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GIOVANA MONGRUEL GOMES

**INFLUÊNCIA DA ADAPTAÇÃO DE PINOS DE FIBRA E DE
TÉCNICAS RESTAURADORAS ALTERNATIVAS PARA
PREENCHIMENTO DE CANAIS RADICULARES EXCESSIVAMENTE
ALARGADOS**

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RESTAURADORAS ALTERNATIVAS PARA PREENCHIMENTO DE
CANAIS RADICULARES EXCESSIVAMENTE ALARGADOS**

Tese apresentada como pré-requisito para obtenção do título de Doutor na Universidade Estadual de Ponta Grossa, no Curso de Doutorado em Odontologia – Área de Concentração Dentística Restauradora.
Linha de Pesquisa: Propriedades físico-químicas e biológicas dos materiais.

Orientadora: Prof^a. Dr^a. Alessandra Reis
Co-orientadores: Prof^o. Dr^o. Alessandro Dourado Loguercio e Prof^a. Dr^a. Osnara Maria Mongruel Gomes

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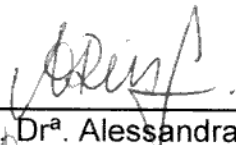
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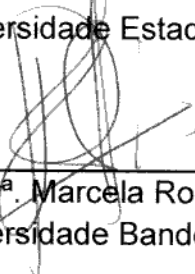
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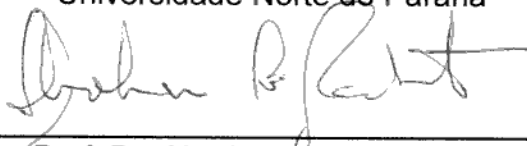
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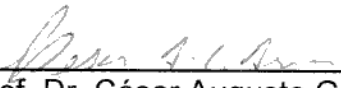
Profª. Drª. Marcela Rocha de Oliveira Carrilho
Universidade Bandeirante de São Paulo



Profª. Drª. Sandra Kiss Moura
Universidade Norte do Paraná



Prof. Dr. Abraham Lincoln Calixto
Universidade Estadual de Ponta Grossa



Prof. Dr. César Augusto Galvão Arrais
Universidade Estadual de Ponta Grossa

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(Paulo Freire)

DADOS CURRICULARES

Giovana Mongruel Gomes

NASCIMENTO 11.07.1985	Ponta Grossa, Paraná – Brasil
FILIAÇÃO	Osnara Maria Mongruel Gomes João Carlos Gomes
2003 - 2007	Curso de Graduação em Odontologia. Universidade Estadual de Ponta Grossa (UEPG). Ponta Grossa – PR, Brasil.
2006 - 2006	Curso de Aperfeiçoamento em Odontologia Estética Adesiva. Escola de Aperfeiçoamento Profissional. Associação Brasileira de Odontologia (ABO) – Regional Ponta Grossa – PR, Brasil.
2007 - 2008	Curso de Aperfeiçoamento em Implantodontia. Escola de Aperfeiçoamento Profissional. Associação Brasileira de Odontologia (ABO) – Regional Ponta Grossa – PR, Brasil.
2008 - 2010	Curso de Pós-Graduação em Odontologia. Área de Concentração em Dentística Restauradora. Nível Mestrado. Universidade Estadual de Ponta Grossa (UEPG). Ponta Grossa – PR, Brasil.
2009 - 2010	Curso de Aperfeiçoamento em Endodontia de Molares. Escola de Aperfeiçoamento Profissional. Associação Brasileira de Odontologia (ABO) – Regional Ponta Grossa – PR, Brasil.
2009 - 2010	Curso de Especialização em Prótese Dentária. Escola de Aperfeiçoamento Profissional. Associação Brasileira de Odontologia (ABO) – Regional Ponta Grossa – PR, Brasil.

2010 – 2011	Professora Efetiva das disciplinas de Clínica Integrada I e II do Centro de Ensino Superior dos Campos Gerais (CESCAGE). Ponta Grossa – PR, Brasil.
2010 – em andamento	Oficial Dentista do Exército Brasileiro. 1º Tenente. Esquadrão de Comando da 5ª Brigada de Cavalaria Blindada. Ponta Grossa – PR, Brasil.
2010 –2013	Curso de Pós-Graduação em Odontologia. Área de Concentração em Dentística Restauradora. Nível Doutorado. Universidade Estadual de Ponta Grossa (UEPG). Ponta Grossa – PR, Brasil.
2011 - 2013	Professora Colaboradora das disciplinas de Dentística Operatória e Prótese Dentária II da Universidade Estadual de Ponta Grossa (UEPG). Ponta Grossa – PR, Brasil.

RESUMO

Gomes, GM. **Influência da adaptação de pinos de fibra e de técnicas restauradoras alternativas para preenchimento de canais radiculares excessivamente alargados.** [Tese - Doutorado em Odontologia – Área de Concentração Dentística Restauradora – Universidade Estadual de Ponta Grossa; 2013].

Os objetivos deste estudo foram 1) avaliar o efeito da influência da espessura de cimento resinoso (ECR) na resistência de união (RU) e na formação de *gaps* (FG) entre pino de fibra de vidro (PFV) e dentina radicular e 2) avaliar a RU e resistência à fratura (RF) de técnicas restauradoras para preenchimento de canais radiculares excessivamente alargados. No experimento 1, as raízes de 24 pré-molares inferiores (n=8 por grupo) foram tratadas endodonticamente. Após uma semana, os condutos foram preparados em função da adaptação do pino no canal radicular, simulando uma adaptação ideal (AdId), média (AdMe) e inadequada (AdIn). Todos os pinos foram cimentados com Excite® DSC e Variolink® II. Uma semana após a cimentação, a ECR e a FG foram mensuradas com o *software* Image Tool versão 3.0 e a RU por meio do teste de *push-out*. No experimento 2, as raízes de 84 pré-molares inferiores foram tratadas endodonticamente e, após uma semana, realizou-se o preparo dos condutos, de maneira a simular um canal radicular excessivamente alargado, com exceção do grupo controle positivo (GCP), em que foi cimentado um pino pré-fabricado (PPF) com calibre compatível ao diâmetro do conduto. Nos outros condutos alargados, técnicas restauradoras alternativas de preenchimento dos canais radiculares foram empregadas: GCN – grupo controle negativo (PPF de diâmetro inferior ao conduto), GPA – PPF + pinos acessórios, GAD – pino anatômico direto, GAI – pino anatômico indireto e GRR – reforço radicular com resina composta + PPF. Todos os pinos foram cimentados com o mesmo sistema adesivo e cimento resinoso. Após cimentação de coroas de resina indireta, os dentes foram submetidos à fadiga mecânica ($1,2 \times 10^6$ ciclos, 40 N) antes de realizar o teste de RU (n=8) e de RF (n=6). Os dados do experimento 1 e 2 foram analisados por ANOVA e teste pareado ($\alpha=0,05$). O experimento 1 mostrou que quanto menor a ECR melhor a adesão dos PFV, ou seja, maior a RU e menor a FG. O experimento 2 mostrou que o uso de pinos anatômicos diretos e indiretos mostrou o melhor desempenho nos testes de RU e RF, e deve ser primeira opção para cimentação de PFV em canais radiculares alargados. Portanto, foi evidenciado que a adaptação do pino ao conduto radicular influenciou significativamente na retenção dos mesmos; quanto mais justa, melhores resultados laboratoriais. Entretanto, na ausência desta condição ideal, o

uso de pinos anatômicos diretos e indiretos pode ser a primeira escolha do clínico para tratamento de canais excessivamente alargados.

Palavras-chave: cimentos resinosos, dentina radicular, *gap*, microscopia eletrônica de varredura, pinos de fibra, raízes enfraquecidas, resistência à fratura, resistência de união.

ABSTRACT

Gomes GM. **Influence of fiber posts adaptation and alternative restorative techniques for flared root canal filling.** [Tese - Doutorado em Odontologia – Área de Concentração Dentística Restauradora – Universidade Estadual de Ponta Grossa; 2013].

The objectives of this study were 1) to evaluate the effect of the influence of the resin cement thickness (RCT) on bond strength (BS) and gap formation (GF) between glass fiber post (FP) and root dentin and 2) to evaluate the BS and fracture resistance (FR) of restorative techniques for filling oversized root canals. In experiment 1, the roots of 24 mandibular premolars (n=8 per group) were endodontically treated. After one week, the post spaces were prepared depending on the post adaptation inside the root canal, simulating an ideal adaptation (IdAd), medium adaptation (MeAd) and inadequate adaptation (InAd). All posts were cemented with Excite[®] DSC and Variolink[®] II. After a week of cementation, the RCT and GF were measured with the Image Tool software version 3.0, and the BS by the push-out test. In experiment 2, the roots of 84 mandibular premolars were endodontically treated and, after a week, the conduits were prepared in order to simulate an oversized root canal, except for the positive control group (PC), which was cemented one prefabricated fiber post (PFP) with the diameter compatible with the conduit. In the other oversized root canals, alternative restorative techniques for filling root canals were tested: NC - negative control (PFP with a smaller diameter than of the root canal), PA - PFP + accessory posts, DAP – direct anatomical post, IAP – indirect anatomical post and RR – root reinforcement with composite resin. All posts were cemented with the same adhesive system and resin cement. After indirect composite crowns cementation, the teeth were submitted to mechanical fatigue (1.2×10^6 cycles, 40 N) before the push-out BS test (n=8) and the FR test (n=6). The data of experiments 1 and 2 were analyzed by ANOVA and paired test ($\alpha=0.05$). The experiment 1 showed that the smaller RCT resulted in better fiber post adhesion, that is, higher BS and lower GF. The experiment 2 showed that the use of direct and indirect anatomical posts resulted in the best performance both in BS and FR tests, and must be the first choice for FP cementation in flared roots with oversized root canals. Therefore, we concluded that the post adaptation to root canal affected significantly its retention. The better the post adaptation, the better the laboratory results. However, in the absence of this ideal condition, the use of direct and indirect anatomic posts should be the first choice for restoring flared root canals.

Keywords: resin cements, root dentin, gap, scanning electron microscopy, fiber posts, flared roots, fracture resistance, bond strength.

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LISTA DE ABREVIATURAS E SIGLAS

AdId	Adaptação ideal
AdIn	Adaptação inadequada
AdMe	Adaptação média
AP	Accessory posts
ANOVA	Análise de variância
BDH	Banco de dentes humanos
Bis-GMA	Bisfenol A glicidilmetacrilato
BS	Bond strength
CIV	Cimento de ionômero de vidro
cm	Centímetro
COEP	Comissão de Ética em Pesquisa
CT	Comprimento de trabalho
DAP	Direct anatomical post
ECR	Espessura de cimento resinoso
EDTA	Ácido etilenodiaminotetracético
FG	Formação de <i>gaps</i>
FP	Fiber post
FR	Fracture resistance
GAD	Grupo anatômico direto
GAI	Grupo anatômico indireto
GCN	Grupo controle negativo
GCP	Grupo controle positivo
GF	Gap formation
GPA	Grupo pinos acessórios
GPa	Gigapascal
GRR	Grupo reforço radicular com resina composta
h	Hora
HEMA	2- Hidroxietilmetacrilato
H ₃ PO ₄	Ácido fosfórico
IAP	Indirect anatomical post
IdAd	Ideal adaptation
InAd	Inadequate adaptation
ISO	Organização Internacional para Padronização (International Organization for Standardization)
Kg	Quilograma
kV	Quilovoltagem
JCE	Junção cimento-esmalte
mA	Miliamperagem
MPa	Megapascal
µm	Micrômetro
MeAd	Medium adaptation
MEV	Microscopia Eletrônica de Varredura
min	Minuto
mm	Milímetro

mm ²	Milímetros quadrado
mm/min	Milímetro por minuto
mL	Mililitros
n	Número amostral
N	Newton
NaOCl	Hipoclorito de sódio
NC	Negative control
PC	Positive control
PFP	Prefabricated fiber post
PFV	Pino de fibra de vidro
PPF	Pino pré-fabricado
PVC	Policloreto de vinila
R	Raio coronário
r	Raio apical
RCT	Resin cement thickness
RF	Resistência à fratura
rpm	Rotações por minuto
RR	Root reinforcement with composite resin
RU	Resistência de união
s	Segundo
S _L	Área adesiva
TEGDMA	Trietilenoglicol dimetacrilato
UEPG	Universidade Estadual de Ponta Grossa
vs	Versus

LISTA DE SÍMBOLOS

#	Número
=	Igual
±	Mais ou menos
%	Porcentagem
&	E
<	Menor
≤	Menor ou igual
>	Maior
≥	Maior ou igual
X	Aumento de lente óptico
α	Alfa (nível de significância)
°C	Grau Célsius
n°	Número
p	Significância estatística
®	Registrado
™	Marca registrada
π	Constante 3,1416

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1 INTRODUÇÃO

Dentes com grande perda de estrutura dentária comumente necessitam de tratamento endodôntico, o que leva, na maioria das vezes, a utilização de retenções intrarradiculares e núcleos de preenchimento para reter a restauração final (Zicari et al.¹ 2008). Atualmente, para a restauração desses dentes, tem-se optado pelo uso de materiais com módulo de elasticidade similar à dentina (18 GPa), sendo que os cimentos resinosos (6,8 – 10,8 GPa), algumas resinas compostas (5,7 – 25 GPa) e os pinos de fibras de vidro (16 – 40 GPa) possuem essa característica (Braem et al.² 1986, Peutzfeldt, Asmussen³ 1992, Asmussen et al.⁴ 1999, Lassila et al.⁵ 2004, Fares et al.⁶ 2005). Isto resulta em biomimetismo (Tay, Pashley⁷ 2007), e acredita-se que esse fenômeno favorece uma distribuição de tensões mais uniforme à estrutura radicular (Qualtrough, Manocci⁸ 2003, Hayashi, Ebisu⁹ 2008, Schmitter et al.¹⁰ 2010), reduzindo assim o risco de fraturas radiculares (Coelho et al.¹¹ 2009, Torabi et al.¹² 2009).

Esses pinos reforçados por fibras devem ser cimentados adesivamente ao canal radicular. Dessa maneira, sua retenção é dependente de uma união efetiva entre sistema adesivo, cimento resinoso e o substrato dentinário. Para esta finalidade, vários agentes cimentantes estão disponíveis no mercado. Entretanto, como este procedimento é comprometido pela dificuldade da irradiação direta da luz em regiões profundas do canal radicular, é prudente empregar cimentos resinosos de ativação química ou dual (Foxton et al.¹³ 2003).

A despeito das vantagens da utilização destes pinos de fibras de vidro, estes são pré-fabricados e, portanto, nem sempre se adaptam intimamente ao canal radicular. Há canais radiculares que exibem amplo alargamento devido ao extenso comprometimento por lesões cariosas, restauração prévia com pinos e núcleos de diâmetro excessivo, super-instrumentação endodôntica, alargamento excessivo da entrada do canal durante endodontia, rizólise incompleta devido a impactos traumáticos, reabsorção interna, anomalias de desenvolvimento ou mesmo canais radiculares com formato oval (Morgano et al.¹⁴ 2004, Baba et al.¹⁵ 2009). Nestes casos, a estrutura radicular remanescente apresenta-se delgada, o que

provavelmente as tornam enfraquecidas mesmo quando um pino de fibra de vidro é cimentado (Zogheib et al.¹⁶ 2008). Situações clínicas desta natureza dificultam o procedimento restaurador e o prognóstico clínico da restauração desses dentes em longo prazo ainda é desconhecido.

Dessa maneira, a restauração de raízes enfraquecidas representa um desafio para os cirurgiões-dentistas. Núcleos metálicos fundidos podem ser confeccionados de forma a se adaptarem bem à estrutura radicular remanescente; porém, por outro lado, podem produzir efeito de cunha sob ação de forças mastigatórias. Pinos pré-fabricados adaptam-se imprecisamente, obrigando o operador a utilizar quantidades excessivas de cimento para substituir a estrutura perdida (Hornbrook et al.¹⁷ 1995). Neste último caso, a deformação resultante da contração de polimerização, quando se emprega camadas espessas de cimento, pode gerar maior tensão de polimerização nas interfaces cimento/dentina e cimento/pino, induzindo descontinuidades estruturais, tais como bolhas, espaços ou fendas, que, por sua vez, reduzem a retenção dos mesmos aos canais radiculares (Grandini et al.¹⁸ 2005).

Porém, poucos estudos na literatura avaliaram a influência da adaptação do pino e conseqüentemente da espessura do cimento resinoso no desempenho de pinos de fibra de vidro cimentados no canal radicular (Perez et al.¹⁹ 2006, D'Arcangelo et al.²⁰ 2007). Além disto, os resultados destes estudos ainda são controversos. Embora a espessura do filme de cimento não ter produzido alterações significativas nos valores de resistência de união ao teste de *push-out* (Perez et al.¹⁹ 2006), um outro estudo mostrou que camadas espessas de cimento podem afetar a resistência ao teste de *pull-out* (D'Arcangelo et al.²⁰ 2007). Apesar da espessura ideal de cimento resinoso para cimentação de pinos de fibra de vidro ainda ser desconhecida, estudos clínicos prospectivos e retrospectivos indicam que uma maior frequência de descolamento ocorre quando a espessura do cimento é maior (Fredriksson et al.²¹ 1998, Ferrari et al.²² 2000).

