitative evaluation of the specimens (17).

Fiber Post Cementation

The fiber post was immersed in hydrogen peroxide solution at 24% for 1 min, dried with compressed air application for 1 min, followed by silane application for 1 min (Silano, Angelus, Londrina, PR, Brazil). All roots were dried with paper points and the fiber posts were cemented using handled mix self-adhesive resin cement (RelyX U200, 3M-ESPE). The resin cement was inserted into the root canal using K-file, the posts were covered with cement and slowly seated by finger pressure. The excess cement was removed after 1 min. After 5 min the resin cement was light-activated with a halogen light source at 800 mW/cm² (Demetron 501; Kerr Corporation, Orange, CA, USA). The specimens were stored in water at 37 °C for 7 days. The roots were submitted to a new micro-CT scan and reconstruction, applying the initial parameter settings described.

Push-out Bond Strength Test

The root cement fiber posts were fixed in acrylic plate of 20 mm X 20 mm with adhesive cyanoacrylate (Super Bonder, Loctite, SP, Brazil), and were transversely sectioned by using the water-cooled low-speed diamond saw (Isomet 1000; Buehler Ltd, Lake Bluff, IL), resulting in two 1.0-mm-thick slices from the apical, middle and coronal root regions. Load indenter tips of 1.5 mm and 2.5 mm base were used for the cervical and middle third and 1.0 mm tip and 2.0 mm base for the apical third. Diameter and thickness of the specimens were obtained by using a stereomicroscope and digital micrometer (Mitutoyo, Santo Amaro, SP, Brazil) with 0.01-mm accuracy digital camera. Each slice was submitted to the push-out bond strength test (DL500; EMIC, São José dos Pinhais, PR, Brazil), with the load applied in the apical-coronal direction at a crosshead speed of 0.5 mm/min. The maximum load at failure was recorded in Newtons (N) and converted into MegaPascal (MPa) by dividing the load applied by the bonded area (A), calculated by using the following formula: $A = \pi (R1 + R2) \sqrt{R1 - R2}\, 2 + h2$; where π is a constant value of 3.14, r and R are the smallest and the largest radius, respectively, of the cross-sectioned tapered post, and h is the thickness of the section.

Failure Mode Analysis

To determine failure mode, three calibrated operators using two methodologies analyzed all specimens: a confocal laser-scanning microscope (Carl Zeiss Laser Scanning Systems, LSM510; META, Oberkochen, Germany) and stereomicroscope at 40x magnification, (Mitutoyo, Tokyo, Japan) (Fig. 2). Failures were classified into 1 of 5 categories: (1) adhesive between post and resin cement; (2) between resin cement and root dentin; (3) mixed, with resin cement covering partially of the post surface; (4) cohesive within the fiber post; and (5) cohesive within the dentin.

Statistical Analysis

The push-out bond strength and bubble volume values were tested for normal distribution (Shapiro-Wilk, $p<0.05$) and equality of variances (Levene test, $p<0.05$), followed by parametric statistical tests. Data were analyzed using one-way ANOVA and multiple comparisons were made using the Tukey post hoc test. The values of bond strength and bubble volume at the same region (cervical, middle and apical root regions) were correlated using Pearson correlation test. The Kappa coefficient was used to assess interoperator agreement and the chi-square test to determine significant differences between the imaging methods. All tests employed a 0.05 level of statistical significance and all statistical analyses were carried out with the statistical package SigmaPlot® System version 12.0 (Systat Institute Inc, San Jose, CA, USA).

3D Finite Element Analysis

Finite element models were created from an image of each slice (cervical, middle and apical) obtained through the Micro-CT scanning with and without bubbles and voids (Figs. 1G,1H and 1I). The *.STL file was used to create 3D meshed with 8 nodes, quadrilateral-hexahedral elements in Mimics and 3-Matric software (Materialise, Leuven, Belgium). To create the same models without porosity for each third, the empty spaces were totally filled with the elements. All structures and materials were considered homogeneous, linear-elastic and isotropic, except for the fiberglass post, which was considered orthotropic. The mechanical properties (elastic modulus (E), Poisson's ratio (υ) and shear modulus (G)) of dentin ($E=18.60$ GPa, $\upsilon=0.30$) (18), resin cement ($E=9.75$, $\upsilon=0.30$) (17), and the fiberglass post ($E_x=9.5$ GPa, $E_y=9.5$ GPa, $E_z=37.0$ GPa; $\upsilon_{xz}=0.27$, $\upsilon_{xy}=0.34$, $\upsilon_{yz}=0.27$; $G_{xy}=3.1$ GPa, $G_{xz}=3.5$ GPa; $G_{yz}=3.1$ GPa) (19) were obtained from the literature. A load of 10 N was applied in the z direction (post's longitudinal direction), with the punch centered on the post. A nonlinear friction contact analysis was performed between the sample and the metallic punch/base (Fig. 1K). A custom-made subroutine (Fortran-based) was used to calculate the modified von Mises equivalent stress (MVM). The MVM takes in account the ratio between the compressive and tensile strength. The used equivalent stress was based on the well-known modified von Mises formulation, modified to take into account the difference between compressive and tensile strength for enamel, dentin, and composite. (20) The compressive/tensile strength ratios used were 37.3, 3.0, and 6.25 for the enamel, dentin, and composite, respectively (20).

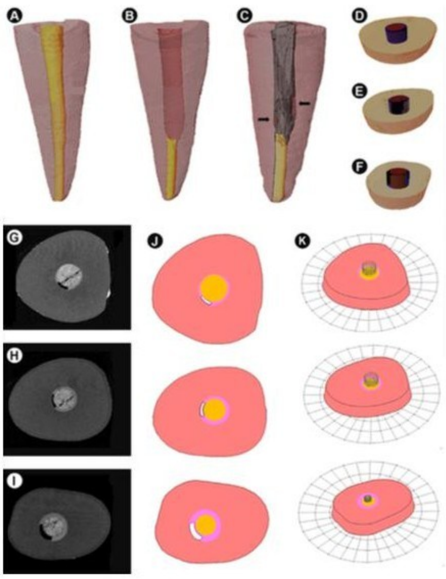

Figure 1. Micro-CT evaluation. A: root canal filling; B: relieved root canal; C: cemented fiber post; D, E and F: slices of three thirds, cervical, medium and apical respectively; G, H and I: slices showing the presence of bubbles on cervical, medium and apical regions respectively; J and K: 3D finite element models of each slice during the push-out test.

Results

Push-out test results and stress distributions are shown in Figure 3. Statistical analysis showed that the factor root

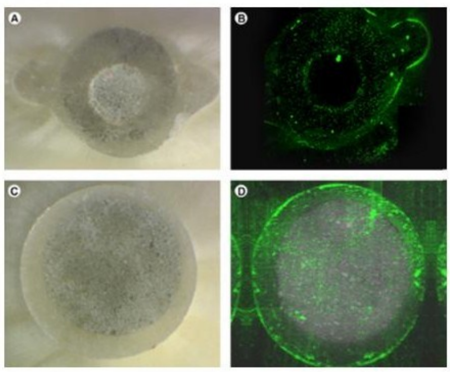

Figure 2. A and C: a stereomicroscope at 40× magnification at the apical region; B and D: a confocal laser-scanning microscope at the medium region.

region affects significantly the bond strength (p=0.03). Tukey test showed that PBS values were significantly higher in the cervical and middle thirds than in the apical region. The bubbles volume values were not affected by root region factor (p=0.723). The bubble volume values had high inverse correlation with push-out bond test on cervical (r=-0.828, p=0.002), middle (r=-0.810, p=0.003) and apical region (r=-0.703, p=0.016). A prevalence of adhesive cement/dentin interface failure was found, irrespective of root region. The stress concentration represented by modified von Mises stress increased on apical slice and on the bubble presence irrespective of region (Fig. 4). Kappa coefficient showed no difference of the inter-operator performance during failure analysis (0.91). The chi-square test showed that confocal laser microscopy had better performance than stereomicroscopy (p=0.022). The failure mode distribution is shown on Table 1. Adhesive dentin/resin cement interface failure was the most frequent type of failure, irrespective of root dentin region.

Discussion

The push-out test offers bond strength values from different locations of the root canal to detect regional differences using samples with minimal thickness (8). The push-out test would seem to be a more appropriate methodology for evaluation of fiberglass posts bonded to root dentin (15,18,19,21,22). For this performance some

Table 1. Push-out test failure mode distribution (n=20, per root third)

Third	Type 1	Type 2	Type 3	Type 4	Type 5
Cervical	1 (5%)	14 (70%)	3 (15%)	0 (0%)	2 (10%)
Middle	2 (10%)	13 (65%)	2 (10%)	1 (5%)	2 (10%)
Apical	1 (5%)	15 (75%)	2 (10%)	0 (0%)	2 (10%)

Failure modes: 1: adhesive between post and resin cement; 2: between resin cement and root dentin; 3: mixed, with resin cement covering partially the post surface; 4: cohesive within the fiber post; and 5: cohesive within the dentin.

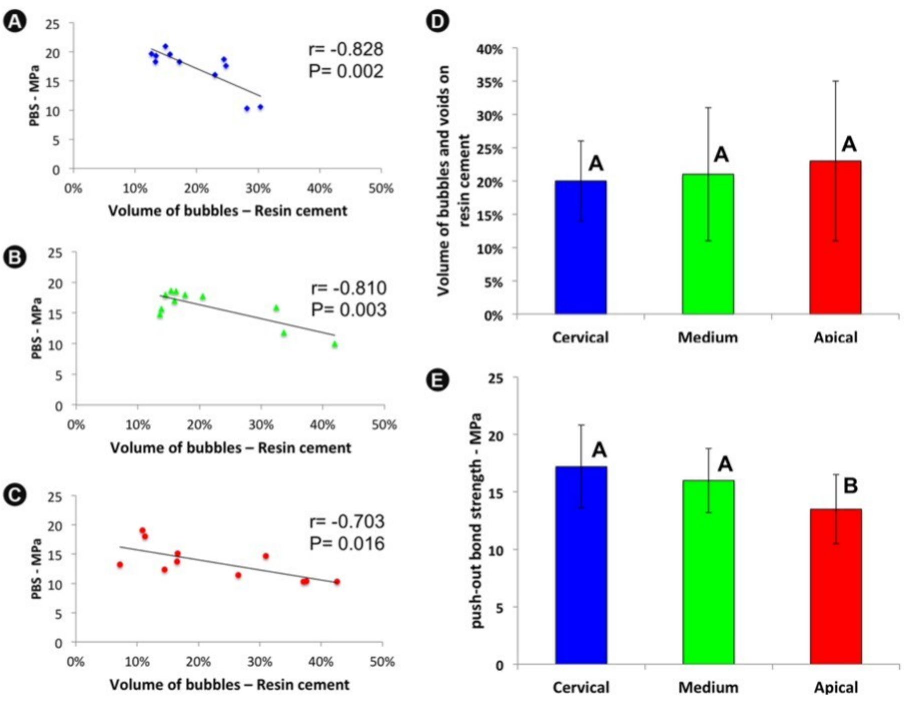

Figure 3. Push-out test results. A, B and C: Significant correlation between volume of bubbles on resin cement and push-out bond strength for cervical, medium and apical thirds respectively. D: Mean values and standard deviation of volume of bubbles on resin cement for root thirds; E: Mean values and standard deviation of push-out bond strength values for each root third, different letters means significant difference found by Tukey's test.

many times and samples remain available after scanning for additional bonding testing. Internal and external anatomy could be demonstrated simultaneously or separately. It is possible to analyze many aspects of the inner structure of a tooth. Therefore, data from micro-CT could serve as a basis for further analysis (26,27). Micro-CT combined with 3D reconstruction allows not only inspecting the internal arrangement rendered by fiberglass adhesively bonded to root dentin, but also estimating the volume of voids between the adhesive interfaces, allowing to obtain comprehensive imaging of the spatial organization of the specimen structures. The bubbles and voids may affect the longevity of adhesive bonding in two ways: first, voids can be located directly at the interface between dentin and cement, decreasing the contact bonded area. Second, as mechanical properties are highly dependent on flaw distribution and void formation, it would be expected that presence of voids decreases the strength of cement and creates sites for crack initiation and propagation as shown in this study. Third, because the bubbles presence acts as stress concentration factor, reducing the bond area and reflecting the higher peak of the stress on the remaining intact interface. The higher porosity on apical region is possible due to the difficulty of the resin cement insertion and the possibility of the air confined during post insertion. This aspect reflected on higher stress concentration, reducing the bond strength on this region.

A possible explanation for such a percentage of voids might be attributed to the cement mixing method, which may have introduced air bubbles into the material. The resin cements nowadays have been available in automix presentation that may reduce the bubble generation. Other explanation for bubbles and voids are the method used to introduce resin cement into the root canal (28). We used the more common method used by clinicians, inserting into the root canal using k-files and on the fiber post concomitantly. However the presence of the resin cement on both sites may increase the resin cement defects.

The most prevalent failure mode observed in this study reinforce the statement that the most sensible interface is between dentin and resin cement. It is the interface where the higher stress concentration is concentrated. The similar performance among three evaluators demonstrated that the training before the analysis is essential and also that the reproducibility of both methods used. The analysis of failure modes revealed that the confocal laser scanning microscopy (CLSM) had better performance than stereomicroscopy, which is in accordance with the results of previous investigation (15). These results show that the confocal analyses of the failure modes allow a more detailed description of failures as described previously and has been used in adhesive dentistry to visualize the micromorphologic characteristics of the dentin-adhesive interface (29). Although the failure mode analysis was conducted using mostly stereomicroscopy and confocal microscopy was used and appears to be a noteworthy alternative for the evaluation of the bond failure pattern in loaded specimens, since it is less time consuming and does not require any preparation of samples. However, its is necessary to consider that confocal is more time consuming, and it is a methodology much more expensive. More than method used for failure mode analysis is to perform this analysis.

Bubbles and voids generated during self-adhesive resin cement insertion into the root canal negatively affect the stress concentration on resin cement/dentin interface and reduced the fiber post bond strength. New studies should be developed using regular resin cement with different flowability and also testing different resin cement insertion methods into root canal. The use of confocal microscopy is recommended for failure analysis after push-out test. Therefore, the clinicians should take into account the method of the resin cement manipulation and application trying to reduce the resin cement/interfaces defect. When the push-out test was selected for testing fiber post bonding interaction with root dentin, the failure analysis is essential and the use of confocal methods tends to generate more predictable classification of the failure mode. In the absence of this method the use of stereomicroscopy is an acceptable alternative.

Resumo

O objetivo deste estudo foi avaliar o efeito da integridade do cimento resinoso autoadesivo, expresso pela presença de bolhas, sobre a distribuição de tensão, resistência adesiva e modo de falha de pinos de fibra cimentados à dentina radicular humana. Dez incisivos centrais superiores humanos com canais radiculares circulares foram selecionados. Os mesmos foram seccionados com 15 mm e tratados endodonticamente. As raízes foram digitalizadas utilizando micro-CT após preparo do pino para avaliação de remanescentes de material obturador. Pinos de fibra foram cimentados utilizando cimento autoadesivo (Rely X U200, 3M-ESPE). Duas fatias de 1 mm de espessura dos terços cervical, médio e apical foram escaneados para mensuração do volume de bolhas no cimento resinoso e submetidos ao teste de push-out. Três operadores classificaram o modo de falha utilizando microscopia confocal à laser e lupa estereoscópica. Distribuição de tensão foi analisada pelo método de elementos finitos 3D. Os valores de resistência adesiva (MPa) foram submetidos ao teste ANOVA em fator único seguido do teste de Tukey. Foi utilizado o coeficiente de Kappa para avaliar a concordância entre operadores. O teste Qui-quadrado foi utilizado para determinar diferenças significativas entre os métodos (α=0,05). A resistência adesiva foi significativamente afetada pela presença de bolhas independentemente da profundidade radicular ($p<0,05$). A concentração de tensão foi maior na presença de bolhas. Maior frequência de falha adesiva ocorreu na interface cimento/dentina. A microscopia confocal foi melhor do que estereomicroscopia para análise de falhas. A presença de bolhas afetou negativamente a distribuição de tensão e a resistência de união. Recomenda-se uso de microscopia confocal para análise de falhas.

