ANDRÉ MARTINS DAS NEVES

INFLUÊNCIA DE DIFERENTES TIPOS DE RETENTORES INTRARRADICULARES DE FIBRA DE VIDRO NA RESISTÊNCIA DE UNIÃO DE UM CIMENTO RESINOSO AUTOADESIVO À DENTINA RADICULAR BOVINA

Faculdade de Odontologia
Universidade Federal de Minas Gerais
Belo Horizonte
2019

André Martins das Neves

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Dissertação apresentada ao Colegiado de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Minas Gerais, como requisito parcial à obtenção do grau de Mestre em Odontologia – área de concentração em Clínica Odontológica

Orientador: Prof. Dr. Allyson Nogueira Moreira

Belo Horizonte
2019

Ficha Catalográfica

N518i
2019
D

Neves, André Martins das.
Influência de diferentes tipos de retentores intrarradiculares na resistência de união de um cimento resinoso autoadesivo à dentina radicular bovina / André Martins das Neves. -- 2019.

93 f. : il.

Orientador: Allyson Nogueira Moreira.

Dissertação (Mestrado) -- Universidade Federal de Minas Gerais, Faculdade de Odontologia.

1. Materiais dentários. 2. Propriedades físicas. 3. Cimentos de resina. 4. Técnica para retentor intrarradicular. 5. Pinos dentários. I. Moreira, Allyson Nogueira. II. Universidade Federal de Minas Gerais. Faculdade de Odontologia. III. Título.

BLACK - D047

Elaborada pela Biblioteca da Faculdade de Odontologia - UFMG

UNIVERSIDADE FEDERAL DE MINAS GERAIS

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

FOLHA DE APROVAÇÃO

INFLUÊNCIA DE DIFERENTES TIPOS DE RETENTORES INTRARRADICULARES NA RESISTÊNCIA DE UNIÃO DE UM CIMENTO RESINOSO AUTOADESIVO À DENTINA RADICULAR BOVINA.

ANDRÉ MARTINS DAS NEVES

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em Odontologia, como requisito para obtenção do grau de Mestre, área de concentração Clínica Odontológica.

Aprovada em 12 de julho de 2019, pela banca constituída pelos membros:

Prof(a). Allyson Nogueira Moreira - Orientador
FO-UFMG

Prof(a). Walison Arthuso Vasconcellos
FO-UFMG

Prof(a). Vinicius de Magalhães Barros
PUC MINAS

Belo Horizonte, 12 de julho de 2019.

AGRADECIMENTO

Obrigado Deus, foi uma longa caminhada e o Senhor me concedeu força e perseverança necessárias para atravessá-la. Agradeço às Instituições e pessoas fundamentais ao longo de toda essa jornada:

À Faculdade de Odontologia da Universidade Federal de Minas Gerais, por ter sido minha segunda casa ao longo de 7 anos. Ao programa de Pós-Graduação em Odontologia, por ter tornado possível esse sonho. Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), por ter financiado minha bolsa de estudo e minha participação no Programa Ciências sem Fronteiras. Ao apoio da FAPEMIG que, por meio do projeto APQ 01352-2015, financiou o preparo de amostras e obtenção de imagens de microscopia eletrônica de varredura. Ao Centro de Microscopia da UFMG e seus funcionários, pela ajuda na obtenção das imagens. Ao Departamento de Odontologia Restauradora (ODR), por exercer papel fundamental no meu crescimento profissional, desde os tempos de Graduação. Ao Colegiado de Graduação da Faculdade de Odontologia da UFMG, em especial na pessoa do coordenador Prof. Dr. Ênio Lacerda Vilaça, pelo suporte durante e após meu período de intercâmbio no Programa Ciências sem Fronteiras.

À área de Clínica Odontológica na pessoa da coordenadora Profa. Dra. Cláudia Silami Magalhães, exemplo de integridade e comprometimento. Aos colegas da área, pela parceria nos estudos e dificuldades passadas juntos. Ao meu orientador, Prof. Dr. Allyson Nogueira Moreira, meus sinceros agradecimentos por ter aceito o desafio de me orientar e todo carinho e disposição com o qual conduziu o trabalho.

À Profa. Dra. Monica Yamauti, agradeço pelo acolhimento, sinceridade e transmissão do conhecimento. Mesmo estando do outro lado do mundo, me forneceu suporte e conselhos que levarei ao longo de toda minha jornada. Sem você nada disso seria possível. Aos Profs. Drs. Herbert Haueisen Sander, Walison Arthuso Vasconcellos agradeço pela agradável convivência e acolhimento dos últimos anos, desde a monitoria em Dentística durante a Graduação. Agradeço, também, pela paciência que tiveram comigo, pelo conhecimento transmitido e pela oportunidade de participar do projeto de restauração de dentes tratados endodonticamente. Levarei as lições que aprendi com vocês para o resto da vida. Tenho certeza que não chegaria aqui sem vossa ajuda. Ao Prof. Dr. Rodrigo de Castro Albuquerque agradeço pelas oportunidades, conversas, conselhos e participação no projeto restauração de dentes traumatizados. Você é um exemplo de profissional e vê-lo trabalhar foi uma oportunidade ímpar em minha vida. Ao Prof. Dr. Hugo Henriques Alvim, agradeço pela oportunidade concedida como monitor e pela convivência durante a Graduação.

Ao Laboratório de Próteses COTERC, em especial ao técnico Telmo Rodrigues dos Santos, pela fresagem dos pinos utilizados no estudo. À Angelus Ciência e Tecnologia, pela disponibilidade e fornecimento dos materiais.

Aos Profs. Drs. Gustavo Mendonça, Daniela Mendonça e Elisa Sartori, agradeço pelos ensinamentos durante meu intercâmbio. Vocês me introduziram à pesquisa e, talvez não fosse a forma como o fizeram, eu não estaria aqui. Serei eternamente grato.

Aos amigos de longa data, em especial Mateus, Gustavo, André (Xará), Ana Flávia, Caio e Thales obrigado por mostrarem o que é uma amizade longa, sincera e verdadeira. Aos amigos que a vida me proporcionou mais recentemente, Lucian, Thales, Diogão, Luizinho, Carlota, Luis Henrique, Gilberto, Ingryd, Sylvio, Dimas, Bruno, Rafael e Gabriel obrigado pelos momentos que passamos juntos.

Aos meus pais, Denise e José Bernardes, exemplos dentro e fora da profissão. Obrigado pelo apoio e incentivo durante toda a jornada. A história de superação de vocês é o que me guia desde sempre. À minha irmã, Isabela, obrigado pela amizade, companheirismo, dedicação e carinho que tem comigo. À minha avó Lucy, meu padrinho e meus avós, *in memoriam*, por todo suporte que me concederam ao longo dos anos. Vocês são exemplo dos valores que a família deve transmitir. Aos meus tios e tias, em especial Irlei, Geni, Antônio e Eliane, obrigado por tudo. Aos meus primos, em especial Luísa, Henrique e Alexandre, obrigado pelos momentos de descontração, celebração, conselhos e por estarem sempre comigo, desde minha infância.

RESUMO

Este estudo experimental *in vitro* seguindo o delineamento de blocos aleatorizados avaliou a resistência de união de diferentes tipos de retentores intrarradiculares de fibra de vidro à dentina radicular bovina, em dentes tratados endodonticamente e extensamente destruídos. Os incisivos inferiores bovinos obtidos foram limpos manualmente. Aqueles que preencheram os critérios de inclusão foram seccionados na junção cemento-esmalte. Em seguida, o comprimento e o diâmetro das raízes foram padronizados e elas foram tratadas endodonticamente e preparadas com brocas do tipo Largo números 2, 3 e 4. Após a utilização da sequência de brocas Largo, foi utilizada a broca número 3, constituinte do conjunto de pinos de fibra de vidro EXACTO. O comprimento de trabalho adotado foi de 11 mm, e foi deixado remanescente de material obturador de 4 mm. A ponta adiamantada número 4137 (ø = 2,5 mm) foi utilizada nos 3,5 mm mais coronários das raízes para simular casos de grande perda de substrato dentário. As raízes preparadas (n=33) foram divididas aleatoriamente em 3 grupos de acordo com o tipo de pino utilizado: 1) pino de fibra de vidro convencional; 2) pino de fibra de vidro reembasado com resina composta; 3) pino de fibra de vidro fresado no sistema CAD/CAM. Após a cimentação dos pinos com o mesmo cimento resinoso autoadesivo (RelyX™ U200, 3M ESPE), cada raiz foi seccionada. Obtiveram-se 6 espécimes de cada raiz, os quais foram submetidos ao teste de cisalhamento por extrusão (*push-out*). Um corpo de prova representativo de cada grupo experimental (n=3) foi submetido à análise em Microscopia Eletrônica de Varredura (MEV), para que fossem avaliadas a adaptação marginal à dentina, a espessura e presença de bolhas na película do cimento resinoso de cada grupo nos terços coronal, médio e apical das raízes. O nível de significância para análise estatística foi de 5% e o poder do teste de 80%. Os valores de resistência de união e os terços radiculares foram comparados utilizando-se One-way ANOVA e teste de Tukey, exceto para o grupo de pinos reembasados, que foram comparados pelos testes Kruskal-Wallis e Games-Howell. O grupo de pinos reembasados obteve melhor desempenho que os outros grupos no terço coronal (8,92 MPa) (p=0,010) e foi o único grupo em que a resistência de união foi afetada pelo terço radicular, sendo o apical aquele com pior desempenho (4,51 MPa) (p=0,037). A fratura predominante nos diferentes grupos de retentores intrarradiculares foi do tipo adesiva entre o cimento e a dentina, exceto nos terços coronais dos grupos reembasado e fresado, onde a fratura principal foi do tipo coesiva em dentina. Concluiu-se que o tipo de retentor intrarradicular e o nível de acesso ao conduto radicular afetaram a resistência de união.

Palavras-chave: Materiais dentários. Propriedades físicas. Cimentos de resina. Técnica para retentor intrarradicular. Pinos dentários.

ABSTRACT

This study evaluated the bond strength of different fiberglass post types to root dentin in cases of severely damaged endodontically treated teeth. A pilot study was carried out and sample size was calculated from the results. Around 340 bovine teeth were obtained in a certified slaughterhouse. Teeth were cleaned and sectioned at dentin-enamel's junction. After selection criteria were met, teeth were selected, the roots were endodontically treated and root canals were prepared with Largo burs #2, 3 and 4. After the treatment with Largo bur #4, the specific bur from EXACTO fiberglass post kit was used. The working length was 11 mm and 4 mm gutta-percha remnant were left to seal the apical region. The #4137 diamond bur (ø 2,5 mm) was used on the roots' most coronal 3,5 mm region to simulate extensive loss of tooth structure. The prepared roots (n=33) received different types of fiberglass posts, which were fixed with self-adhesive resin cement (RelyX™ U200, 3M ESPE), and were randomly divided into 3 groups: 1) conventional glass fiber posts; 2) relined glass fiber posts; 3) glass fiber posts milled on CAD/CAM units. After posts fixing procedure, each root (n=30) was sectioned in different root thirds (coronal, medium and apical), originating 2 specimens/third in a total 6 specimens/root, that were submitted to push-out bond strength test. Other additional root from each experimental group (n=3) was prepared and analyzed using Scanning Electron Microscopy to describe the marginal adaptation to radicular dentin, presence of voids and thickness of the resin cement film, in each root third (coronal, medial and apical. To perform statistical analysis, alpha was pre-set at 0.05 and 80% power test. The values of bond strength and root third was analyzed using One-way ANOVA and Tukey post-hoc test. The relined fiberglass post group presented better performance than the other two groups at the coronal level (8,92 MPa) (p=0,010). Additionally, the relined fiber post group was also the only group which bond strength values were influenced by root third, and the apical third reported the worst results (4,51MPa) (p=0,037). Therefore, it was concluded that the type of fiberglass post and the root third affected the bond strength to root dentin.

Keywords: Dental materials. Physical properties. Resin cements. Post and core technique. Dental pin.

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LISTA DE ABREVIATURAS E SIGLAS

µm	Micrometro
CAD-CAM	Desenho Assistido por Computador e Manufatura Assistida por Computador
U200	Cimento Resinoso Autoadesivo Dual RelyX™ U200
mm	Milímetro
^{o}C	Grau Celsius
ANVISA	Agência Nacional de Vigilância Sanitária
ml	Mililitro
rpm	Rotações por Minuto
%	Por Cento
R	Raio
nº	Número
N	Newton
º	Graus
MEV	Microscopia Eletrônica de Varredura
mm/min	Milímetro por Minuto
MPa	Megapascal
h	Altura
π	PI
EDTA	Ácido Etilenodiamino Tetra- Acético
PBS	Resistência de União ao Teste de Push-Out
RCT	Ensaio Clínico Controlado e Randomizado
GFP	Grupo de Pinos Pré-Fabricados de Fibra de Vidro
RFP	Grupo dos Pinos Pré-Fabricados em Fibra de Vidro Reembasados
MFP	Grupo dos Pinos Fresados em Fibra de Vidro

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1 CONSIDERAÇÕES INICIAIS

O tratamento restaurador de dentes tratados endodonticamente representa um desafio clínico para o cirurgião-dentista. A presença de lesões cariosas extensas e o preparo mais amplo dos dentes tratados endodonticamente alteram suas propriedades físicas e mecânicas (DIETSCHI *et al., 2007*; DIESTSCHI *et al., 2008).* Após o preparo endodôntico, o dente se apresenta mais fragilizado estruturalmente devido à ausência de paredes circundantes, previamente presentes, e pode necessitar de materiais que contribuam para a estabilidade da futura prótese (FERRARI *et al.,* 2012).

Vários tipos de materiais e sistemas de pinos intrarradiculares, visando auxiliar esse remanescente fragilizado, são descritos na literatura, destacando-se os núcleos metálicos fundidos e os pinos pré-fabricados em fibra de vidro (NAUMANN *et al*., 2017). Tais materiais objetivam aumentar não a resistência do remanescente, mas sim a estabilidade e retenção do preenchimento coronário e seu material restaurador, contribuindo para menor ocorrência de fraturas verticais (GULDENER *et al*., 2017; MARCHIONATTI *et al*., 2017; PERDIGÃO; GOMES; AUGUSTO, 2007).

Fatores relacionados aos retentores intrarradiculares, como espessura, comprimento, composição e desenho geométrico são elementos importantes para sucesso clínico do tratamento restaurador. As propriedades dos retentores intrarradiculares podem alterar a distribuição de tensões e deformação na estrutura dental remanescente (SARKIS-ONOFRE *et* al., 2014; VERÍSSIMO *et al*., 2014*).*

Núcleos metálicos fundidos foram, por muito tempo, considerados os retentores intrarradiculares de maior sucesso clínico (GÓMEZ-POLO *et al.,* 2010; SARKIS-ONOFRE *et al*., 2014). Porém, devido ao seu alto módulo de elasticidade em relação à dentina, falhas consideradas irreversíveis, em especial fraturas radiculares, foram associadas ao seu uso (SOARES *et al.,* 2012). Além disso, núcleos metálicos fundidos são esteticamente insatisfátorios. Nesse cenário, pinos pré-fabricados, principalmente aqueles em fibra de vidro, ganharam espaço e se desenvolveram.