Dessa forma, algumas alternativas para reduzir a espessura de cimento resinoso durante a cimentação de pinos de fibra têm sido sugeridas na literatura para tratamento de canais radiculares extremamente alargados, já que a escolha de

pinos pré-fabricados como opção de retentor intrarradicular pode não proporcionar um preenchimento ideal dos condutos radiculares.

Uma proposta é reduzir a largura do canal radicular promovendo o seu reforço com resina composta (Lui²³ 1994, Saupe et al.²⁴ 1996, Zogheib et al.¹⁶ 2008). Essa técnica aumenta a espessura interna de dentina nas paredes radiculares, reduzindo a espessura de cimento resinoso, o que, conseqüentemente, aumenta a resistência à fratura desses dentes (Zogheib et al.¹⁶ 2008). Entretanto, a fotoativação da resina composta na região apical dos canais radiculares é dificultada, o que pode comprometer essa técnica (Lui²⁵ 1994, Roberts et al.²⁶ 2004, Faria e Silva et al.²⁷ 2007).

Adicionalmente, foi sugerida a técnica de individualização do pino às paredes internas do conduto radicular por meio de seu reembasamento direto com uma camada de resina composta fotoativada. Esta técnica é comumente conhecida como pino anatômico (Grandini et al.²⁸ 2003). Da mesma forma que a técnica anterior, uma íntima adaptação do pino ao conduto seria obtida, reduzindo a espessura de cimento e melhorando as propriedades retentivas dos pinos anatômicos (Grandini et al.²⁸ 2003, Clavijo et al.²⁹ 2009, Faria e Silva et al.³⁰ 2009, Macedo et al.³¹ 2010).

A despeito das vantagens advindas da individualização do pino, uma nova interface (pino de fibra de vidro e resina composta) é produzida e pode estar sujeita a falhas. Com a finalidade de evitar essa nova interface, Clavijo et al.²⁹ (2009), sugeriram a utilização desses pinos anatômicos, porém confeccionados de maneira indireta. Nestes casos, moldagens dos canais radiculares são realizadas e pinos padrões em resina acrílica são confeccionados no modelo de gesso. Sobre estes padrões são realizadas réplicas dos canais, a partir das mesmas são confeccionados pinos anatômicos indiretos em fibras de vidro, as quais são impregnadas com resina composta laboratorial para reforço. Isto permite uma perfeita adaptação do pino ao canal radicular.

Outra proposta recente é a inserção de pinos acessórios em torno do pino de fibra de vidro principal (Martelli et al.³² 2008, Clavijo et al.²⁹ 2009). Nesses casos,

esses pinos acessórios são utilizados para proporcionar um preenchimento uniforme do conduto radicular, favorecendo a distribuição do estresse gerado durante a função mastigatória (Martelli et al.³² 2008).

Entretanto, pesquisas demonstrando a eficácia dessas técnicas alternativas apresentam resultados controversos e são escassas na literatura, além de empregarem diferentes metodologias dificultando a comparação das mesmas (Marchi et al.³³ 2003, Gonçalves et al.³⁴ 2006, Zogheib et al.¹⁶ 2008, Clavijo et al.²⁹ 2009, Silva et al.³⁵ 2011, Zogheib et al.³⁶ 2011). Adicionalmente, a maioria dos estudos disponíveis não mimetiza as reais condições clínicas aos que os dentes estão sujeitos na cavidade oral (Marchi et al.³³ 2003, Gonçalves et al.³⁴ 2006, Martelli et al.³² 2008, Clavijo et al.²⁹ 2009, Torabi et al.¹² 2009, Zogheib et al.³⁶ 2011), como, por exemplo, as raízes não são restauradas com coroas totais e não são submetidas à fadiga mecânica, o que pode limitar os seus resultados.

Dessa maneira, essa tese teve como objetivo avaliar o efeito da influência da espessura de cimento resinoso na resistência de união e na formação de *gaps* entre pino de fibra de vidro e dentina radicular; assim como avaliar técnicas restauradoras alternativas de preenchimento de canais radiculares excessivamente alargados, por meio de testes de resistência de união e resistência à fratura após terem sido submetidos à fadiga mecânica.

2 PROPOSIÇÃO

2.1 Proposição geral

2.1.1 Avaliar a influência da **espessura de cimento resinoso** na resistência de união entre pino de fibra de vidro e dentina radicular, bem como na formação de *gaps* na interface adesiva cimento/dentina/pino.

2.1.2 Avaliar a resistência de união entre pino de fibra de vidro e dentina radicular e a resistência à fratura de dentes com condutos alargados aplicando diferentes **modalidades restauradoras**.

2.2 Proposição específica

2.2.1 Avaliar, por meio do teste de *push-out*, a influência de três espessuras (pequena, média e grande) de cimento resinoso na **resistência de união** entre pino de fibra e dentina radicular mediada por um cimento resinoso convencional.

2.2.2 Avaliar a influência de três espessuras (pequena, média e grande) de cimento resinoso na **formação de *gaps*** na interface adesiva cimento/dentina/pino.

2.2.3 Avaliar, por meio do teste de *push-out*, a **resistência de união** entre pino de fibra e dentina radicular mediada por um cimento resinoso convencional em dentes tratados endodonticamente com condutos alargados e restaurados com pinos acessórios, pinos anatômicos diretos, pinos anatômicos indiretos e com condutos alargados reforçados com resina composta, após terem sido submetidos à **fadiga mecânica**.

2.2.4 Avaliar a **resistência à fratura** de dentes tratados endodonticamente com condutos alargados e restaurados com pinos acessórios, pinos anatômicos diretos, pinos anatômicos indiretos e com condutos alargados reforçados com resina composta quando submetidos à carga compressiva constante, após terem sido submetidos à **fadiga mecânica**, bem como avaliar seus **padrões de fratura**.

3 MATERIAL E MÉTODOS

A realização de toda a parte experimental dessa tese foi aprovada por meio do parecer nº 25/2011 pela Comissão de Ética em Pesquisa da Universidade Estadual de Ponta Grossa – COEP – UEPG, tendo sido protocolado sob o número 18741/10. Para realização deste estudo foram selecionados 108 pré-molares inferiores permanentes, obtidos por meio do Banco de Dentes Humanos (BDH) da UEPG (Anexo A).

A fase experimental desse trabalho foi dividida em dois experimentos: 1 – Efeito da adaptação do pino de fibra aos condutos radiculares e 2 – Efeito de diferentes modalidades restauradoras para preenchimento de canais radiculares excessivamente alargados.

3.1 EXPERIMENTO 1 – Efeito da adaptação do pino de fibra aos condutos radiculares

3.1.1 Seleção dos dentes

Para esse experimento foram selecionados 24 pré-molares unirradiculares inferiores permanentes, obtidos no BDH da UEPG. Previamente ao estudo, os dentes foram limpos com curetas periodontais (Duflex, SS White, Rio de Janeiro, RJ, Brasil) e armazenados em água destilada à 4°C até 6 meses após extração (ISO/TS 11405)³⁷. Os dentes selecionados para o presente estudo obedeceram aos seguintes critérios de inclusão: ausência de cárie, de dilacerações radiculares, de tratamento endodôntico prévio, de ápice incompleto, além de um comprimento radicular medido da junção cimento-esmalte (JCE) de pelo menos 14 mm (Figura 1A).

3.1.2 Preparo dos dentes

Os dentes foram seccionados perpendicularmente em relação ao seu longo eixo, imediatamente abaixo a junção cimento-esmalte, com disco de diamante montado em uma máquina de corte ISOMET 1000 (Buehler, Lake Bluff, IL, EUA) a uma velocidade de 300 rotações por minuto (rpm) sob refrigeração com água constante, de modo a criar um acesso ao canal radicular. O comprimento das raízes foi então aferido com uma régua milimetrada (Figuras 1B, 2A).



Figura 1 – **A** – Dente selecionado para o estudo; **B** - Mensuração do comprimento da raiz após corte da coroa dentária.

3.1.2.1 Tratamento endodôntico

O esvaziamento dos condutos foi realizado com limas tipo K (Dentsply Maillefer, Ballaigues, Suíça) # 10, associando solução de hipoclorito de sódio (NaOCl) 1% para suspensão da matéria orgânica. A instrumentação dos canais foi realizada com NaOCl 1%, sendo o preparo apical realizado até lima # 40; e, em

seguida, até lima # 55 pela técnica de escalonamento (Figura 2B), padronizando-se assim o diâmetro dos condutos. Após esse procedimento, foi efetuada a neutralização dos canais com soro fisiológico, irrigação e aspiração final com solução de ácido etilenodiaminotetraacético (EDTA) 17% (Fórmula e Ação, São Paulo, SP, Brasil) durante 3 min (Figura 2C) seguidos de irrigação final com soro fisiológico. Terminada a instrumentação, os canais foram secos com pontas de papel absorvente (Dentsply Maillefer, Petrópolis, RJ, Brasil) (Figura 2D) e obturados pela técnica de condensação vertical, utilizando cones de guta-percha aquecidos (Tanari, Manacapuru, AM, Brasil) e cimento obturador à base de resina epóxica (AH Plus, Dentsply Indústria e Comércio Ltda, Petrópolis, RJ, Brasil), o qual foi manipulado de acordo com as instruções do fabricante (Figuras 2 E-F). Em seguida, foi realizada a desobturação imediata dos canais, respeitando os 4 mm apicais de material obturador, e um vedamento da entrada dos canais radiculares com cimento de ionômero de vidro (CIV) convencional (Vitro Fil, DFL, Rio de Janeiro, RJ, Brasil).

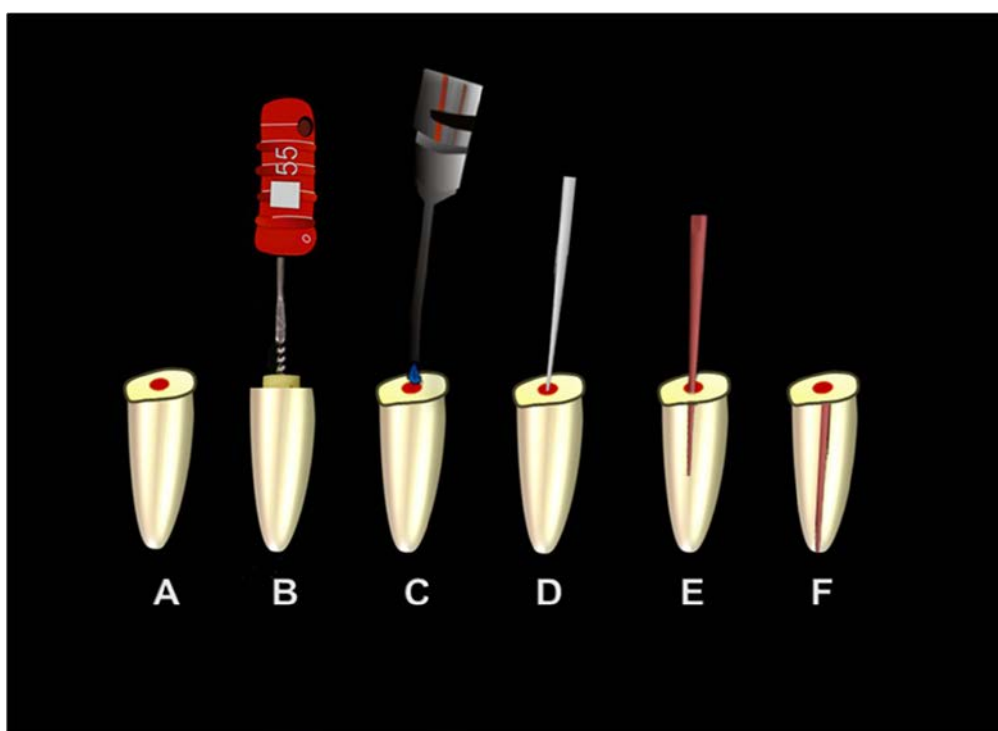


Figura 2 – Desenho esquemático do tratamento endodôntico. **A** – Raiz após o corte da coroa dentária; **B** – Preparo do canal (instrumentação até a lima # 55); **C** – Irrigação com soro fisiológico e EDTA 17%; **D** – Secagem com ponta de papel absorvente; **E** – Prova do cone de guta-percha; **F** – Obturação do canal.

3.1.3 Preparos radiculares e Grupos experimentais

Após uma semana de armazenamento em umidade relativa com água destilada a $37^{\circ}\text{C} \pm 1^{\circ}\text{C}$ os condutos radiculares foram preparados, sendo que as raízes foram aleatoriamente divididas em três grupos (n=8), em função da adaptação do pino no conduto radicular: Adaptação ideal (pequena espessura de cimento resinoso [ECR]), adaptação média (média ECR) e adaptação inadequada (grande ECR). Para esse propósito, os condutos foram preparados com brocas de diferentes diâmetros. Em seguida, um fluxograma do delineamento metodológico desse experimento (Figura 3).

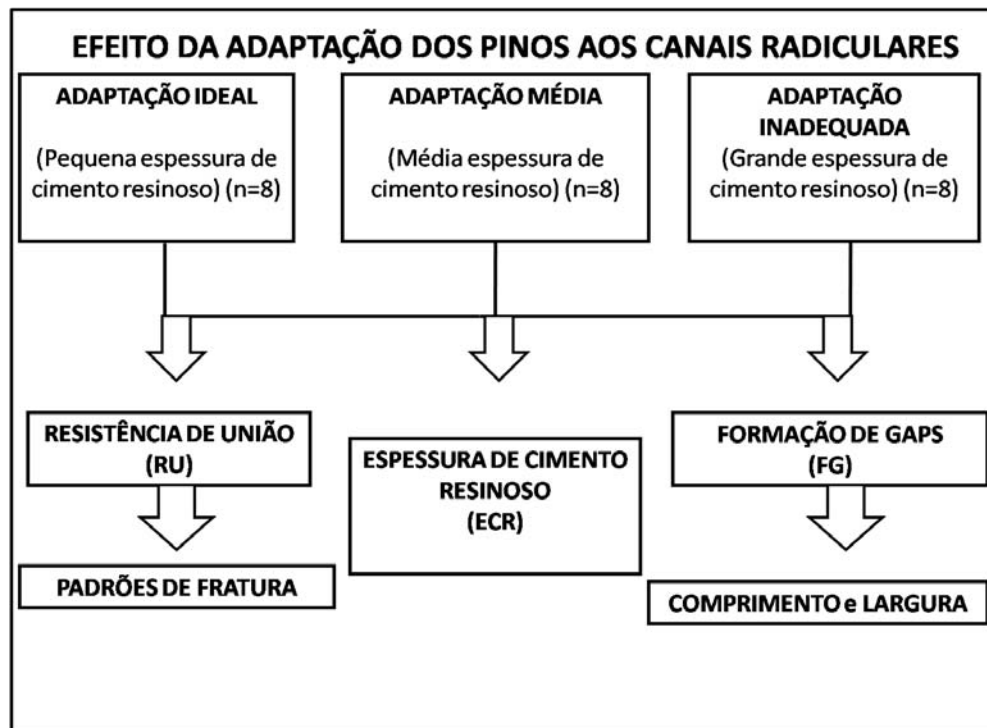


Figura 3 – Fluxograma dos grupos experimentais do experimento 1.

Nos grupos adaptação ideal e adaptação média, os condutos radiculares foram preparados com brocas de baixa rotação fornecidas pelo fabricante do pino (Whitepost DC, FGM, Joinvile, SC, Brasil). No grupo que simula uma adaptação ideal, o preparo dos condutos foi realizado com a broca correspondente ao pino n°

0.5, a qual apresenta o mesmo diâmetro coronário do pino (1,4 mm) (Figura 4A); e no grupo que simula uma adaptação média, os condutos foram preparados com uma broca correspondente ao pino nº 3, com 2,0 mm de diâmetro coronário (Figura 4B). No grupo adaptação inadequada, o preparo foi realizado com uma ponta diamantada tronco-cônica nº 4137 (KG Sorensen, São Paulo, SP, Brasil) de 2,6 mm de diâmetro coronário (Figura 4C); adaptada em baixa rotação, seguido pela mesma broca utilizada no grupo adaptação ideal, com a finalidade de padronizar a *smear layer* obtida na dentina radicular.



Figura 4 – Brocas utilizadas para preparos dos condutos radiculares. A – Broca correspondente ao pino nº 0.5 (Whitepost DC nº 0.5); B - Broca correspondente ao pino nº 3 (Whitepost DC nº 3); C - Ponta diamantada tronco-cônica nº 4137.

Em todos os grupos o mesmo pino de fibra de vidro (Whitepost DC nº 0.5, FGM, Joinville, SC, Brasil), com diâmetro coronário de 1,4 mm foi cimentado. O comprimento de trabalho foi de 10 mm para todos os dentes, respeitando o limite

apical do material obturador de 4 mm. A cada quatro preparos a broca de preparos dos canais foi substituída.

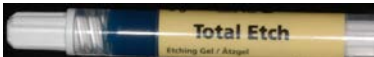
Após o preparo mecânico dos canais radiculares (Figura 5A), os canais foram irrigados com 10 mL de água destilada (Figura 5B) e secos com jato de ar por 3 s e 2 pontas de papel absorvente (Figura 5C). Foram realizadas tomadas radiográficas periapicais dos canais radiculares (películas radiográficas Kodak Ultra, Eastman Kodak, NY, EUA) para verificação da completa ausência de material obturador além dos 4 mm apicais dos canais.