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Capítulos

Capítulo 2

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Effect of the visualization method for post space preparation on root cleanness and fibre post bond strength.

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Effect of the visualization method for post space preparation on root cleanness and fibre post bond strength.

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Short title: visualization method for root canal preparation

Key Words: Bond strength, Fibre glass post, Magnification devices, Post space, Surgical microscope, Surgical magnifying glass.

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Effect of the visualization method for post space preparation on root cleanness and fibre post bond strength.

Abstract

AIM: Evaluate the effect of visualization method for post space preparation on root cleanness and on fibre post bond strength.

METHODOLOGY: Thirty human central upper incisors with circular root canal were selected, decoronated to 15 mm and endodontically filled. The teeth were assigned into 3 groups (n=10), according to the method of magnification used for post space preparation inspection: Control, using naked eye; loupe, using a dental surgical 3x magnifying glass; surgical microscope, using a 6x surgical microscope. The roots were scanned using micro-CT before and after post space preparation for residue remnants evaluation. Fibre posts were cemented using self-adhesive resin cement (Rely X U200, 3M-ESPE). Two 1-mm-thick slices from the cervical, medium and apical thirds were submitted to a push-out test (PBS). Failures modes were classified. PBS data were analyzed using two-way ANOVA with repeated measurement and the Tukey test. The significance level was set at 5%.

RESULTS: The method of visualization had no effect on PBS ($P = 0.556$). The cervical region had higher values than apical region irrespective of the inspection method ($P = 0.012$). Adhesive failure between the resin cement and dentine was the prevalent failure mode for all groups. Micro-CT analysis showed no difference on root cleanless into the root canal after post space preparation.

CONCLUSION: The use of magnification devices as loupes and microscopes while performing post space preparation do not improve the PBS and did not affect in the sealer remain of anterior teeth.

Introduction

The most common complications of adhesively cemented fibre pots are post debonding (Bitter *et al.* 2012). The endodontic cement used to seal the root canal, as well as the density and orientation of the root dentine tubules and deposition of cementum and secondary dentine are factors that may compromise the fibre post retention (Ferrari *et al.* 2000). The residues of endodontic sealer accidentally left on the root canal walls, might originate defects of polymerization within the cement and this could affect the bond strength of a post to root dentine (Grassi *et al*.2012). Moreover the voids that may be introduced within the cement layer, as a result of luting manipulation and root insertion and inadequate cement thickness are contributing factors that can possibly affect the quality of adhesion (Lorenzoni *et al.* 2013, Rengo *et al.* 2014, Da Silva *et al*. 2015). Histological characteristics of the root dentine following endodontic treatment and the properties of the different bonding materials make the cementation of fibre posts a challenging procedure (Goracci *et al.* 2004; Suzuki *et al.* 2015).

The self-adhesive resin cement has primary adhesion mechanism based on the micromechanical retention and chemical interaction between the monomer acidic groups and hydroxyapatite (Goracci *et al.* 2005). The multifunctional monomers with phosphoric acid groups simultaneously demineralize and infiltrate enamel and dentine (Goracci *et al*. 2005). This mechanism has been reported as incapable of dissolving the smear layer (Radovic *et al.* 2008). Consequently, they are unable to etch through the smear layer formed after the post space preparation (Goracci*et al*. 2005). The removal of the smear layer is indicated during the biomechanical preparation of the root in order to allow better infiltrate the collagen, increasing the contact surface of the filling material with dentine and to obtain properly cleaned dentin surfaces (Scotti *et al.* 2014, Alkhudhairy *et al*. 2016).

The use of a clinical microscope while performing mechanical cleaning during post space preparation has been reported to improve the bond strength of a fibre glass post to dentine (Ferreira *et al*. 2015). It is also important to ensure that all gutta-percha remnants are removed (Ferreira *et al*. 2015). Magnifying aids are becoming increasingly more common in dental practices and attention must be paid especially to the early onset of presbyopia around the age of 40 (Eichenberger *et al.* 2015). Optical aids such as loupes or microscopes should be used early enough to compensate for individual or a generated visual deficiency (Eichenberger *et al.* 2015). Professionals that use loupes and microscopes are convinced that these instruments have advantages and improve both the quality and ergonomics of their work (Eichenberger *et al.* 2015). Intraradicular visual tests in a simulated clinical setting objectively demonstrated the significance of the operating microscope for endodontic acuity and the visual acuity, with the microscope was not dependent on the location within the endodontic system or on the dentists' age (Perrin *et al.* 2014). The microscope was the only means of achieving measurable results inside the root canal, irrespective of the age of the examiner (Perrin *et al.* 2014).

No significant difference in the improvement of clinical and radiographic outcomes was found among patients treated using magnifying loupes, surgical microscope or endoscope in endodontic procedures (Del Fabbro *et al.* 2010). Surprisingly, little studies about the visual acuity of dentists, the influence of the different optical devices and the relationship between visual acuity and precision in dental work has been published (Eichenberger *et al.* 2011).

High-resolution micro-computed tomography (micro-CT) can measure the volume of three-dimensional shapes such as canals and gaps, analysing the resin cement thickness and the voids presence around post materials (Uzun *et al.* 2016). This methodology has been proved to be a powerful non-destructive 3D analysis, rapid, and powerful tool for visualizing the void parameters, the resin matrix, the internal structure and mechanical properties overcoming the limitations of the conventional methods (Swain *et al.* 2009, Robinson *et al.* 2012, Gandolfi *et al.* 2013, Lorenzoni *et al.* 2013, Moeller *et al.* 2013, Keleş *et al.* 2014, Rengo *et al.* 2014, Uzun *et al.* 2016).

Thus, the aim of this study was to investigate the effect of visualization method for post space preparation on root cleanness and on glass fibre post bond strength. The null hypotheses tested were: 1) that the micro-CT analysis would not show difference on residue remnants into the root canal after post space preparation using different magnification devices microscope, loupes and naked eyes; 2) that the different levels of root canal (coronal, middle and apical thirds of post space dentine) would not influence the push-out bond strength (PBS).

Materials and Methods

Sample Selection and Root Canal Preparation

This study was approved by the local Ethics Committee (Protocol 227/09). Thirty single-rooted human maxillary central incisors permanent, with root length of more than 15 mm, similar size and anatomic shape as well as straight roots were selected and stored in distilled water at 4°C until use. Teeth with caries, cervical erosion, previous endodontic treatment, post or crown were also excluded. The specimens were decoronated by transversally sectioning the roots at 15 mm from the apex with a double-faced diamond disc (KG Sorensen, Barueri, SP, Brazil) at a low speed with air/water spray coolant.

The root canal systems were located using 10 K-file (Dentsply Malleifer, Petrópolis, RJ, Brazil) which was introduced into the root canal until it was visible at the apical foramen. The working length was determined to be 1.0mm less than this length. The root canals were shaped by rotary instruments (ProTaper system, Dentsply Malleifer, Petrópolis, RJ, Brazil) sequenced in order (SX, S1, S2,F1, F2, F3, F4) applying the crown-down technique. One rotary kit was used to prepare 5 specimens and then replaced. Throughout the preparation process, the root canals were irrigated with 2.5% sodium hypochlorite (Chlorine Rio, São José do Rio Preto, SP, Brazil) using a syringe and a 27-gauge needle throughout progression of file sizes. Final irrigation was done with 17% ethylene diamine tetra acetic acid (EDTA; Biodynamics, Ibiporã, PR, Brazil) for three minutes followed by 2,5% NaOCl solution for one minute and with 5 mL physiologic saline solution (NaCl) to remove the remaining debris. The instrumented root canals were dried with sterile paper points and immediately obturated by lateral condensation, the root canal was filled with a gutta-percha master cone F4 ProTaper Universal (Dentsply), conventional gutta-percha accessory cones and calcium hydroxide cement (Sealer 26; Dentsply, Sao Paulo, SP, Brazil). Root canal opening was sealed with resin modified glass ionomer cement (Vitremer; 3M-ESPE, St Paul, MN, USA). The endodontically treated roots were stored at 37C and 100% relative humidity for 7 days.

Micro-CT Analysis

Each specimen was air-dried, mounted on a custom attachment and scanned using a commercially available high-resolution micro-CT system (SkyScan 1272; Bruker-microCT, Kontich, Belgium). The scanner operated at 100 kV and 100 mA (0.11-mm Cu filter). The resolution used was 1224/820 cross-sectional pixels' size and intersection distances were 20µm, which resulted in 380 transverse cross sections per specimen. The scanning was performed at 180° rotation around the vertical axis, a camera exposure time of 1000 ms, a rotation step of 0.5°, frame averaging of 2 and random movement of 20. Each specimen was scanned for a total of 35 min 41s. Images of each specimen were reconstructed using NRecon version 1.6.10.1 (Bruker-microCT). For each tooth, evaluation was performed for the full canal length in approximately 380 slices per specimen. CTAn v.1.14.4.1 software (Bruker-microCT) was used for the 3-dimensional (3D) quantitative analysis (Figure 1). The volumes of interest for the endodontic sealer of the root were selected. The volumes of gutta-percha and endodontic cement inside the region of interest were analysed. CTVol v.2.2.3.0 software (Bruker-microCT) was used for three-dimensional visualization and qualitative evaluation of the specimens.

Post space preparation

The root canal relief was performed to remove the gutta-percha to a depth of 10 mm. The specimens were randomly assigned to 3 groups (n=10), according to the magnification device used to prepare the post space:

Control group: Naked eye, after post space preparation with a heat condenser (Paiva condenser; Golgran, São Paulo, SP, Brazil) used at 10 mm using no magnification. Then, a Gates Glidden n° 5 bur was used at 8 mm, and a specific bur of the post system (White Post DC #2; FGM, Joinville, SC, Brazil) with dimensions similar to a glass fibre post (height 20 mm, higher and lower diameter 1.8 mm and 1.1 mm, respectively) was used at 10 mm (Novais *et al.* 2016). The post space was cleaned by copious irrigation with distillate water. The canals were dried with paper points. All procedures were performed under reflector lighting.

Loupe magnification group: cleaning with a dental surgical magnifying glass 3x with light led light. The same post space preparation procedure described in the control group was performed by using 3.0× magnification loupes (Goldensun, Jiangsu, China - Mainland) and physically determined working distance of 420mm.

Microscope magnification group: The same post space preparation procedure described in the control group was performed by using a microscope (Alliance Comercial, São Carlos, SP, Brazil) which presented magnification factor of 6.0×, 10x, 16x, 25x and 40x. However, the magnification factor used in this study was 6.0× and physically determined working distance of 200-250mm.

After the post space preparation, the roots were submitted to a new micro-CT scanned reconstruction, applying the initial parameter settings as described previously.

Glass fibre post cementation

The glass fibre post was etched with 24% hydrogen peroxide for 1 min (de Sousa Menezes *et al.* 2011), was rinsed with distilled water and air dried. After that a silane agent was applied for 1 min (Silano; Angelus, Londrina, PR, Brazil). All roots were dried with paper points and the fibre posts were cemented using handled mix self-adhesive resin cement (RelyX U200, 3M-ESPE) that was prepared according to the manufacturer's instructions, introduced into the canal with a K-file and the posts were covered with cement and slowly seated under digital pressure for 5 min. After 5 min (Pereira *et al.* 2015), the resin cement was light-cured at each coronal root surface (buccal, lingual and occlusal) for 40 s using a halogen curing lamp (Optilux 501; Kerr Corporation, Orange, CA, USA) with 1000 mW/ cm^2 light intensity. The specimens were stored in humidity 100% at 37 °C for 7days.

Push-out Bond Strength Test

The samples were fixed in acrylic plate of 20 mm X 20 mm with adhesive cyanoacrylate (Super Bonder, Loctite, SP, Brazil) and were transversely sectioned by using the water-cooled low-speed diamond saw (Isomet1000; Buehler Ltd, Lake Bluff, IL). Two 1.0-mm thick slices from the apical, middle and coronal root regions were obtained. Load indenter tips of 1.5 mm and 2.5 mm base were used for the cervical and middle third and 1.0 mm tip and 2.0mm base for the apical third (Zanatta*et al.* 2015). Diameter and thickness of the specimens were obtained by using a stereomicroscope and digital micrometre (Mitutoyo, Santo Amaro, SP, Brazil) with 0.01-mm accuracy digital camera. Each slice was submitted to the push-out bond strength test (DL500; EMIC, São José dos Pinhais, PR, Brazil), with the load applied in the apical-coronal direction at a crosshead speed of 0.5 mm/min. The maximum load at failure was recorded in Newton (N) and converted into Mega Pascal (MPa) by dividing the load applied by the bonded area (A), calculated by using the following formula: A = π (R1 + R2) √R1 - R2) 2 + h2; where π is a constant value of 3.14, r and R are the smallest and the largest radius, respectively, of the cross-sectioned tapered post, and h is the thickness of the section.

Failure Mode Analysis

To determine failure mode the calibrated operator used a stereomicroscope at 40× magnification, (Mitutoyo, Tokyo, Japan). Failures were classified into 1 of 5 categories: (1) adhesive between post and resin cement; (2) between resin cement and root dentine; (3) mixed, with resin cement covering partially of the post surface; (4) cohesive within the fibre post and (5) cohesive within the dentine.

Statistical Analysis

PBS data were statistically analysed using a one-way analysis of variance with repeated measurement test and the Tukey post hoc test to evaluate differences in visualization methods study factor and the repeated measurement being root regions. The volume of endodontic filling material was analysed using 1-way analysis of variance test and the Tukey post hoc test to evaluate differences in visualization methods. The significance level was set at 5%. All statistical analyses were performed using Sigma Plot 12.1 (Stata Corp, College Station, TX).

Results

Push-out Bond Strength Test

PBS means and standard deviations are shown in Figure 1A. One-way ANOVA showed significant differences only for the factor ‘‘root region’’ (P = 0.012). No difference was found for ‘‘method of visualization’’ (P = 0.556) and neither for the interaction between the factors (P = 0.324). The Tukey test showed that the cervical region had higher values than apical region irrespective of the visualization method used. In general, deeper root canal region resulted in lower bond strength. No significant difference was found for failures modes among groups (Figure 1B). The prevalent failures were adhesive between the fibre post and resin cement.

Micro-CT analysis

The micro-CT analysis showed no difference on residue remnants into the root canal after post space preparation (Figure 2). The residue remnants was located only close to the end of the post space preparation resulted by shape of the drill used for post preparation.

Discussion

Adhesive cementation of glass fibre posts, establishment of a highly durable bond between resins cement and root dentine is an essential factor to provide a coronal seal and adequate retention (Bitter *et al.* 2012). According to the results of this study, the first null hypothesis has to be accepted; micro-CT analysis showed no difference on residue remnants into the root canal after post space preparation using clinical microscope, loupes and naked eye visualization methods. Consequently, the visualization method had no effect on PBS. However, the cervical region had higher values than apical region irrespective of the visualization method used, therefore the second null hypothesis was rejected, the self-adhesive resin cement didn’t show equal bond strength in all root regions.