Com módulo de elasticidade semelhante ao da dentina e estética satisfatória (SOARES *et al.,* 2012; VERÍSSIMO *et al.,* 2014; ZHANG *et al*., 2014), pinos pré-fabricados em fibra de vidro têm demonstrado desempenho clínico semelhante aos núcleos metálicos fundidos, com a vantagem de apresentarem menor risco à estrutura dentária remanescente (SARKIS-ONOFRE *et al.,* 2014; SOARES *et al.,* 2012). O principal fator de insucesso relacionado a este tipo de pino é a limitada união à dentina radicular (GÓMEZ-POLO *et al.,* 2010).

Pinos pré-fabricados em fibra de vidro são confeccionados com tamanho e desenho padronizados, o que limita, em alguns casos, seu uso. Dentes com grande destruição da região da polpa coronária e dentes restaurados com lesões de cárie recorrentes podem ser limitantes quanto ao uso dos pinos pré-fabricados em fibra de vidro (NAUMANN *et al*., 2017). Essa limitação se justifica devido ao procedimento de fixação dos pinos nos condutos radiculares, que pode levar à formação de um amplo espaço a ser preenchido pelo cimento resinoso. Esse fato resultaria na formação de espessa película de cimento resinoso (PERDIGÃO, GOMES & AUGUSTO, 2007).

O preparo do conduto radicular para uso de pino pré-fabricado em fibra de vidro deve ser o mais conservador possível, preservando o máximo de estrutura dentária sadia. O selamento apical de guta-percha de 4 a 5 mm tem se mostrado bastante eficaz na manutenção do sucesso do tratamento endodôntico (FERRARI *et al*., 2012; GULDENER *et al*., 2017). No entanto, existem situações em que o conduto radicular se encontra muito amplo, como em casos de paciente jovens, pacientes com necessidade de retratamento e/ou presença lesões cariosas muito extensas. Nestes casos, até mesmo os pinos de maior diâmetro não representam opção restauradora adequada no que se refere à espessura de película de cimento aceitável, ao redor de 100-120 µm (COSTA *et al*., 2017; MIRMOHAMMADI *et al*., 2013).

A película de cimento resinoso formada pode variar de acordo com anatomia dos canais radiculares e preparo empregado. Espessuras maiores de película de cimento resinoso têm sido relacionadas à presença de bolhas e "espaços vazios", que poderiam representar fatores preditores de falhas, como selamento deficiente da interface entre resina e dentina radicular e perda de adesão (CACERES *et* al., 2017; GRANDINI *et* al., 2005). Além disso, ainda é um desafio atingir altos valores de união e conversão de monômeros, tanto nos adesivos quanto em cimentos resinosos (CACERES *et al*., 2017; MARLOULAKOS, HE, NAGY., 2018).

Visando melhores propriedades biomecânicas do conjunto pino retentor/restauração/dente e diminuição da espessura da película de cimento, foi descrita a técnica de reembasamento do pino de fibra de vidro com resina composta

(GRANDINI, SAPIO, SIMONETTI, 2003). Esta técnica mostrou-se capaz de promover melhor adaptação do pino ao conduto radicular, película de cimento resinoso menos espessa e melhores propriedades retentivas e mecânicas do dente restaurado (CLAVIJO *et al.,* 2009; GOMES *et al.,* 2014; WANDSCHER *et al*., 2014). Porém, essa modificação apresenta desafios, tais como: contração de polimerização da resina composta, sensibilidade técnica de fotoativação ou da técnica incremental, possível formação de bolhas e a resina ser separada do pino, ou seja, os dois não formarem um corpo único. Tais problemas culminam em perda de propriedades mecânicas e estruturais das resinas compostas, comprometendo a estabilidade do pino reembasado de fibra de vidro.

Buscando superar dificuldades técnicas da confecção de pinos reembasados e conseguir película de cimento resinoso mais delgada, foram lançados no mercado blocos de fibra de vidro CAD-CAM (C*omputer-Aided Design, Computer-Aided Manufacturing*) para confecção de pinos intrarradiculares personalizados. Esses blocos, além de serem estéticos, possibilitam confecção do preenchimento coronário e pino intrarradicular em corpo único, o que poderia, em tese, contribuir para maior homogeneidade de distribuição de cargas pelo conjunto. A literatura, ainda, carece de estudos utilizando esses materiais, porém casos clínicos (CHEN *et al*., 2013; LIU *et al*., 2010) e estudos *in vitro* (COSTA *et al*., 2017; GARCIA *et* al., 2018; TSINTSADZE *et al*., 2017; TSINTSADZE *et al*., 2018) foram publicados.

Os cimentos resinosos podem ter cura puramente química, ativada por luz (foto), ou combinação dos dois (dual). Devido à dificuldade de transmissão da luz até a região apical, cimentos resinosos totalmente dependentes dela (ou seja, os chamados cimentos fotoativados) não devem ser empregados na fixação de pinos. Assim sendo, cimentos de cura puramente química e cimentos duais são os indicados nessa situação. Quanto à estratégia de união aos substratos dentários, esses cimentos podem necessitar de condicionamento ácido prévio com posterior aplicação de adesivos (chamados cimentos resinosos convencionais), ou podem dispensar tratamento prévio dos substratos (denominados cimentos autoadesivos).

Cimentos autoadesivos foram desenvolvidos com intuito de otimizar tempo clínico e diminuir sensibilidade técnica. A união deste tipo de cimento aos substratos dentários ocorre pela ação de metacrilato com pH ácido que, ao mesmo tempo que desmineraliza e infiltra substratos dentais, possui propriedade de se ligar quimicamente à hidroxiapatita. A capacidade do cimento resinoso em condicionar o substrato e simultaneamente promover sua união ao mesmo possibilita maior praticidade clínica e proporciona menor sensibilidade técnica. Cimentos resinosos autoadesivos têm demonstrado, ao longo dos anos, valores de resistência de união confiáveis (BERGOLI *et al*., 2018; DALEPRANE *et al., 2016*; SILVA *et al*., 2010), justificando e embasando, assim, seu uso para fixação dos pinos intrarradiculares.

Finalmente, torna-se relevante estudar a adaptação de diferentes tipos de pinos intrarradiculares cimentados com cimento resinoso autoadesivo em dentes tratados endodonticamente e que apresentam extensa perda de substratos dentários e/ou amplo lúmen.

2 OBJETIVOS

2.1 Objetivo geral

- Avaliar a influência de diferentes sistemas de retentores intrarradiculares à base de fibra de vidro na união à dentina radicular

2.2 Objetivos específicos

- Avaliar e comparar a resistência de união de diferentes retentores intrarradiculares à dentina radicular, nos diferentes terços radiculares (coronal, médio, apical)
- Verificar o modo de fratura em função dos diferentes retentores intrarradiculares à dentina radicular
- Verificar o modo de fratura dos diferentes retentores intrarradiculares à dentina radicular em função dos diferentes terços radiculares
- Observar a espessura, presença de fendas e presença de bolhas nas camadas de resina composta do pino reembasado e de cimento resinoso RelyX™ U200 nos diferentes terços radiculares (coronal, médio, apical), para cada tipo de pino de fibra de vidro

3 METODOLOGIA EXPANDIDA

3.1 Delineamento do estudo

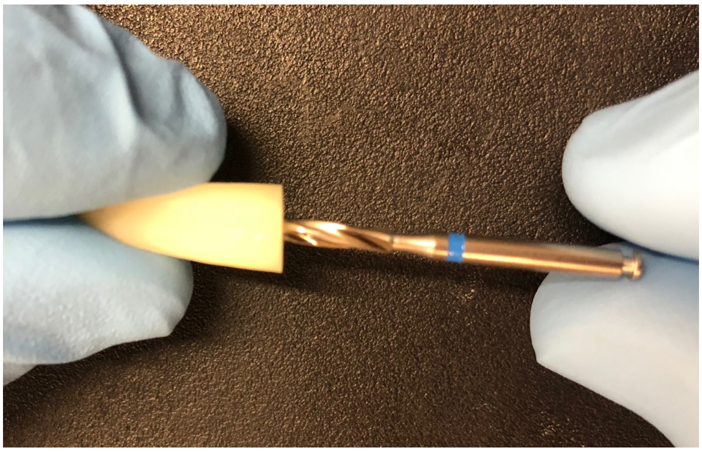
Trata-se de estudo *in vitro* qualitativo e quantitativo realizado com um desenho de blocos aleatorizados. As variáreis independentes investigadas foram o tipo de retentor intrarradicular, em três níveis: pino pré-fabricado em fibra de vidro, pino pré-fabricado em fibra de vidro reembasado com resina composta e o pino fresado em bloco de fibra de vidro para CAD/CAM. Além disso, outra variável independente foi a região radicular, também em três níveis: terços coronário, médio e apical. As variáveis dependentes foram a película de cimento resinoso por meio da análise de imagens de microscopia eletrônica de varredura (análise 2D), resistência ao cisalhamento por extrusão (*push-out*) e tipo de fratura.

3.2 Seleção dos dentes

Aproximadamente 340 incisivos inferiores bovinos foram extraídos de acordo com as normas preconizadas pela ANVISA, em abatedouro devidamente certificado. Após extração, os dentes foram limpos manualmente com curetas do tipo Gracey, para remoção dos tecidos moles, e foram armazenados em água destilada a 4ºC. Raízes com ápice radicular incompleto e com curvatura acentuada foram descartadas imediatamente. As coroas dentárias foram seccionadas utilizando-se discos adiamantados (KG Sorensen, Cotia, SP, Brasil) na junção cemento-esmalte, em baixa rotação, sob constante refrigeração.

A broca do conjunto de pinos de fibra de vidro #3 (Exacto/Angelus, Londrina, Paraná, Brasil) foi utilizada para padronização do diâmetro dos condutos dos dentes selecionados. Para raízes serem incluídas nesse estudo, até 1/3 da ponta ativa dessa broca deveria penetrar o conduto radicular passivamente (FIGURA 1).

Figura 1 – Exemplo de raiz incluída no estudo



Fonte: Elaborado pelo autor, 2019.

3.3 Cálculo amostral

Um estudo piloto foi realizado e, utilizando-se a menor diferença (D) entre as médias e desvios padrão, calculou-se o tamanho amostral por meio da fórmula rápida de Lehr:

$$N= \frac{16}{(D)^2}$$, para 80% de poder e 5% de nível de significância.

O resultado do cálculo foi de 24 raízes. Porém, foi considerado 20% de margem de perda e uma amostra para envio à microscopia, resultando em um total de 33 raízes (N=11), com comprimento mínimo e mais próximo a 15 mm. Utilizou-se a cortadeira de precisão (Isomet/Büehler, Lake Buff, EUA) para padronizar o comprimento radicular em 15 mm. Essa medida foi conferida com auxílio de paquímetro digital (Mitutoyo, Suzano, SP, Brasil) e foram realizadas tomadas radiográficas visando comprovar a presença de apenas um canal radicular.

Após essa etapa, as raízes ficaram armazenadas em água destilada a 4˚C por 24 horas, previamente ao tratamento endodôntico.

3.4 Preparo das raízes para o estudo principal

3.4.1 Tratamento endodôntico

O tecido pulpar remanescente foi removido dos canais radiculares com a lima K-file #10 (Dentsply Maillefer, Petrópolis, RJ, Brasil). Os canais foram preparados utilizando instrumentos rotatórios de níquel-titânio do Sistema Protaper Universal (Dentsply Maillefer, Petrópolis, RJ, Brasil) com equipamento Xmart (Dentsply, Petrópolis, RJ, Brasil), configurado com torque de 3,5 N/cm e velocidade de 350 rpm. Os condutos foram irrigados entre a utilização de cada instrumento com 5 ml de hipoclorito de sódio a 2,5% (Biodinâmica, Ibiporã, PR, Brasil). Após finalização da instrumentação rotatória, a limpeza final do conduto foi realizada utilizando solução de EDTA (Biodinâmica, Ibiporã, PR, Brasil).

Os condutos foram obturados com guta-percha e cimento à base de resina epóxica (AH Plus/Dentsply Sirona, York, PA, EUA) pela técnica de condensação lateral. Radiografia final foi realizada para avaliar a qualidade do tratamento endodôntico. Em seguida, os espécimes foram armazenados em água destilada a 37°C, durante 7 dias.

3.4.2 Fragilização das raízes

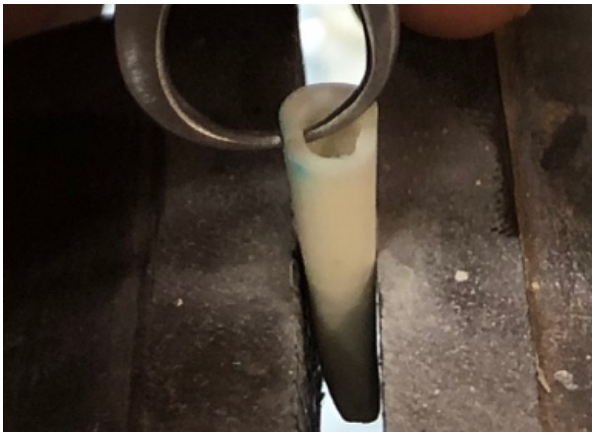
Para fragilizar as raízes, foram utilizadas pontas adiamantadas cônicas de extremo arredondado nº 4137 (ø 2,5 mm) (KG Sorensen, Barueri, SP, Brasil). Essas pontas foram marcadas com grafite vermelho, para garantir sua utilização apenas nos 3,5 milímetros mais coronais do conduto radicular, até que se obtivesse espessura residual de paredes dentinárias de 1 mm (FIGURA 2).

Figura 2 - Marcação padronizada da parte ativa da ponta adiamantada

Fonte: Elaborado pelo autor, 2019.

Tal medida foi conferida utilizando-se espessímetro (Fava, São Paulo, Brasil) (FIGURA 3).

Figura 3 – Verificação do remanescente dentinário coronário



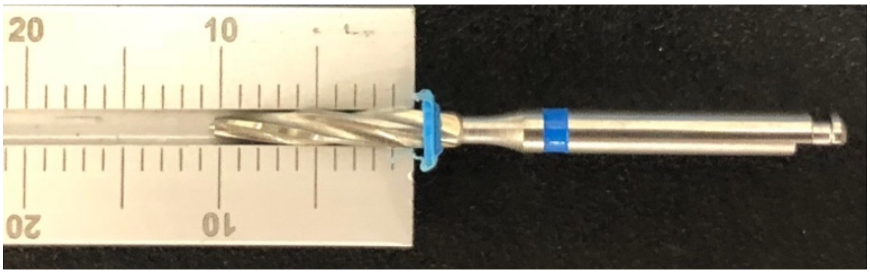
Fonte: Elaborado pelo autor, 2019.