3.1.4 Cimentação dos pinos

Antes de iniciarem os procedimentos de cimentação todos os pinos (N=24) foram seccionados transversalmente, por meio de um disco diamantado de dupla face (KG Sorensen, São Paulo, SP, Brasil) sob refrigeração em água constante, resultando em 13 mm de comprimento, de uma maneira que 10 mm do pino atingisse o comprimento de trabalho radicular, e os outros 3 mm servisse como um guia para a distância do aparelho fotoativador durante os procedimentos de fotoativação dos espécimes. Desta maneira, além de ser padronizada a distância da fotoativação, foi possível verificar o completo assentamento dos pinos nos condutos preparados (10 mm). Ainda previamente ao procedimento de cimentação, os pinos de fibra de vidro foram limpos com álcool 70% durante 5 s conforme especificação do fabricante.

A composição detalhada dos materiais utilizados para o procedimento de cimentação está especificada no Quadro 1.

Quadro 1 – Materiais utilizados para cimentação dos pinos, fabricante, composição e lote.

Figura	Material/ Fabricante	Composição*	Lote
	Total-Etch / Ivoclar Vivadent	Ácido fosfórico (37% em peso, em água), agente de espessamento e pigmentos.	P56449
	Adesivo Excite® DSC / Ivoclar Vivadent	Excite® DSC contém HEMA, dimetacrilatos, acrilato do ácido fosfônico, dióxido de silício altamente disperso, iniciadores e estabilizadores em uma solução alcoólica. O pincel Excite® DSC é revestido com iniciadores.	N01061
	Cimento resinoso Variolink® II / Ivoclar Vivadent	A matriz de monômero é composta de Bis-GMA, dimetacrilato de uretano e trietilenoglicoldimetacrilato. A carga inorgânica é constituída por vidro de bário e alumínio e óxidos mistos esferoidais. Além disso, contém catalisadores, estabilizadores e pigmentos.	N44255

Nota: * Composição de acordo com o fabricante

Todos os pinos de fibra de vidro foram cimentados com o sistema adesivo convencional dual Excite® DSC (Ivoclar-Vivadent, Schann, Liechtenstein) e o cimento resinoso dual Variolink® II (Ivoclar-Vivadent, Schann, Liechtenstein). O processo de cimentação dos pinos (Figura 5D) foi realizado seguindo as recomendações do fabricante (Quadro 2 e Figura 6 A-H).

Quadro 2 – Modo de aplicação dos materiais utilizados (sistema adesivo e cimento resinoso).

Sistema Adesivo/ Fabricante	Modo de Aplicação	Cimento Resinoso/ Fabricante	Modo de Aplicação
Excite® DSC / Ivoclar Vivadent	1- Aplicar gel de ácido fosfórico 37% (Total Etch, Ivoclar Vivadent) no interior do canal endodôntico por 15 s, lavar abundantemente durante 15 s, e remover excessos de água com 1 jato de ar e 1 ponta de papel absorvente. Não desidratar a dentina. 2- Aplicar duas camadas do sistema adesivo convencional dual (Excite® DSC) no interior do canal endodôntico durante 10 s, remover excesso com 1 fraco jato de ar e 1 ponta de papel absorvente.	Variolink® II / Ivoclar Vivadent	Sobre o bloco de mistura manipular as pastas base e catalisadora em mesma proporção durante 10 s, aplicar o cimento ao redor e no interior do canal endodôntico com auxílio de uma seringa específica, assentar o pino no interior do conduto, remover o excesso de cimento e fotoativar por 40 s através da superfície oclusal.

A fotoativação foi realizada com um aparelho fotopolimerizador com luz emitida por diodo (L.E.Demetron I, Kerr Corporation, Orange, CA, EUA), com uma intensidade de luz de 800 mW/cm². Durante a fotoativação, a ponteira do aparelho fotopolimerizador foi posicionada a 3 mm do término coronário do pino (Figura 5E). A intensidade de luz foi monitorada periodicamente por meio de um radiômetro (Curing radiometer Model 100, Demetron Research Corp., Danburg, CT, EUA). Após os procedimentos de cimentação (Figura 5F), os pinos expostos foram cobertos com CIV convencional (Vitro Fil, DFL, Rio de Janeiro, RJ, Brasil), e todas as raízes foram armazenadas em água destilada a 37°C ± 1°C durante uma semana.

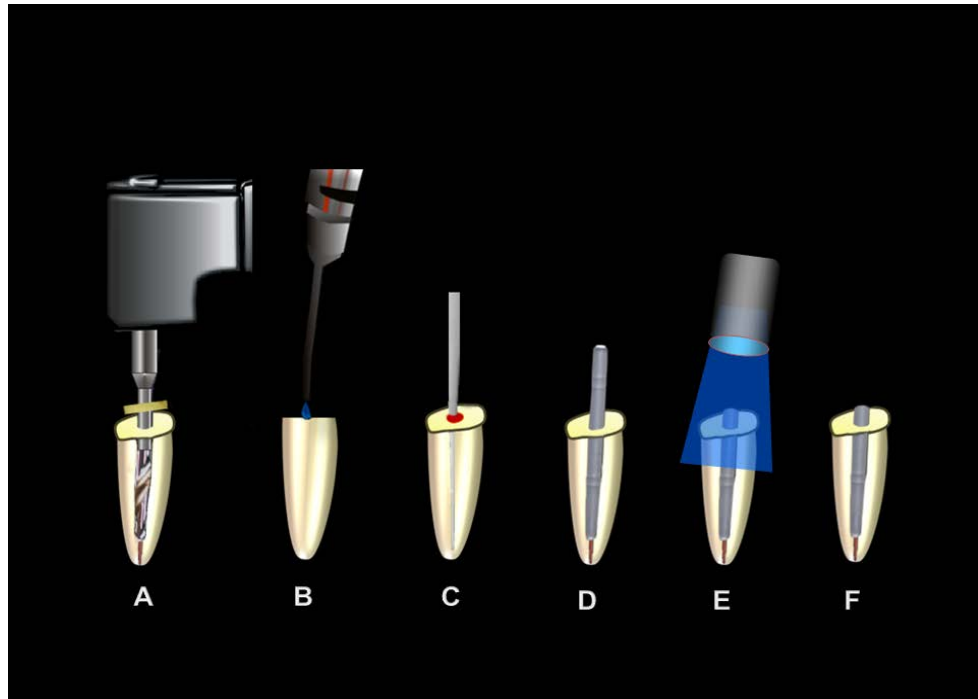


Figura 5 – Desenho esquemático da cimentação dos pinos. **A** – Preparo mecânico do canal radicular; **B** – Limpeza do canal radicular; **C** – Secagem com ponta de papel absorvente; **D** – Cimentação do pino de fibra de vidro (Whitepost DC nº 0.5); **E** – Fotoativação e **F** – Aspecto final da cimentação.

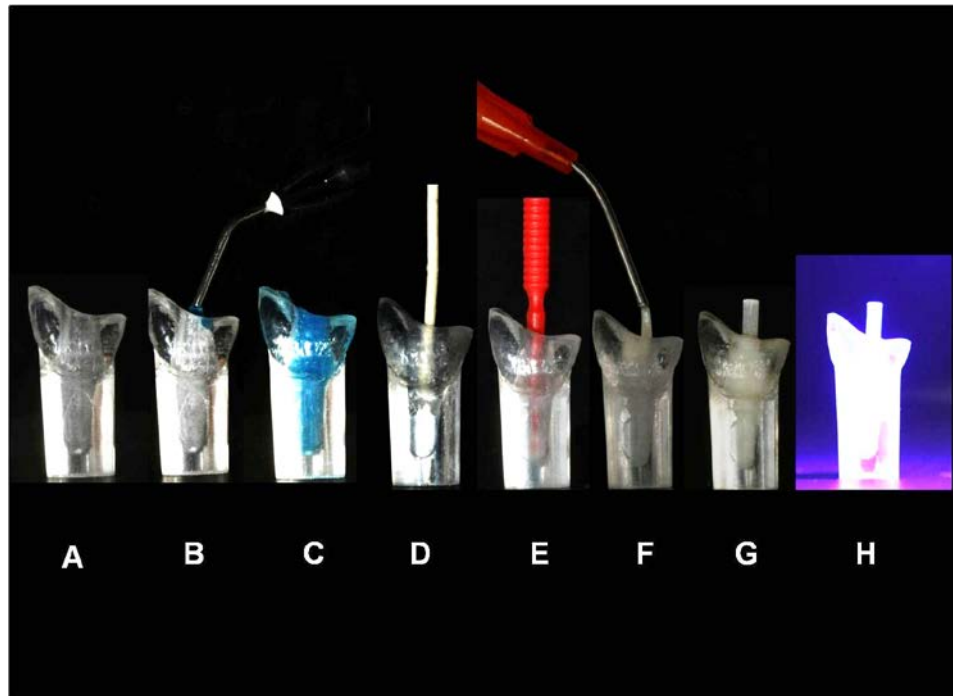


Figura 6 – Cimentação dos pinos de fibra de vidro. **A** – Canal radicular preparado para recebimento do pino; **B, C** – Condicionamento do canal com ácido fosfórico 37%; **D** – Secagem com ponta de papel absorvente; **E** – Aplicação do sistema adesivo no interior do canal; **F** – Aplicação do cimento resinoso no interior do canal; **G** – Pino posicionado no interior do conduto; **H** – Fotoativação do cimento resinoso.

3.1.5 Preparo dos espécimes

Decorrida uma semana da cimentação, as raízes foram embutidas em tubos de PVC (policloreto de vinila) com resina acrílica Duralay (Reliance, Dental Mfg. Co., Worth, IL, EUA) (Figuras 7 A-B, 12A). Em seguida, os espécimes foram seccionados perpendicularmente em relação ao seu longo eixo com um disco de diamante montado em uma máquina de corte ISOMET 1000 (Buehler, Lake Bluff, IL, EUA) sob refrigeração com água constante (Figuras 7 C-F). Seis fatias com espessura média de $1 \pm 0,1$ mm (Figuras 8A,12B) foram obtidas, as quais foram verificadas por meio de um paquímetro digital de precisão de 0,01 mm (Mitutoyo Digimatic Caliper, Tóquio, Japão) (Figura 8B). Dessas fatias obtidas, duas representaram o terço coronário, duas o terço médio e duas o terço apical do canal radicular.

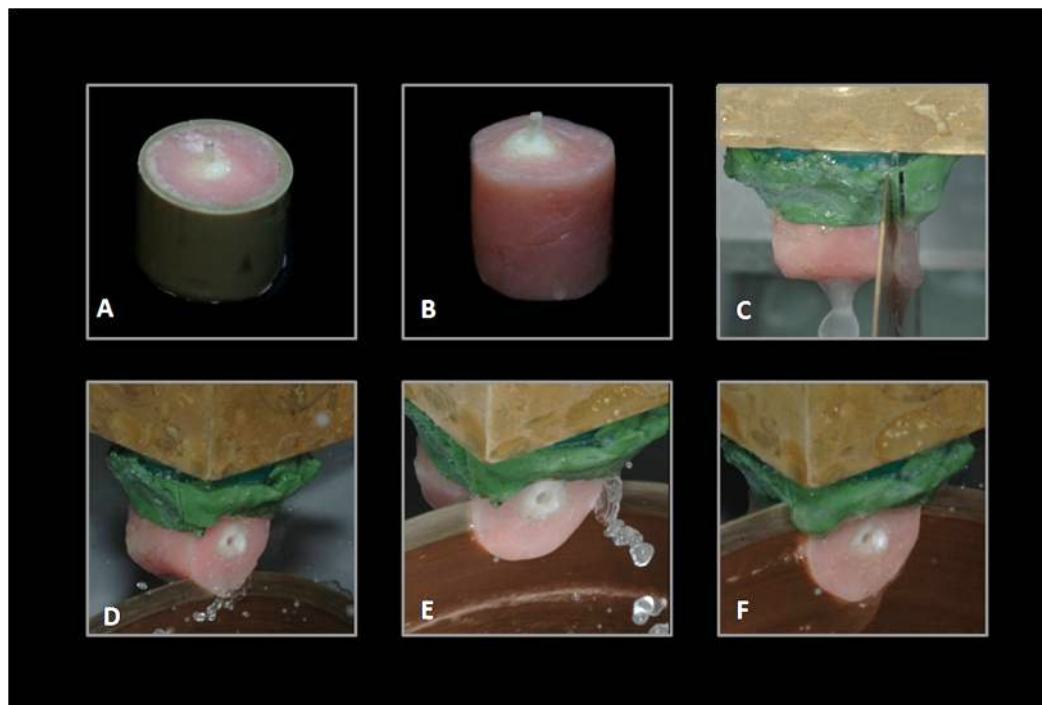


Figura 7 – Preparo dos espécimes. **A e B** – Raiz embutida com pino cimentado; **C** – Vista frontal do seccionamento da raiz, **D, E e F** – Vista lateral do seccionamento da raiz.

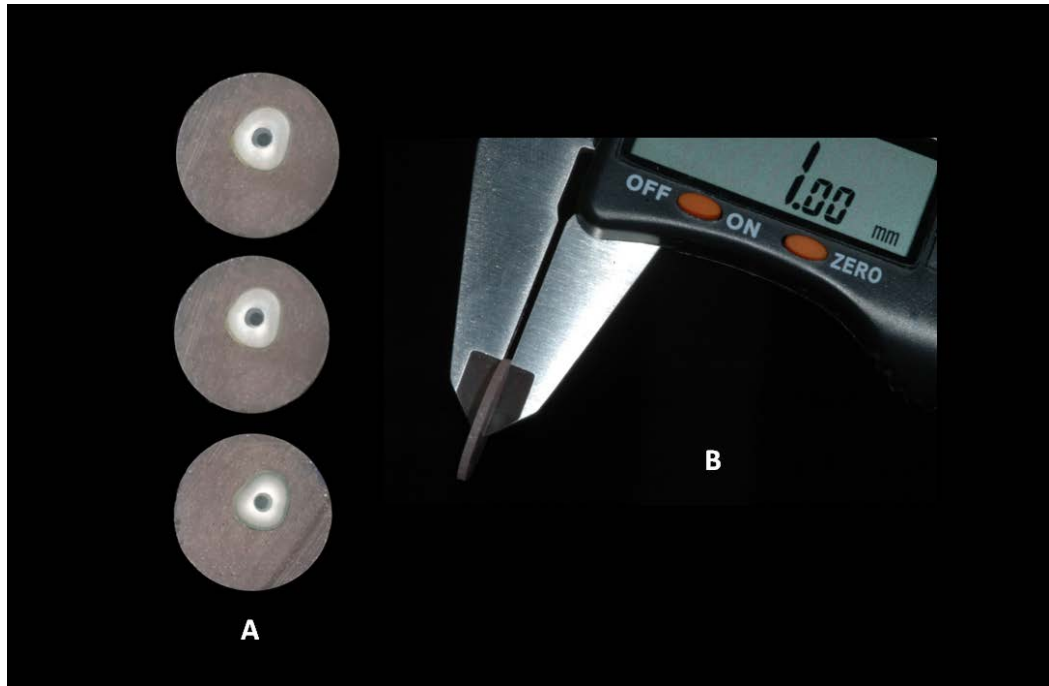


Figura 8 – **A** - Fatias obtidas após o corte da raiz; **B** – Mensuração da espessura das fatias por meio de paquímetro digital.

3.1.6 Avaliação da espessura de cimento resinoso

Todas as fatias foram fotografadas com um microscópio óptico (Olympus, model BX 51, Olympus, Tokyo, Japão) com ampliação de 100 X, com a finalidade de mensurar a espessura de cimento resinoso, a qual foi mensurada com o auxílio do *Software Image Tool* versão 3.0 (Departamento de Diagnóstico, Universidade do Texas, Centro de Ciência da Saúde, San Antonio, Texas, EUA). A espessura de cimento resinoso (μm) média para cada fatia foi obtida por meio de 4 medidas realizadas nos 4 lados opostos de cada amostra. Uma linha virtual tangente foi traçada, e as medidas foram realizadas perpendiculares a essa linha (Figura 9).

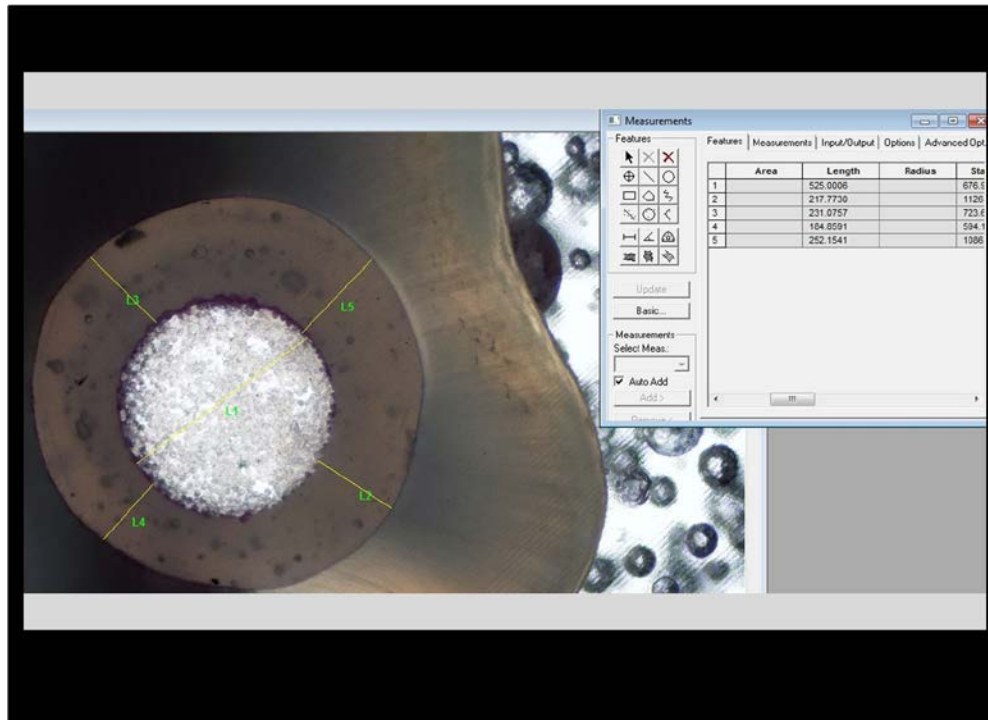


Figura 9 – Mensuração da espessura de cimento resinoso utilizando o *Software Image Tool*.