Dentists may compensate for visual deficiencies by using different magnification devices, once it can be concluded that near visual acuity varies highly between individuals and decreases during the lifetime (Eichenberger *et al.* 2015). The optical advantages come at the cost of ergonomic constraints due to the weight of the loupes (Perrin *et al.* 2016). However, the possibility of attachment to a headband that allows for the wearing of glasses. Thus, this system enabled improved visual acuity at the typical working distance for dentists (Eichenberger *et al.* 2013). Since the 1990s, the operating microscope has been promoted as a necessary part of dental equipment (Eichenberger *et al.* 2013). The microscope is highly superior visually and ergonomically, and it is indispensable for the visual control of endodontic treatments (Perrin *et al*. 2016). Furthermore, the natural visual acuity varies highly between individuals (Eichenberger *et al.* 2013).

Previous results demonstrated that only the microscope allowed the observation of structures much smaller than 0.06mm inside the root canal, in all locations, independent of age (Perrin *et al.* 2014). The unaided vision and loupes with an integrated light source could not provide any measurable vision inside the root canal (Perrin *et al.* 2014). Dentists over 40 years of age were dependent on the microscope to inspect the root canal system (Perrin *et al*. 2014).

The vision of dentists using a surgical microscope by the miniaturized eye charts in tooth cavities, considered adequate for magnifications of 4× and 6.4× (Eichenberger *et al.* 2013). Higher magnifications, common in fact, when working clinically with the surgical microscope, could not be evaluated and even though the examined magnifications were within the range of the Keplerian loupes. Also, the comparably low microscopic magnification of 6x, similar in this study, is a compromise between ergonomics and vision, but allowed the dentists to see structures much smaller than 0.06 mm in all locations (Perrin *et al.* 2014). The results of the impact of loupes and microscope on vision in endodontic were similar in a root canal at the medium third that represents the depth of 5mm and at the apex (Perrin *et al.* 2014).

In the present study, considering the results of the micro-CT analysis and the bond strength, statistically differences were not found between microscope group and the other two groups. The use of a magnification device as microscope and loupe while performing the post space mechanical cleaning did not influence the retention of glass fibre posts. It could be explained by the fact that anterior teeth were used in this study. They have straight roots with similar length, round internal anatomy and diameter equivalent and hence this samples prepare was not conducted intraorally at the actual clinically relevant location of interest. The anatomical shape permits work at direct view during the post space preparation.

Previous study described that the molars treatment have a statistically significant greater probability of success providing best available evidence on the influence of high-power magnification rendered by the dental operating microscope and premolars and anterior teeth was slightly greater but was not statistically significant (Setzer *et al.* 2012). It could be due the difficult by anatomical location molar teeth what complicating the access for instruments and the proper positioning of the magnifier, and, consequently, a correct view angle (Del Fabbro *et al.* 2010). In another situation the clinical microscope improved the bonded strength of fibre glass posts to bovine dentine of anterior teeth (Ferreira *et al.* 2015).

The PBS values were significantly higher in the cervical region and middle thirds than the apical third. It could be attributed to the higher stress concentration of the apical slice due the higher porosity on apical region because the difficulty of the resin cement insertion and the possibility of the air confined during post insertion (Da Silva *et al.* 2015). High polymerization shrinkage stresses have been reported in resin cements because of the high C-factor in the root canal (Zanatta *et al.* 2015). Under shrinkage effect, gaps occur when those stresses are higher than bond on adhesive interface. Also, light intensity that reaches the cervical and middle thirds provided higher bond strengths to dentine (Radovic *et al.* 2008). Additionally, the limited light-transmitting ability of fibre posts reflecting in a reduction of the degree of conversion of resin cement with increased length of simulated root canals (Le Bell *et al*. 2003, Goracci *et al.* 2008). Hence, the most prevalent failure mode observed in this study reinforce the statement that the most sensible interface is between dentine and resin cement. It is the interface where the higher stress concentration is located (Da Silva *et al.* 2015).

In conclusion, the micro-CT analysis showed no difference on endodontic filling material into the root canal after post space preparation using clinical microscope, loupes and naked eye as visualization methods, and the use of a clinical microscopy while performing mechanical cleaning during post space and or loupes had no effect on micropushout bond strength. However, the cervical region had higher values than apical region irrespective of the visualization method used.

More studies to evaluate the effect of the higher magnification device in molars teeth, with simulated clinical setting using a phantom head on the patient's dental chair, during the post space preparation, on fibreglass post bond strength to root dentine are recommended. Also, there is the necessity for randomized clinical trials for confirming the real effectiveness of the magnification to make an informed decision for clinical practice.

Acknowledgments

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The authors deny any conflicts of interest related to this study.

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Figures

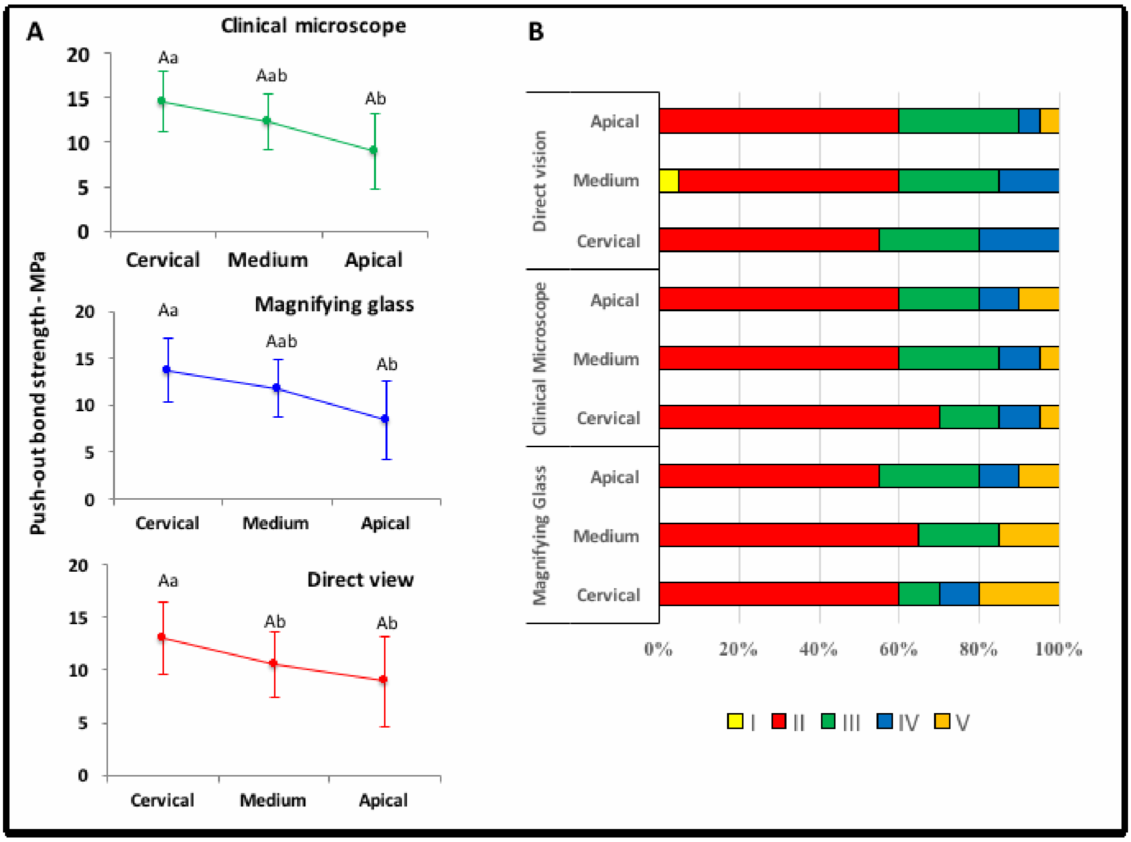

Figure 1. A. Mean and Standard Deviations of PBS (MPa) for the visualization methods and root regions. Different letter means significant difference, upper caser letter used to compare visualization methods and lower caser letter for root regions; B. failure mode distribution Expressed as Percentage – I, adhesive between post and resin cement; II, between resin cement and root dentine; III, mixed, with resin cement covering partially of the post surface; IV, cohesive within the fibre post; V, cohesive within the dentine.

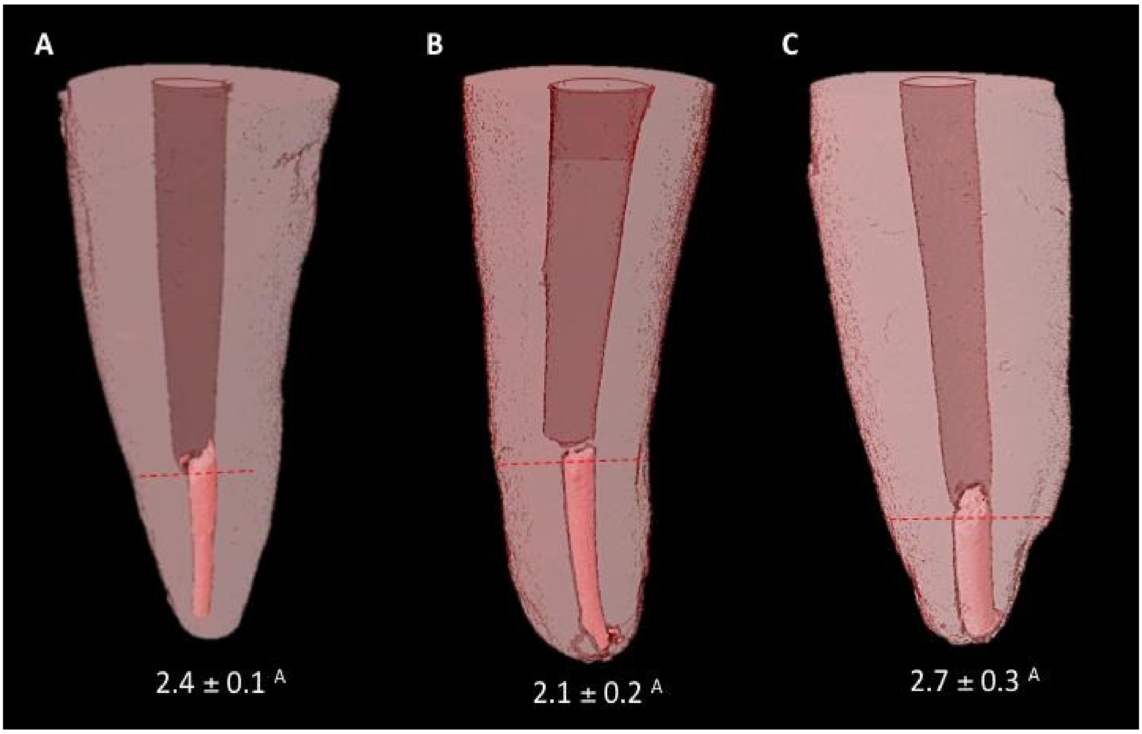

Figure 2. Lateral vision of 3D reconstruction qualitative analysis teeth after post space preparation suing different visualization methods – A. clinical microscopy; B – magnification glass; C – Direct view. Mean and Standard Deviations of volume of endodontic filling material of post space preparation (%) quantitative analysis for all visualization methods.

Capítulos

Capítulo 3

Artigo a ser enviado para publicação no periódico International Endodontic Journal

Effect of the resin cement mixing and insertion method into the root canal on cement porosity and fiberglass post bond strength

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Running title: porosity on fiber post/cement

Keywords: fiber post, insertion technique, micro-CT, porosity, root canal, resin cement

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Effect of the resin cement mixing and insertion method into the root canal on cement porosity and fiberglass post bond strength

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Abstract

Aim:To evaluate the method of resin cement mixing and insertion into the root canal on resin cement porosity and fiberglass post push-out bond strength (PBS).

Methodology: One hundred and twenty human single rooted teeth were sectioned to a length of 15 mm, endodontically filled and had fiberglass post cemented with 3 self-adhesive resin cements (RelyX U200; seT; Panavia SA); using4mixing methods/insertion techniques (handmix/endodontic file; handmix/Centrix syringe; automix/conventional tip; automix/endo tip). The samples were scanned using micro-CT. Two slices from the cervical, medium and apical thirds were submitted to a push-out bond strength (PBS) test and failures mode were classified. The PBS, the volume of

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Results: The porosity was lower at cervical and higher at apical third, irrespective of the resin cement. The porosity was lower for automix/endo tip and higherfor handmix/endodontic file. The use of Centrixor endo tip reduced the porosity and increased the PBS at the apical third when compared with use of endodontic files. The root canal depth reduced the PBSfor U200 and seTwhen used handmix/endodontic files. U200 and seTusingautomixincreased the PBS thus eliminating the effect of the root region, irrespective of the insertion technique. In general, U200 showed higher and Panavia resulted in lower PBS. The adhesive failure between root dentin and resin cement was predominant.

Conclusions: Automixing the cement and using endo tipproducesfewer voids and increased the bond strengths.

Introduction

Fiber glass posts (FGP) are often used to provide retention of the final restoration in endodontically treated teeth (Naumann *et al.* 2012) because their elastic modulus is closer to that of dentin and this may reduce the risk of root fracture (Santos *et al.* 2010, Da Silva *et al.* 2015).The relatively mono-block structure composed by dentin, resin cement, and the FGP allows for more uniform stress distribution and reduces the formation of vertical cracks in the root (Soares *et al.* 2010).However, the effectiveness of the bonding procedures when luting these posts plays an important role on the clinical performance of FGP-composite resin restorations (Ferrari *et al.* 2009).A high, durable bond between resin cement and root dentin is required to provide a coronal seal and adequate retention of the FGP (Naumann *et al.* 2012).Adequate bonding also reduces micro-leakage at the dentin-cement interface (Furuya*et al.* 2014).

Due to the passive retention of FGP into root canals, their retention is mainly attributed to the resin cement and the cementation technique used (’A *et al.* 2008). Cementing FGP into root canals can be a clinical challenge due to the complex cementation techniques,the high level of technique sensitivity, and the variability of the substrate (Naumann *et al.* 2012). Simplifying luting procedures would be helpful in overcoming technical problems observed with multi-step cements systems, that may require enhanced moisture control or there may be chemical incompatibility between simplified adhesives and dual-cured methacrylate-based resin cements (Carrilho*et al.* 2004, Tay *et al.* 2003). Self-adhesive cements possess different chemical compositions that can differentiate their bonding mechanisms (Mazzitelli*et al.* 2012).This category of resin cement requires no acid etching, priming, or bonding. These are all are technique sensitive steps (De Munck*et al.* 2004). The bonding mechanism these cements represent an important difference when compared with other resin cement that are micromechanically bonded to dental tissues (Van Meerbeek*et al.* 1993).