Ao final dessa etapa, as raízes foram analisadas quanto à presença de trincas que, caso presentes, culminaram em seu descarte.

3.4.3 Preparo do conduto radicular para fixação dos pinos de fibra de vidro

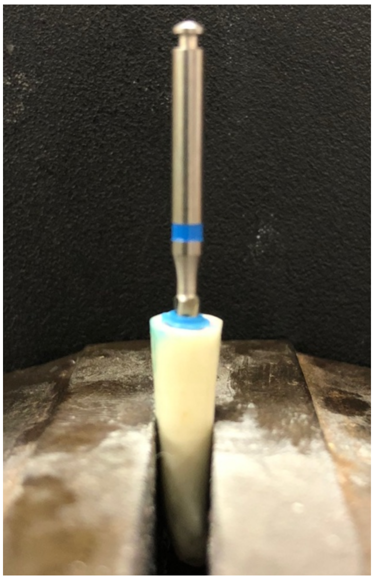
O comprimento de trabalho determinado foi de 11 mm, mantendo-se um remanescente de obturação do conduto de 4 mm. Os condutos radiculares foram inicialmente preparados com brocas do tipo Largo números 2, 3 e 4 (Jota, Florianópolis, Santa Catarina, Brasil). Após essa desobstrução inicial, foi utilizada a broca de conformação do conduto pertencente ao conjunto de pinos de fibra de vidro #3 (Exacto, Angelus, Brasil), respeitando o comprimento de trabalho (11 mm) trabalho e conforme recomendações do fabricante (FIGURAS 4 e 5).

Figura 4 – Marcação realizada em uma das brocas utilizadas no estudo



Fonte: Elaborado pelo autor, 2019.

Figura 5 – Broca introduzida em raiz devidamente posicionada



Fonte: Elaborado pelo autor, 2019.

As raízes foram distribuídas aleatoriamente nos grupos experimentais utilizando o programa Microsoft Excel (Office Excel Software; Microsoft Corp.)

3.5 Obtenção dos pinos fresados

Inicialmente, os condutos foram moldados utilizando resina acrílica autopolimerizável de presa rápida (DuraLay/Reliance, IL, EUA). As raízes foram armazenadas em ambiente úmido, à temperatura ambiente. O molde em acrílico foi enviado ao laboratório de prótese dentária, onde foi escaneado (CEREC System/ Dentsply Sirona, York, PA, EUA) e fresado em blocos de fibra de vidro (Fiber-CAD/Angelus, Londrina, PR, Brasil). Em seguida, a adaptação do pino foi avaliada com "spray de oclusão" (Arti-Spray/Bausch, Köln, Alemanha) e ajustes, quando necessários, foram realizados utilizando-se pontas adiamantadas de extremo arredondado nº4138 (KG Sorensen, Cotia, SP, Brasil).

3.6 Obtenção dos pinos anatômicos

Os pinos de fibra de vidro nº3 desse grupo foram limpos e desengordurados utilizando-se solução alcoólica a 70%. Depois de lavados e secos, uma camada do agente silano (Angelus, Londrina, Paraná, Brasil) foi aplicada com auxílio de aplicador descartável (*micro-brush*) por 1 minuto. O excesso de silano foi removido com auxílio de outro aplicador descartável, e o solvente foi evaporado com auxílio de leves e breves jatos de ar, conforme recomendações do fabricante.

O conduto radicular desse grupo foi lubrificado com gel hidrossolúvel. Incrementos padronizados, através de duas voltas completas da embalagem de resina composta translúcida (Filtek™ Z350 XT, 3M ESPE, St Paul, MN, EUA), foram acomodados aos pinos e o conjunto foi introduzido e fotoativado em posição por 5 segundos, submetidos a uma carga estática de 10 N. Esse conjunto foi removido, fotoativado por mais 40 segundos e, caso necessário, excessos de material foram removidos com auxílio de pontas adiamantadas.

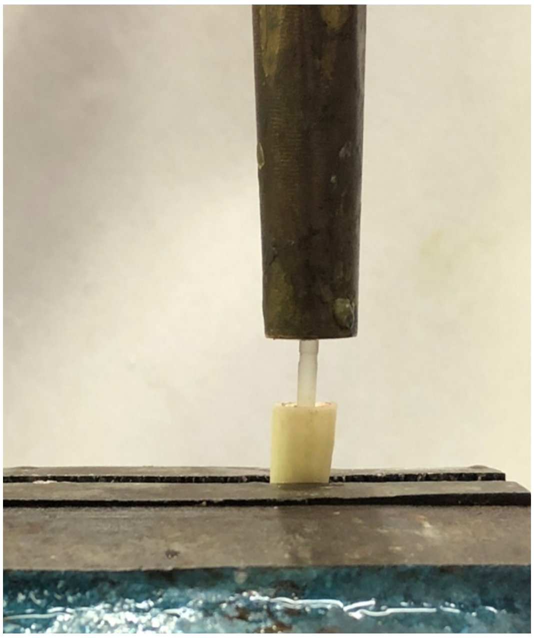
3.7 Fixação dos pinos intrarradiculares

Previamente à fixação dos pinos intrarradiculares, os ápices das raízes foram fixados, em base metálica perpendicular ao solo, buscando maior apoio e estabilização. Posteriormente, os dentes foram envoltos em fita adesiva preta, para que o acesso à luz ocorresse apenas pela entrada do conduto radicular, simulando o ambiente bucal.

Os pinos de fibra de vidro pré-fabricados, reembasados e fresados foram limpos e desengordurados utilizando-se solução alcoólica a 70%. Depois de lavados e secos, camada do agente silano (Angelus, Londrina, PR, Brasil) foi aplicada com auxílio de aplicador descartável, por 1 minuto. O excesso de silano foi removido, bem como o solvente evaporado, conforme recomendações do fabricante.

Cada conduto radicular foi lavado com água destilada em abundância, irrigado com cloreto de sódio 0,9% (Eurofarma, São Paulo, Brasil) e seco com cones de papel absorvente. O cimento resinoso RelyX™ U200 (3MESPE, MN, USA) foi aplicado no conduto radicular com auxílio do sistema Centrix™. Os pinos retentores foram corretamente posicionados e submetidos à carga estática de 10 N (DALEPRANE *et al., 2016)* (FIGURA 6).

Figura 6 – Aplicação de carga estática na fixação dos retentores intrarradiculares



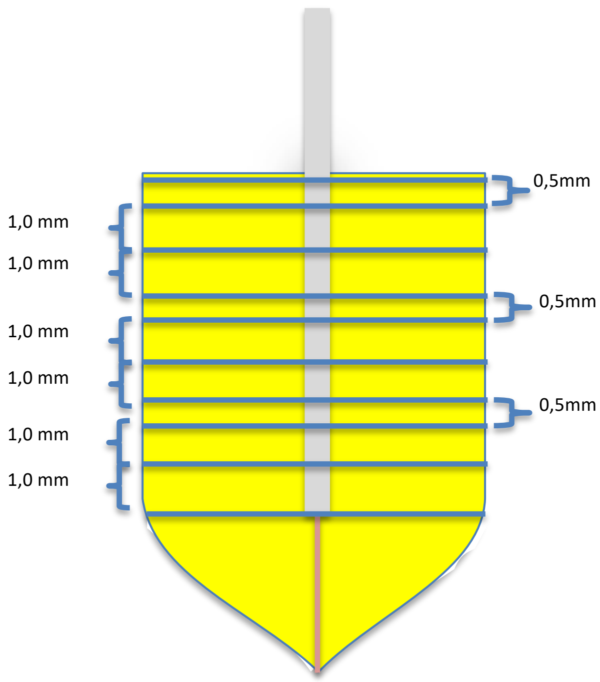
Fonte: Elaborado pelo autor, 2019.

Excessos de cimento foram removidos, e o conjunto foi fotoativado com aparelho fotoativador de LED (BluePhase, @800mW/cm^{2,} Ivoclar Vivadent, Schaan, Liechtenstein) posicionado a 45º em relação ao pino, nas faces vestibular e lingual, durante 40 segundos cada. Cada bloco experimental consistiu em seis raízes, que foram armazenadas durante 24 horas em meio úmido, a 37ºC, previamente ao corte para o teste de cisalhamento por extrusão. Um total de trinta raízes foram submetidas a esse teste e, então, as 3 raízes remanescentes foram armazenadas em meio úmido para posterior análise de microscopia eletrônica de varredura (MEV).

3.8 Ensaio de cisalhamento por extrusão (Teste de *Push-Out*)

As trinta raízes armazenadas durante 24 horas em meio úmido, a 37ºC, foram seccionadas em fatias, perpendicularmente ao seu longo eixo, utilizando-se cortadeira de precisão (Isomet, Büehler, Lake Buff, EUA). Dois espécimes com espessura de aproximadamente 1,0 mm foram obtidos de cada um dos terços radiculares (coronário, médio e apical). Secções de 0,5 mm nos limites coronário, coronário-médio e médio-apical foram descartadas (FIGURA 7).

Figura 7 – Representação esquemático dos cortes realizados para o teste de cisalhamento por extrusão



Fonte: Elaborado pelo autor, 2019.

A espessura dos espécimes foi conferida com auxílio de paquímetro digital para o teste de cisalhamento por extrusão (*push-out*). Cada corpo-de-prova foi posicionado sobre base metálica com orifício central de 2,0 mm de diâmetro. Êmbolo com extremidade de 1,0 mm de diâmetro foi adaptado à máquina de ensaio universal (EZ-LX, Shimadzu, Barueri, SP, Brasil) e posicionado sobre o espécime, de tal maneira que apenas o pino tenha sido tocado pelo aparelho, preservando as paredes do conduto. A força foi aplicada no sentido ápico-coronário.

O teste de *push-out* foi realizado em máquina de ensaios universal, com uma célula de carga de 20 N, à velocidade de 0,5 mm/min, até que a força máxima para deslocar o pino no interior do conduto fosse alcançada.

Para obtenção da resistência de união em MPa, a força obtida em Newtons foi dividida pela área da interface de união, calculada pela fórmula:

$A = \pi (R+r) \sqrt[2]{h^2 + (R-r)^2}$, onde:

$\pi = 3{,}14$;

R= raio do pino intrarradicular na porção coronária;

r = raio do pino intrarradicular na porção apical;

h = espessura do corte, em mm.

3.9 Estereoscopia

Após realização do teste de *push-out*, os corpos de prova foram analisados em estereomicroscópio (Zeiss, Jena, Oberkochen, Alemanha) para determinação do modo de fratura. A análise foi realizada por dois examinadores devidamente calibrados, e as fraturas foram classificadas em: 1) adesiva entre pino e cimento; 2) adesiva entre cimento e dentina; 3) mista; 4) coesiva do pino; 5) coesiva da dentina. No caso de discordância, a mesma foi solucionada por meio de consenso. O percentual de cada tipo de fratura foi registrado.

3.10 Observação da película de fixação

Um espécime de cada grupo foi preparado, a fim de avaliar sua interface adesiva em microscopia eletrônica de varredura. As raízes foram embutidas em resina ortoftálica (Cristal, Belo Horizonte, MG, Brasil), e, depois de 24 horas, foram longitudinalmente seccionadas, em cada terço (coronário, médio e apical). Então, foram polidas com lixas de carbeto de silício de granulações #600, #800, #1200 e #2400 (Carborundum Abrasivos, Guarulhos, SP, Brasil) em politriz metalográfica (APL-4 Arotec, Brasil), sob irrigação com água. Entre cada lixa, os espécimes foram colocados em banho de ultrassom com água destilada durante 5 minutos, para remoção dos detritos das lixas. Foi realizado polimento com pastas de diamante (diâmetros de 1, 0.5 e 0.25 µm) em discos de feltro, sucedido de banhos em ultrassom.

Em seguida, a superfície dos espécimes foi desmineralizada com ácido fosfórico a 50% por 3 segundos, seguido de enxágue em água corrente por 1 minuto e desproteinização por imersão em hipoclorito de sódio a 2,5% por 10 minutos. Então, os espécimes foram lavados três vezes com água destilada e imersos em soluções crescentes de etanol (25, 50, 75, 95 e 100%), permanecendo por cerca de vinte minutos em cada uma. A solução de concentração 100% foi repetida por três vezes, com imersão por 10 minutos a cada troca de solução.

Concluída essa etapa, os espécimes foram mantidos em temperatura ambiente por 10 minutos, e, então, acondicionados em recipiente hermeticamente fechado, contendo sílica gel, por pelo menos 24 horas antes da metalização. Os espécimes foram metalizados com carbono (*Sputtering* modelo Balzers SCD 050) e observados em microscópio eletrônico de varredura (MEV) (Quanta 3D FEG; FEI, Hillsboro, OR, EUA), sob aceleração de voltagem variável entre 15 e 30 kV e distância de trabalho variável entre 9 e 14 mm. As imagens foram obtidas com magnificações progressivas, buscando-se descrever características morfológicas das linhas de fixação de cada grupo experimental e seus respectivos terços.

A linha de cimento foi observada nas 3 regiões radiculares (coronal, média e apical). Em cada terço radicular foram observadas a espessura, a presença de bolhas e a presença de fendas na linha de cimento. A camada de resina composta, utilizada para reembasar os pinos reembasados, também foi verificada quanto à presença de bolhas.

3.11 Análise estatística

Análise estatística foi realizada utilizando o programa SPSS versão 20.0 (SPSS, Chicago, IL, USA). O nível de significância adotado foi de 5% para todos os testes. A distribuição normal e homocedasticidade foram verificadas utilizando testes de Shapiro Wilk e Levene, respectivamente. Os terços radiculares ou tipos de retentores intrarradiculares foram avaliados utilizando One-Way ANOVA e teste de Tukey, exceto para análise dos resultados dos pinos anatômicos. Neste caso, o teste Kruskal-Wallis foi empregado.

4 ARTIGOS CIENTÍFICOS

Journal: The Journal of Prosthetic Dentistry (Qualis A2)

Title: Performance of CAD/CAM glass fiber posts in restoring oval shaped root canals: an in vitro study

Authors: André M. Neves, DDS, MSc[a]; Monica Yamauti, DDS, MS, PhD[b,c*] ;Herbert H. Sander, DDS, MSc, PhD[d]; Cláudia S. Magalhães, DDS, MS, PhD[e] ;Walison A. Vasconcellos, DDS, MS, PhD[d] ; Allyson N. Moreira, DDS, MS, PhD[e]

Affiliations: [a] Graduate Student in Clinical Dentistry, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

[b] Adjunct Professor, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

[c] Associate Professor, Graduate School of dental Medicine, Faculty of Dentistry, Hokkaido University, Sapporo, Japan

[d] Associate Professor, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

[e] Professor, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

*Corresponding author:

Monica Yamauti, Department of Restorative Dentistry, Faculty of Dentistry, Universidade Federal de Minas Gerais, Av. Pres Antonio Carlos, 6627, Belo Horizonte-MG, 31270-901, Brazil, email: myamauti@gmail.com

Acknowledgements:

The authors thank Angelus® for providing the fiber resin blocks and COTERC prosthetic lab, specially Mr. Telmo Santos, for milling the fiber resin blocks in the CAD/CAM units.