3.1.7 Avaliação da formação de *gaps* na interface adesiva cimento - dentina radicular

Três fatias de cada dente foram selecionadas para avaliação da formação de *gaps*, sendo uma fatia correspondente ao terço cervical, uma ao terço médio e a última ao terço apical do canal radicular. Para cada fatia selecionada foram realizadas impressões de silicone por adição (Virtual[®], Ivoclar Vivadent, Schaan, Liechtenstein) das superfícies, e réplicas positivas foram então obtidas usando resina epóxica (Alpha Resiqualy, Curitiba, PR, Brasil), com a finalidade de serem observadas em Microscopia Eletrônica de Varredura (MEV) (SSX-550, Shimadzu, Tóquio, Japão).

Cada réplica foi posicionada sobre um suporte metálico e foi submetida à incorporação da liga áurica com 200 Å de ouro-paládio em um metalizador (Polaron SC7620, Quorum Technologies Ltd., East Sussex, UK) durante 5 min numa corrente de 10 mA. Em seguida, cada amostra foi observada em MEV em diferentes ampliações (30 X a 1200 X), utilizando 15 kV, com a finalidade de se avaliar a

formação de *gaps* na interface adesiva cimento resinoso - dentina radicular (Figura 10).

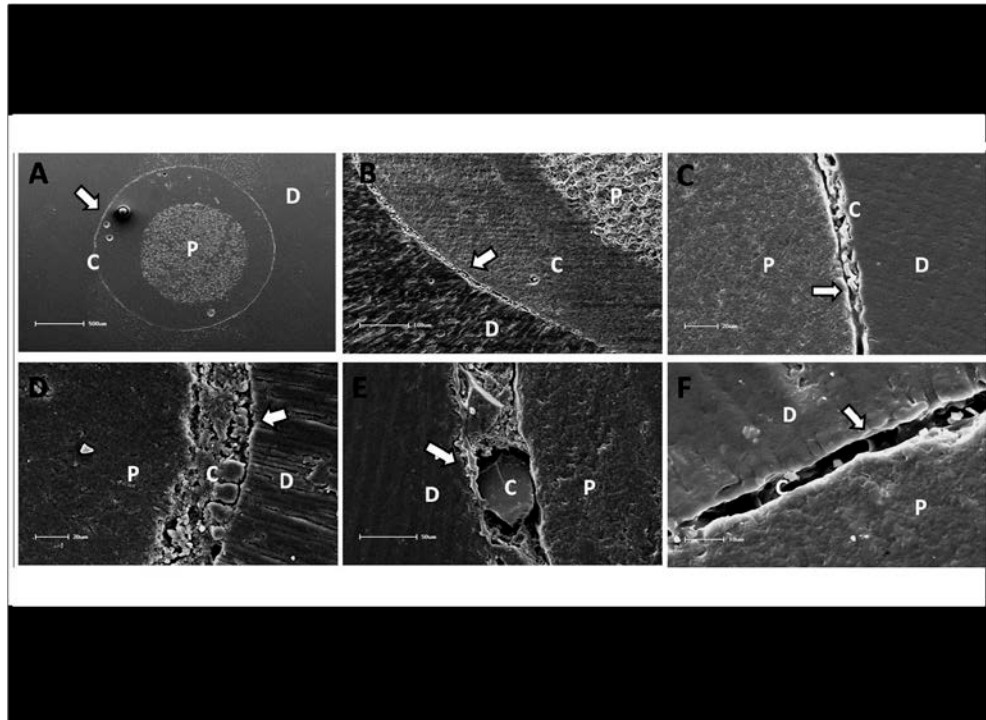


Figura 10 - Réplicas em resina epóxica de cada amostra foram observadas em MEV, e a largura média e o comprimento médio dos *gaps* formados na interface pino-cimento-dentina foram mensurados utilizando o *Software Image Tool 3.0*. *Gaps* podem ser observados em diferentes magnificações (**A** – 30 X, **B** – 150 X, **C** – 350 X, **D** – 500 X, **E** – 600 X e **F** – 1200 X). D- dentina, P – pino, C – cimento, Flecha – *gap*.

As mensurações dos *gaps* (largura e comprimento) existentes nas interfaces adesivas foram realizadas com o auxílio do *Software Image Tool* versão 3.0 (Department of Dental Science Diagnostic, Universidade do Texas, Centro de Ciência da Saúde, San Antonio, Texas, EUA). Em cada fatia, o *gap* mais largo na interface cimento - dentina foi mensurado (μm). Em seguida, foi calculado o perímetro total da interface adesiva (cimento - dentina) em μm em pequena ampliação (40 X) no MEV, e foi calculada a porcentagem dessa interface que apresentava *gaps*, sendo os valores (%) expressos como uma porcentagem da descontinuidade da interface adesiva.

Ambas as medições (comprimento e largura dos *gaps*) foram realizadas por dois avaliadores previamente calibrados; e se qualquer divergência ocorresse durante a avaliação, um consenso deveria ser obtido. Para fins estatísticos, foi realizada uma média dos valores obtidos a partir das três fatias de cada dente para ambas as medidas.

Cada fatia também foi classificada como apresentando bolhas/espacos vazios (vácuos) dentro da camada de cimento resinoso. Este procedimento também foi realizado por dois avaliadores, os quais precisavam chegar a um consenso em caso de divergências.

3.1.8 Avaliação da resistência de união pelo teste de *push-out*

Previamente ao ensaio de *push-out* todas as fatias foram fotografadas nos dois lados, com aumento de 40 X, em microscópio óptico (Olympus, modelo BX 51, Olympus, Tóquio, Japão) para aferição dos diâmetros coronário e apical dos pinos (Figura 11A), bem como dos diâmetros da área interna do canal radicular (Figura 11B), com o objetivo de calcular a área adesiva para cada fatia obtida. Esta mensuração foi realizada com o auxílio do *Software Image Tool* versão 3.0 (Department of Dental Science Diagnostic, Universidade do Texas, Centro de Ciência da Saúde, San Antonio, Texas, EUA).

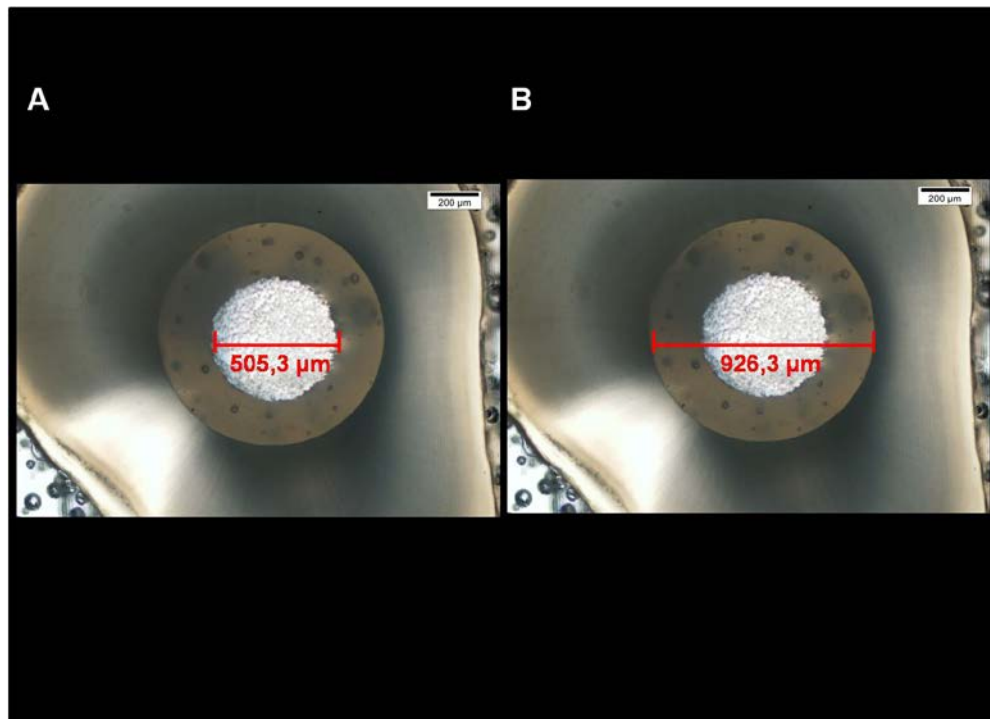


Figura 11 – **A** - Mensuração do diâmetro coronário do pino medido no *Software Image Tool*; **B** - Mensuração do diâmetro coronário da área interna do canal radicular medido no *Software Image Tool*.

Cada corpo-de-prova foi então submetido ao teste de *push-out* (Figuras 12 C-D, 13 A-E), sendo posicionado sobre um dispositivo metálico com uma pequena abertura central (Figura 13A), com sua porção mais coronária posicionada para baixo, de tal forma que a carga exercesse uma força compressiva constante (Figura 13 B-E) no sentido ápico-coronal até promover o deslocamento do pino intrarradicular. Foram elaboradas pontas metálicas cilíndricas (atuadores) correspondentes ao diâmetro do pino que estava sendo ensaiado. O atuador foi posicionado no centro de cada fragmento de pino, de modo que a ponta aplicadora da carga tocasse somente a área dos pinos, sem estressar as paredes laterais dos canais radiculares (Figura 13E). O conjunto foi ensaiado em uma máquina de ensaio universal (AG-I, Shimadzu Autograph) com uma célula de carga de 50 Kgf a uma velocidade de 0,5 mm/min até o deslocamento do pino.

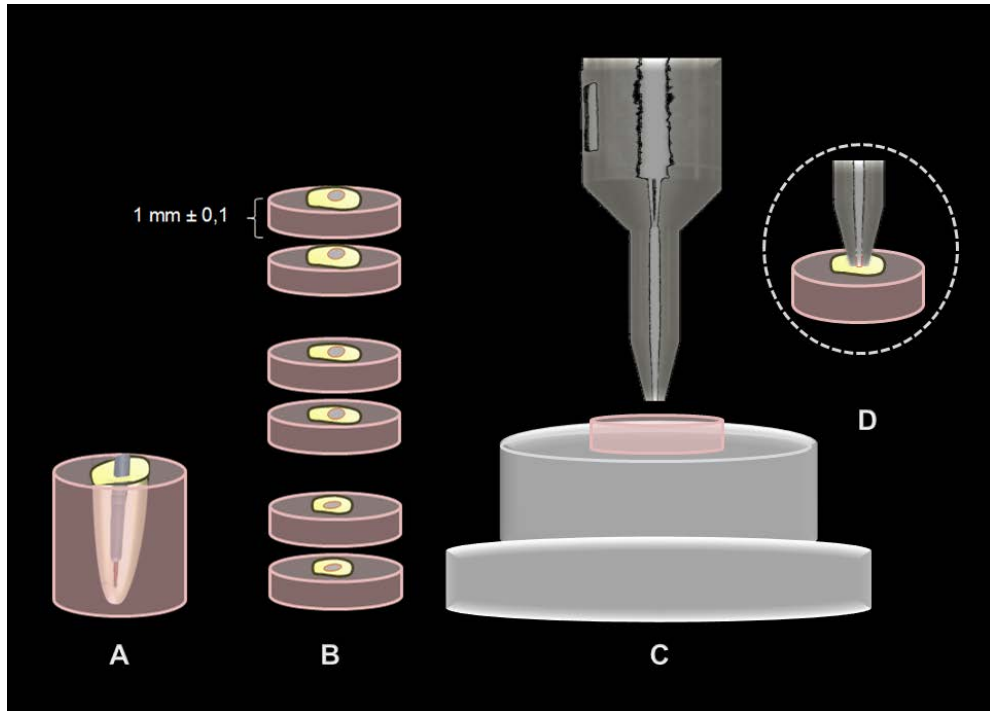


Figura 12 – Desenho esquemático. **A** - Raiz dentária com pino cimentado embutida; **B** – Fatias obtidas após corte da raiz; **C** – Corpo-de-prova sendo submetido ao teste de *push-out* e **D** – Close-up do teste de *push-out*.

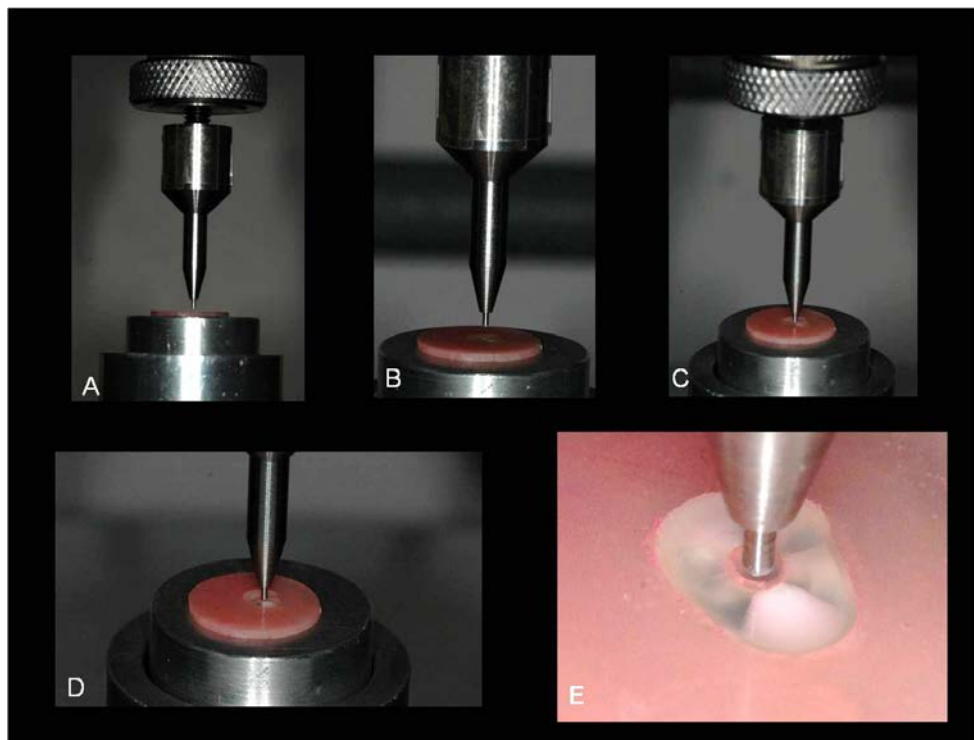


Figura 13 – Teste de *push-out*. **A** – Atuador e dispositivo metálico; **B** - Atuador posicionado paralelo ao longo eixo do pino; **C** e **D** – Ponta ativa exercendo carga compressiva sobre o pino e **E** – Vista aproximada do teste de *push-out*.

Em seguida, o valor da carga foi registrado em Newtons (N) e foi calculado o valor da resistência de união em MPa dividindo o valor da carga (N) pelo valor da área adesiva (mm^2). Duas áreas adesivas foram utilizadas para o cálculo da resistência de união, a superfície lateral da área dos pinos de fibra e a superfície lateral da área do canal radicular (pino + cimento resinoso). Para ambos os cálculos, a área adesiva (S_L) foi estimada por meio da fórmula utilizada para calcular a área de superfície lateral de um cone truncado:

$$S_L = \pi(R + r)[h^2 + (R - r)^2]^{0.5}$$

Onde:

π é a constante 3,1416;

R representa o raio coronário do pino ou do canal radicular (mm);

r representa o raio apical do pino ou do canal radicular (mm);

h representa a espessura dos corpos-de-prova (mm).

3.1.9 Avaliação dos padrões de fratura

Após o ensaio de *push-out* o padrão de fratura de todos os espécimes foi avaliado em um microscópio óptico (Olympus, model BX 51, Olympus, Tóquio, Japão) com ampliação de 40 X, onde foram classificados em: 1- fraturas adesivas entre cimento resinoso e dentina radicular, 2- fraturas adesivas entre cimento resinoso e pino de fibra, 3- fraturas coesivas de cimento resinoso, 4- fraturas coesivas de pino de fibra, 5- fraturas coesivas de dentina radicular e 6- fraturas mistas.

3.1.10 Análise estatística

A unidade experimental para todas as propriedades avaliadas (espessura de cimento resinoso, resistência de união e formação de *gaps*) foi a raiz, portanto, foi realizada uma média dos valores obtidos nas fatias de cada conduto radicular, de forma a obter um valor médio por dente para fins estatísticos.

Os dados obtidos de cada teste foram analisados estatisticamente por meio da análise de variância (ANOVA) de um critério e teste de *Tukey* para contraste das médias a um nível de significância de 5%. As duas abordagens utilizadas para o cálculo da resistência de união foram comparadas pelo teste-t pareado a um nível de significância de 5%.