A homogenous and adequate thickness of resin cement layer is a prerequisite for retention of the FGP. Gaps at the resin cement or at the interfaces with FGP and root dentin, may negatively affect the mechanical properties of the resin and reduce the survival of the restorations (Pereira *et al.* 2013). Defects within the cement can cause localized high-stress concentration in the root canal that could then initiate crack propagation at relatively low applied loads. To ensure homogeneity of resin cement, how the cement is delivered into the root canal is important to avoid the introduction of any trapped air within the cement layer (Shiratori*et al.* 2013).Improved delivery systems have recently been developed in order to mix and providea bubble-free paste-paste mixture (Pedreira*et al.* 2016). Moreover, it is also reported that the self-adhesive cements have good flow ability under pressure. However, the cement penetration into the dentin substrate may be limited (Monticelli et al. 2008). The high viscosity, the effects of neutralization generated by the setting reaction and the buffering of the dentin, as well as the presence of a secondary smear layer can negatively affect the ability of the self-adhesive resin cement to demineralize and penetrate intothe dentin(Monticelli*et al.* 2008). The relatively high viscosity of the resin monomer may also be responsible for the reduced degree of conversion of the resin (Floyd & Dickens 2006). Ultimately, the materials used, as well as the bonding interaction between the biological tissues and the biomaterials will influence the outcome of the final restoration (Grassi *et al.* 2012).

Micro-computed tomography (micro-CT) has been proved to be noninvasive3 dimensional (3D) analysis, and powerful tool that can evaluate the resin matrix, the internal structure, mechanical properties and detect voids (Da Silva *et al.* 2015, Pedreira*et al.* 2016, Rengo *et al.* 2014, Uzun*et al.* 2016, Lorenzoni*et al.* 2013). Micro-CTalso, allows for reconstruction and volumetric evaluation of the internal and external structures either completely or separately, and overcomes the limitations of conventional methods that are more invasive (Uzun*et al.* 2016, MV &Xue J *et al.* 2009, Keles*et al.* 2014).The push-out strength test allows for an accurate analysis of the overall bonding mechanism and the ability to better simulate a clinical scenario (Goracci*et al.* 2007, Armstrong *et al.* 2010). Furthermore, an analysis of any correlation between the morphological characteristics of the root dentin-adhesive interface and bond strength might better explain the bonding ability of resin cements to root dentin (Da Silva *et al.* 2015).

Therefore, the purpose of this study was to investigate the effect of the resin cement type and how the cement is mixed and inserted into the root canal on the resin cement porosity and bond strength to the tooth. The null hypotheses tested were:

1) the micro-CT analysis would not show any difference in the porosity due to different cement manipulation and insertion techniques;

2) that the pushout bond strength (PBS) would not be affected by the different cement manipulation and insertion techniques;

3) that the resin cement type and the root depth would not influence the PBS.

Material and Methods

Sample Selection and Root Canal Preparation

This study was approved by the local Ethics Committee (Protocol 227/09). One hundred and twenty single-rooted human adult maxillary central incisors, with root length greater than 15 mm, of similar size and anatomic shape as well as having straight roots were selected and stored in distilled water at 4°C until use. Teeth with caries, cervical erosion, previous endodontic treatment, a post or a crown were excluded. The specimens were decoronated by transversally sectioning the roots 15 mm from the apex with a double-faced diamond disc (KG Sorensen, Barueri, SP, Brazil) at a low speed with air/water spray coolant (Isomet 1000, Buehler Ltd, Lake Bluff, IL, USA).

The root canal was located using 10 K-file (Dentsply Malleifer, Petrópolis, RJ, Brazil) that was introduced into the root canal until it was visible at the apical foramen. The working length was determined at 1.0mm prior to the apical limit. The root canals were shaped by rotary instruments (ProTaper system, Dentsply Malleifer, Petrópolis, RJ, Brazil) sequenced in order (SX, S1, S2, F1, F2, F3, F4) applying the crown-down technique. One rotary kit was used to prepare 5 specimens and then replaced. The root canals were irrigated with 2.5% sodium hypochlorite (Chlorine Rio, São José do Rio Preto, SP, Brazil) using a syringe and a 27-gauge needle throughout progression of file sizes. Final irrigation was with 17% ethylene diamine tetra acetic acid (EDTA; Biodynamics, Ibiporã, PR, Brazil) for three minutes followed by 2,5% NaOCl solution (Chlorine Rio, São José do Rio Preto, SP, Brazil) for one minute and with 5 ml physiologic saline solution (LBS Laborasa, São Paulo, SP, Brazil) to remove the remaining debris. The instrumented root canals were dried with sterile paper points

(Dentsply, Malleifer, Petrópolis, RJ, Brazil) and then immediately obturated using a lateral condensation technique with a gutta-percha master cone F4 ProTaper Universal (Dentsply, Malleifer, Petrópolis, RJ, Brazil) and conventional gutta-percha accessory cones and calcium hydroxide basedcement (Sealer 26; Dentsply, Sao Paulo, SP, Brazil). The root canal opening was sealed with resin modified glass ionomer cement (Vitremer; 3M-ESPE, St Paul, MN, USA). The endodontically treated roots were stored at 37°C and 100% relative humidity for 7 days.

Post space preparation

A heated instrument (Paiva condenser, Golgran, São Paulo, SP, Brazil) was used to remove the gutta-percha to a depth of 10 mm. The specimens were randomly assigned to 12 groups (n=10), according to the resin cement mixing and insertion technique (handmix/endodontic file; handmix/Centrixserynge; automix/conventional tip; automix/endo tip) and to the self-adhesive resin cement brand (Rely X U200, 3M ESPE; seT, SDI; Panavia SA Cement, Kuraray). The resin cements are described in Table 1.

After post space preparation with a heated condenser (Paiva condenser; Golgran, São Paulo, SP, Brazil) to 10 mm, a Gates Glidden no. 5 drill was used at 8 mm, and the bur specific to the post system (White Post DC #3; FGM, Joinville, SC, Brazil) with dimensions similar to a glass fiber post (height 20 mm, higher and lower diameter 2.0 mm and 1.25 mm, respectively). The post space was cleaned by copious irrigation with distilled water. The canals were then dried with paper points (Dentsply, Malleifer).

Glass fiber post cementation

The post cementation protocol was the same for all resin cement tested. The glass fiber post (White Post DC #3; FGM, Joinville, SC, Brazil) was etched with 24% hydrogen peroxide for 1 min and (Menezes *et al.* 2014), rinsed with distilled water, and then air dried. A silane agent was then applied to the post for 1 min (Silano; Angelus, Londrina, PR, Brazil). All roots were dried with paper points and the fiber posts were cemented using the following four different techniques:

Handmix/endodontic file: the self-adhesive resin cement was dispensed and hand mixed

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introduced into the canal by using a K-file and the post portion was covered with cement. The post was seated and held using finger pressure for 5 min, the resin cement excess was removed and light activated for 40 seconds from the buccal, lingual and incisal (Pereira *et al.* 2015).

Handmix/Centrix: handl mix resin cement, inserted into the canal using Centrix syringe (NOVA DFL, Rio de Janeiro, RJ, Brazil) with AccuDose tips.

Automix/conventional tip: the resin cement was mixed through a dual barrel syringe (mixing tip regular) and dispensed directly into the canal using a dedicated tip, with 24mm length, 3.8mm larger diameter and 1.4mm smaller diameter, according to the

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Automix/endo tip: the cement was mixed trough a dual barrel syringe (18 mm mixing tip) and dispensed directly into the canal using a root canal tip (endo tip, 0.98mm

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After 1 min, the resin cement excess was removed, and 5 min after seating the post, the resin cement was light-cured at each coronal root surface (buccal, lingual and occlusal) for 40 s using a halogen curing lamp (Optilux 501; Kerr Corporation, Orange, CA, USA) that delivered an irradiance at the tip of 1000 mW/cm^2. The specimens were stored in 100% humidity at 37 °C for 7days.

Micro-CT Analysis

Each specimen was air-dried, mounted on a custom attachment and scanned using a high-resolution micro-CT system (SkyScan 1272; Bruker, Kontich, Belgium). The scanner operated at 100 kV and 100 mA (0.11-mm Cu filter). The resolution used was 1224/820 cross-sectional pixel size w 20µ . T resulted in 380 transverse cross sections per specimen. The scanning parameters were: 180° rotation around the vertical axis, a camera exposure time of 1000ms, a rotation step of 0.5°, a frame averaging of 2, and random movement of 20. Each specimen was scanned for a total of 35 min 41s. Images of each specimen were reconstructed using NRecon version 1.6.10.1 (Bruker). For each root, approximately 380 slices were made per specimen. CTAn v.1.14.4.1 software (Bruker) was used for the 3-dimensional (3D) quantitative analysis (volume of resin cement/mm^3 and volume of porosity/%) of each root canal. The 3D analysis provided the quantitative porosity, which corresponds to the percentage (%)void volume values within of the resin cement layer. The influence of the types of resin cement, the cements mixing and insertion method in the root canal, and the values separated by apical, middle and cervical slices were obtained. CTVol v.2.2.3.0 software (Bruker) was used for three-dimensional visualization and qualitative evaluation of the specimens (Fig. 1).

Push-out Bond Strength Test

The restored teeth were fixed on a 20 mm X 20 mm acrylic plate with cyanoacrylate (Super Bonder, Loctite, SP, Brazil), and were sectioned transversely using the water-cooled low-speed diamond saw (Isomet1000; Buehler Ltd, Lake Bluff, IL). Two 1.0-mmthickslices from the apical, middle and coronal root regions were obtained. Load indenter tips of 1.5 mm and 2.5 mm base were used for the cervical and middle third and smaller 1.0 mm tip and 2.0mm base for the apical third (Zanatta*et al.* 2015). The diameter and thickness of the specimens were measured using a stereomicroscope and digital micrometer digital camera(Mitutoyo, Tokyo, Japan)that had a 0.01-mm accuracy. Each slice was subjected to a push-out bond strength test (DL500; EMIC, São José dos Pinhais, PR, Brazil), with the load applied in the apical-coronal direction at a crosshead speed of 0.5 mm/min. The maximum load at failure was recorded in Newton (N) and converted into Mega Pascal (MPa) by dividing the load (A) u u w u : A = π (R1 + R2) √R1 - R2) 2 + 2; w π u 3.14 R the largest radius, respectively, of the cross-sectioned tapered post, and h is the thickness of the sectioned root with the post.

Failure Mode Analysis

Failures were classified by a blinded calibrated operator using a stereomicroscope (Mitutoyo, Tokyo, Japan) at 40× magnification (Figure 2), according to these 5 categories: (1) adhesive failure between post and resin cement; (2) failure between resin cement and root dentin; (3) mixed failure, with resin cement covering partially of the post surface; (4) cohesive failure within the fiber post; and (5) cohesive failure within the dentin.

Statistical Analysis

The PBS data were statistically analysed using a 2-way analysis of variance (resin cement and mixing/insertion method) with repeated measurement (root depth) and the Tukey test post-hoc multiple comparison test. The volume of resin cement and the volume of porosities were analysed using 1-way analysis of variance (mixing/insertion method) with repeated measurement (root depth) and the Tukey Test. Chi-square test was used to analyse the failure modes. The significance level was set at 5%. All statistical analyses were performed using Sigma Plot 12.1 (Stata Corp, College Station, TX).

Results

Micro-CT analysis

The volume of the resin cement calculated using micro-CT is shown in Figure 3. Representative micro-CT images of the resin cement porosity produced by different mixing and insertion method are shown in Figure 1. ANOVA showed no significant difference on the total volume occupied by resin cement and voids into the root canal irrespective of manipulation and insertion method ($P = 0.134$). The volume of porosity on the resin cements mixed and inserted using different methods at different root regions are shown on Figure 4. ANOVA indicated a significant effect of the interaction between mixing and insertion of resin cement method and root regions ($P < 0.001$). Tukey test demonstrated that the hand mixed resin cement had lower porosity at cervical third, followed by middle third and the highest porosity was found at apical third, irrespective of the resin cement. Lower porosity was for resin cement mixed automatically and inserted into the root canal by using endo tip. The highest porosity was for the resin cement mixed manually and inserted into the root canal using endodontic file. The use of a Centrix syringe reduced the porosity at apical third for all resin cement when compared with hand mixing group inserted by using endodontic file.

The resin cement automixed and inserted using endo tip eliminated completely the effect of root canal region on the porosity of the resin cement.

Push-out Bond Strength Test

The bond strength values in MPa (mean and standard deviation) in terms of the resin cement, mixing and insertion methods and region for the experimental groups, are shown in Figures 2 A, B and C. ANOVA showed significant influence for the interaction between the mixing/insertion method and root region factors only for RelyX U200 (P = 0.002) and seT cement (P = 0.014). No difference was found for all factors for Panavia resin cement (P = 0.456). The root depth reduced significantly the bond strength values for RelyX U200 and seT when manually mixed and inserted using endodontic files. The use of Centrix syringe to insert the resin cements manually mixed significantly increased the bond strength values from apical third compared to when they were inserted with endodontic files. Automatically mixing RelyX U200 and seT resin cements increased the bond strength values eliminating the effect of the root region. The endo tip resulted in similar bond strength values to the conventional tip for all resin cements. In general, the RelyX U200 showed higher values than other resin cements and Panavia resulted in lower values than other resin cements tested.

The failure modes in terms of the resin cement, mixing and insertion methods and region for the experimental groups, are shown in Fig. 2 C, D and E. Qui-square test showed no significant difference among failure mode, irrespective of root region and mixing/insertion method (P = 0.456). The adhesive failure between root dentin and resin cement was the prevalent failure mode for all experimental groups.

Discussion

How the resin cement is inserted into the root canal is one of the main steps to ensure good bonding to both the post and the root dentin walls (Pedreira*et al.* 2016).The voids presence and their regional distribution were affected by the resin cement mixing and insertion method (Uzun*et al.* 2016).Delivery systems that use a syringe to extrude the mixed cement through mixing tips directly into the root canal should deliver a consistent bubble-free cement mixture(Pedreira*et al.* 2016). When using dual syringe mixed resin cements, the mixing process does not generate voids because both catalyst and base pastes are not in contact with air (Uzun*et al.* 2016).Resin cement mixed manually (handmix) and inserted using Centrix syringe presented greater void formations than automixedresin cement inserted using conventional tip or endo tip, demonstrating that the mixing method influenced void formation in cement (Uzun*et al.* 2016, Durski*et al.* 2016). Cements mixed manually include several small voids both during the mixing and while placing the post into the canal (Uzun*et al.* 2016).

In the present study, the use of Centrix syringe to insert the resin cement manually mixed, reduced the apical porosity for all resin cements when compared with hand mixed resin cements that were inserted using endodontic files. Similar results were found in another study that observed larger number of voids and bubbles occurred when the conventional technique was used in comparison with the Centrix dispensing application, which allowed a more homogenous cement interface for the self-adhesive luting materials tested(Pedreira*et al.* 2016).Theinjection of the resin cement into the root canal, mainly into the deeper root canal avoided air retention into the root canal, thus reducing the bubbles. Additionally, the use of the specific endo tip associated to automixing reduced significantly the porosity of the resin cement, irrespective of resin cement. If the tip is thin enough to reach the bottom of the prepared root canal,thus inserting the resin cement from the apical to the cervical thirds, much lower porosities are observed. This createsa more homogeneous cement layer along the entire root surface and permitsbetter bonding between resin cement and root dentin and a in better stress distribution along at the both post and dentin interface (Da Silva *et al.* 2015). Thus, the use of a flexible root-canal-shaped application aid should reduce the number of voidsat the self-adhesive cement interface(Pedreira*et al.* 2016, Watzke *et al.* 2008).