Title: Performance of different glass fiber posts in restoring oval shaped root canals: an *in vitro* study

ABSTRACT:

Statement of problem. Numerous glass fiber post systems have been developed over the past years and the most precise, reproducible and less sensitive technique is still unknown, concerning post adaptation and cement bond strength to root canal.

Purpose. The purpose of this *in vitro* study was to evaluate the push-out bond strength (PBS) of different glass fiber post systems prepared with different techniques and cemented to bovine root dentin using the same luting protocol.

Materials and methods. Thirty bovine teeth (n=30) had their crown sectioned leaving 15 mm of remaining root length. The coronal thirds of all roots were fragilized with a diamond bur. Endodontic treatment was carried out by rotatory instruments. Root canals were prepared using Largo burs and finished with the drill provided by post manufacturer (Exacto #3). Three post systems were evaluated: pre-fabricated glass fiber post without any customization; pre-fabricated glass fiber post relined with composite resin; and milled CAD/CAM glass fiber post. Posts were luted using RelyX™ U200 resin cement. The roots were prepared for push-out bond strength (PBS) test, transversally sectioned, resulting in six 1-mm segments at 3 different thirds (coronal, medial and apical). Each root segment was submitted to compression in a universal testing machine (EZ-LX; Shimadzu) at 0.5 mm/min until failure. Specimens were evaluated using a stereoscope and failure modes were registered. Data were analyzed by One-way ANOVA and the Tukey post hoc test (α=.05), except for the analysis of relined post results. In this case, Kruskal-Wallis followed by Games-Howell were used. Three additional roots were prepared for scanning electron microscopy observation of the resin cement's film.

Results. Only the coronal third of the relined glass fiber post showed statistical difference in PBS among post systems (p=0.01). For each type of post, the apical portion of the relined glass fiber post presented the worst PBS values than other thirds (p=0.037).

Conclusions. Relined glass fiber posts showed higher PBS values at coronal level than other groups. The apical third of relined glass fiber posts reported the worst PBS values within the group.

Clinical Implications. Restoring oval shaped root canals remains challenging. The possibility of making a unique glass fiber post-and-core would be very useful for clinical practice, however this post type needs further evaluation.

Introduction

Restoring endodontically treated teeth remains challenging to everyday clinical practice. The presence of extensive carious lesions and endodontically treated teeth alter teeth's mechanical and physical properties[1,2]. Due to the loss of previously sound surrounding teeth substrate walls, the restorative treatment should focus on retention to the remaining tooth structure and on recovering tooth´s strength. The future indirect restorations or prosthesis should present high stability[3], which is obtained by placing, for example, intraradicular posts. The posts aids in retaining core material and properly distribute the occlusal tensions through the root[4,5].

Different materials and systems have been described in the literature as intraradicular posts, with special regard to cast metal post and core and glass fiber posts[6]. These materials aim to increase the stability and retention of the core material, contributing to a lower occurrence of vertical fractures[4,7,8].

Factors related to intraradicular posts such as its' thickness, length, composition and geometric design are key elements to achieve clinical success. These posts' properties can alter strain and deformation distribution through the remaining tooth structure[5,9].

Metal post and cores were, for a long time, considered the intraradicular posts with greatest clinical success[9,11]. However, due to their high elastic modulus in relation to root dentin, catastrophic failures, specially root fractures, were related to its usage[12]. Besides that, metallic post and cores are unaesthetic. In this scenario, pre-fabricated posts, especially those made of fiber glass, attracted the market has since improved their physicomechanical properties.

With similar values of root dentin's elastic moduli[5,12,13], the pre-fabricated glass fiber posts have reported similar clinical performance of the metallic post and cores, with the advantage of providing better aesthetics and less risk to the remaining tooth structure[9,12]. The main factor related to unsuccess of these posts is absence of proper bonding to root dentin, causing detachment[11].

Pre-fabricated glass fiber posts are manufactured with standardized size and geometry, which can limit their usage. Teeth with extensive coronal/root destruction or extensive pulp chamber provide poor adaptation of the pre-fabricated post to the root canal[6], which can lead to a huge space that would be filled by the resin cement[8]. In this case, hardly, the resin cement film thickness would be in the range of 100-120 μm, that is known to be ideal[14,15]. Thicker resin cement films have been related to the presence of bubbles and “void spaces”. Entrapped air and spaces are possible failure predictors due to loss of adhesion and/or mal-formation of the hybrid layer[16,17]. The bond strength to dentin and monomer conversion of resin cements remains limitations of this type of luting material[17,18]. Resin cements which are not fully dependent on light to polymerize (dual or chemical) present some advantages when used to fix intraradicular posts.

Aiming to obtain better mechanical properties, the relining technique of pre-fabricated fiber posts has been described[19]. This technique is reported to be able to provide better adaptation of the post to the root canal, to generate thinner resin cements’ film and better mechanical properties[20-22]. However, this relining procedure has some drawbacks such as: composite resins’ polymerization shrinkage, photoactivation or technique sensibility, possible formation of bubbles, and presence of other interface (between fiber post and relining resin composite).

Seeking to overcome those challenges, CAD/CAM glass fiber post and cores were introduced in the market. However, literature is still scarce in studies employing these materials, which justifies the need of studying different posts' systems cemented with auto adhesive resin cement in fragilized teeth.

Material and methods

This experimental *in vitro* study was delineated according to a complete randomized block design. The independent variables were root third (coronal, medial, and apical) and type of post (pre-fabricated glass fiber post, relined pre-fabricated glass fiber post and CAD/CAM-milled glass fiber post). The dependent variable were the resin cement's layer morphology, acquired by scanning electron microscopy, push-out bond strength (PBS) values and failure mode.

A pilot study was conducted to calculate the sample size according to Lehr's formula. A power of 80% and a two-sided significance level of 0.05 were adopted. Thirty anterior bovine teeth with similar dimensions were selected, cleaned and stored in distilled water for up to 2 months. The crowns were sectioned with a double-faced diamond disk (#7020, KG Sorensen), in a low speed handpiece with water cooling and the final root length was 15 mm.

Endodontic treatment was performed by a single operator using rotatory instruments (Xmart; Dentsply Intl) and files (Dentsply Maillefer; Dentsply Intl). Root canals were rinsed between each rotatory instrument with 2.5% sodium hypochlorite (Hipoclorito de Sódio; Biodinâmica). After instrumentation, root canals were rinsed with 24% EDTA solution (EDTA trissódico, Biodinâmica) and obturated using the lateral condensation technique with gutta percha cones and epoxy-based resin cement (AH Plus; Dentsply Intl). Once finished, roots were stored in distilled water at 37 °C for 7 days. Teeth were fragilized using cylindrical ogival shaped diamond burr (4137, KG Sorensen) (Ø 2,5mm) in the first 3,5 mm of root canal, until there was a 1 mm remaining root dentin (Fig. 1). The post space was prepared with Largo burs #2 to #4 and then finished with the bur that belongs to the glass fiber post kit (Exacto 3; Angelus). The post space length was 11 mm, maintaining 4-mm apical filling material.

The prepared roots were divided into 3 groups (n=10) according to the type of post: pre-fabricated glass fiber post (GFP) (Exacto #3, Angelus); relined pre-fabricated glass fiber post (RFP) (Composite resin + Exacto #3; Angelus) and CAD/CAM-milled glass fiber post (MFP) (Fiber CAD; Angelus). Randomization was performed using the Excel RAND function (Office Excel Software; Microsoft Corp).

For the CAD/CAM-milled post group, a fast setting auto polymerizing acrylic resin (DuraLay, Reliance) was used to produce a pattern of each root canal belonging. The roots were stored in humid environment, at 37 °C. The acrylic resin casts were sent to the prosthetic laboratoy, where they were scanned (inEos X5, Dentsply Sirona) and milled (inLab MC XL, Dentsply Sirona) in CAD/CAM glass fiber blocks (Fiber CAD, Angelus). Upon arrival, the posts had their adaptation checked using liquid carbon (Arti-Spray, Bausch) and, if necessary, excesses were removed with diamond burs.

For all groups, the posts were cleaned for 30 seconds with 70% ethanol, water rinsed and air dried. Then, silane agent (Silano, Angelus) was applied for 60 seconds and air dried.

For the RFP group, root canals were lubricated using hydro soluble glycerin gel (K-Y Jelly; Reckitt Benckiser Group PLC). After silane agent application, glass fiber posts received a standard layer of composite resin (Z350 XT CT; 3M ESPE). The amount of composite resin was volumetrically standardized by twisting the package cable twice. Subsequently, post covered with composite resin was inserted into the root canal and the post was submitted to a static load of 10 N for 5 seconds[24]. A brief polymerization of 5 seconds was performed, using an LED polymerization light device

(BluePhase, 800mW/cm^{2,} Ivoclar Vivadent). Then, the entire set was pulled out from the root and photoactivated for 40 seconds from 4 directions. The root canal was rinsed with distilled water, so remains of the glycerin gel were washed away.

The same resin cement (RelyX™ U200; 3M ESPE) was used for all experimental groups. All roots were rinsed with sodium chloride 0.9% and dried with absorbent paper points. The resin cement was inserted into the root canal with a syringe and a needle tip (Centrix®; DFL). The post was then placed into the canal and held in position under a static load of 10 N for 5 seconds, excess of resin cement was removed with disposable applicator (micro-brush), followed by light activation for 40 seconds. After cementation, the specimens were stored in a humid environment at 37°C for 24 hours before being prepared for mechanical testing.

Roots were sectioned transversally with low-speed precision cutting machine (Isomet 1000; Buehler) to obtain 2 specimens of each root third with a thickness of 1.0 mm each. The first section of each root, with approximately 0.5 mm each, was discarded (Fig. 2). The thickness of specimens was checked with a digital caliper (Mitutoyo Series 500; Mitutoyo). The specimens were positioned on a metal base with a central hole of 2.0 mm in diameter. A plunger with a 1.0 mm diameter tip was adapted to the testing machine (EZ-LX; Shimadzu) and a compressive load was applied in the apical-coronal direction, at a crosshead speed of 0.5 mm/min, until shear bond failure. Load at failure was recorded (N) and divided by the bonded surface area (mm^2) of each specimen, resulting in bond strength values (MPa). Data were analyzed by One-way ANOVA and the Tukey post hoc test (α=.05).

After failure, the specimens had their failure mode classified as cohesive in dentin, adhesive between cement and dentin, adhesive between post and cement and mixed, using a stereoscope (Carl Zeiss AG) at x40 magnification.

In addition, to observe the cementation film, three roots with cemented posts (n=1) were submitted to SEM evaluation (Quanta 3D FEG; FEI). Qualitative aspects of the specimen were visualized, such as: presence of bubbles within the resin cement layer; presence of bubbles within the composite resin layer; thickness of the resin cement layer; thickness of the composite resin layer; and presence of gaps between the root dentin and the resin cement.

Results

PBS (MPa) means (SD) of all post systems to root dentin is shown in Table 1. When bond strength was measured in the coronal third, the relined post showed the highest value when compared to the results from other posts (p=0.010). In the medium and coronal thirds, there were no significant differences between the bond strength results when distinct types of posts were used. The root third variable only affected the bond strength of the relined post; and in this case, the apical third presented the lowest result (p=0.037).

Failure mode distribution is shown in Figure 3. The coronal third of RFP and MFP's groups reported failure predominantly different from the rest of the specimens, being this cohesive in dentin. All other root thirds had adhesive failure between cement and dentin as being the main failure.

SEM showed continuous lines for all post systems. GFP group showed, at coronal level, an apparent thick layer of resin cement with huge amount of bubbles (Fig. 4). The RFP group showed an apparent thin and continuous resin cement film and just a few bubbles within the composite resin layer (Fig.5). In the MFP group it is possible to visualize a homogeneous distribution of glass fibers within the post and a thin resin cement film (Fig. 6).

Discussion

The need to place an intraradicular post and their influence upon the occurrence of radicular fractures are still contradictory[9,10]. In a recent systematic review[6] comparing the performance of different intrarradicular posts, only 3 Randomized Controlled Trials (RCT) were classified by the author as with low risk of bias. Nonetheless, the same study refers to the way remaining coronal tooth structure is described: by having at least 1 mm of dentin surrounding the root canal. In our study, the surrounding remaining dentin thickness after the teeth were fragilized was also 1 mm. Trying to minimize bias, this study took some precautions: sample size calculation from the pilot study; randomization of the specimens; standardization of root dimensions; endodontic treatment carried out by a unique operator; execution of procedures using a block design; root preparation and posts' cementation done by the same operator; standardization of the resin composite's layer used to reline the post; and using the same resin cement and application protocol in all groups, which included the use of a standardized static load.

Pursuing to better understand the influence of the post system itself, an auto adhesive resin cement was used in this study, the RelyX™ U200. This resin cement has been widely evaluated[15,23-26] and has reported to present a good combination of low technique sensitivity and adequate mechanical properties[26-28]. Because of the presence of acidic methacrylate as a compound[25], auto-adhesive resin cements avoid application of phosphoric acid and/or adhesive systems within the root canal, which makes the technique much less sensitive.

The bonding between intraradicular posts and root dentin can be influenced by numerous factors from the morphology of dentinal tubules to the thickness of resin cement's film. Previous *in vitro* studies reported high standard deviation values when push-out tests were employed[8,24,28-31]. Mean bond strength values between pre-fabricated glass fiber posts and bovine root dentin in medial and apical root thirds reported in this study (4.915 MPa) are similar to the value (4.625 MPa) encountered by another group of researchers[28], using the same resin cement and substrate.

The coronal third of the relined group presented higher bond strength value than the other two groups (p=0.01). This may be due to the wider contact and friction area between the post and the root (Fig. 5) than that of pre-fabricated glass fiber post itself (Fig.4). Previous studies have related poor posts' adaptation to the root canal with lower values of PBS[21,32]. In addition, glass fiber is much different, chemically and functionally, from the composition of the resin cement and the composite resin which were used to fix and to reline the post. The resin cement materials are composed by monomers, which react through a polymerization reaction process (chemical; photo or dual activated) and result in polymers[25]. Thus, the chemical affinity between similar materials (composite resin and resin cement) may explain the high PBS values presented by the relined pre-fabricated glass fiber posts luted to the bovine root dentin. On the contrary, it has been reported that a very thin film did not present the best mechanical results and it was concluded that the ideal resin cements' thickness should be around 120 μm[15]. Probably, in the present study, the poor results obtained when milled glass fiber post was used could be attributed to the extremely thin cement layer (Fig.6).