A porcentagem de fatias com bolhas/vácuos foi avaliada através do teste *chi-square* ($\alpha = 0,05$). Correlações entre espessura de cimento resinoso vs resistência de união, espessura de cimento resinoso vs comprimento médio dos *gaps*, espessura de cimento resinoso vs largura média dos *gaps*, resistência de união vs comprimento médio dos *gaps*, e resistência de união vs largura média dos *gaps* foram avaliadas usando o teste de correlação de Pearson ($\alpha = 0,05$). Comparações aos pares dos padrões de fratura foram analisadas utilizando o teste exato de Fisher ($\alpha = 0,05$).

Todos os cálculos foram realizados por meio do software estatístico Sigma Plot 11 (Systat Software, San Jose, CA, EUA).

3.2 EXPERIMENTO 2 – Efeito de diferentes modalidades restauradoras para preenchimento de canais radiculares excessivamente alargados

3.2.1 Seleção dos dentes

Para esse experimento foram selecionados outros 84 pré-molares inferiores unirradiculares permanentes obtidos no BDH da UEPG. Todos os procedimentos de limpeza e critérios de inclusão dos dentes ocorreram da mesma maneira descrita no

experimento 1 desse projeto (Efeito da adaptação do pino de fibra aos condutos radiculares).

3.2.2 Preparo dos dentes

As etapas de preparo dos dentes e tratamento endodôntico dos mesmos também ocorreram da mesma maneira realizada no experimento 1 do projeto, diferindo apenas que os dentes foram seccionados perpendicularmente em relação ao seu longo eixo 2 mm acima da junção cimento esmalte.

3.2.3 Preparo do canal radicular

Após uma semana de armazenamento em umidade relativa com água destilada a $37^{\circ} \pm 1^{\circ} \text{ C}$ foram realizados os preparos dos condutos para posterior fixação de um pino intrarradicular cônico (Whitepost DC nº 0.5, FGM, Joinville, SC, Brasil) com diâmetro coronário de 1,4 mm. Um total de 14 dentes foi aleatoriamente selecionado para o grupo controle positivo. Nesse grupo, uma adaptação ideal do pino no conduto radicular foi simulada, assim, a broca correspondente ao pino nº 0.5 foi utilizada para o preparo dos condutos (Figura 4A).

Os canais radiculares dos 70 dentes remanescentes foram preparados utilizando uma ponta diamantada tronco-cônica nº 4137 (KG Sorensen, São Paulo, SP, Brasil), com 2,6 mm de diâmetro coronário, (Figura 4C) adaptada em baixa rotação, de maneira a simular um canal radicular excessivamente alargado nesses dentes. Após o alargamento dos canais, suas paredes foram ligeiramente preparadas com a broca correspondente ao pino nº 0.5 (Whitepost DC, FGM) com a finalidade de padronizar a *smear layer* obtida.

Para todas as raízes, após o preparo mecânico dos canais para recebimento dos pinos, os mesmos foram irrigados com 10 mL de água destilada e secos com jato de ar por 3 s e 2 pontas de papel absorvente.

O comprimento de trabalho foi de 12 mm para todos os dentes, respeitando o limite apical do material obturador de 4 mm. A cada seis preparos a broca de preparo dos canais também foi substituída.

3.2.4 Grupos experimentais

Nessa etapa as raízes foram aleatoriamente divididas em seis grupos (n=14) de acordo com as técnicas restauradoras alternativas de preenchimento de canais radiculares excessivamente alargados (Figura 14), sendo: 1. Grupo controle positivo: pino pré-fabricado de diâmetro compatível ao conduto radicular; 2. Grupo controle negativo: pino pré-fabricado de diâmetro inferior ao conduto; 3. Grupo com pinos acessórios: pino pré-fabricado + pinos acessórios; 4. Grupo pino anatômico direto; 5. Grupo pino anatômico indireto; 6. Grupo reforço radicular com resina composta + pino.

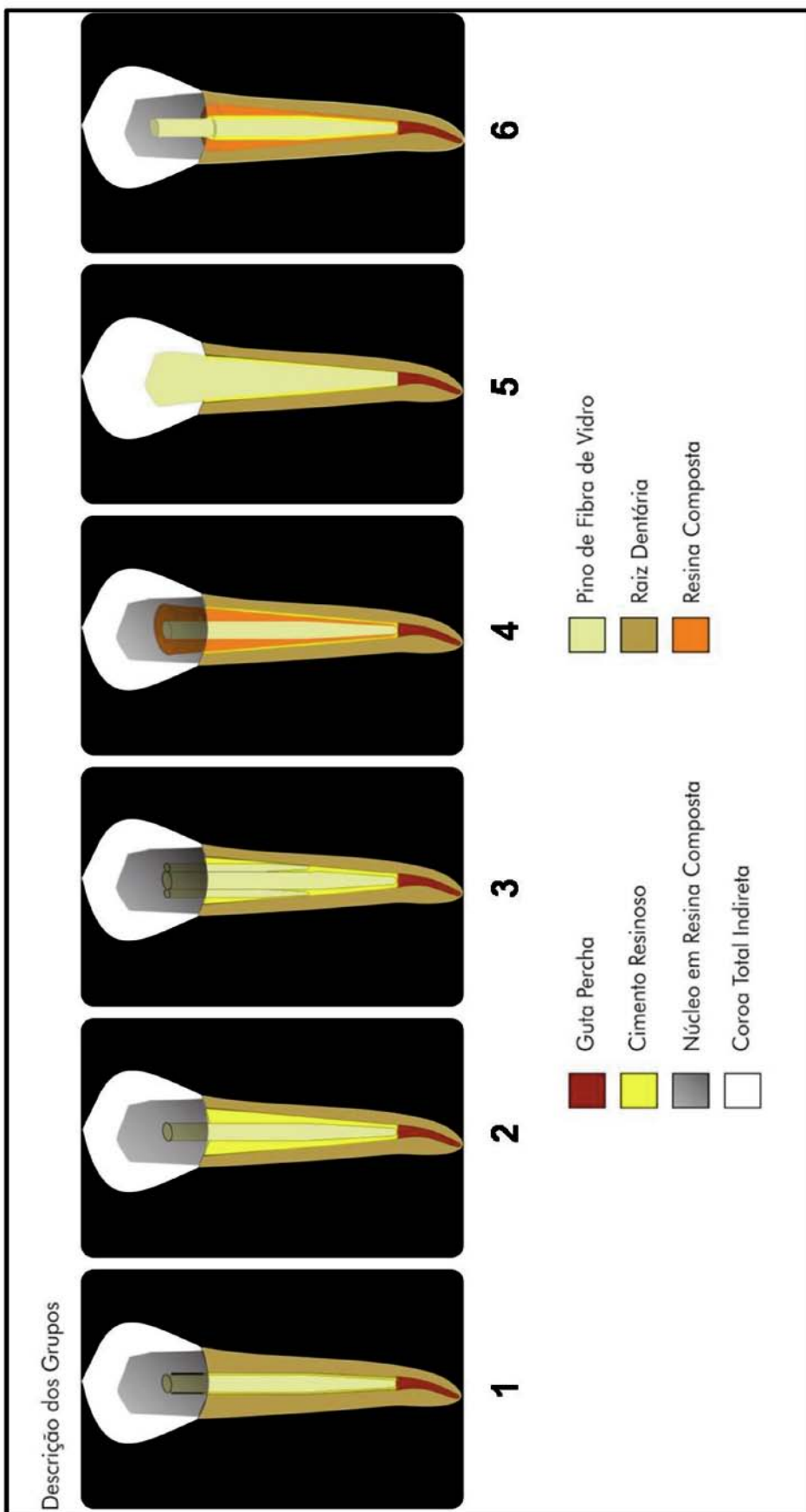


Figura 14 - Técnicas restauradoras alternativas de preenchimento de canais radiculares excessivamente alargados. 1. Grupo controle positivo; 2. Grupo controle negativo; 3. Grupo com pinos acessórios; 4. Grupo pino anatômico direto; 5. Grupo pino anatômico indireto e 6. Grupo reforço radicular com resina composta.

Em seguida, um fluxograma do delineamento metodológico desse experimento (Figura 15). A composição detalhada dos materiais restauradores utilizados está especificada no Quadro 1 e no Quadro 3.

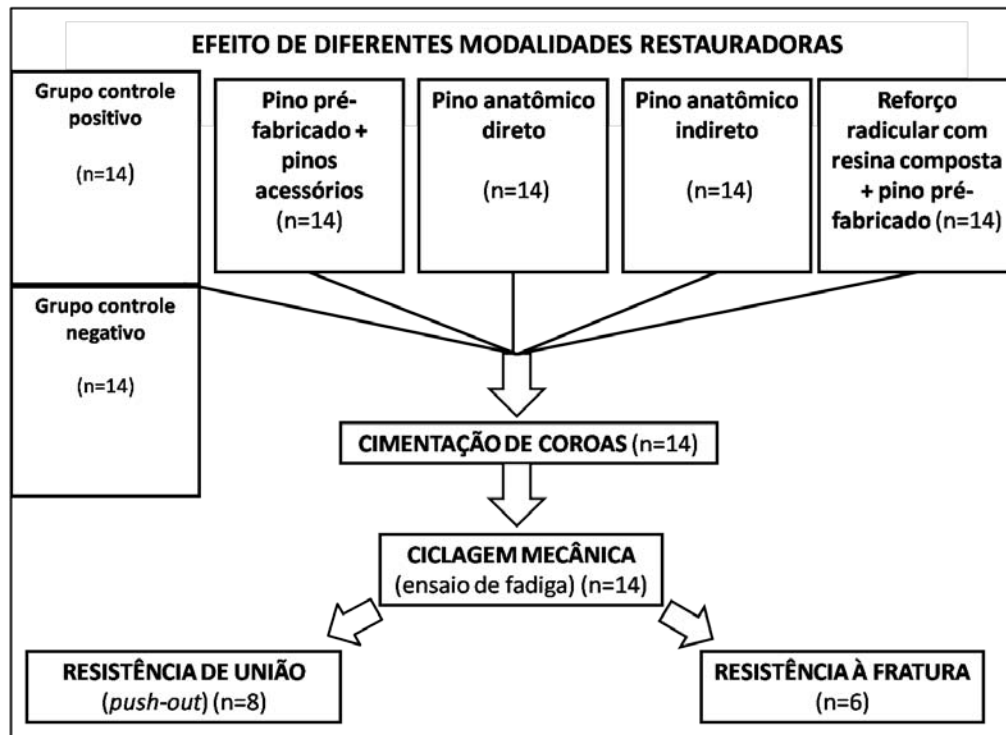


Figura 15 – Fluxograma dos grupos experimentais do experimento 2.

Quadro 3 – Materiais restauradores utilizados no estudo, fabricante, composição e lote.

Figura	Material/ Fabricante	Composição*	Lote
	Tetric® N-Bond / Ivoclar Vivadent	Contém acrilato do ácido fosfórico, HEMA, Bis-GMA, dimetacrilato de uretano, etanol, agente formador de película, catalisadores e estabilizadores.	N64295
	Tetric® N-Flow / Ivoclar Vivadent	Contém 36% em peso de dimetacrilatos (incluindo TEGDMA), 63% em peso de partículas (óxido de bário, trifluoreto de itérbio, sílica altamente dispersa e óxidos mistos) e 1% em peso de pigmentos, catalisadores e estabilizadores. O total de partículas inorgânicas é de 39% em volume. O tamanho das partículas inorgânicas varia entre 40 nm e 3000 nm.	N74353
	Tetric® N-Ceram / Ivoclar Vivadent	Consiste de dimetacrilatos (19-20% em peso). As partículas são constituídas de vidro de bário, trifluoreto de itérbio, óxidos mistos e copolímeros (80-81% em peso). Aditivos, catalisadores, estabilizadores são componentes adicionais (< 1% em peso). O total de partículas inorgânicas é de 55-57% em volume. O tamanho das partículas inorgânicas varia entre 40 nm e 3000 nm.	L54096

Nota: * Composição de acordo com o fabricante

Grupo controle positivo (n=14):

Nesse grupo foi cimentado o pino de fibra de vidro pré-fabricado nº 0.5 (Whitepost DC, FGM), com diâmetro compatível ao conduto radicular (Figura 16), simulando uma adaptação ideal do pino.

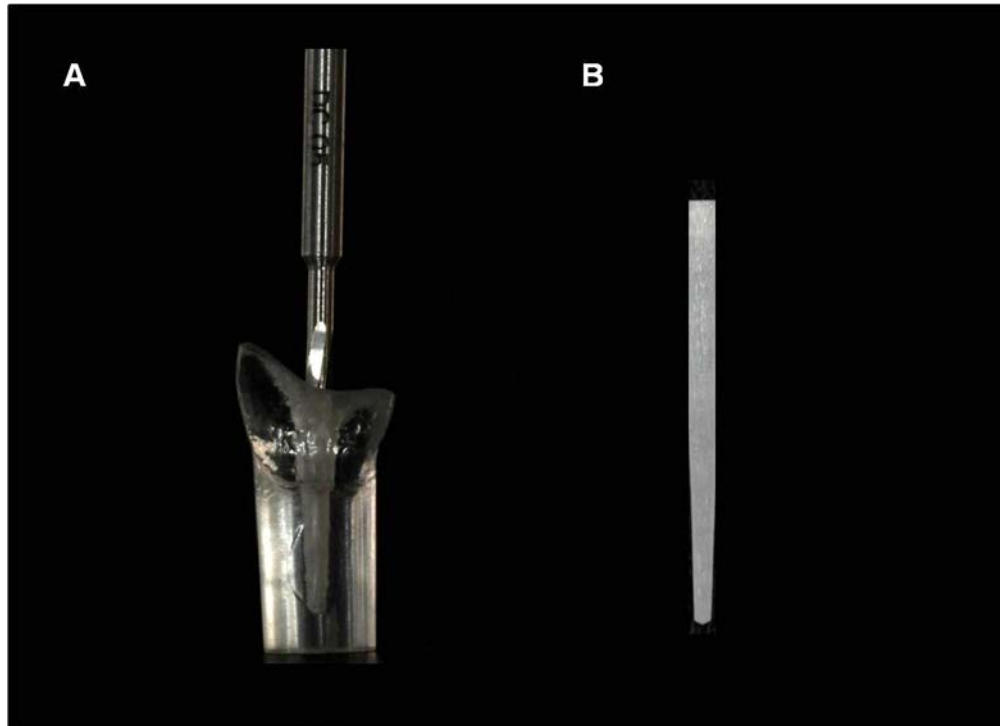


Figura 16 – **A** - Preparo do conduto com broca correspondente ao pino nº 0.5; **B** – Pino de fibra de vidro Whitepost DC nº 0.5.

Grupo controle negativo (n=14):

O mesmo pino pré-fabricado (Whitepost DC nº 0.5, FGM) foi cimentado nas raízes enfraquecidas com canais radiculares excessivamente alargados, simulando uma adaptação inadequada do pino (Figura 17).

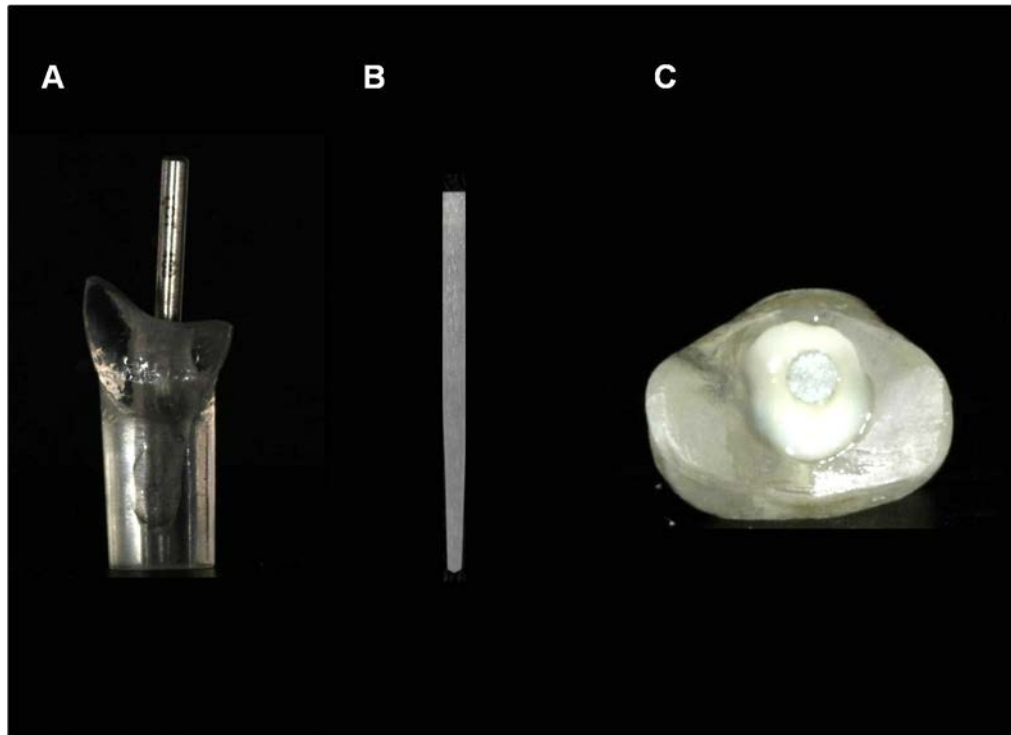


Figura 17 – **A** - Preparo do conduto com ponta diamantada tronco-cônica nº 4137; **B** – Pino de fibra de vidro Whitepost DC nº 0.5; **C** – Simulação de adaptação inadequada do pino (grande espessura de cimento resinoso).