The second and third null hypothesis were also rejected. Automatically mixing the RelyX U200 and seT resin cements increased the bond strength values eliminating the effect of the root region. Additionally, when these cements were manually mixed and inserted using endodontic files, the apical third had significantly lower PBS values. A negative effect was observed of void formations on the reduction the bonding strength by restricting the available area for cementation, which results in shortened survival time of the restoration (Uzun*et al.* 2016). Greaterpush-out strength values were obtained for adhesive cements when the endo tip was used (Durski*et al.* 2016). When the sample defects occupying more than 12 % of the total transverse section area of the endodontic cement layer, led to interfacial shear strength values 70% smaller than those found for the samples without defects. Those occupying less than 2 %, instead, had negligible effects on the interfacial shear strength (Grassi *et al.* 2012). Higher porosity presence, higher stress concentration occurred on dentin/resin cement surface, and consequently lower bond strength was measured, mainly at the apical region (Da Silva *et al.* 2015).

Push out bond strength decreased towards the apical direction, and it may be due to several factors, including the numerous variables involved in root canal bonding technique, such as humidity control, access to light inside the root canal and C-factor (Pedreira*et al.* 2009). It is rather difficult to achieve an effective bonding within the root canal because to the small root-canal geometry, any controlled application of several agents of the adhesive bonding system is difficult. A visual control is almost impossible. Remnants of post space preparation and conditioning may remain. Improved bond strength of self-adhesive resin cements at apical third rely on the fact that the mixing and insertion method using a delivery system (Centrix syringe) for handmix and mainly the use of automixed resin cement inserted using endo tip improved interaction with root dentin. High viscosity of the luting materialnegatively affecting the demineralization and penetration potential into dentin of self-adhesive resin cements (Yang *et al.* 2006). A decrease in the cement viscosity allows the monomer/comonomer systems to enhance the diffusion of the reacting species, leading to an increased rate of reticulation, especially in the initial stages of polymerization (Charton*et al.* 2007). The method used to mix and insert the resin cement into the root canal may influence the resin cement viscosity. The self-adhesives do not have the ability to penetrate the smear layer and dentin and to form a hybrid layer as do conventional bonding agents (Aguiar *et al.* 2012). Immediately after mixing the base and catalytic pastes, when delivering the resin cements after the settings reactions, and due to their rheological properties, the cements are able to flow according to each material (’A *et al.* 2015). It occurs a simultaneous neutralization effect with cement setting reaction, due to buffering of the dentin and to chemical reactions involving water release and alkaline filler that might help to increase the pH level (Cantoro*et al.* 2011). Resin infiltration is proportional to the applied concentration, molecular weight or size, the affinity of monomers for the substrate and the time allowed for penetration (Nakabayashi & Pashley 1998).Therefore the automixing and insertion using endo tip may also contribute with the time reduction, reducing the viscosity increasing effect.

Decreased bond strength as a function of coronal-apical direction also can be explained by inability of the dual-cured cements to reach a similar degree of conversion in the total extension, in which the curing light is unable to reach the apical areas (Durski*et al.* 2016 ’A *et al.* 2015, Kim *et al.* 2009).As the polymerizing network develops further, the rate of radical propagation becomes limited eventually by diffusion, and the polymerization rate decelerates, providing only a limited conversion, even in the presence of unreacted monomer and free radicals (Halvorson *et al.* 2002). Therefore, the chemical cure mechanism proceeds slowly and under a delayed photo activation condition. The cements are activated chemically at first and the polymerization reaction progresses slowly, especially in areas where the curing light is unable to reach the material (Pereira *et al.* 2010). However, it can be speculated that the dynamic process, in which the acidity of the cements is progressively neutralized, as well as the polymerization process, is influenced by the self-adhesive cement composition and by the activation protocol (’A *et al.* 2015).

In general, RelyX U200 showed higher values than other did resin cement and Panavia SA resulted in lower values than other resin cement tested. Some authors suggest that the maintenance of a low pH could have an adverse effect on the bond strength of self-adhesive cements to root dentin (Stona*et al.* 2013). Acid monomers presented in simplified adhesive systems are known to promote the consumption of the tertiary amines included in chemical paste for resin cements, which results in incomplete polymerization and, consequently, low bond strength values when occurs a reduction in light polymerization (Tay *et al.* 2003). U200 tends to increases pH in 24 h (from 2.8 to 7.0) (Pedreira*et al.* 2009). The initial low pH of self-adhesive cements or their residual unpolymerized acidic monomersmay cause coronal or radicular exposed dentin collagens degradation by the activation of matrix metalloproteinases (MMPs) and cathepsins (Luhrs*et al.* 2013). Furthermore, the smear layer and underlying dentin have been regard as solid buffers that probably rapidly buffer the acidity of viscous solutions, thereby limiting the etching ability of acidic monomers(Yang *et al.* 2006). Scarce information is also available on the resin cement seT. According to the manufacturer, the cement establishes a chemical bond with dental substrates (seT Brochure) (Cantoro*et al.* 2011). However, no details are provided on the functional acidic monomers and the way their activation occurs in the absence of water (Cantoro*et al.* 2011). In the microscopic observations of seT specimens, neither the cement–substrate interfaces, nor the cement layer appeared gap-free, and the highly-filled cement showed the inability to penetrate dental tubules. It should be considered that the absence of HEMA might have limited the ability of the material adequately wet the hydrophilic dental substrate (Van Landuyt*et al.* 2008).

Clinically, restoration longevity depends on the numerous steps before a restorative process is complex. The simplification of clinical steps in using materials is critical to the success of a restorative procedure, because many aspects need to be considered ('A *et al.* 2015). The mixing and insertion method of the self-adhesive resin cement is an important factor to improve the bond strength and reduces resin cement porosity, which could be affecting the restoration longevity. It could be indicated to use Centrix syringe for hand mixed resin cement insertion into de the root canal and for auto mixed cement employed the endo tip associated to mix tip. More studies are necessary and the results of in vitro studies should be carefully interpreted before being extrapolated to a clinical context.

Conclusions

Within the limitations of this in vitro study, the results suggest the following:

1. The least porosity was observed when resin cement was automatically mixed and inserted into the root canal using endo tip. The greatest porosity was observed for resin cement mixed manually and inserted into the root canal using endodontic file.
2. RelyX U200 and seT mixed manually and inserted using endodontic files had significantly lower bond strength values. Automaticmixing increased the bond strength values and eliminated the effect of the root region.
3. In general, the RelyX U200 showed greater bond strength values than other did resin cements and Panavia resulted in lower values than other resin cements tested.
4. The mode of failure was predominantly between root dentin and resin cement for all experimental groups.

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Conflict of interest statement

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Table 1: Self-adhesive resin cements, Batch number, Manufacturer and Composition.

Material	Manufacturer	Batch Number	Composition
RelyX™ U200	3M ESPE	506742	Base paste: Methacrylate monomers containing phosphoric acid groups, Methacrylate monomers, Silanated fillers, Initiator components, Stabilizers, Rheological additives Catalyst paste : Methacrylate monomers, Alkaline (basic) fillers, Silanated fillers, Initiator components, Stabilizers, Pigments
PANAVIA SA Cement	Kuraray Noritake Dental Inc, Okayama, Japan	0070AA	Paste A: 10-Methacryloyloxydecyl dihydrogen phosphate (MDP), Bisphenol A diglycidylmethacrylate (Bis-GMA), Triethyleneglycoldimethacrylate (TEGDMA), Hydrophobic aromatic dimethacrylate 2-Hydroxymethacrylate (HEMA), Silanated barium glass filler, Silanated colloidal silica, dl-Camphorquinone, Peroxide, Catalysts, Pigments. Paste B: Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Silanated barium glass filler, Surface treated sodium fluoride, Accelerators, Pigments; Inorganic filler - 40 vol%. The particle; size of inorganic fillers 0.02 μ 20 μ .
seT PP	SDI Limited,	61304011	35% by weight methacrylate ester; 65% by

Victoria,Australia	weight inorganic filler

* ’ u u .

Figure legends

Figure 1. Micro-CT reconstruction of the root endodontically treated with Just be consistent with spelling of fiber/fibre post cemented using resin cement; (a) handmix group; (b) Centrix group; (c) automix group; (d) endo tip group.

Figure 2. The bond strength values in MPa (mean and standard deviation) in terms of the resin cement, mixing/insertion methods and region for (a) Panavia; (b) seT and (d) RelyX U200. Mean values followed by different letters differ among them by the Tukey test ($P < 0.05$). Upper caser letter used for comparing the root region and lower caser letter used for comparing mixing/insertion methods for each resin cement.

Figure 3. The resin cement volumes in mm^3 (mean and standard deviation) in terms of the resin cement, mixing/insertion methods. Mean values followed by different letters differ among them by the Tukey test ($P < 0.05$). Upper caser letter used for comparing the resin cement and lower caser letter used for comparing mixing/insertion methods.

Figure 4. The porosity of resin cement volumes in mm^3 (mean and standard deviation) in terms of the mixing/insertion methods and root regions. Mean values followed by different letters differ among them by the Tukey test ($P < 0.05$). Upper caser letter used for comparing the root region for each resin cement and mixing method and lower caser letter used for comparing mixing/insertion methods for each root region.

Figures and legends.

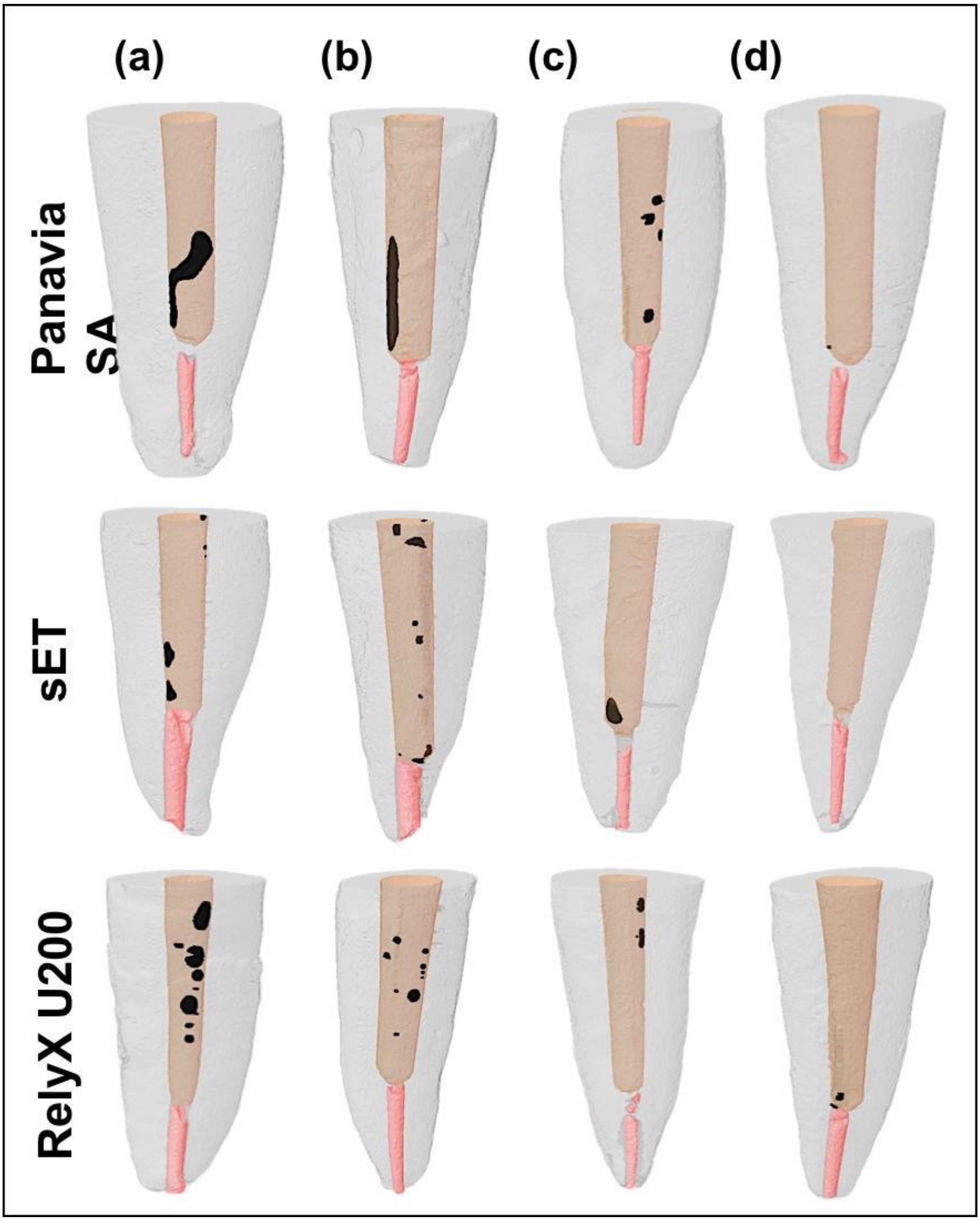


Figure 1 Micro-CT reconstruction of the root endodontically treated with fibre post cemented using resin cement; (a) handmix group; (b) Centrix group; (c) automix group; (d) endo tip group.