Regarding the root levels, the apical portion of relined pre-fabricated glass fiber posts had PBS values lower than those of coronal and medial thirds (p=0.037). This finding is corroborated by other studies[15,33]. The RelyX™ U200 resin cement presents dual polymerization, which means that some of the monomeric components need photo excitation to have their chemical bond broken, resulting in polymers. If this process does not occur, free monomeric products stays within resin cement's film, weakening its mechanical properties[25]. The apical level of the post remains in a deep position, far from the tip of the light source, reducing the light power density at this region.

The use of CAD/CAM glass fiber post is still scarce. One of the indications of this technique is when a tooth presents an extensive root canal, which is also known as oval shaped root canals. When oval shaped root canals are employed to evaluate bond strength using push out, it is important to be careful when calculating the area submitted to the testing tip device. It might be more adequate to consider not only the post radius, but the root canal radius. A previous study simulated the calculation that considered the root canal radius to obtain the bond strength results from poorly adapted posts and statistical difference between the conventional and the new calculation formulas´ data was found[21]. In the current study, only the coronal portion was fragilized and, when using the root canal radius to calculate the PBS values, they presented a significant change. Using the root canal radius, the PBS mean (standard deviation) values of each group were as follow: 4.52 (2.21) MPa, for the milled post group; 4.86 (6.77) MPa for the relined post group; and 1.17 (0.83) MPa for the pre-fabricated post group. In this case, One-Way ANOVA and Games-Howell *post hoc* test were used and statistical difference could be detected between the customized posts groups and the pre-fabricated post group (p=0.013). Differently, a recent study using fragilized tooth restored with milled glass fiber posts still used the conventional formula to obtain its results[29]. This issue concerning the formula to calculate the bond strength results should be further addressed.

The coronal thirds of the groups presenting thinner resin cements' film (milled and relined) (Figs. 5 and 6) reported, predominantly, cohesive failures within dentin.

Apparently, the relined group showed the thinnest resin cements' film through the entire root, in comparison to the other groups (Fig. 5). It is suggested that once the coronal third presented thin and fragile dentin surrounding the posts, that favored failure of root wall's remnant. In cases where resin cements' film was thick (specially for the pre-fabricated posts), the main failure was adhesive between resin cement and root dentin. In clinical situations, adhesive failure is more acceptable, once the post can be re-attached or another post can be cemented on its place.

Scanning electron microscopy showed continuous cement lines for all posts, regarding their third. Images features suggest that the amount of bubbles and voids on the coronal third of the GFP group is much bigger than the other two groups (Fig. 4). The relined group showed the thinnest resin cements' film through the entire root, in comparison to the other groups (Fig. 5). However, care should be taken when considering the SEM observations as only one sample was prepared for each group. Further evaluation of a large number of samples is necessary to quantitatively analyze the resin cements´ line features.

Conclusion

Based on the findings of this *in vitro* study, the following conclusions were drawn:

1. The relined glass fiber post had better coronal bond strength values than the others (p=0.01).
2. The apical third of the relined glass fiber post performed worse than the other thirds within the same post group (p=0.037).
3. The predominant failure was adhesive between resin cement and root dentin, except for the coronal portions of milled and relined fiberglass posts groups, which was cohesive in dentin.

4. The pre-fabricated fiberglass post group presented thick resin cement's layer, containing many voids. The relined fiberglass post group showed a thin and homogenous resin cement layer. The milled fiberglass post group irregular and thin resin cement layer.

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Table(s) page

Table 1. Push-out bond strength for each group and root third, mean (±SD)

Root third	Root post system		
	Milled (MFP)	Relined (RFP)	Pre-fabricated (GFP)
Coronal	4,58 (1,99) aA	8,92 (4,48) bA	5,12 (2,31) aA
Medial	6,20 (2,41) aA	9,48 (6,31) aA	4,96 (2,66) aA
Apical	4,91 (2,26) aA	4,51 (2,39) aB	4,87 (1,97) aA

Means followed by different letters (uppercase in the columns and lowercase in the rows) are significant different (P<0.05).

FIGURES

Fig.1. Schematic depicting roots' fragilization process

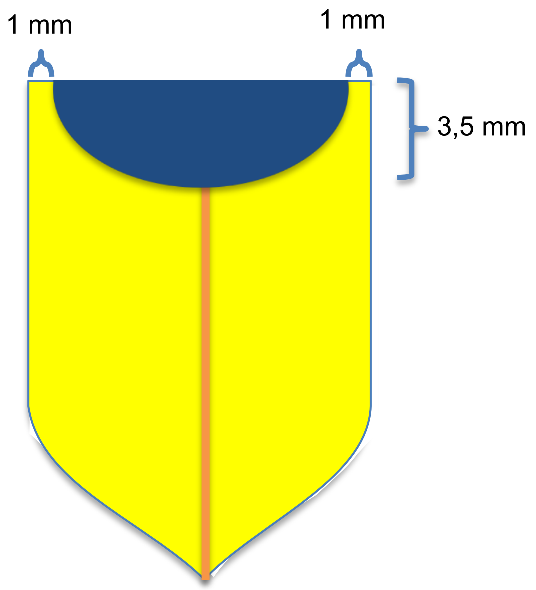


Fig. 2. Schematic depicting specimen sectioning preparation for evaluated depths. All the 0.5mm slices were discarded.

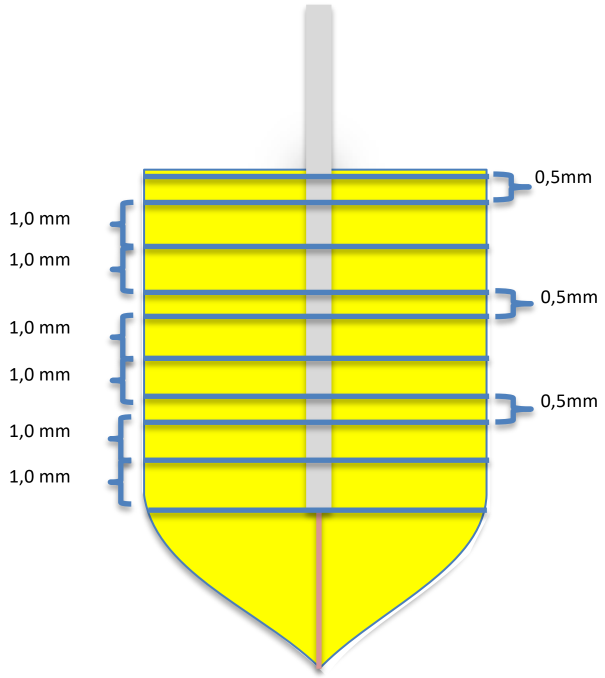


Fig. 3. Distribution of failure modes (%) among groups as observed by spectroscopy. Post-Cement: Adhesive failure between the post and the resin cement; Cement-Dentin: Adhesive failure between the resin cement and the dentin; Mixed: mixed failure; Dentin: Cohesive failure in dentin.

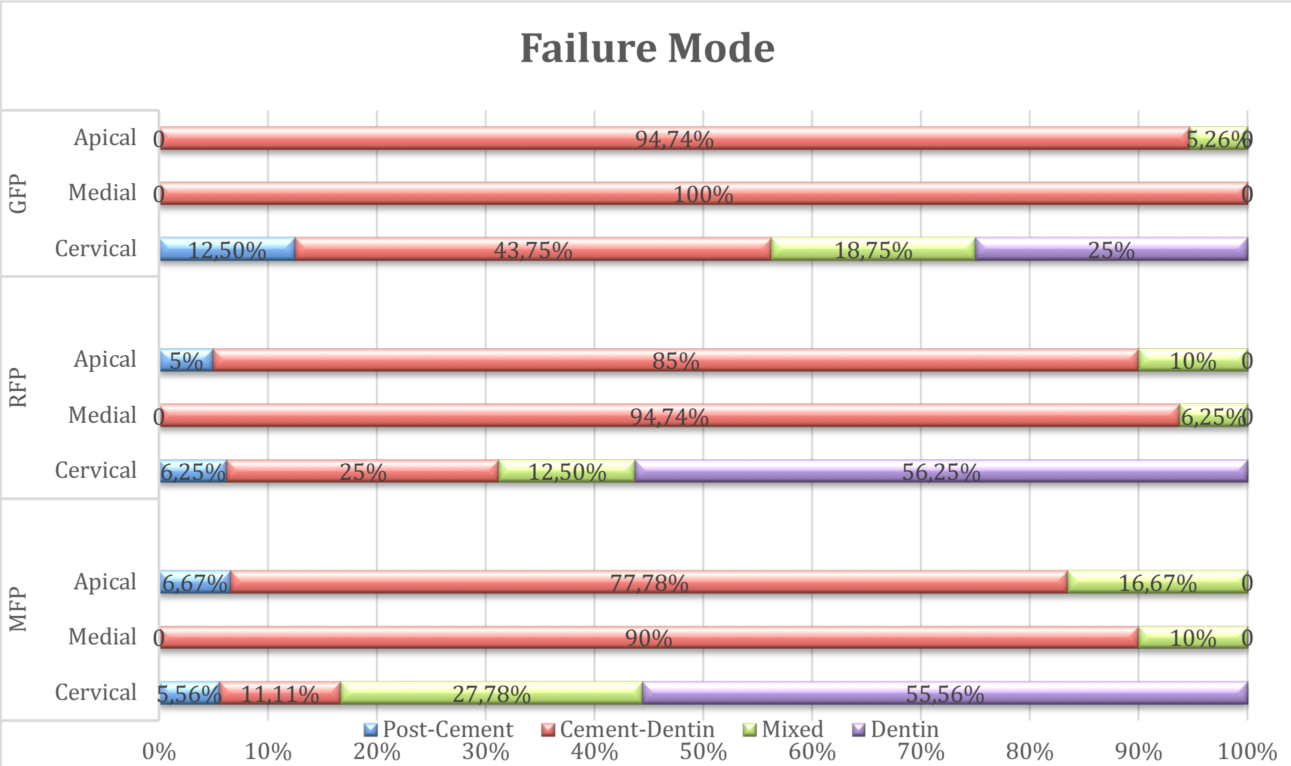


Fig. 4. SEM image originated from the coronal slice of GFP’s group.

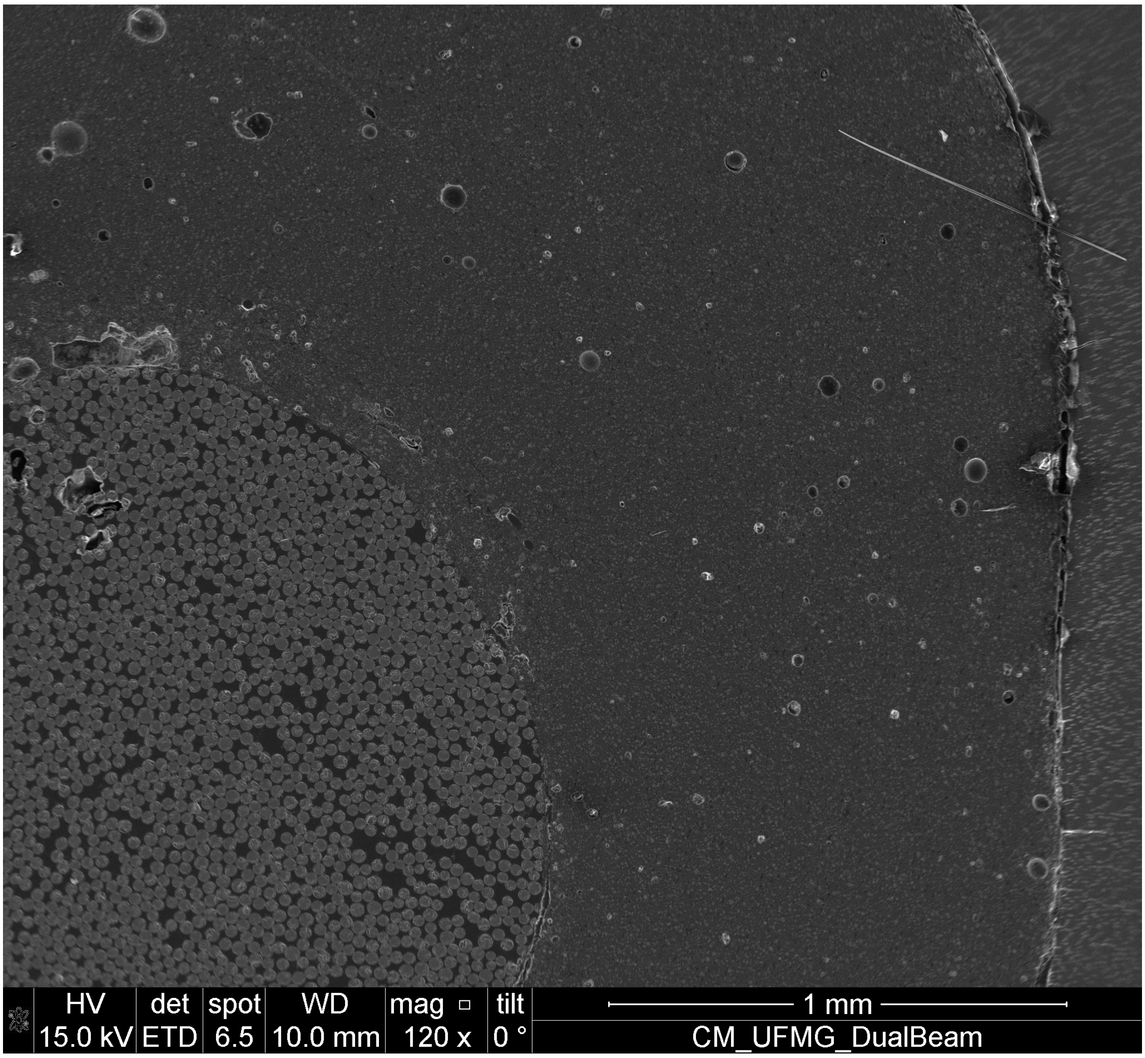


Fig.5. SEM image originated from the coronal slice of RFP's group.