Pino pré-fabricado + pinos acessórios (n=14)

Nesse grupo foi cimentado o pino pré-fabricado combinado com pinos de fibra de vidro acessórios (Reforpin nº 1, Ângelus, Londrina, PR, Brasil), de formato cônico e liso com diâmetro coronário de 1,1 mm.

Esses pinos acessórios foram provados no interior do canal radicular juntamente com o pino principal em posição (Figura 18A), tendo seu comprimento ajustado da maneira que a altura do seu término coronário coincidissem com altura do término coronário do pino principal, sendo então seccionados horizontalmente, por meio de um disco diamantado de dupla face (KG Sorensen, São Paulo, SP, Brasil) sob refrigeração em água constante. Em seguida, os pinos acessórios e o principal foram limpos com álcool 70% durante 5 s.

Após o condicionamento ácido, aplicação do sistema adesivo e do cimento resinoso no interior do canal (Quadro 2), o pino de fibra principal foi posicionado

(Figura 18B) seguido dos pinos de fibra acessórios (Figura 18C), os quais foram inseridos em torno do pino principal, até o preenchimento completo do conduto (Figura 18D). A seguir, o conjunto foi fotoativado por 40 s através da superfície oclusal (Figura 18E).

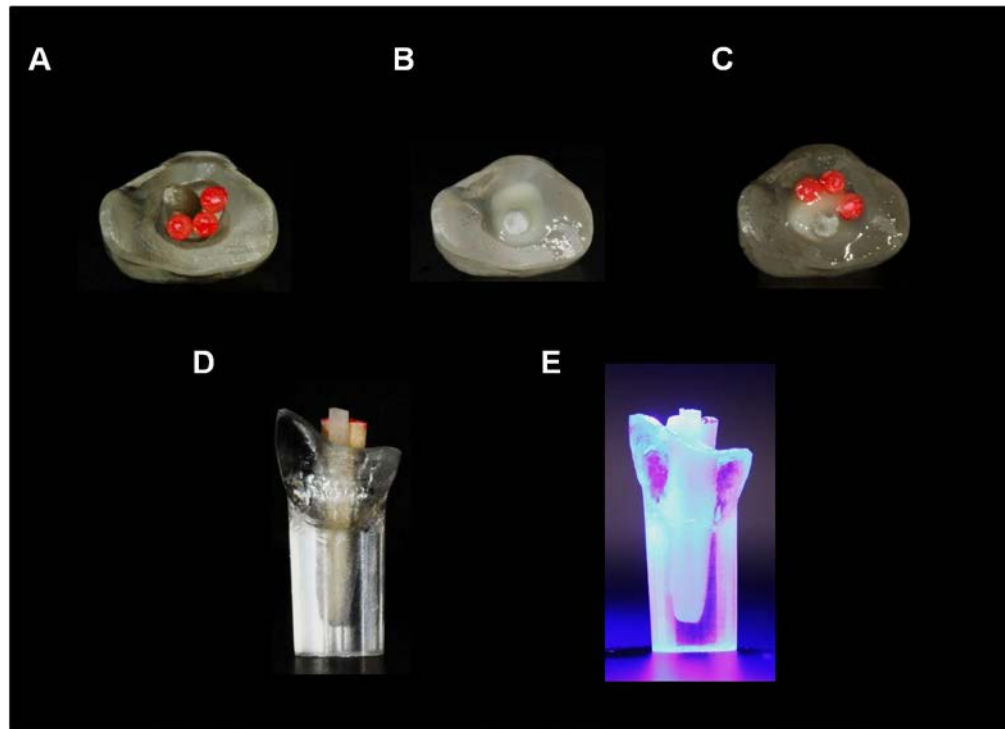


Figura 18 – **A** – Prova dos pinos acessórios no interior do canal radicular juntamente com o pino principal em posição; **B** - Pino de fibra principal posicionado durante a cimentação; **C** – Posicionamento dos pinos de fibra acessórios; **D** - Preenchimento do conduto (pino principal + pinos acessórios); **E** – Fotoativação do cimento resinoso.

Pino anatômico direto (n=14)

A superfície do pino pré-fabricado (Whitepost DC nº 0.5, FGM) foi condicionada com ácido fosfórico a 37% (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) durante 15 s (Figura 19A), seguido de lavagem com água e secagem (Figura 19B). O agente de união silano (Prosil, FGM, Joinville, SC, Brasil) foi aplicado no pino por 1 min (Figura 19C), e a superfície foi seca com jato de ar por 5 s. Duas camadas do sistema adesivo convencional (Tetric® N-Bond, Ivoclar-Vivadent,

Scchann, Liechtenstein) foram então aplicadas no pino por 20 s (Figura 19D), seguido de jato de ar (5 s) e fotoativação (10 s) (Figura 19E).

A seguir, os condutos radiculares foram lubrificados com gel hidrossolúvel (KY gel lubrificante, Johnson & Johnson, São José dos Campos, SP, Brasil) (Figura 19F). O pino pré-fabricado foi envolvido com a resina composta nanohíbrida (Tetric[®] N-Ceram, Ivoclar-Vivadent, Scchann, Liechtenstein) (Figura 20A), e este conjunto (pino + resina) foi inserido no conduto radicular, marcando a região vestibular do pino e do remanescente coronário (Figura 20B). Este conjunto foi retirado (Figura 20C) e recolocado (Figura 20D) por duas vezes, removendo o excesso de resina composta, fotoativando-a por 20 s com o pino em posição no interior do conduto (Figura 20E). O conjunto foi então removido do interior do conduto (Figura 20F) e a resina composta foi novamente fotoativada por 20 s adicionais em todas as superfícies do pino reembasado (Figura 20G). O pino anatômico obtido (Figura 20H) foi então provado no interior de seu respectivo canal radicular (Figura 20I), para verificar sua completa adaptação.

Na seqüência os condutos e os pinos anatômicos foram lavados abundantemente com água e secos antes da realização do procedimento de cimentação.

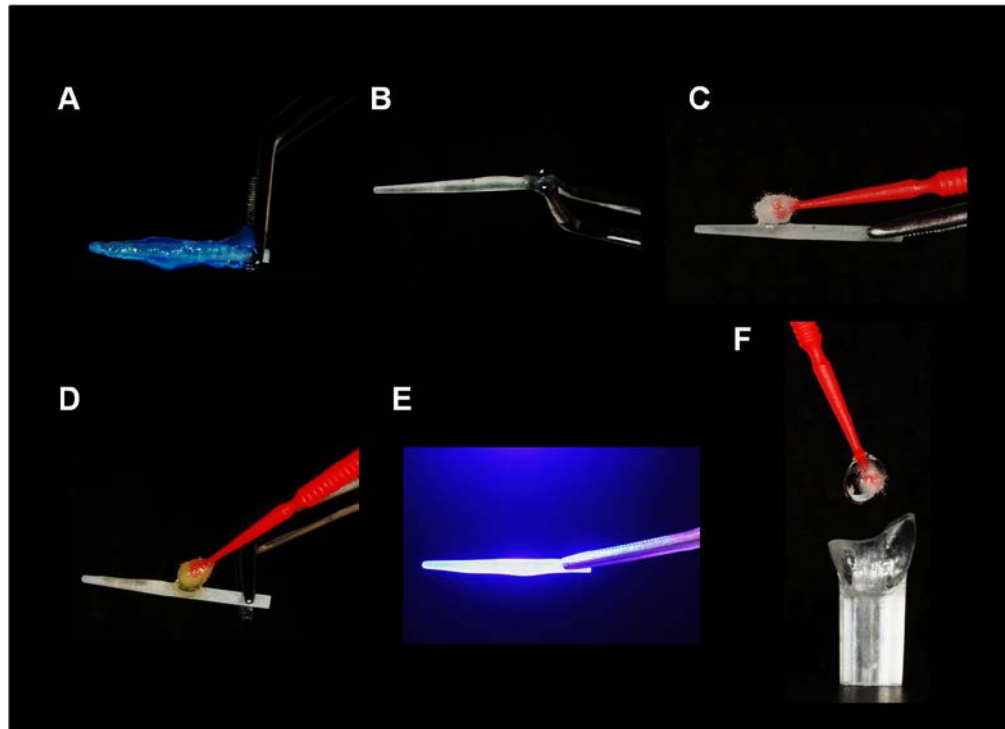


Figura 19 – **A** – Condicionamento do pino com ácido fosfórico a 37%; **B** – Lavagem e secagem do pino; **C** – Aplicação de silano no pino; **D** – Aplicação de sistema adesivo no pino; **E** – Fotoativação do sistema adesivo; **F** – Lubrificação do conduto radicular com gel hidrossolúvel.

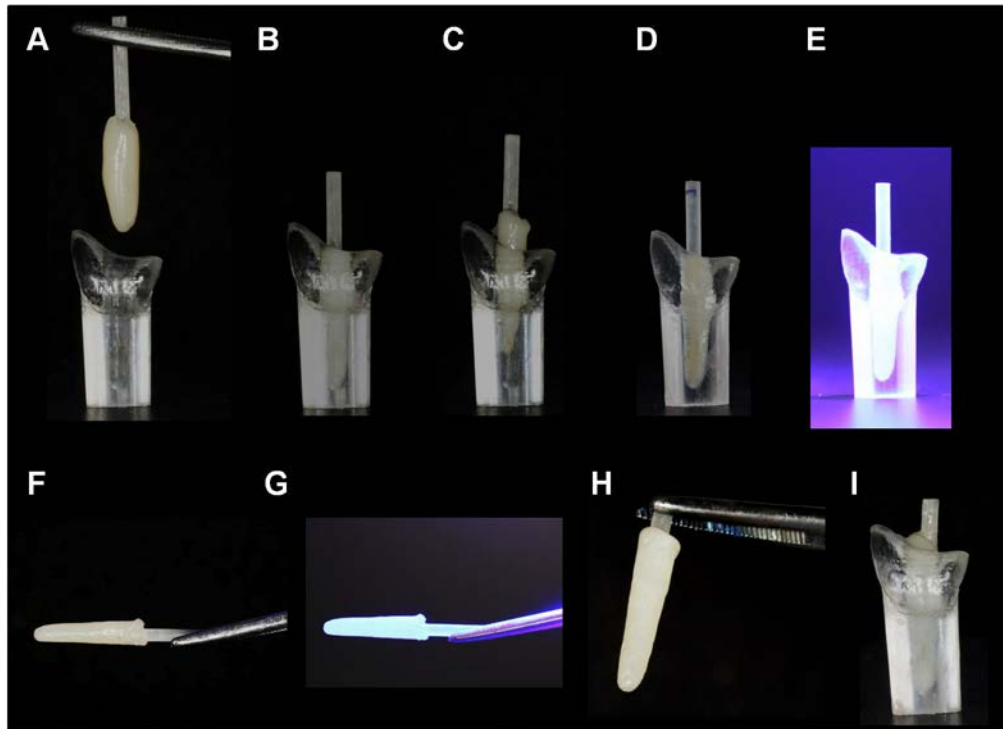


Figura 20 – **A** – Pino envolvido com resina composta nanohíbrida; **B** - Conjunto (pino + resina composta) inserido no conduto radicular; **C** – Conjunto retirado do conduto radicular; **D** – Conjunto introduzido novamente no conduto radicular; **E** – Fotoativação da resina composta; **F** – Conjunto removido do conduto radicular; **G** – Fotoativação complementar da resina composta; **H** – Pino anatômico obtido; **I** – Prova do pino anatômico no conduto radicular.

Pino anatômico indireto (n=14)

Para a confecção desses pinos, foi utilizado o sistema Fibrex-Lab (Ângelus, Londrina, PR, Brasil), o qual consiste num sistema formado por fibras de vidro impregnadas por resina composta laboratorial fotopolimerizável, utilizado para reforço estrutural de componentes protéticos.

Inicialmente foi confeccionado um pino intrarradicular padrão de resina acrílica (Duralay, Reliance, Dental Mfg. Co., Worth, IL, EUA) para cada canal radicular (Figura 21). Esse pino padrão foi enviado para um laboratório de prótese (Laboratório Dental Prodent, Cascavel, PR, Brasil). Nesse laboratório, o pino padrão foi copiado com cola quente (Ângelus, Londrina, PR, Brasil), de maneira a obter uma réplica (molde) do mesmo. Com a cópia fiel do padrão, a fibra de vidro medial (Ângelus, Londrina, PR, Brasil) com sua respectiva resina laboratorial tipo *flow* e

sistema adesivo foram inseridos no molde e levados ao aparelho de vácuo, e o conjunto foi fotopolimerizado por 5 min de acordo com as recomendações do fabricante. Os pinos foram então removidos dos moldes, obtendo-se assim os pinos anatômicos indiretos de fibras de vidro (Figura 21).



Figura 21 – Pinos padrões em resina acrílica com seus respectivos pinos anatômicos indiretos de fibras de vidro.

Reforço radicular com resina composta + pino pré-fabricado (n=14)

Nesse grupo foi realizado um reforço radicular com resina composta previamente à cimentação do pino de fibra pré-fabricado. O reforço radicular consiste na criação de uma dentina radicular artificial, diminuindo a luz do conduto, reforçando assim as paredes radiculares enfraquecidas.

Para a realização desse reforço, foi utilizada uma resina composta nanohíbrida tipo *flow* (Tetric® N-Flow, Ivoclar-Vivadent, Scchann, Liechtenstein) em combinação com um sistema adesivo convencional fotoativado (Tetric® N-Bond,

Ivoclar-Vivadent, Scchann, Liechtenstein). O interior dos condutos radiculares foi condicionado com ácido fosfórico a 37% (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) durante 15 s (Figura 22A), seguido de lavagem com água e secagem (Figura 22B). Em seguida, duas camadas do sistema adesivo (Tetric® N-Bond, Ivoclar-Vivadent) foram aplicadas em toda a superfície do canal radicular (Figura 22C), seguido de jato de ar (5 s) e fotoativação (10 s). O interior do conduto radicular foi então preenchido pela resina composta tipo *flow* (Tetric® N-Flow, Ivoclar-Vivadent, Scchann, Liechtenstein) em direção apical à cervical, com a finalidade de evitar a formação de bolhas de ar (Figura 22 D-E). Posteriormente, um gel lubrificante hidrossolúvel (KY gel lubrificante, Johnson & Johnson) foi aplicado no pino pré-fabricado (Figura 22F), sendo o mesmo, em seguida, posicionado no interior do conduto (Figura 22G). O pino foi removido e novamente posicionado no interior do canal, e o excesso de resina composta foi removido. Sobre o pino posicionado, foi realizada a fotoativação da resina composta por 20 s (Figura 22H), e o pino foi removido do canal; realizando uma fotoativação complementar do canal por 20 s.

Na seqüência os condutos e os pinos foram lavados abundantemente com água para remoção do gel lubrificante e os condutos foram re-preparados com a broca correspondente ao pino nº 0.5 (Whitepost DC, FGM) (Figura 22 I-J).

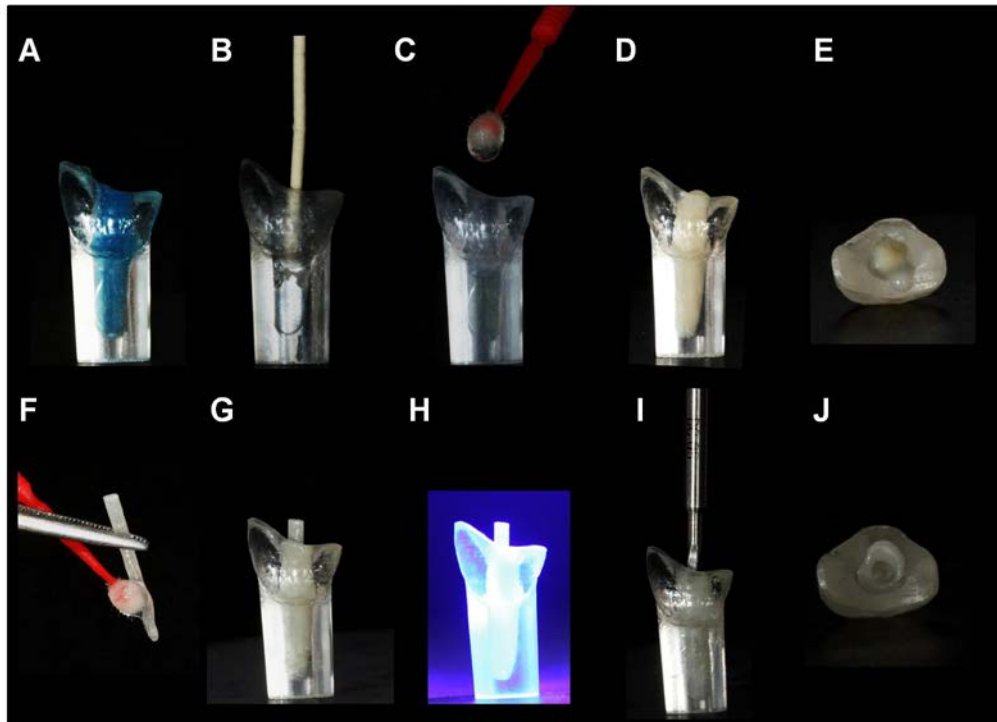


Figura 22 – **A** – Condicionamento do conduto radicular com ácido fosfórico a 37%; **B** - Secagem do conduto radicular com cone de papel absorvente; **C** – Aplicação de sistema adesivo no conduto radicular; **D,E** – Conduto radicular preenchido com resina composta; **F** – Aplicação de gel lubrificante hidrossolúvel no pino; **G** – Posicionamento do pino no interior do conduto; **H** – Fotoativação da resina composta; **I** – Re-preparo do conduto com a broca correspondente ao pino Whitepost DC nº 0.5; **J** – Vista oclusal do conduto reforçado com resina composta.