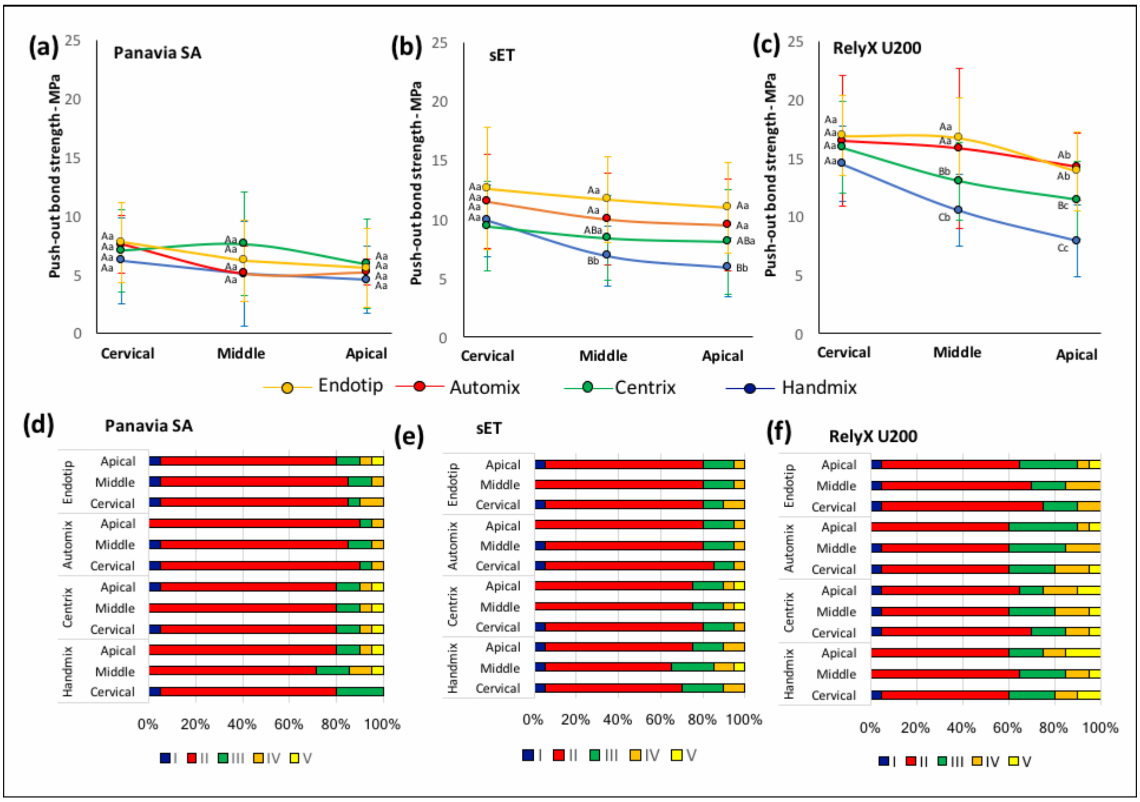
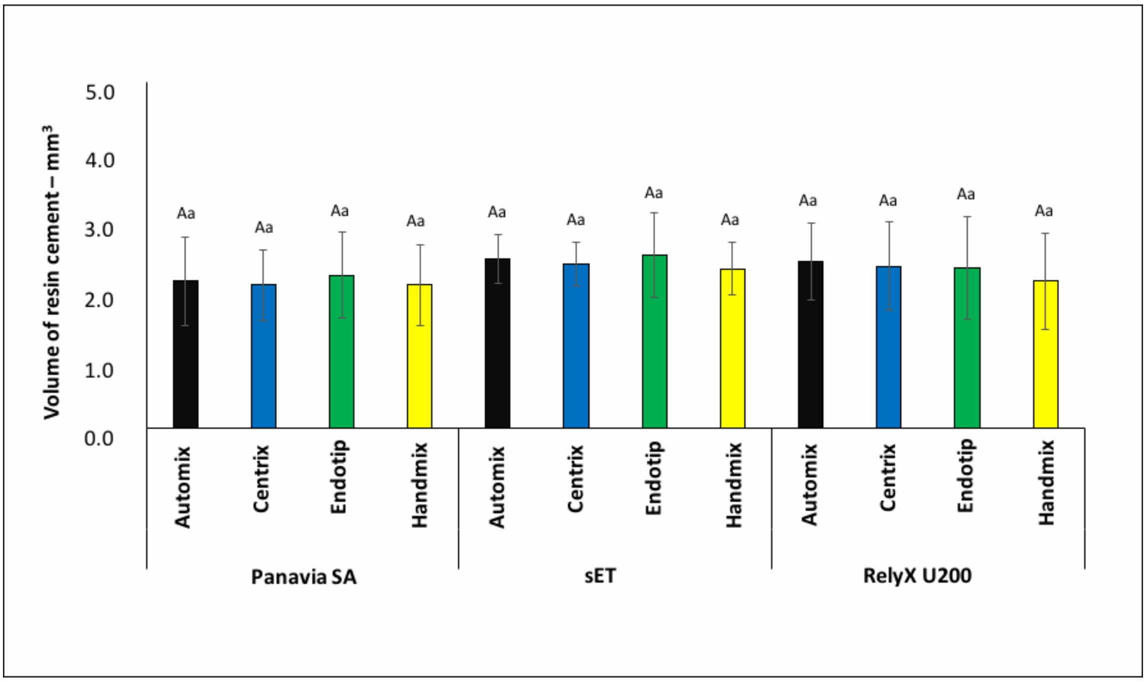


Figure 2 The bond strength values in MPa (mean and standard deviation) in terms of the resin cement, mixing/insertion methods and region for (a) Panavia; (b) seT and (d) RelyX U200. Mean values followed by different letters differ among them by the Tukey test (P < 0.05). Upper caser letter used for comparing the root region and lower caser letter used for comparing mixing/insertion methods for each resin cement.



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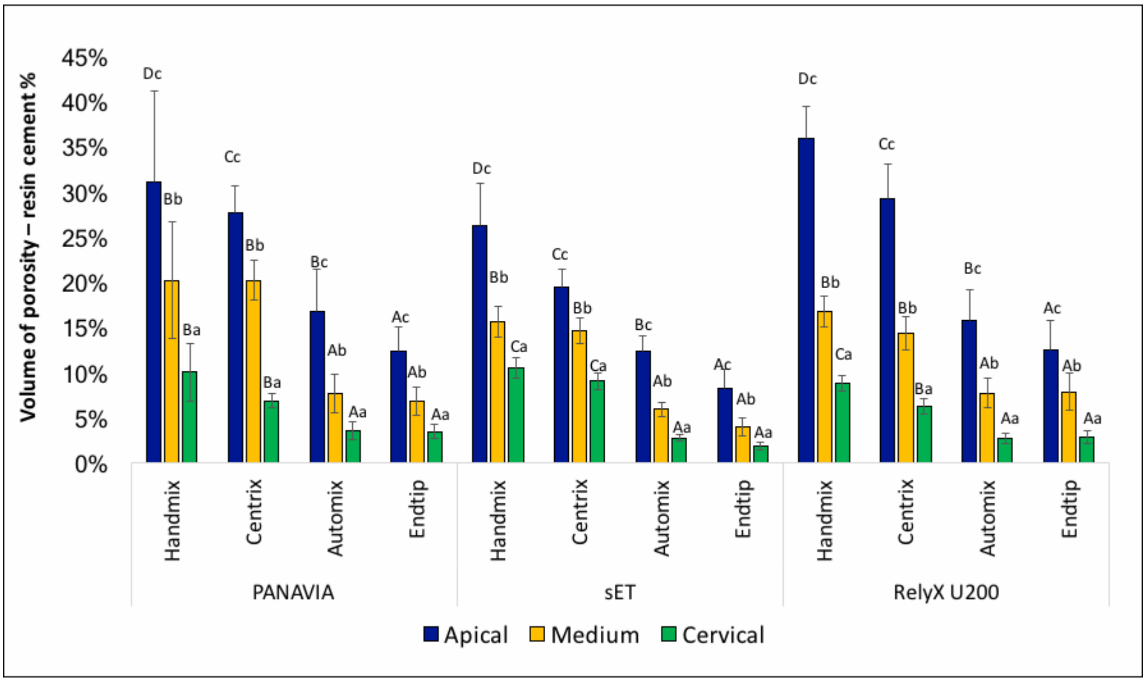

Figure 4 The porosity of resin cement volumes in mm^3 (mean and standard deviation) in terms of the mixing/insertion methods and root regions. Mean values followed by different letters differ among them by the Tukey test ($P < 0.05$). Upper caser letter used for comparing the mixing/insertion and lower caser letter used for comparing methods root region for each resin cement.

Capítulos

3.4 Capítulo 4

Artigo a ser enviado para publicação no periódico Clínica – International Journal of Brazilian Dentistry

Cimentação pinos de fibra de vidro – mistura e inserção de cimento resinoso

Cementation of fiber glass post – mixing and insertion of resin cement

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Cimentação pinos de fibra de vidro – mistura e inserção de cimentos resinosos auto-adesivos

RESUMO

Inúmeros fatores biológicos, mecânicos e estéticos estão envolvidos no sucesso dos procedimentos restauradores em dentes tratados endodonticamente. Estes dentes geralmente requerem o uso de pinos para retenção da restauração devido à extensa perda de estrutura dental coronária. A preservação de estrutura é fator decisivo para longevidade de restaurações. Este trabalho tem por objetivo definir protocolo de cimentação de pinos de fibra de vidro, estabelecendo guia clínico na técnica de mistura e inserção de cimentos resinosos autoadesivos. Será relatado um caso clínico de reabilitação estética do sorriso, associando, pino de fibra de vidro e restauração. Serão destacadas condutas clínicas associadas a uma revisão de aspectos biomecânicos e estéticos da reabilitação de dentes tratados endodonticamente.

PALAVRAS CHAVES

Técnica para Retentor Intrarradicular; Cimentos de Resina.

SIGNIFICÂNCIA CLÍNICA

A técnica de mistura e inserção de cimento resinoso autoadesivo pra fixação de pino de fibra de vidro pode interferir no processo de adesão e consequentemente na longevidade da restauração de dentes tratados endodonticamente. É apropriado definir guia de orientação para o clínico visando informá-lo sobre uma conduta mais apropriada para obter adesão efetiva entre os diversos substratos da interface adesiva pino, cimento e dentina e proporcionar o sucesso do restabelecimento estético e funcional de dentes com grandes perdas estruturais.

INTRODUÇÃO

Dentes tratados endodonticamente usualmente necessitam de pino de fibra de vidro quando a quantidade de estrutura dentária coronária é severamente comprometida pela cárie, fratura ou pelos sucessivos tratamentos empregados[1]. Os pinos de fibra de vidro provêm retenção ao preenchimento coronário, garantindo adequada estabilidade funcional e mimetizam o comportamento mecânico do dente natural.[1-3] Os pinos de fibra apresentam propriedades favoráveis, como a possibilidade de adesão aos materiais resinosos e por apresentar módulo de elasticidade semelhante ao da dentina, diminuindo risco de fratura radicular. [4,5,6] A efetiva união dos substratos composto por dentina, cimento resinoso e pino de fibra de vidro, formam estrutura de corpo único, que permite distribuição de tensão mais uniforme, prevenindo a ocorrência de trincas verticais na raiz e reinfecção da região periapical.[7]

Essa união adequada é fator crítico para o sucesso do procedimento reabilitador e é influenciada por inúmeros fatores, como efetiva polimerização do cimento resinoso,[8,9] presença de resíduos de materiais obturadores endodônticos e dificuldade de remoção dos mesmos,[10] densidade e orientação dos túbulos dentinários.[11] A formação de bolhas no interior da camada de cimento e as propriedades destes materiais de fixação dos pinos são fatores que podem interferir na qualidade da união, principalmente nas regiões apicais, tornando o procedimento de cimentação de pinos de fibra de vidro um protocolo desafiador.[6,12-14] As bolhas são incluídas no corpo do cimento durante o processo de manipulação e ou inserção dos cimentos resinosos no espaço do conduto radicular.[15] Além disso, o fator de configuração cavitário desfavorável encontrado em adição à elevada contração de polimerização observada quando da cimentação de pinos representam ainda um grande obstáculo á efetiva adesão ás paredes do canal radicular.[16] Assim, a melhora no sistema de mistura e inserção dos cimentos resinosos, pelo uso de cimentos automix que disponibilizam o cimento já misturado por meio de uma ponta misturadora diretamente no interior do canal radicular, visa obter uma mistura das pastas base e catalisadora livres de bolhas.[15]

Teoricamente esses cimentos autoadesivos são compostos por monômeros acídicos polimerizáveis a base de metacrilato que na presença de água devem desmineralizar a camada de smear layer da dentina subjacente e simultaneamente infiltrar a superfície dentinária porosa devido às suas propriedades hidrofílicas. Contudo, a microscopia eletrônica de transmissão (TEM) mostra que não há formação de efetiva camada híbrida na interface adesiva cimento dentina, e ainda evidencia-se a incapacidade do cimento em penetrar na dentina desmineralizada.[17] Tem sido proposto que estes cimentos possuem a habilidade de se difundirem e descalcificar a dentina subjacente gerando aumento da viscosidade devido à reação ácido-base que ocorre após a mistura das pastas.[18] Isso é particularmente importante para os cimentos autoadesivos porque os mesmos dependem do maior contato com os tecidos dentários para reagir com a hidroxiapatita, permitindo melhor interação dos monômeros com a dentina e garantindo o potencial de selamento.[19]

Assim, o objetivo deste estudo foi, por meio de um relato de caso clínico, abordar técnicas mais adequadas de mistura e inserção do cimento resinoso autoadesivo no interior do conduto radicular para permitir interação efetiva do cimento com a dentina radicular e pino de fibra de vidro. Ao associar a descrição de caso clínico com evidências científicas busca-se proporcionar ao clínico suporte para executar técnica mais adequada visando desempenho biomecânico satisfatório dos procedimentos de reabilitação de dentes tratados endodonticamente.

RELATO DE CASO

O objetivo deste trabalho foi de descrever relato de caso clínico de reabilitação estética do sorriso, associando, pino de fibra de vidro e restauração em resina composta em incisivos centrais e lateral superior tratados endodonticamente (Figuras 1). Paciente sexo masculino apresentou-se à Clínica de Pesquisa do Programa de Pós-Graduação da Faculdade de Odontologia da Universidade Federal de Uberlândia (FOUFU) queixando-se de insatisfação estética de seu sorriso após trauma por acidente de moto. Ao exame clínico e radiográfico, verificou-se fratura coronária dos dentes 12, 11 e 21. Mediante diagnóstico e plano de tratamento foi indicado tratamento endodôntico dos dentes envolvidos (Figura 2), emprego de pino de fibra de vidro, restauração direta em resina composta associado à cirurgia periodontal para aumento de coroa clínica na região ântero-superior.

Nos tratamentos endodônticos foi empregado cimento a base de resina epóxica (AH Plus, Dentsply, Brasil) associado a cones de guta-percha. Todo procedimento foi realizado empregando microscópio clínico e lupa de aumento que possibilitam melhor resolutividade (Figura 3). Após anestesia e aferição das profundidades de sondagem foram realizadas incisões em toda extensão da margem gengival compreendida entre os dentes 13 a 23. As incisões foram em bisel interno de 45° em relação à gengiva. Foi removido excesso gengival com cureta periodontal tipo Grayce e houve a necessidade de realizar osteotomia para restabelecer o espaço biológico por meio do uso de ponta esférica diamantada em alta rotação e sob irrigação abundante com soro fisiológico. Em seguida, foi realizada a sutura de modo a posicionar a margem gengival ao nível da junção amelocementária proporcionando o novo contorno gengival (Figura 4). Foi feita a proservação no período de 15 e 45 dias pós cirurgia periodontal. Nessa sessão, foi realizada moldagem de estudo para obtenção de modelo de estudo e posterior enceramento diagnóstico dos dentes 12, 11 e 21 (Figura 5). Foi feito também, o selamento provisório coronário com cimento de ionômero de vidro ativado quimicamente após descontaminação da cavidade pulpar com hipoclorito de sódio 2,5% e em seguida foi feita radiografia periapical do dente 21 (Figura 6).

Como protocolo reabilitador foi indicado restauração direta em resina composta associada a pino de fibra de vidro (PFV) cônico liso (WhitePost DCE 2, FGM, Brasil) dos dentes 11 e 21, pois o paciente não apresentava condições financeiras de custear coroas em cerâmica pura. A seleção do pino foi realizada usando radiografia periapical, tendo como padrão a largura do canal, evitando assim remoção desnecessária e prejudicial de dentina radicular. Lembrando sempre que o profissional deve selecionar o pino em função do diâmetro do canal aliviado e não remover dentina saudável para viabilizar pinos mais espessos. A desobstrução do conduto radicular do dente 11 foi realizada com brocas Gates n°2 (Dentsply Maillefer, Brasil) e para finalização a broca específica do sistema do pino associada ao uso de dispositivo de aumento da visão como lupa de aumento de 3 vezes (Figura 3) para verificação da remoção efetiva de remanescente obturador endodôntico da superfície da dentina radicular preparada; conservando remanescente de guta percha de 5 mm na região apical do canal radicular, objetivando bom selamento apical. Já para a desobstrução do dente 21, foi realizada usando microscópio clínico com aumento de 6 vezes (Figura 7) e verificação da remoção efetiva do material obturador endodôntico da superfície da dentina radicular preparada com aumento de 10 vezes. Foi realizada limpeza do canal radicular por meio de irrigação com água destilada e secagem com pontas de papel absorvente e em seguida foi realizada a radiografia periapical para verificar a quantidade remanescente de material obturador endodôntico do dente 21 (Figura 8)

Para cimentação do PFV (White Post DCE 2, FGM, Brasil) foi utilizado cimento resinoso autoadesivo (RelyX U200, 3M-ESPE, Brasil). Foi realizada limpeza do canal radicular por meio de irrigação com água destilada e secagem com pontas de papel absorvente. O PFV foi introduzido no canal para a avaliação radiográfica e verificação da adaptação. O tratamento de superfície do PFV foi feito com aplicação de gel de peróxido de hidrogênio 24% (Whitness HP, Brasil) utilizado para clareamento em consultório seguido de lavagem abundante com água, secagem com papel absorvente e aplicação por 1 minuto de silano pré-hidrolisado (Silano, Angelus, Brasil).[20]

O cimento resinoso (RelyX U200, 3M-ESPE, Brasil) foi preparado seguindo as instruções do fabricante, misturado em seringa de barra dupla misturadora com 18,00mm de comprimento e diâmetro de 1mm (“ u x”). A çã

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conduto e reduzir a possibilidade de formação de bolha dentro da camada de cimento resinoso (Figuras 9 e 10). Em seguida, o PFV foi inserido e estabilizado por pressão digital. Foi aguardado um minuto para remoção do excesso (Figura 11) e após 5 minutos foi realizada a ativação do cimento, este passo visa minimizar as tensões de contração de polimerização do cimento resinoso com unidade de fotoativação de luz halógena (Demetron LC, Kerr, EUA).[21] Após a cimentação do PFV e corte do excesso de PFV no dente 11, as paredes circundantes da câmara pulpar foram condicionadas com ácido fosfórico 37% (Condac 37, FGM, Brasil) (Figura 12) durante 15s, lavadas com jatos de ar/água por 15s e secas com papel absorvente. Foi utilizado sistema adesivo convencional de 2 passos (Adper Single Bond 2, 3M-ESPE, Brasil) de acordo com as instruções do fabricante.