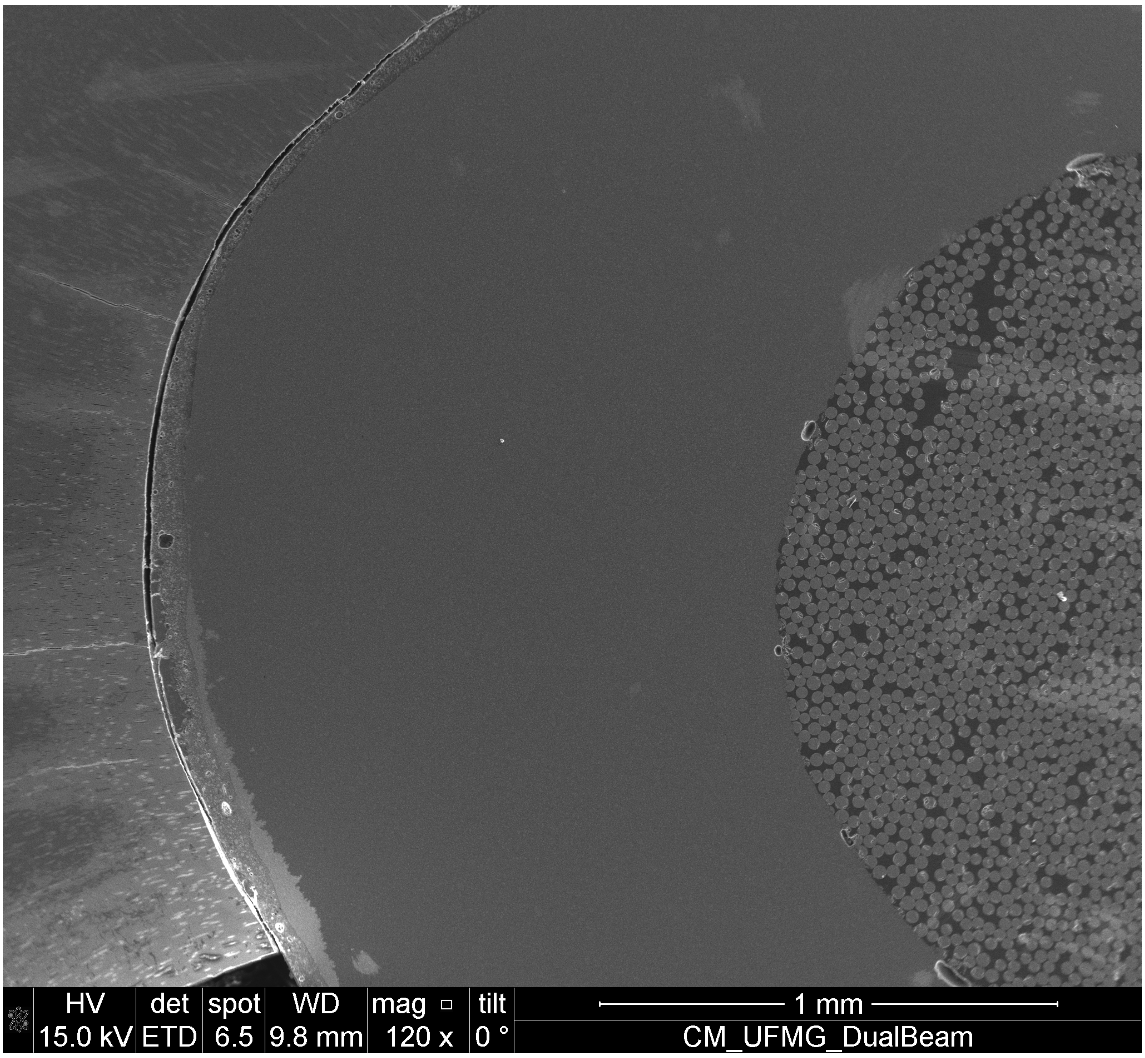
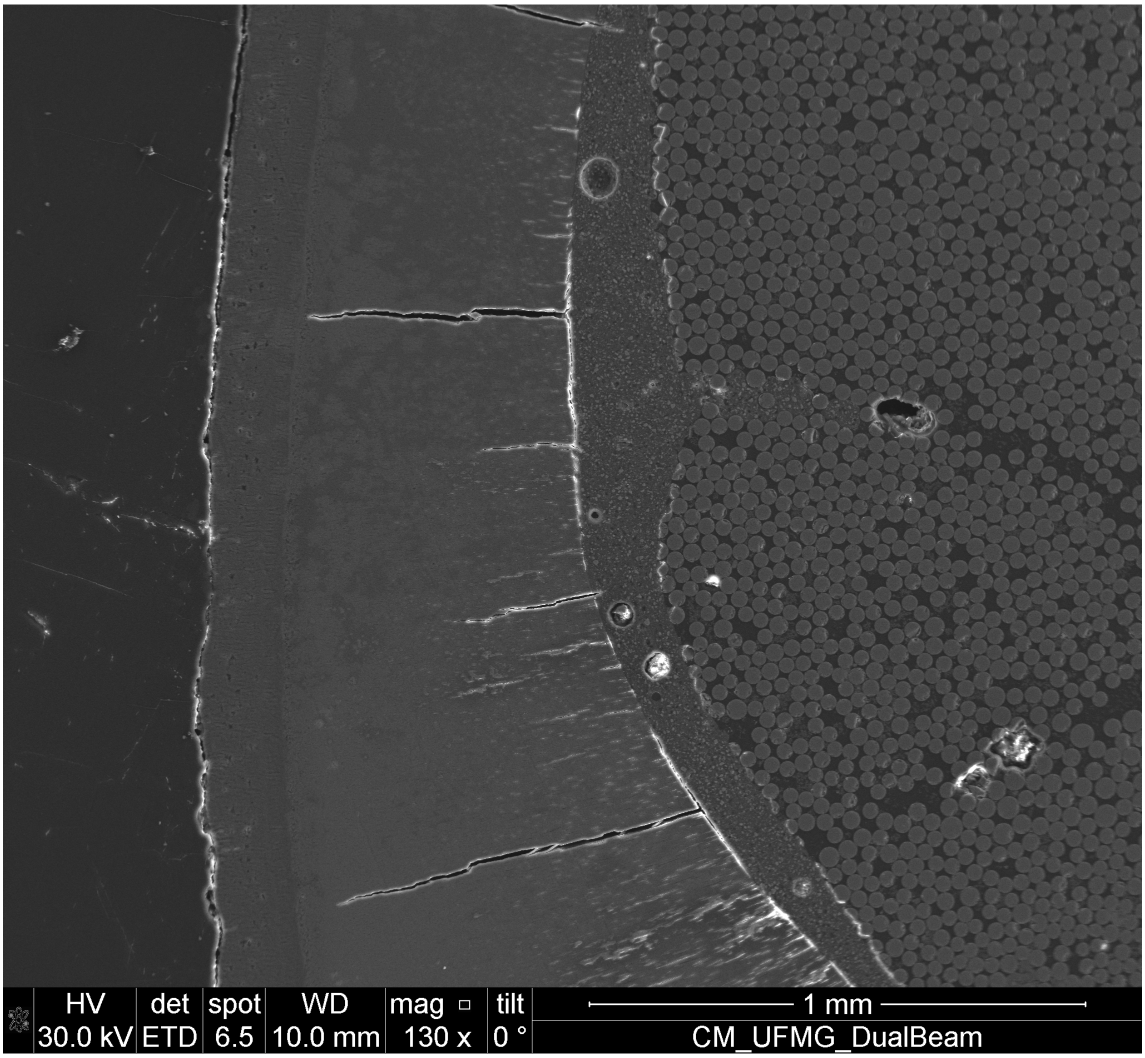


Fig. 6. SEM image originated from the coronal slice of MFP's group.



4 CONSIDERAÇÕES FINAIS

Dentro das limitações do estudo, as conclusões encontradas foram:

1. O pino reembasado com resina composta apresentou valor de união estatisticamente significativo em relação aos outros grupos, no terço coronal (p=0,01).
2. O terço apical do grupo de pinos reembasados com resina composta apresentou pior desempenho, em relação aos terços coronário e médio do mesmo grupo (p=0,037).
3. O grupo de pinos reembasados com resina composta apresentou a película de cimento resinoso mais fina.
4. O modo de falha predominante foi do tipo adesiva entre cimento resinoso e dentina radicular, exceto para o terço coronal dos grupos de pinos fresados e reembasados, cuja falha predominante foi coesiva em dentina.
5. Mais estudos devem ser realizados para melhor entendimento do sistema de pinos fresados em fibra de vidro para CAD/CAM.
6. É importante que os valores de resistência de união para dentes fragilizados sejam melhor averiguados no futuro.

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ANEXO A – Normas para publicação – The Journal of Prosthetic Dentistry

Research and Education/Clinical Research

The research report should be no longer than 10-12 double-spaced, typed pages and be accompanied by no more than 12 high-quality illustrations. Avoid the use of outline form (numbered and/or bulleted sentences or paragraphs). The text should be written in complete sentences and paragraph form.

Abstract (approximately 400 words): Create a structured abstract with the following subsections: Statement of Problem, Purpose, Material and Methods, Results, and Conclusions. The abstract should contain enough detail to describe the experimental design and variables. Sample size, controls, method of measurement, standardization, examiner reliability, and statistical method used with associated level of significance should be described in the Material and Methods section. Actual values should be provided in the Results section.

Clinical Implications: In 2-4 sentences, describe the impact of the study results on clinical practice.

Introduction: Explain the problem completely and accurately. Summarize relevant literature, and identify any bias in previous studies. Clearly state the objective of the study and the research hypothesis at the end of the Introduction. Please note that, for a thorough review of the literature, most (if not all references) should first be cited in the Introduction and/or Material and Methods section.

Material and Methods: In the initial paragraph, provide an overview of the experiment. Provide complete manufacturing information for all products and instruments used, either in parentheses or in a table. Describe what was measured, how it was measured, and the units of measure. List criteria for quantitative judgment. Describe the experimental design and variables, including defined criteria to control variables, standardization of testing, allocation of specimens/subjects to groups (specify method of randomization), total sample size, controls, calibration of examiners, and reliability of instruments and examiners. State how sample sizes were determined (such as with power analysis). Avoid the use of group numbers to indicate groups. Instead, use codes or abbreviations that will more clearly indicate the characteristics of the groups and will therefore be more meaningful for the reader. Statistical tests and associated significance levels should be described at the end of this section.

Results: Report the results accurately and briefly, in the same order as the testing was described in the Material and Methods section. For extensive listings, present data in tabular or graphic form to help the reader. For a 1-way ANOVA report of, F and *P* values in the appropriate location in the text. For all other ANOVAs, per guidelines, provide the ANOVA table(s). Describe the most significant findings and trends. Text, tables, and figures should not repeat each other. Results noted as significant must be validated by actual data and P values.

Discussion: Discuss the results of the study in relation to the hypothesis and to relevant literature. The Discussion section should begin by stating whether or not the data support rejecting the stated null hypothesis. If the results do not agree with other studies and/or with accepted opinions, state how and why the results differ. Agreement with other studies should also be stated. Identify the limitations of the present study and suggest areas for future research.

Conclusions: Concisely list conclusions that may be drawn from the research; do not simply restate the results. The conclusions must be pertinent to the objectives and justified by the data. In most situations, the conclusions are true for only the population of the experiment. All statements reported as conclusions should be accompanied by statistical analyses.

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PRODUÇÃO CIENTÍFICA (2017-2019)

Artigo 1: From provisional to ceramic crowns: CAD/CAM technology for customized esthetic rehabilitation – SUBMETIDO;

Artigo 2: Clinical performance of GIOMER restorative composites in comparison to different types of dental restorative materials: a systematic review and meta – analysis – SUBMETIDO.

From provisional to ceramic crowns: CAD/CAM technology for customized esthetic rehabilitation

André M. Neves, DDS, MSc[a]; Herbert H. Sander, DDS, MSc, PhD[b]; Allyson N. Moreira, DDS, MS, PhD[c]; Monica Yamauti, DDS, MS, PhD[d,e]; Walison A. Vasconcellos, DDS, MS, PhD[f]

[a]Graduate Student in Clinical Dentistry, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil
[b]Associate Professor, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil
[c]Professor, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil
[d]Adjunct Professor, Graduate School of Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil
[e]Associate Professor, Graduate School of dental Medicine, Faculty of Dentistry, Hokkaido University, Sapporo, Japan
[f]Associate Professor, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

Corresponding author: Monica Yamauti, Department of Restorative Dentistry, Faculty of Dentistry, Universidade Federal de Minas Gerais, Av. Pres Antonio Carlos, 6627, Belo Horizonte-MG, 31270-901, Brazil; Department of Restorative Dentistry, Faculty of Dental Medicine, Hokkaido University,
Kita 13, Nishi 7, Kita-ku, Sapporo, 060-8586, Japan, Phone: +81 (11) 706-4261, Fax: +81 (11) 706-4878; Email: myamauti@gmail.com

Acknowledgements: The authors thank Angelus® for providing the fiber resin blocks.

Title: From provisional to ceramic crowns: CAD/CAM technology for customized esthetic rehabilitation

ABSTRACT: This report describes a customized treatment of severely damaged anterior teeth that compromised the aesthetics of the patient´s smile. CAD/CAM technology was used to obtain glass fiber posts-cores and ceramic full crowns. The technique was feasible, less sensitive, with good cost-benefit. The choice of technique and the use of dental digital technology is increasing and could improve the treatment of endodontically treated teeth.

INTRODUCTION

Endodontically treated teeth are prone to loss of physical and mechanical properties.[1,2] The insertion of a intraradicular post is important to retain core material and properly distribute the occlusal tensions through the root.[3,4] Cast metal post and core are the traditional options to restore endodontically treated teeth.[5-7] Nevertheless, high elastic modulus of metal post and core has a tendency to cause catastrophic failures, specially vertical root fractures.[5-7] Pre-fabricated fiber glass posts have better aesthetics and present more similar elastic modulus to the root dentin than metal post and cores.[4,5,8] Their clinical performance is similar to metal post and cores[5,6] and, instead of root fracture, their main failure is detachment from root dentin.[9] On the other hand, pre-fabricated glass fiber posts do not have that precise adaptation to roots as metal post and cores.[8]

Aiming to associate esthetical and mechanical properties of glass fiber posts, with the unique body structure presented by traditional metallic post-and-cores, this clinical case aims to report a new post/core and ceramic crowns preparation technique using CAD/CAM technology.

CLINICAL REPORT

A female patient went to the clinics for routine dental appointment, complaining about her dissatisfaction with the front teeth and her facial esthetics. Extensive unsatisfactory composite resin restorations in teeth 12, 11 and 21 were diagnosed (Fig. 1). The patient showed good oral hygiene and healthy periodontal tissues. Radiographs were taken, and the analysis indicated successful endodontic treatment. Lithium disilicate ceramic total crowns were planned with the use of intraradicular retention.

The unsatisfactory coronal resin composite restorations were totally removed using cylindrical ogival shaped diamond burs. Crowns and root canals were prepared to receive CAD/CAM-fabricated lithium disilicate crowns and glass fiber posts-cores (Fig. 2 and Fig.3). Root canals were prepared with a low-speed instrument (Largo, KG Sorensen). Removal of guta-percha was performed so that a 4-mm remaining of gutta-percha was left (Fig. 5).[10] To ensure adequate remnant of gutta-percha periapical radiographs were taken. Then, root canals were spread with solid petroleum jelly to prevent the retention of acrylic resin inside the canal. A layer of self-curing acrylic resin (DuraLay, Reliance) was used with polycarbonate posts (Pinjet, Angelus) for shaping and impression of root canals. The coronal portion was also shaped with acrylic resin as dentin core for total crown preparation. Impressions of the surrounding and antagonist teeth was taken using vinyl polysiloxane (Express XT, 3M ESPE). The posts, core build-ups and the vinyl polysiloxane impressions were scanned (InEos X5, Sirona), and a digital 3D model was developed (inLab SW 18.0, Sirona). In the same session, acrylic resin blocks were milled (inLab MC XL, Sirona), and 3 provisional restorations were obtained.