3.2.5 Cimentação dos pinos

As etapas de corte e limpeza dos pinos, bem como limpeza dos canais radiculares ocorreram da mesma maneira realizadas na primeira fase do projeto, diferindo apenas que os pinos foram seccionados horizontalmente, resultando em um comprimento de 15 mm, de uma maneira que 12 mm do pino atingisse o CT radicular, e os outros 3 mm servisse como um guia para a distância do aparelho fotoativador durante os procedimentos de fotoativação dos espécimes.

Todos os pinos foram cimentados com o sistema adesivo convencional dual Excite® DSC (Ivoclar-Vivadent, Schann, Liechtenstein) e o cimento resinoso dual Variolink® II (Ivoclar-Vivadent, Schann, Liechtenstein), seguindo as recomendações do fabricante (Quadro 2 e Figura 6).

Após os procedimentos de cimentação dos pinos, foi realizado um núcleo direto em resina composta nanohíbrida (Tetric[®] N-Ceram, Ivoclar-Vivadent, Scchann, Liechtenstein) na parte coronária de todos os retentores dessas raízes. Uma técnica incremental foi utilizada para inserir a resina composta, e cada incremento (2 mm) foi fotoativado por 20 s.

Todos os procedimentos de fotoativação, desse experimento 2, foram realizados com um aparelho fotopolimerizador com luz emitida por diodo (Radii Plus, SDI Limited, Victoria, Austrália), com uma intensidade de luz de 1500 mW/cm².

3.2.6 Confecção de coroas indiretas

Após uma semana de armazenamento em água destilada a 37°C ± 1°C foram confeccionados preparos para coroas totais *metal-free* sobre todos os núcleos de resina composta (N=84). Os preparos foram realizados com as pontas diamantadas nº 2135 e nº 3098MF (KG Sorensen, Barueri, SP, Brasil) adaptadas em alta rotação, sob refrigeração em água constante. Todos os preparos apresentaram férula no término cervical de 2,0 mm de extensão (altura), 1,2 mm de ombro (espessura) e redução oclusal de 1,5 mm. Os ângulos axiais e ocluso-axiais foram arredondados, e a linha de término cervical foi contínua, definida e nítida.

Todos os preparos foram submetidos aos procedimentos de acabamento e polimento com o sistema de discos Sof-LexTM (3M-ESPE, St Paul, MN, USA) aplicados em granulação decrescente (grossa, média, fina e extrafina) por 20 s cada, adaptados em baixa rotação, com movimentos circulares (Figura 23).



Figura 23 – Preparos concluídos para coroas totais *metal-free* sobre núcleos de resina composta.

Os preparos foram então moldados com silicone de adição (Virtual[®], Ivoclar Vivadent, Schaan, Liechtenstein) (Figura 24 A-B) e as coroas foram confeccionadas laboratorialmente com o sistema restaurador SR Adoro (Ivoclar Vivadent, Schaan, Liechtenstein) reforçado com fibras (Fibrex-Lab Coronal, Ângelus, Londrina, PR, Brasil) (Figura 25).

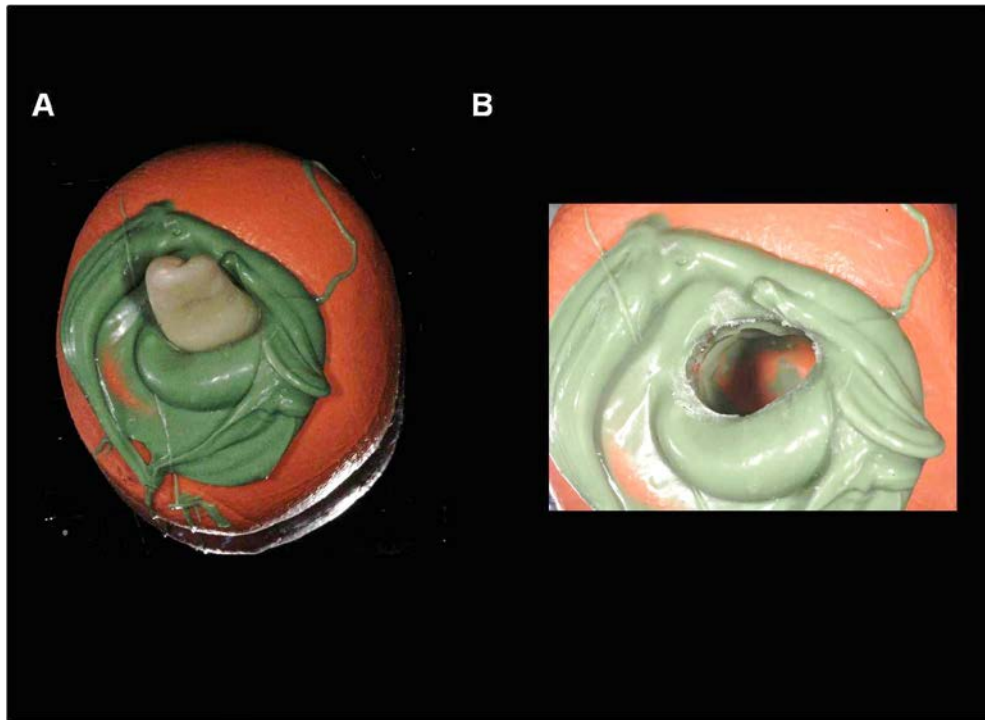


Figura 24 – **A** – Moldagem do preparo com silicone de adição; **B** – Molde obtido do preparo.



Figura 25 – Coroas confeccionadas laboratorialmente com o sistema restaurador SR Adoro reforçado com fibras.

Após a prova (Figura 26) e ajuste das coroas, as mesmas foram cimentadas com o sistema adesivo Excite[®] DSC e o cimento resinoso Variolink II[®], seguindo o mesmo protocolo descrito para a cimentação dos pinos (Quadro 2 e Figura 27).



Figura 26 – Prova das coroas indiretas.

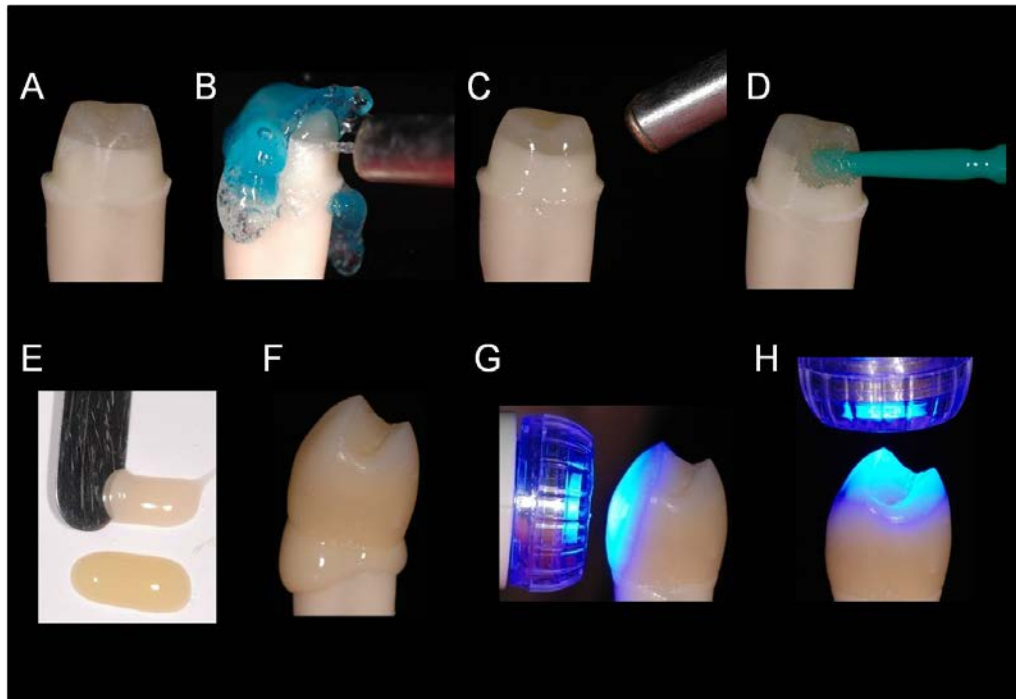


Figura 27 – Cimentação das coroas indiretas. **A** – Preparo concluído para coroa total sobre núcleo de resina composta; **B** – Condicionamento do preparo com ácido fosfórico 37%; **C** – Secagem com jato de ar; **D** – Aplicação do sistema adesivo; **E** – Manipulação do cimento resinoso (pasta base + pasta catalisadora); **F** – Posicionamento da coroa; **G, H** - Fotoativação do cimento resinoso.

3.2.7 Envelhecimento dos espécimes

3.2.7.1 Simulação do ligamento periodontal

Com a finalidade de reproduzir uma situação clínica foi realizada a simulação do ligamento periodontal em todas as raízes para representar a movimentação no osso alveolar, de acordo com a metodologia descrita por Soares et al.³⁸ 2005.

Inicialmente, as superfícies radiculares foram cobertas com cera utilidade derretida (Horus, Herpo Produtos Dentários, Petrópolis, RJ, Brasil) até 3 mm abaixo da JCE (Figura 28 A-B), de modo progressivo, com o uso de espátula nº 7, lamparina à gás, esculpador Lecron e esculpador Hollembach nº 3S, resultando em uma camada de cera de aproximadamente 0,3 mm de espessura.

Um tubo de PVC de ½ polegada com 25 mm de diâmetro e 40 mm de altura foi utilizado como suporte para o dente. Resina acrílica (Duralay, Reliance, Worth, IL, EUA) foi manipulada de acordo com as recomendações do fabricante e foi vertida imediatamente no interior do tubo de PVC, sendo, em seguida, o dente posicionado no centro do mesmo, até o limite de cera (Figura 28 C-D).

Após 24 h da polimerização da resina, os dentes foram removidos dos tubos de PVC, e a cera foi removida das superfícies radiculares e do alvéolo artificial recém obtido com água morna (Figura 28E). Esse espaço foi preenchido com material de moldagem à base de poliéter (ImpregumTM Soft, 3M ESPE, St. Paul, MN, EUA) por meio de uma seringa de elastômero (Figura 28F) e as raízes foram novamente inseridas nos seus respectivos alvéolos artificiais (Figura 28 G-H). O excesso de material de moldagem foi removido. Dessa maneira, o poliéter preencheu o espaço anteriormente ocupado pela cera, resultando na simulação de um ligamento periodontal, com espessura padronizada de 0,3 mm (Soares et al.³⁸ 2005).

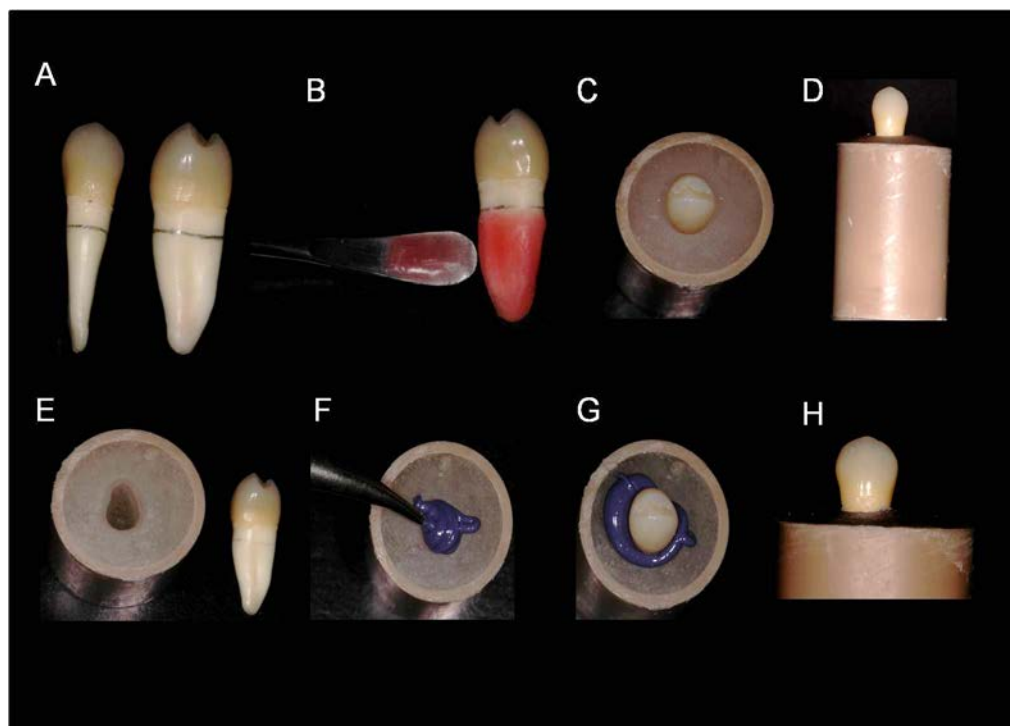


Figura 28 – **A** – Demarcação 3 mm abaixo da JCE; **B** – Cera utilizada derretida sendo posicionada abaixo da demarcação; **C,D** – Dente posicionado no interior do tubo de PVC, o qual foi preenchido com resina acrílica; **E** – Dente removido do interior do tubo de PVC e cera removida do dente e do alvéolo recém obtido; **F** – Alvéolo sendo preenchido com

material de moldagem à base de poliéter por meio de uma seringa de elastômero; **G,H** – Raiz novamente inserida no seu respectivo alvéolo artificial.

3.2.7.2 Ciclagem mecânica

Para este teste, foi utilizada uma máquina de ensaios de fadiga de material (Elquip, São Carlos, SP, Brasil). Os espécimes foram posicionados a 90° em relação ao plano do solo e submetidos a impactos repetitivos direcionados na face oclusal das coroas de todos os dentes. A carga aplicada foi de 40 N (4,0 Kgf) com frequência de 2 Hz em um total de 1.2×10^6 ciclos, simulando aproximadamente 5 anos de uso clínico (Pontius, Hutter³⁹ 2002, Naumann et al.⁴⁰ 2010). Durante os ciclos, os corpos-de-prova foram mantidos imersos em água na temperatura de $37^\circ\text{C} \pm 1^\circ\text{C}$ (Figura 29 A-B).

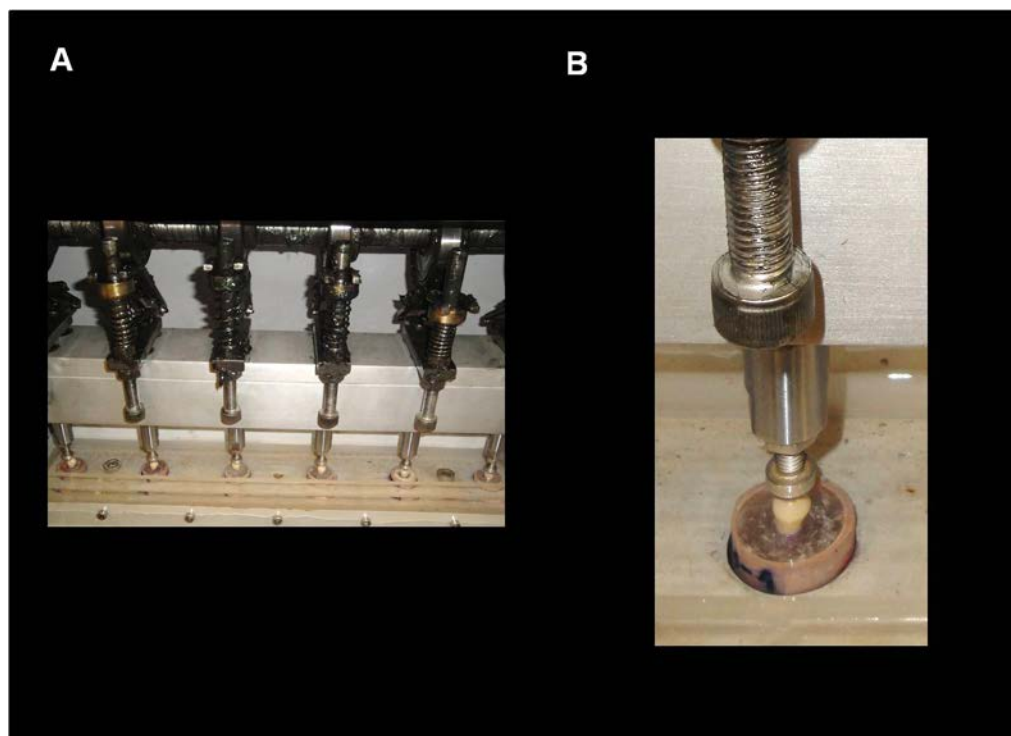


Figura 29 – **A** – Corpos-de-prova submetidos ao ensaio de fadiga; **B** - *Close-up* do teste de fadiga.