Para a restauração direta classe IV foi confeccionada em resina composta (Filtek Z350 3M-ESPE, Brasil) por meio de técnica incremental, seguida de fotoativação por 40s cada incremento da resina de dentina e 20s da resina de esmalte com unidade de fotoativação de luz halógena (Demetron LC, Kerr, EUA). Além disso, foi realizada a confecção da restauração em resina composta (Filtek Z350, 3M-ESPE, Brasil) associada ao uso de guia de matriz de silicone de condensação. Uma fina camada de resina na cor incisal foi aplicada sobre a matriz de silicone e posicionada na estrutura dental (Figura 13 e 14). Para construção da dentina utilizou-se resina A2D e A3B (Figura 15). E a resina de esmalte A1E.

Para o acabamento inicial foi usado pontas finas e extrafinas. Em seguida foi feito ajuste oclusal de modo a possibilitar contatos bem distribuídos em máxima intercuspidação e alivio dos dentes posteriores em movimentos protrusivos ou látero-protrusivos. E o polimento foi realizado com pontas abrasivas de sílica nas sequências das cores verde, amarela e branca. E o aspecto final após finalização do tratamento pode ser observado na figura 16.

DISCUSSÃO

Na cimentação adesiva de pinos de fibra de vidro o estabelecimento de união altamente durável entre o cimento resinoso e a dentina radicular é fator essencial para proporcionar selamento coronário e retenção adequada da restauração.[22] O cimento autoadesivo U200 foi selecionado para cimentar o pino de fibra de vidro, por apresentar maiores valores de resistência de união comparado a outros cimentos resinosos e tendem a aumentar o pH por um período de 24 horas de 2,8 para 7,0[23] a fim de não provocar efeito adverso na adesão decorrente da manutenção de um ph baixo.[24] O método de mistura e inserção dos cimentos autoadesivos como o uso de seringa centrix para cimentos misturados manualmente e o uso de pontas capazes de terem acesso à porção mais apical do espaço u “ ”

à u “ u x” çã do cimento com a dentina radicular e promover maior resistência de adesão ao retentor.

Os cimentos resinosos misturados u “ x” endodôntica apresentaram formação de bolhas no terço apical e o volume total dessas bolhas em maior número quando comparado aos cimentos inseridos por meio de métodos de injeção,[6,25,26] u “Centrix” para inserir os cimentos misturados manualmente reduziu as bolhas para todos os cimentos quando comparados à inserção com lima endodôntica. Esse método possibilitou a formação de interface adesiva mais homogênea.[15]

As bolhas e espaços vazios podem afetar a longevidade de união adesiva. Espaços vazios podem estar localizados diretamente na interface entre a dentina e cimento, diminuindo o contato da área de união.[6] Como as propriedades mecânicas são afetadas pela presença de espaços vazios, é observado que a presença de bolhas diminui a resistência do cimento e cria locais para iniciação e propagação de trincas. E a presença de bolhas funciona como fator de concentração de tensões, reduzindo a área adesiva e provoca maior pico de tensão quando comparado à interface intacta.[6] A maior porosidade na região apical é possível devido à dificuldade de inserção do cimento resinoso e à possibilidade de o ar ser confinado durante a inserção do pino. Esse aspecto resulta na maior concentração de tensão e reduz a resistência de união na região do terço apical radicular.[6]

Dessa forma, o método de mistura e inserção dos cimentos resinosos autoadesivos deve ser considerado como uma estratégia importante para obter maior interação dos substratos dentina radicular, cimento resinoso e pino de fibra de vidro.

Além disso, o pequeno campo de operação e as demandas de habilidade e precisão dos procedimentos odontológicos são particularmente adequados para o uso da ampliação ótica na odontologia. Os profissionais podem compensar as deficiências visuais usando diferentes dispositivos de ampliação, uma vez que a acuidade visual de perto varia muito entre indivíduos e diminui com o aumento da idade. Independente da idade ou da visão natural, a acuidade visual pode ser significativamente melhorada usando dispositivos de ampliação.[27] Nesse caso clínico foi usado dispositivo de
u ã ó u u “Galile ” (magnificação de 3.0×) durante a realização de preparo do espaço do pino no conduto radicular para verificação da remoção de todo material selador endodôntico. No entanto, outro estudo demonstrou que apenas o tratamento de molares tem maior probabilidade de influência significativa do uso do microscópio, já a ampliação de alta potência produzida pelo microscópio cirúrgico em pré-molares e dentes anteriores a melhora não é significativa.[28] Além disso, o uso de dispositivos de ampliação da visão como lupas de aumento e microscópio cirúrgico não são considerados primordiais no processo de desobstrução do conduto radicular para cimentação de pinos de fibra de vidro.

Dessa forma, a escolha dos materiais e de técnicas mais adequadas e a habilidade necessária, sempre aliada a decisões e práticas devem ser baseadas em evidências científicas a fim de proporcionar ao paciente uma reabilitação estética e funcional. A indicação correta de pinos de fibras de vidro adequadamente aderidos à dentina radicular associado à restauração direta com resina composta pode sim se constituir em alternativa viável para restaurar dentes anteriores severamente comprometidos para o serviço público e para pacientes com limitações financeiras.

CONCLUSÕES E ORIENTAÇÕES AO CLÍNICO

1. Seleção correta do sistema de pino – pinos só devem ser indicados na ausência de retenção para reconstrução coronária;

2. Priorize o desgaste mínimo da estrutura dentária, defina o diâmetro do pino limitado ao diâmetro do conduto radicular;

3. Realize isolamento adequado do campo operatório na cimentação do pino de fibra de vidro a fim de evitar possível contaminação do canal radicular;

4. Utilize cimento resinoso autoadesivo, reduzindo assim os passos clínicos e possíveis erros de técnica na cimentação de pinos de fibra de vidro;

5. Misture e insira o cimento autoadesivo com o uso de pontas com acesso à porção mais apical do canal radicular (centrix para os cimentos de mistura manual e pontas endo tips para os cimentos automix).

6. O uso de dispositivos de ampliação da visão como lupas de aumento e microscópio cirúrgico não são primordiais na desobstrução do conduto radicular para cimentação de pinos de fibra de vidro.

ABSTRACT

Numerous biological, mechanical and aesthetic factors are involved in the success of restorative procedures in endodontically treated teeth. These teeth often require the use of a posts system to promote retention to the restoration due to extensive loss of coronary tooth structure. The preservation of tooth structure is a decisive factor for the longevity of restorations. The aim of this study was to define fiber glass post cementation protocol, establishing guidelines to use the better technique for mixing and insertion of self-adhesive resin cements. In addition, a clinical case of smile aesthetic rehabilitation will be reported, associating fiber glass post and direct restoration.

KEYWORDS

Post and Core Technique; Resin Cements.

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Figura 1: Aspecto inicial dos dentes 12, 11 e 21 com fratura coronária.

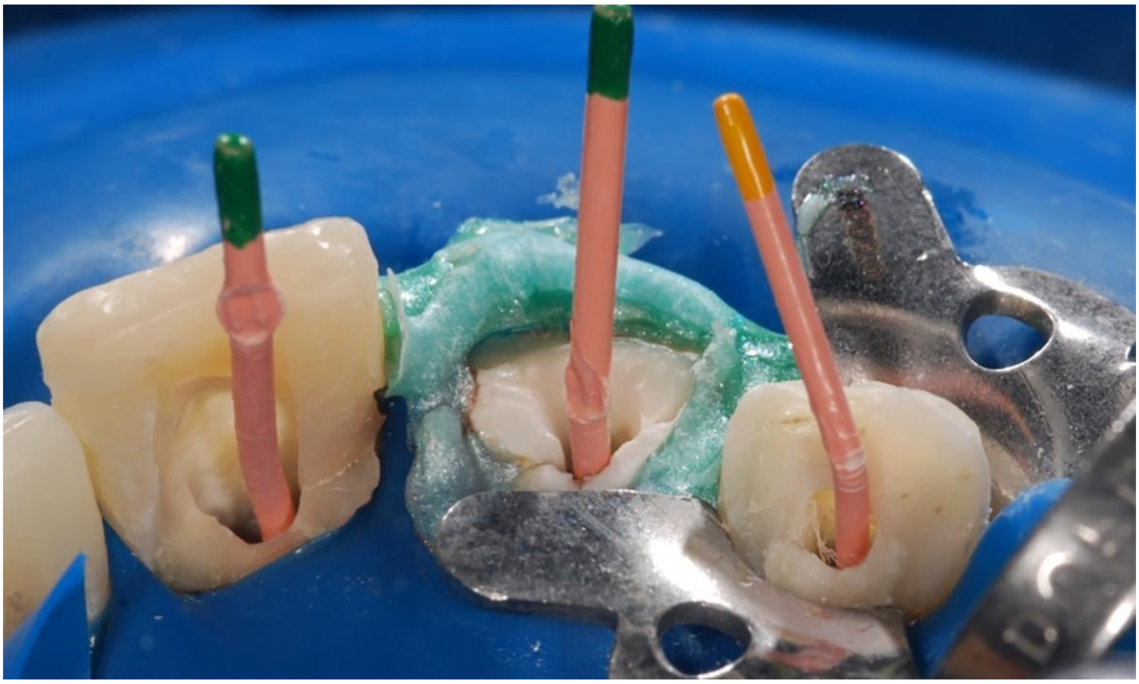

Figura 2: Tratamento endodôntico dos dentes 12, 11 e 21.

visão.

Figura 3: Utilização de lupa com aumento de 3 vezes como dispositivo de aumento da visão.

Figura 4: Vista palatina após cirurgia periodontal para aumento de coroas clinicas em região antero-superior.

Figura 5: Enceramento diagnóstico dos dentes 12, 11 e 21.

Figura 6: Radiografia periapical do dente 21.

Figura 7: Desobstrução do conduto radicular do dente 21 usando microscópio clínico com aumento de 6 vezes.

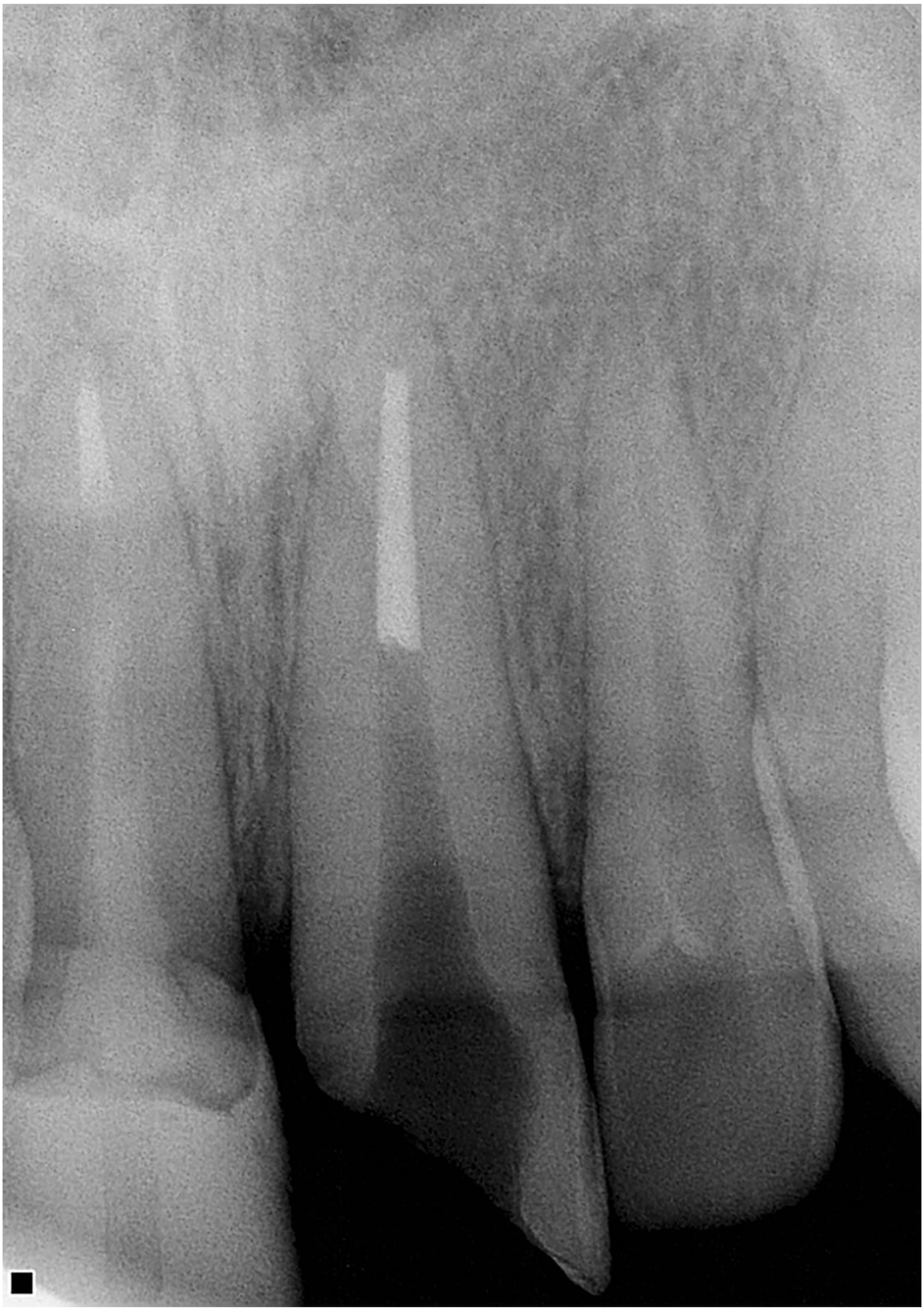

Figura 8: Radiografia periapical do dente 21 após a desobstrução do conduto radicular

Figura 9: Ponta misturadora do cimento resinoso automix acoplada à “ ”.

Figura 10: Técnica de manipulação e inserção do cimento resinoso automix no interior do conduto radicular.

Figura 11: Pino de fibra de vidro cimentado e remoção do excesso de cimento.

Figura 12: Condicionamento com ácido fosfórico 37%.