The one-piece glass fiber post and core used (Fiber CAD, Angelus) was milled on a longitudinally spaced glass fiber within the block, so, when milled, the fiber is not sectioned in the middle. The CAD-CAM fabricated glass fiber post and cores were adapted to the root canals. The gingival tissue was not as much healthy as it could be due to patient´s oral hygiene relapse, what was immediately addressed. Glass fiber posts-cores were cleaned with alcohol and dried, a layer of silane was applied and let to rest for 1 min, following manufacturer’s instructions. Root canals were rinsed with 2,5% sodium hypochlorite and dried using absorbent paper points. Self-adhesive resin cement (RelyX U200, 3M ESPE) was injected into each root canal, and fiber glass post and cores were seated (Fig.4). Excess of resin cement was removed with small disposable brushes and 40 s photo-activation on each side of the crowns was performed, using a LED unit (@1200 mW/cm^2, Radii-Cal, SDI). After the resin cement set completion, an impression of the teeth coronal portion (Express XT, 3M ESPE) was taken, so CAD/CAM fabricated crowns (Emax CAD, IvoclarVivadent) could be processed and milled. The lithium disilicate crowns were perfectly adapted in all margins, and occlusion was checked using articulating papers with progressive color transfer. The ceramic crowns were cemented using the self-adhesive resin cement, which was photo activated for 40 s on each side (Fig.6). The patient was recalled for control after 2 weeks, 1 and 5 months after treatment was completed. At each recalling period, prophylaxis was performed, and the importance of oral hygiene was reinforced. The patient reported to be highly satisfied with the treatment.

DISCUSSION

Teeth presenting severe loss of coronal structure and flared root canals have a wide space to be filled with post and core material. The CAD/CAM technology can be used to produce a one-piece glass fiber post and core, from the same resin block. It is speculated that this procedure promotes better adaptation and homogeneity between core and post materials. The elastic modulus of human dentin varies from 25.1 to 28.1 GPa.[11] Comparing various fiber post systems, flexural strength values up to 835.9 MPa have been reported.[13] Those flexural strength values are greater than masticatory force of maxillary central and lateral incisors.[12] According to the CAD/CAM fiber glass block manufacturer, the material present flexural strength value of 1100 MPa and 25 GPa of elasticity modulus, which is closer to the human dentin.[12] The shade of the fiberglass block is similar to the human teeth and very compatible with ceramic crowns.[13]

The use of CAD/CAM enabled the confection of a glass fiber post, which aligns the adaptation of metallic posts and aesthetics/favorable mechanical properties of pre-fabricated glass fiber posts, achieving the patient expectations. As the demand for natural aesthetic restorations with adequate physical properties, CAD-CAM systems tend to become more popular.

SUMMARY

This clinical report describes a method to restore severely damaged teeth using full CAD/CAM-fabricated restorations. This digital workflow is ideal for milling one-piece glass fiber post and core, contributing to the achievement of enhanced aesthetics and mechanical properties.

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Figure legends

Fig. 1: Initial photo showing extensive resin composite restorations

Fig. 2: Teeth preparation for total crowns

Fig. 3: Root canals after preparation for intraradicular posts

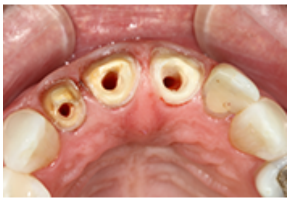

Fig. 4: Glass fiber post-and-cores adapted to teeth preparations and cemented with self-adhesive resin cement

Fig. 5: Periapical radiograph taken 5 months after post cementation.

Fig. 6: CAD/CAM lithium disilicate restorations cemented showing proper aesthetics.

Clinical performance of GIOMER restorative composites in comparison to different types of dental restorative materials: a systematic review and meta-analysis

Clóvis Ciryllo Limonge Neto[1], André Martins das Neves[1], Diandra Costa Arantes[2], Tassiana Cançado Melo Sa[2], Monica Yamauti[3,4], Cláudia Silami de Magalhães[5], Lucas Guimarães Abreu[6], Allyson Nogueira Moreira[5]

[1]DDS, MS student. Department of Restorative Dentistry, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.

[2]DDS, MS, PhD student. Department of Restorative Dentistry, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.

[3]DDS, MS, PhD. Adjunct professor, Department of Restorative Dentistry, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.

[4]Associate Professor, Department of Restorative Dentistry, Faculty of Dental Medicine, Hokkaido University, Sapporo, Japan

[5]DDS, MS, PhD. Titular professor, Department of Restorative Dentistry, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.

[6] DDS, MS, PhD. Adjunct professor, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, MG, Brazil.

Author for correspondence

Dr. Lucas Guimarães Abreu

E-mail: lucasgabreu01@gmail.com

Telephone: 55 31 34092470

Av. Antônio Carlos, 6627. Campus Pampulha, CEP 31270-091, Belo Horizonte, MG, Brazil.

Contribution to the paper: all listed authors have made substantial contributions to the paper. Clóvis Ciryllo Limonge Neto contributed to the design of the study, bibliographic search, data analysis and drafting of the paper. André Martins das Neves contributed to the design of the study, bibliographic search, data analysis and drafting of the paper. Diandra Costa Arantes contributed to the design of the study, data analysis and drafting of the paper. Tassiana Cançado Melo Sá contributed to the design of the study, data analysis and drafting of the paper. Monica Yamauti contributed to the design of the study, critical review and proofread the paper. Claudia Silami de Magalhães contributed to drafting of the paper and proofread the paper. Lucas Guimarães Abreu contributed to the design of the study, bibliographic search, data analysis, drafting of the paper and proofread the paper. Allyson Nogueira Moreira contributed to the design of the study, critical review and proofread the paper.

Clinical performance of GIOMER restorative composites in comparison to different types of dental restorative materials: a systematic review and meta-analysis

Introduction

Due to the demand for esthetic procedures and the advocacy for the minimum removal of dental tissues during dental preparation, composite resins have been widely used in Restorative Dentistry.[1,2] Several studies have demonstrated the clinical evidence of the survival of this restorative material.[3-5] On the other hand, composite resins are susceptible to failures due to their physical and chemical properties,[6] as well as the risk of secondary carious lesions adjacent to the restorations.[7]

Materials through which fluoride is released, such as glass ionomer cements (GICs), have the capacity to neutralize the pH of the saliva with proven efficacy for control and the reduction of bacterial growth.[8] The release of fluoride and strontium ions forms an acid-resistant layer and reinforces the dental structure, converting hydroxyapatite into fluorine-apatite and strontium-apatite with proven anti-cariogenic efficacy.[8] GICs are widely used for restorations in deciduous teeth or as temporary restorations in permanent teeth due to their properties of low resistance and weight loss over time, which, ultimately, lead to the increase of roughness on their surface and the consequent accumulation of plaque.[4]

GIOMER is a new class of restorative material introduced by Shofu Inc, which combines the fluoride-releasing properties of glass ionomer cement and the strength and aesthetics of composite resins.[9-11] The main difference between GIOMER materials and compomers is the presence of pre-reacted glass ionomer particles (S-PRG) incorporated into the resin matrix.[10,12] S-PRG particles enable the mechanical strength, durability, and aesthetics of a composite material ,[13] as well as the release of various ions (fluorine ions, sodium ions, silicate ions, aluminum ions, borate ions, and strontium ions)[14] that provide multiple biological functions including the release and recharge of fluoride, an anti-plaque effect, an anti-biofilm effect, and pH modulation.[10]

There are several studies in the literature on the clinical efficacy of composite resins, however there are few studies comparing this clinical efficacy with fluoride-releasing materials as GIOMER. Thus, the objective of the present systematic review and meta-analysis was to compare the clinical performance of GIOMER restorative composites with the clinical performance of restorations performed with other types of direct restorative materials. The null hypothesis of this study is that the clinical performance of GIOMER restorative composites is similar to the clinical performance of restorations with other types of direct restorative materials.

Material and Methods

Protocol and registration

This systematic review and meta-analysis were registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42018110634. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was followed.[15]

Eligibility criteria

This systematic review and meta-analysis aimed to answer the following question: Is there any difference in the clinical performance of dental restorations with GIOMER restorative composite in permanent teeth compared to other direct restorative materials? The PICO question described below was applied.

(P) Population - adults or adolescents with restorations in anterior or posterior permanent teeth.

(I) Intervention - restorations with GIOMER restorative composite.

(C) Comparison - restorations with other restorative material.

(O) Outcome - primary outcome: clinical performance of dental restorations evaluated by postoperative sensitivity, color match, marginal adaptation, anatomic form, surface roughness, staining, marginal staining, secondary caries, retention criteria, and the influence of isolation (rubber dam or cotton roll) on the primary outcome.

Randomized clinical trials comparing the clinical performance of dental restorations with GIOMER restorative composite and restorations with other restorative materials performed in permanent teeth of adults or adolescents were included. Letters, literature reviews, case reports, case series, non-randomized clinical trials, *in vitro*, and *in situ* studies were excluded. Restrictions on language or date of publication was not imposed in any way.

Information sources and search strategy

In September 2018, electronic searches were performed in the following databases: PubMeb, Web of Science, Scopus, Medline Ovid, and the Cochrane Library. A grey literature search in Google Scholar, limiting the search to the first 300 hits was performed. Manual searches of the reference list of the included articles were also carried out. In May 2019, an update of the search was carried out to verify if there were any new potential publications.

The search strategy for PubMed, Web of Science, Medline Ovid, and Cochrane Library was as follows: [giomer OR s-prg OR pre-reacted glass ionomer OR s-prg filler OR beautifil]. For Scopus, the search strategy was tailored according to the characteristics of the database.

Study Selection

Endnote Web (Clarivate Analytics, Philadelphia, US) was used to manage the bibliographic references. Any duplicated references were removed upon identification. Titles and abstracts were evaluated independently by two review authors (CCLN and AMN), who applied the eligibility criteria. The full text of the references with insufficient information in the titles and abstracts was also evaluated by the two review authors. The references that fulfilled the eligibility criteria were included. If any divergence between the review authors took place, a third review author (MY) decided if the reference should be included or otherwise.

Data collection process and data items

Data collection of the included articles was carried out by two review authors (CCLN and AMN). Divergences were also resolved by a third review author (MY). The following data were collected from the included articles: identification of the study (last name of the first author and year of publication), study design, period of follow-up, age of participants, total number of restorations, and total number of the participants at study's onset, type of dental materials assessed and number of restorations per group at the end of the study, isolation method, evaluation criteria, outcomes evaluated, and results.

Risk of bias in individual studies

The risk of bias assessment of the included articles was performed by two review authors (CCLN and AMN) according to the Cochrane Risk of Bias Tool for Randomized Clinical Trials (http://handbook.cochrane.org). The aspects of bias were evaluated individually in order to assess the selection, performance, attrition, reporting, and detection bias.

Six domains were assessed: random sequence generation, allocation concealment, blinding of outcome assessors, blinding of participants and personnel, incomplete outcome data, and selective outcome reporting. A low risk, an unclear risk, or a high risk of bias were used to classify each domain. Divergences between the two review authors were resolved by a third review author (DCA).

Synthesis of results

Included studies with methodological homogeneity were incorporated into the meta-analysis. The results of the meta-analysis were reported as odds ratio (OR) and 95% confidence intervals (CI). In the meta-analysis, statistical heterogeneity was assessed by means of the I^2 statistics.[16] Analyses with a value of I^2 greater than or equal to 40% were classified as having a high statistical heterogeneity and the random effect model would be used. Analyses with a value of I^2 lower than 40% were classified as having a low statistical heterogeneity and the fixed effect model would be used. The meta-analysis was performed using the software Review Manager (Rev.Man), version 5.3 software

(Review Manager. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014).

Additional analysis

Depending on the outcomes evaluated in the included studies, subgroup analyses were carried out considering the results of two clinical performance criteria (surface roughness and marginal adaptation) at two follow-up periods (six and twelve months). For studies that analyzed other clinical performance criteria, only these two criteria were incorporated into the meta-analysis.

Quality of evidence rating and strength of recommendations grading

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE)[17] system was used to analyze the quality of the evidence and the strength of recommendations using the GRADEpro GDT online software. The selected outcomes were marginal adaptation and surface roughness six and twelve months after restoration with GIOMER and RMGIG. For each one, the GRADE evaluated the number of studies included in the meta-analysis, the studies' design, risk of bias, inconsistency, indirectness, imprecision, and other considerations, such as publication bias. The evidence could be downgraded in one or two levels according to the seriousness of the limitation. The certainty of the assessment of the outcome could be classified as high, moderate, low, or very low.

Results

Study selection

The searches across the five electronic databases retrieved 910 references. After the removal of duplicates, 552 references remained. Titles and abstracts were assessed, and ten articles were selected for the evaluation of the full text. Among the ten articles, four studies were excluded because the focus of the analysis was on periodontal outcomes and not outcomes related to the clinical performance of the restorative material.[18-21] Therefore, six studies fulfilled the eligibility criteria and were included in this systematic review and meta-analysis.[22-27] No study meeting the eligibility criteria was identified in Google Scholar or in the reference list of the included studies. Figure 1 displays the process of the study selection of this systematic review and meta-analysis.

Characteristics of included studies

The characteristics of the included studies are described in Table 1. Two studies compared composite resin and GIOMER.[22,25] One study used two types of GIOMER.[23] One study compared RMGIC and GIOMER.[24] In one study,[26] composite resin and GIOMER were compared with bases pre-filled with RMGIC or compomer. One study compared restorations with RMGIC, GIC, and GIOMER.[27]

In two included studies, rubber dam isolation was used.[22,23] In three studies, cotton rolls were used.[24,25,27] In one study, no information on the isolation method was provided.[26] In four included studies, Class IV restorations were evaluated.[22-24,27] In one study[23], both carious and non-carious coronal lesions were evaluated, and Class I restorations with only one type of GIOMER were assessed. In two studies, Class II restorations were evaluated [25,26]. The minimum period of the follow-up period was six months, and the maximum was 72 months. The participants' age ranged from 16 to 75 years. The total number of restorations evaluated in the included studies was 547.

Risk of bias within studies

In all included studies, information on the blinding of participants and personnel was unclear.[22-27] In one study, the random sequence generation and the allocation concealment were of a low risk of bias and the authors reported that the cards were sequentially numbered and placed in opaque and sealed envelopes.[27] Three included articles presented a low risk of bias[24,25,27] (Jyothi *et al.*, 2011; Dijken *et al.*, 2013; Priyadarshini *et al.*, 2017) and three presented an unclear risk of bias[22,23,26] for the blinding of the outcome assessor. In regards to incomplete outcome bias, only one included study showed an unclear risk of bias[26] and five showed low risk of bias. [22-25,27] For selective reporting, two included studies presented a low risk of bias[24,27], three presented a high risk of bias[22,23,25], and one presented an unclear risk of bias.[26] No other bias was observed in any of the included studies. Figure 2 displays the assessment of the risk of bias for each included study, and Figure 3 shows a summary of the risk of bias assessment.

Synthesis of results and subgroup analysis

Two included studies were incorporated into the subgroup analyses.[24,27] One subgroup analysis compared marginal adaptation between GIOMER and RMGIC, six months and twelve months after the restoration placement. The subgroup analysis showed no difference with respect to marginal adaptation between GIOMER and RMGIC at 6 months (OR = 1.54, CI = 0.59–4.02, I^2 = 38%) and 12 months (OR = 1.36, CI = 0.51–3.60, I^2 = 31%) after restoration placement (Figure 4). One subgroup analysis compared surface roughness between GIOMER and RMGIC, six and twelve months after restoration placement. RMGIC was 6.56 times more likely to present Bravo scores six months after restoration placement than GIOMER (OR = 6.56, CI = 2.38–18.13, I^2 = 0%). RMGIC was 8.76 times more likely to present Bravo scores twelve months after restoration placement than GIOMER (OR = 8.76, CI = 3.19–24.07, I^2 = 0%) (Figure 5). In all subgroup analyses, the fixed effect model was used.

Quality of evidence rating and the strength of recommendation grading

The certainty of the evaluation of the outcomes marginal adaptation and surface roughness, after dental restoration with GIOMER materials and RMGIG, was low for marginal adaptation (6- and 12-month follow up) and moderate for surface roughness (6- and 12-month follow up) (Table 2).

Discussion

The present systematic review and meta-analysis was conducted due to the lack of evidence of the clinical efficacy of GIOMER restorative composites. One of the most important properties of GIOMERS is the ability to release and recharge fluoride to prevent secondary caries.[9,28,29] RMGIC materials were also associated with a higher reduction of demineralization in adjacent hard tooth tissue under caries challenge than composite resins without fluoride.[30] There are no other systematic reviews comparing the clinical efficacy of GIOMER restorative composites with different types of restorative materials.

In the studies included in this systematic review and meta-analysis, dental restorations were evaluated by the United States Public Health Service (USPHS) criteria.[22-27] However, those studies did not explicitly mention if CONSORT recommendations were followed. It would have been very helpful if the studies had used those recommendations to write, review, or assess reports. The CONSORT statement collaborates to improve the quality of randomized clinical trials. In addition, no study cited the protocol registration number for *in vivo* trials in any specific database.

The present systematic review and meta-analysis included six studies that evaluated the clinical performance of materials in the short- and long-term periods. [22-27] In general, the present results demonstrated that the clinical performance of GIOMER restorative composite was like that of RMGIC, concerning marginal adaption and surface roughness. The included studies employed different designs regarding the type of cavity (Class I, II, V) and restorative material (GIOMER, composite resin, GIC, and RMGIC). Thus, it was only possible to perform the meta-analysis of two outcomes using two studies.[24,27] The subgroup analyses of both outcomes compared GIOMER with RMGIC in non-carious Class V restorations at the same time periods (6- and 12-months).

In the included studies, the GIOMER restorative composites used were Beautifil, Beautifil II, and Reactmer. This class of material has properties of GIC related to fluoride release and fluoride recharge along with better esthetics, resistance, and easy polishing.[23] PRG-technology is classified into two categories: F-PRG (full reaction type), with which the entire filler particle is attacked by polyacrylic acid, and the S-PRG (surface reaction type), with which only the surface of the glass filler is attacked by polyacrylic acid, and a glass core remains. In fact, S-PRG has replaced F-PRG. A previous Reactmer (Shofu, Kyoto, Japan) used F-PRG technology, but this material was indicated only for coronal cavities.[23] Current versions of the Beautifil resins and FL-Bond adhesive system

(Shofu, Kyoto, Japan) developed using S-PRG technology are indicated for Class I through Class VI cavities.[23] Beautifil II is considered a second-generation GIOMER introduced into the market.[27]

Two studies were suitable for meta-analysis. One subgroup analysis showed a significant difference between GIOMER and RMGIC with respect to the surface roughness at the 6- and 12-month follow-up. In both studies, the restorations were submitted to polishing procedures to get the surfaces as smooth as possible.[22-27] Several factors related to the restorative procedures, the characteristics of composites, and the operator may affect the surface roughness. According to some authors, increased surface roughness enlarges the area available for bacterial adhesion[31] and biofilm formation. This could happen in the case of the absence of good polishing or a smooth state, which could lead to secondary caries[31] and inflammation of gingival tissue.[10,18,31-34] The presence of biofilm is one of the factors that may stimulate surface degradation,[31] compromising the longevity of resin composite restorations.

Moreover, no significant difference between the marginal adaptation of GIOMER and RMGIC restorations was found at the 6- and 12-month follow-up. Jyothi *et al*.[24] and Priyadarshini *et al*.[27] also reported that GIOMER presented a better color match and worse retention than GIC.

The GIOMER restorative composites were considered suitable as definitive restorative materials.[22-24,26,27] Dijen *et al*.[25] found a higher failure rate in GIOMER than in composite resin due to fracture or secondary caries. However, Matis *et al.*[22] have not found a significant difference between GIOMER and composite resins in all the evaluated periods and outcomes. Saveanu & Dănilă[26] reported that GIOMER restorative composite presented an inferior quality for marginal staining and color match when compared with composite resin. This was the only study included in this systematic review and meta-analysis that used the compomer and RMGIC as a restorative base, using the composite resin or GIOMER as a restoration for enamel in class II cavities.[26]

There is still poor information on this type of material. The major limitation of this study was the scarce number of non-randomized clinical trials using GIOMER materials. Therefore, it was unfeasible to perform subgroup analyses with other outcomes. For future research, it would be convenient to follow the CONSORT's recommendations for designing and reporting studies, in particular regarding the blindness of operators and evaluators. A detailed report of the results is highly relevant to describe the gross values of the analysis of each outcome in each period for the eventual meta-analyses.

Conclusion

The GIOMER restorative composite presented a similar performance to that of RMGIC restorations concerning marginal adaption. However, GIOMER presented better surface roughness when compared to RMGIC. It is still premature to assert that the clinical behavior of GIOMER restorative composites is similar to the clinical performance of restorations with other types of direct restorative materials. Randomized clinical trials with long-term follow-ups are still necessary to compare the clinical performance of GIOMER restorative composites and other materials.

Acknowledgements

The authors declared no conflict of interest. This study was financed in part by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior Brasil (CAPES), Finance Code 001, and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) grant APQ01352-15.

Conflicts of interest

The authors do not have conflicts of interest.

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Table 1. Characteristics of the included studies.

Author Year (Country)	Study Design	Follow-up (months)	Age of participants	Initial number of restorations and participants	Type of dental materials and final number of restorations per group	Isolation method	Evaluation criteria	Outcomes	Results
Matis *et al.* 2004 (USA)	Split mouth Randomized Clinical Trial	6, 18, and 36	Mean age = 45 years Range = 30–75 years	80 restorations (Class V) 30 individuals	Microfield Composite (Scotchbond Multi-Purpose Plus Dental Adhesive + Silux Plus[a]) = 39 GIOMER (FL-Bond + Beautifil[b]) = 39	Rubber dam and retraction cord when necessary	Modified USPHS	POS, MA, AF, SR, S, MS, SC, and R	POS, MA, AF, SR, S, SC, R: There were no significant differences in the evaluated periods among all the evaluated outcomes. MS: 7 teeth exhibited margin with discoloration restored with Beautifil and 4 with Silux Plus, but without significant differences. Neither material was significantly different from each other in the outcomes evaluated. Both materials meet the clinical portion of the Acceptance Program Guidelines for Dentin and Enamel Adhesives Materials established by the American Dental Association.
Sunico *et al.* 2005	Split mouth	6 and 24	Mean age = 35 years	62 restorations	GIOMER (Imperva FluorBond[b] + Beautifil[b]) = 20	Rubber dam	Modified USPHS	POS, CM, MA, AF,	POS, CM: There was no significant differences in the evaluated periods for both materials.

(Phillippines)	Randomized Clinical Trial		Range = 20–50 years	(42 Class V and 20 Class I) 15 individuals	Class V and 20 Class I) (Reactmer[b] + Reactmer Bond[b]) = 21 Class V			SR, MS, SC, and R	MA: There were significant differences for MA in CL V restorations with Beautifil at periods evaluated ($p < 0.05$). MA, MS: Both GIOMER materials presented failures in marginal adaptation, marginal discoloration, and wear in the evaluated periods. MA, AF, MS were the criteria that had the most Charlie and Delta ratings at both six months and two years for the Reactmer CL V restorations. SC: 20% of restorations with Reactmer showed secondary caries at the 24-month evaluation. SR: Not reported. R: At 6 months, 19% (n = 4) of the restorations with Reactmer dislodged and after 24 months another restoration was lost. While for Beautifil, any restoration lost retention. Beautifil CL V restorations were better retained then Reactmer

									CL V restorations in the evaluated periods. At 24 months, there was an 80% success rate for Beautifil and only a 71% success rate for Reactmer.
Saveanu & Dănilă 2010 (Romania)	Split mouth Randomized Clinical Trial	6, 12, 24, and 36	Mean age = not reported Range = 16–55 years	90 restoration (Class II)	Composite Resin with RMGIC (Filtek Supreme[a] + Vitrmer[a]) = 24 GIOMER with RMGIC (Beautifil[b] + Vitremer[a]) = 23 GIOMER with Compomer Flow (Beatutifil[b] + Dyract Flow[e]) = 21 Composite Resin with Compomer Flow (Filtek Supreme[a] + Dyract Flow[d]) = 22	Not reported	Modified USPHS	POS, CM, MS, and R	POS: There was higher sensitivity for composite resin restorations compared to restorations made with GIOMER, but without significant difference. CM: There were no significant differences at 6 and 12 months. But with 24 months, restorations with composite resin showed 33,33 (8) score Alpha, while restorations with GIOMER showed only 4.34 (1) score Alpha with significant differences ($p < 0.05$). MS: There were significant differences at 12 months for restorations with p = 0037 with favor to composite Resin with rating Alpha (95.65%) and GIOMER with rating Alpha (73.91%), the rest is bravo. R: None of restorations lost in the evaluated periods.

Jyothi *et al.* 2011 (India)	Split mouth Randomized Clinical Trial	15 days, 6 and 12 months	Mean age = not reported Range = 20–60 years	80 restorations (Class V) 32 individuals	RMGIC (Fuji II LC [c]) = 40 GIOMER (FL-Bond II[b] + Beatufil II[b]) = 40	Cotton Rolls, saliva ejector and gingival retraction cords	Modified USPHS	POS, MA, SR, S, MS, and R	SR: There were significant differences in the evaluated periods. GIOMER-exhibited a superior surface finish compared to RMGIC. MA, R: There were no significant differences in the evaluated periods. POS, S, MS: There was no marginal discoloration, staining, and postoperative sensitivity for all the restorations.
Dijken 2013 (Sweden)	Split mouth Randomized Clinical Trial	12, 24, 36, 48, 60, and 72	Mean age = 57.1 years Range = 24–77 years	115 restorations (Class II) 54 individuals	Hybrid Resin (G-Bond[c] + Gradia Direct Posterior[c]) = 58 GIOMER (FL-Bond[b] + Beautifil[b]) =53	Cotton Rolls and suction device	Modified USPHS	POS, CM, AF, MA, SR, MS, and SC	POS: No post-operative sensitivity was reported. CM: There was a significant decrease in color match at the period evaluated for both materials ($p < 0.05$). AF: There were no significant differences in the evaluated periods. MS: There were changes for both materials, but this was significantly higher for the GIOMER material

									MA, SC: During the total period evaluated, 5 (8,5%) restorations with composite resin and 9 (17,7%) restorations with GIOMER failed due to receding caries or fracture (p <0.05). SR: Not reported.
Priyadarshini *et al.* 2017 (India)	Split mouth Randomized Clinical Trial	6 and 12	Mean age = not reported Range =35–65 years	120 restorations (Class V) 20 individuals	RMGIC (Self Conditioner[c] + Fuji Filling LC[c]) = 40 GIC (Ketac N100 Nano Ionomer Primer[a] + Ketac N100[a]) = 40 GIOMER (FL Bond II LC[b] + Beautifil II[b]) = 40	Cotton rolls, saliva ejector, and gingival retraction cords	Modified USPHS	POS, CM, MA, SR, MS, and R	There was a significant reduction for some outcomes such as CM and SR for RMGIC, R for GIOMER, MS, and CM for GIC, after 12 months with $p < 0.05$. CM, SR, MS, R: There was a significant difference with $p < 0.05$ from 6 to 12 months for all materials. R: GIV and RMGIC restorations were better retained than GIOMER restorations in the evaluated periods with significance differences. MS: It was higher for GIC than others material with significance differences.

									CM: GIOMER was better than GIC and RMGIC in the evaluated periods. SR: GIOMER was better than RMGIC with a significance difference. POS, MA: There were no significant differences in the evaluated periods.

RMGIC = Resin-Modified Glass Ionomer Cement; GIC = Glass Ionomer Cement; POS = Postoperative Sensitivity; CM = Color Match; MA = Marginal Adaptation; AF = Anatomic Form; SR = Surface Roughness; S = Staining; MS = Marginal Staining; SC = Secondary Caries; R = Retention. [a] = 3M Dental Products, St. Paul, Minn; [b] = Shofu, Kyoto, Japan; [c] = GC Corp., Tokyo, Japan; [d] = 3M ESPE, St. Paul, USA; [e] = Dentsplay Sirona, Sidney, Australia.

Table 2. GRADE quality of evidence.

Outcome	Nº of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Relative (95% CI)	Quality
Marginal adaptation 6 months	2	randomized trials	serious [a]	not serious	not serious	serious [b]	none	OR 1.54 (0.59 to 4.02)	⊕⊕◯◯ LOW
Marginal adaptation 12 months	2	randomized trials	serious [a]	not serious	not serious	serious [b]	none	OR 1.36 (0.51 to 3.60)	⊕⊕◯◯ LOW
Surface roughness 6 months	2	randomized trials	serious [a]	not serious	not serious	not serious	none	OR 6.56 (2.38 to 18.13)	⊕⊕⊕◯ MODERATE
Surface roughness 12 months	2	randomized trials	serious [a]	not serious	not serious	not serious	none	OR 8.76 (3.19 to 24.07)	⊕⊕⊕◯ MODERATE

CI: Confidence interval; **OR:** Odds ratio.
a. The evidence has been downgraded by one level because of serious concern regarding the risk of bias. According to the Cochrane Tool, most information is from studies at moderate risk of bias.
b. The evidence has been downgraded by one level because confidence intervals cross threshold.