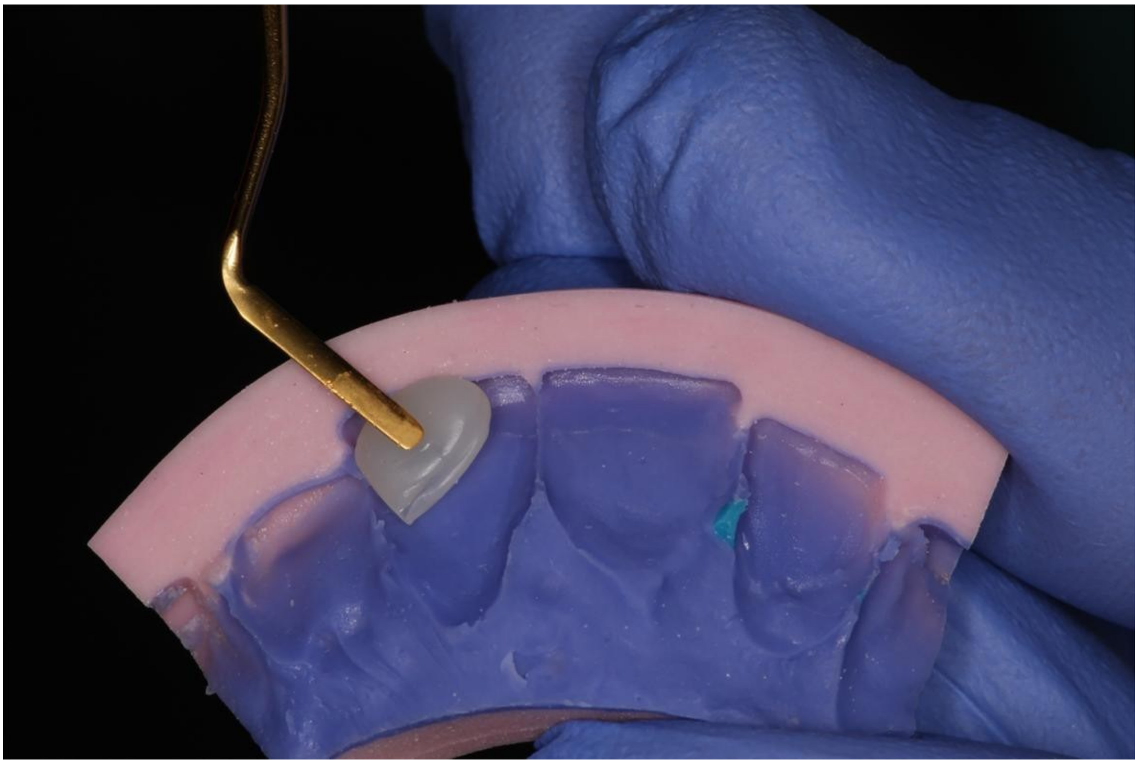

Figura 13: Adaptação de fina camada de resina cor incisal na matriz de silicone.

Figura 14: - Adaptação da matriz de silicone á superfície palatina dos incisivos anteriores superiores e inserção em incrementos de fina camada de resina cor incisal nos dentes 12 e 21.

Figura 15: Inserção em incrementos de camada de resina composta nos dentes 12 e 21.

Figura 16: Aspecto Final.

Conclusões

4- Conclusões

Dentro das limitações metodológicas dos estudos que envolveram três estudos laboratoriais e computacionais e um relato de caso clínico pode-se concluir que:

- A presença de bolhas afetou negativamente a distribuição de tensão e a resistência de união.
- Recomenda-se uso de microscopia confocal para análise de padrão de falha.
- O uso de dispositivo de aumento da visão como a lupa e microscópio clínico no preparo do espaço do pino não melhorou a resistência adesiva e não interferiu na quantidade de material obturador endodôntico remanescente no preparo de dentes anteriores unirradiculares.
- A resistência adesiva e porosidades são negativamente influenciadas pela mistura manual e inserção do cimento com lima endodôntica na cimentação de pinos de fibra de vidro.
- O método de mistura e inserção dos cimentos resinosos auto-adesivos, como o uso de pontas capazes de acessar porções mais apicais do conduto radicular, chamadas endo-tips, acopladas às pontas de auto misturas, deve ser preconizado na busca por melhorar a interação do cimento com a dentina radicular.
- Condutas clínicas associadas à revisão de aspectos biomecânicos e estéticos da reabilitação de dentes tratados endodonticamente devem ser destacadas.

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5- Referências

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Anexos

6- Anexos

6.1- Normas do Periódico 2

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Acknowledgements: Under acknowledgements please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study and any potential conflict of interests if appropriate. Please find more information on the conflict of interest form in section 2.6.

Ethical Approvals

Experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical AssociationDeclaration of Helsinki (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.
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Randomised control clinical trials should be reported using the guidelines available at www.consort-statement.org. A CONSORT checklist and flow diagram (as a Figure) should also be included in the submission material.

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Submitting authors of epidemiological human observations studies are required to review and submit a 'strengthening the reporting of observational studies in Epidemiology' (STROBE) checklist and statement. Compliance with this should be detailed in the materials and methods section. (www.strobe-statement.org)

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5. MANUSCRIPT FORMAT AND STRUCTURE

Format

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• **Results**: Give the main results of the study, including the outcome of any statistical analysis.

• **Conclusions**: State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

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Abstract for Mini Review Articles should be non-structured of no more than 250 words, including a clear research question, details of the literature search strategy and clear conclusions.

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Discussion: may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.
Conclusion: should contain a summary of the findings.
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Examples of correct forms of reference follow:

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Bergenholtz G, Nagaoka S, Jontell M (1991) Class II antigen-expressing cells in experimentally induced pulpitis. *International Endodontic Journal* **24**, 8-14.

Corporate author

British Endodontic Society (1983) Guidelines for root canal treatment. *International Endodontic Journal* **16**, 192-5.

Journal supplement

Frumin AM, Nussbaum J, Esposito M (1979) Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). *Blood* **54** (Suppl. 1), 26a.

Books and other monographs

Personal author(s)

Gutmann J, Harrison JW (1991) *Surgical Endodontics*, 1st edn Boston, MA, USA: Blackwell Scientific Publications.

Chapter in a book

Wesselink P (1990) Conventional root-canal therapy III: root filling. In: Harty FJ, ed. *Endodontics in Clinical Practice*, 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper

DuPont B (1974) Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication

Ranofsky AL (1978) Surgical Operations in Short-Stay Hospitals: United States-1975. DHEW publication

no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.8

Dissertation or thesis

Saunders EM (1988) In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis). Dundee, UK: University of Dundee.

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7 Guidelines for reporting of DNA microarray data

The *International Endodontic Journal* gives authors notice that, with effect from 1st January 2011, submission to the *International Endodontic Journal* requires the reporting of microarray data to conform to the MIAME guidelines. After this date, submissions will be assessed according to MIAME standards. The complete current guidelines are available athttp://www.mged.org/Workgroups/MIAME/miame_2.0.html. Also, manuscripts will be published only after the complete data has been submitted into the public repositories, such as GEO (http://www.ncbi.nlm.nih.gov/geo/) or ArrayExpress (http://www.ebi.ac.uk/microarray/submissions_overview.html), in MIAME compliant format, with the data accession number (the identification number of the data set in the database) quoted in the manuscript. Both databases are committed to keeping the data private until the associated manuscript is published, if requested.

Prospective authors are also encouraged to search for previously published microarray data with relevance to their own data, and to report whether such data exists. Furthermore, they are encouraged to use the previously published data for qualitative and/or quantitative comparison with their own data, whenever suitable. To fully acknowledge the original work, an appropriate reference should be given not only to the database in question, but also to the original article in which the data was first published. This open approach will increase the availability and use of these large-scale data sets and improve the reporting and interpretation of the findings, and in increasing the comprehensive understanding of the physiology and pathology of endodontically related tissues and diseases, result eventually in better patient care.

- Normas do Periódico 3

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   - list of materials used

- potential problems
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- references (see below)

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    - a clinical relevance statement based on the conclusions of the review
    - conclusions based on the literature review…without this, the review is just an exercise
    - references (see below)

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REFERENCES must be numbered (superscripted numbers) consecutively as they appear in the text and, where applicable, they should appear after punctuation.

The reference list should be arranged in numeric sequence at the end of the manuscript and should include:

1. Author(s) last name(s) and initial (ALL AUTHORS must be listed) followed by the date of publication in parentheses.
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3. Full journal name in italics (no abbreviations), volume and issue numbers and first and last page numbers complete (i.e. 163-168 NOT attenuated 163-68).
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7. Papers in the course of publication should only be entered in the references if they have been accepted for publication by a journal and then given in the standard manner with "In press" following the journal name.
8. **DO NOT** include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.

EXAMPLES OF REFERENCE STYLE

- Journal article: two authors
  Evans DB & Neme AM (1999) Shear bond strength of composite resin and amalgam adhesive systems to dentin *American Journal of Dentistry* **12(1)** 19-25.

- Journal article: multiple authors
  Eick JD, Gwinnett AJ, Pashley DH & Robinson SJ (1997) Current concepts on adhesion to dentin *Critical Review of Oral and Biological Medicine* **8(3)** 306-335.

- Journal article: special issue/supplement
  Van Meerbeek B, Vargas M, Inoue S, Yoshida Y, Peumans M, Lambrechts P & Vanherle G (2001) Adhesives and cements to promote preservation dentistry *Operative Dentistry* **(Supplement 6)** 119-144.

- Abstract:
  Yoshida Y, Van Meerbeek B, Okazaki M, Shintani H & Suzuki K (2003) Comparative study on adhesive performance of functional monomers *Journal of Dental Research* **82(Special Issue B)** Abstract #0051 p B-19.

- Corporate publication:
  ISO-Standards (1997) ISO 4287 Geometrical Product Specifications Surface texture: Profile method – Terms, definitions and surface texture parameters *Geneve: International Organization for Standardization* **1st edition** 1-25.

- Book: single author
  Mount GJ (1990) *An Atlas of Glass-ionomer Cements* Martin Duntz Ltd, London.

- Book: two authors
  Nakabayashi N & Pashley DH (1998) *Hybridization of Dental Hard Tissues* Quintessence Publishing, Tokyo.

- Book: chapter
  Hilton TJ (1996) Direct posterior composite restorations In: Schwarts RS, Summitt JB, Robbins JW (eds) *Fundamentals of Operative Dentistry* Quintessence, Chicago 207-228.

- Website: single author
  Carlson L (2003) Web site evolution; Retrieved online July 23, 2003 from: http://www.d.umn.edu/~lcarlson/cms/evolution.html

- Website: corporate publication
  National Association of Social Workers (2000) NASW Practice research survey 2000. NASW Practice Research Network, 1. 3. Retrieved online September 8, 2003 from:http://www.socialworkers.org/naswprn/default

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6.3- Normas do Periódico 4

Clínica
INTERNATIONAL JOURNAL OF BRAZILIAN DENTISTRY

Início

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Normas

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b) Relato de casos clínicos e de técnicas: título em português e inglês (máximo de 12 palavras), nomes, titulação e filiação institucional dos autores, endereço completo do autor principal (apenas na folha de rosto), resumo (máximo de 10 linhas), palavras-chave, introdução, revisão da literatura, relato do caso, discussão, conclusões ou considerações finais, abstract (máximo de 10 linhas), keywords, referências, agradecimentos e legenda das figuras;

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EXEMPLOS DE REFERÊNCIAS

De um a seis autores

Lodish H, Baltimore D, Berk A, Zipursky SL, Matsudaira P, Darnell J. Molecular cell biology. 3rd ed. New York: Scientific American; 1995.

Com mais de seis autore

Liebler M, Devigus A, Randall RC, Burke FJ, Pallesen U, Cerutti A, et al. Ethics of esthetic dentistry. Quintessence Int. 2004 Jun;35(6):456-65.

Livro

Marzola C. Técnica exodôntica. 3a ed. rev. ampl. São Paulo: Pancast; 2001.

Capítulo de livro

Soviero C, Garcia RS. Músculos da mímica facial. In: Oliveira MG, organizadora. Manual de anatomia da cabeça e do pescoço. 3a ed. Porto Alegre: EDIPURS; 1998. p. 66-73.

Sem indicação de autoria

Council on Drugs. List no. 52. New names. JAMA. 1966 Jul 18;197(3):210-1.

Instituição como autor

Conselho Nacional de Saúde(BR). Resolução no 196/96, de 10 de outubro de 1996. Dispõe sobre as diretrizes e normas regulamentares de pesquisa envolvendo seres humanos. Brasília: O Conselho; 1996.

Editor como autor

Murray JJ, editor. O uso correto de fluoretos na saúde pública. São Paulo: Santos;1992.

Trabalho em congresso

Lorenzetti J. A saúde no Brasil na década de 80 e perspectivas para os anos 90. In: Mendes NTC, coordenadora. Anais do 41º Congresso Brasileiro de Enfermagem; 1989 Set 2-7; Florianópolis, Brasil. Florianópolis: ABEn-Seção SC; 1989. p. 92-5.

Dissertação e tese

Tavares R. Avaliação da resistência de fundações de amalgama, através da tração de coroas totais metálicas [dissertação]. Florianópolis SC):Programa de Pós-Graduação em Odontologia/UFSC; 1988.

Documentos legais

Brasil. Portaria no 569, de 1 de junho de 2000. Institui o Programa de Humanização no Pré-natal e Nascimento. Diário Oficial da República Federativa do Brasil, 8 jun 2000. Seção 1.

Material não publicado

Tian D, Araki H, Stahl E, Bergelson J, Kreitman M. Signature of balancing selection in Arabidopsis. Proc Nath Acad Sci U S A. In press 2002.

Artigo padrão

Kidd EA. How 'clean' must a cavity be before restoration? Caries Res. 2004 May-Jun;38(3):305-13.

Artigo com número e suplemento

Fitzpatrick KC. Regulatory issues related to functional foods and natural health products in Canada: possible implications for manufacturers of conjugated linoleic acid. Am J Clin Nutr. 2004 Jun;79(6 Suppl):1217S-1220S.

Artigo sem número e com volume

Ostengo Mdel C, Elena Nader-Macias M. Hydroxylapatite beads as an experimental model to study the adhesion of lactic Acid bacteria from the oral cavity to hard tissues. Methods Mol Biol. 2004;268:447-52.

Artigo sem número e sem volume

Browell DA, Lennard TW. Inmunologic status of the cancer patient and the effects of blood transfusion on antitumor responses. Curr Opin Gen Surg. 1993:325-33.

Artigo indicado conforme o caso

Collins JG, Kirtland BC. Experimental periodontics retards hamster fetal growth [abstract]. J Dent Res. 1995;74:158.

Artigo de jornal

Tynan T. Medical improvements lower homicide rate:study sees drop in assault rate. The Washington Post. 2002 Aug 12; Sect. A:2 (col.4).

Material eletrônico

Abood S. Quality improvement initiative in nursing homes: the ANA acts in an advisory role. Am J Nurs [serial on the Internet]. 2002 Jun [cited 2002 Aug 12];102(6):[about 3 p.]. Available from:

Foley KM, Gelband H, editors. Improving palliative care for cancer [monograph on the Internet]. Washington: National Academy Press; 2001[cited 2002 Jul 9]. Available from: Anderson SC, Poulsen KB. Anderson's electronicatlas of hematology [CDROM]. Philadelphia: Lippincott Willians &Wilkins; 2002.

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