Terminado os ciclos, o teste foi interrompido e com o auxílio de uma lupa foram verificadas possíveis falhas como: falha da cimentação completa ou parcial (coroa ou pino), fratura e/ou trinca radicular utilizando sonda exploradora nº 5.

3.2.8 Avaliação da resistência de união por *push-out*

Oito dentes de cada grupo (n=8) foram selecionados aleatoriamente para o teste de resistência de união. As coroas cimentadas nesses dentes foram seccionadas na altura da junção cimento esmalte, sendo desprezadas nesse momento. Em seguida, as raízes foram preparadas e submetidas ao teste de *push-out* da mesma maneira realizada no experimento 1 (Figura 13 A-E).

3.2.9 Avaliação da resistência à fratura sob compressão

Os seis dentes restantes de cada grupo (n=6) foram empregados para o teste de resistência à fratura. Os corpos-de-prova foram fixados na máquina de ensaios universal (Shimadzu AG-I, Columbia, EUA) por meio de um suporte em aço inoxidável (100 mm de altura por 70 mm de base) possuindo um plano inclinado de 30° em relação ao plano do solo, com uma cavidade cilíndrica na porção central para adaptação do tubo de PVC. O dispositivo metálico formou um ângulo de 150° entre o cone de aço do mordente superior da máquina de ensaio universal e o longo eixo das raízes, simulando o componente de forças que atuam sobre os dentes posteriores (Figura 30). O conjunto foi adaptado em uma máquina de ensaios universal que foi carregada com uma célula de carga de 3000 N e velocidade de 0,5 mm/min. A carga foi aplicada com uma ponta em forma de lâmina de faca com largura de 10 mm por 5 mm de espessura, a qual foi apoiada na cúspide vestibular (cúspide de trabalho) das coroas (Figura 31A).

A máquina de ensaios foi programada de forma que a carga fosse automaticamente descontinuada (paralisação da máquina) quando o sistema de

alguma forma falhasse (deslocamento ou fratura da coroa, ou da porção coronária ou ainda fratura da raiz) (Figura 31B). Os valores foram registrados em Newton.

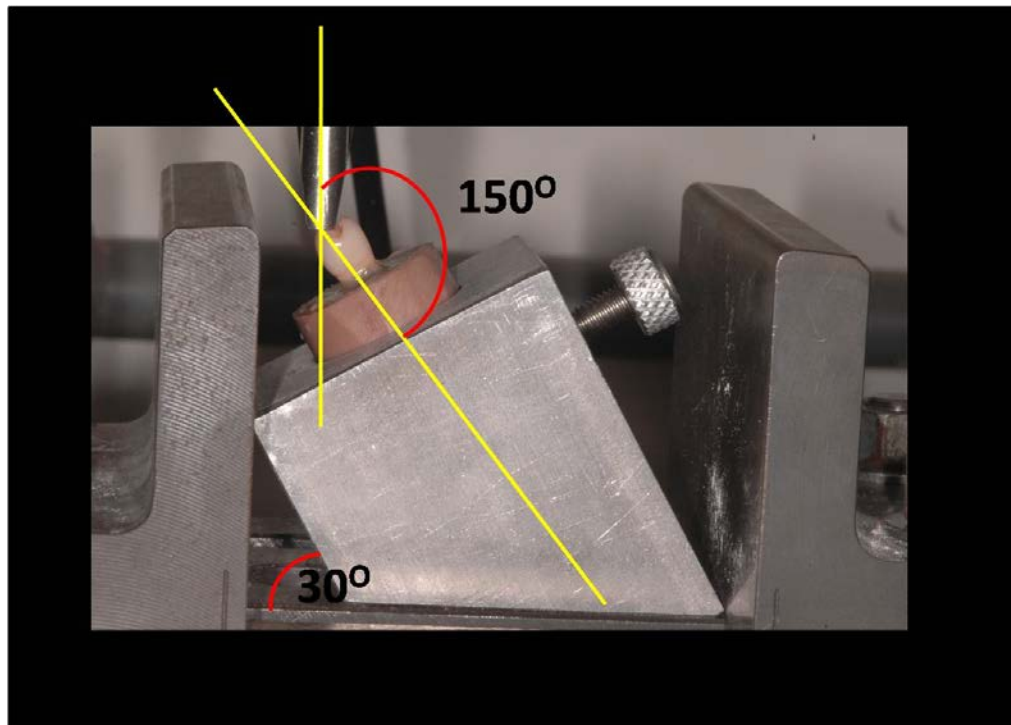


Figura 30 – Posicionamento do corpo-de-prova para o teste de resistência à fratura.

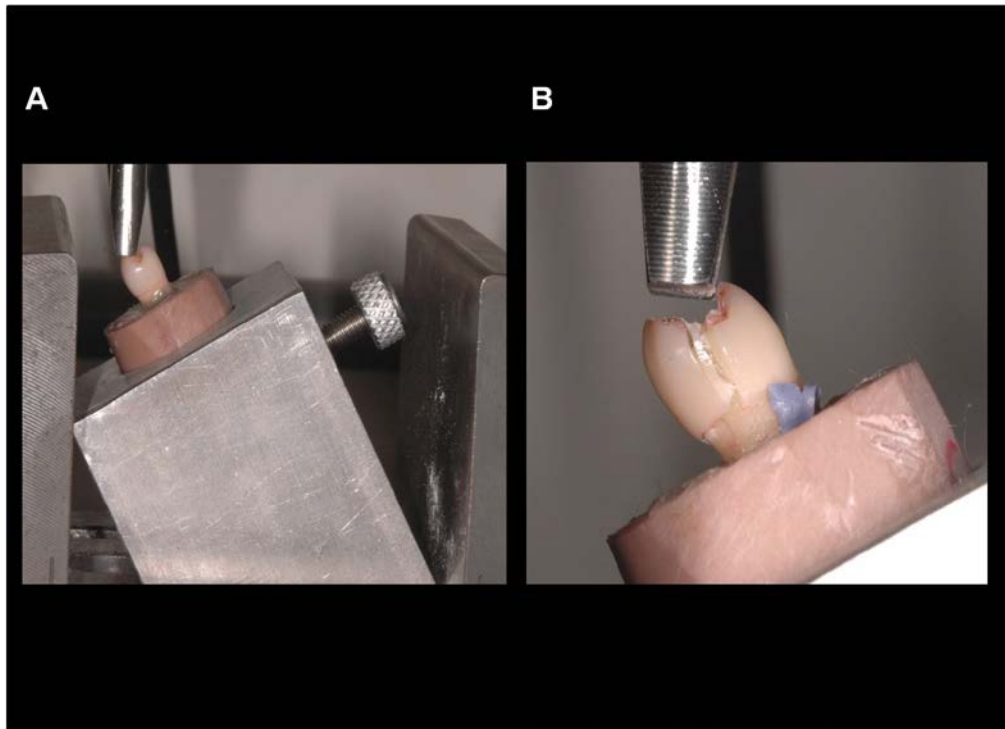


Figura 31 – **A** – Corpo-de-prova submetido ao teste de resistência à fratura; **B** – Paralisação da máquina após falha do sistema restaurador (fratura coronária).

3.2.10 Avaliação do padrão de fratura

Após o teste de resistência à fratura, as raízes foram removidas dos tubos de PVC, o ligamento periodontal artificial foi removido com auxílio de curetas periodontais e foram observados os padrões de fraturas, classificando-os de acordo com o grau de destruição dentária: favorável – deslocamento e/ou fratura da coroa, do pino ou fratura radicular acima do nível cervical, as quais permitiriam a realização de uma nova restauração (Figura 32), e desfavorável – fratura abaixo do terço cervical radicular, fratura radicular vertical ou oblíqua e fratura radicular horizontal nos terços médio e apical, as quais condenariam o dente à extração (Figura 33) (Maccari et al.⁴¹ 2007, Zogheib et al.³⁶ 2011).



Figura 32 – Fraturas favoráveis.

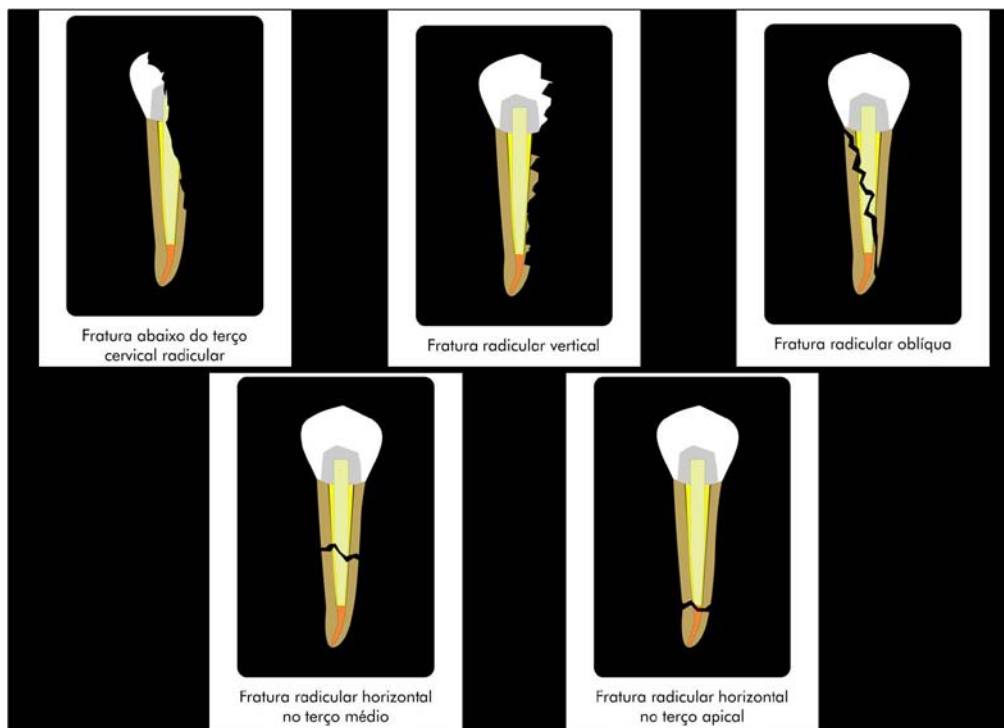


Figura 33 – Fraturas desfavoráveis.

3.2.11 Análise estatística

A unidade experimental para as propriedades avaliadas foi a raiz, portanto, foi realizada uma média de todos os valores obtidos para cada raiz para fins estatísticos.

Os dados obtidos de resistência de união e resistência a fratura foram analisados estatisticamente por meio da análise de variância (ANOVA) de um critério e pós teste de *Sheffe* para contraste das médias a um nível de significância de 5%. Os diferentes padrões de fratura foram analisados utilizando o teste exato de Fisher ($\alpha = 0,05$).

Todos os cálculos foram realizados por meio do software estatístico Sigma Plot 11 (Systat Software, San Jose, CA, EUA).

4 CAPÍTULOS

4.1 Artigo **Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin** aceito para publicação na revista *Journal of Adhesive Dentistry*.

4.2 Artigo **Evaluation of different restorative techniques for filling flared roots: fracture resistance and bond strength after mechanical fatigue** submetido para avaliação na revista *Journal of Adhesive Dentistry*.

4.3 Artigo **Use of a direct anatomic post in a flared root canal: a case report** submetido para avaliação na revista *Journal of Esthetic and Restorative Dentistry*.

4.1 Artigo **Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin** aceito para publicação na revista *Journal of Adhesive Dentistry*.

Journal of Adhesive Dentistry

manuscript: 1697

Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin

Date submitted: 2013-03-27

Decision date: 2013-04-27

Decision: Accept

Decision letter:

Dear Professor

DECISION: Accept

You have recently submitted the above manuscript to the Journal of Adhesive Dentistry. The paper has now been reviewed by external experts in the field and one of the editors.

It is our pleasure to inform you that your paper has been accepted for publication in the Journal of Adhesive Dentistry.

Two to three months before publication you will receive page proofs with instructions from our printing office.

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Sincerely yours

Jean-Francois Roulet
Editor-in-Chief

Decision and reviewer reports

TITLE PAGE

Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin

Giovana Mongruel Gomes¹ [DDS, MS], Eluise Cristina de Rezende² [DDS, MS], Osnara Maria Mongruel Gomes³ [DDS, MS, PhD], João Carlos Gomes³ [DDS, MS, PhD], Alessandro Dourado Loguercio³ [DDS, MS, PhD], Alessandra Reis³ [DDS, PhD].

¹ Professor and PhD student. Department of Restorative Dentistry, School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

² Professor and PhD student. Department of Microbiology, School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

³ Professors. Department of Restorative Dentistry. School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

Authors address:

Universidade Estadual de Ponta Grossa
Avenida Carlos Cavalcanti 4748 – Uvaranas, Ponta Grossa, Paraná, Brazil
84030-900

Corresponding author:

Giovana Mongruel Gomes
Rua Engenheiro Schamber 452, ap 21 Ponta Grossa, Paraná, Brazil
84010-340
Telephone: 00554232226560 Fax: 00554232247351
Email: giomongruel@gmail.com

Keywords: Bond strength; fiber posts; gap; resin cements; root dentin; scanning electron microscopy.

Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin

Abstract

Purpose: The purpose of this research is to evaluate the effect of the resin cement thickness (RCT) on bond strength (BS) and gap formation (GF) of fiber posts bonded to root dentin. **Materials and Methods:** The roots of 24 extracted human mandibular premolars were treated endodontically, and the post spaces were prepared using drills with different diameters, according to the following groups (n=8): well-adapted (WeAd), moderately well-adapted (MoAd) and poorly adapted (PoAd). The fiber glass posts were cemented (Excite DSC and Variolink II) in accordance with the manufacturer's instructions. After 1 week, the roots were transversely sectioned into six 1-mm thick discs and photographed using an optical microscope, to determine the RCT. After this, epoxy resin replicas of each sample were observed by SEM, and the mean length and width of the gaps formed in the cement-dentin-post interface were measured. Finally, each sample was subjected to the push-out test (0.5 mm/min), and the data were statistically analyzed by one-way ANOVA and Tukey's tests (5%). **Results:** The lowest RCT (μm) were observed for WeAd, and the highest were observed for PoAd. The group MoAd showed an intermediate value. Significantly higher push-out BS were observed for WeAd compared to the other groups. The MoAd and PoAd groups were statistically similar. The highest mean gap length (%) and width (μm) were observed for PoAd. The groups MoAd and WeAd were statistically similar. **Conclusion:** The smaller RCT resulted in better fiber post adhesion, that is, higher BS and lower GF.

Keywords: Bond strength; fiber posts; gap; resin cements; root dentin; scanning electron microscopy.

Clinical relevance: It is advisable to prepare post spaces that allow the chosen fiber post to fit into the space as accurately as possible.

Introduction

Teeth with considerable loss of dental structure often require endodontic treatment, and in the majority of cases, this leads to the use of intraradicular retainers and filling cores to retain the final restoration.⁴⁹ Moreover, to restore these teeth, an attractive option has been to use materials with a modulus of elasticity similar to that of dentin,^{4,8,24,32} resulting in biomimetics between the properties of dentin and the post/cement set.⁴² This favors a more uniform stress distribution in the root structure,^{21,33,38} which, thus, reduces the risk of root fractures.

In spite of the advantages of using these glass fiber posts, they are prefabricated and, therefore, do not always adjust closely to the root canal. There are root canals that exhibit extensive tissue destruction due to carious lesions, previous restoration with excessive post and core diameters, endodontic over-instrumentation, incomplete physiological root development due to traumatic impacts, internal resorption, developmental anomalies, or even oval-shaped root canals.^{5,29} In these cases, the remaining root structure is thin, which probably weakens it, even when a glass fiber post is cemented.⁵⁰ Clinical situations of this nature make the restorative procedure difficult, and the long-term clinical prognosis of these teeth is still unknown. Thus, the restoration of weakened roots presents a challenge to dentists.

The treatment of highly widened root canals using prefabricated posts may not provide ideal for root canal fillings, thereby obliging the operator to employ excessive quantities of cement to replace lost structure.²² The deformation resulting from polymerization shrinkage when thick layers of cement are used may cause greater polymerization stress at the cement/dentin and cement/post interfaces, inducing structural discontinuities, such as bubbles, spaces, or gaps, which, in turn,

reduce the retention of posts to root canals.²⁰ Prospective and retrospective clinical studies have indicated that fiber post displacement occurs with greater frequency when there is a larger cement thickness.^{13,15}

Although some clinical alternatives has been described in the literature, such as the use of accessory fiber posts²⁷ and the restoration of weakened roots with composite resins and glass fiber posts,⁵⁰ the ideal thickness of resin cement for cementation of glass fiber posts is still unknown. Few studies in the literature have evaluated the effect of the size discrepancy between root canal openings and fiber post diameter on bond strength (BS) and gap formation at the cement/dentin interfaces. In addition, the results of these studies are controversial.^{10,31}

Therefore, the aim of this study was to evaluate the effect of resin cement thickness (RCT) on BS between the glass fiber post and root dentin and gap formation at the cement/dentin and cement /post interfaces, mediated by conventional dual resin cement. Two null hypotheses were tested: 1) there are no differences in the push-out BS to dentin for different RCT between the fiber post and root walls; and 2) there are no differences in the gap formation at the adhesive interfaces for different RCT between the fiber post and root walls.

Material and Methods

This research project was approved by the Research Ethics Committee of the School of Dentistry, State University of Ponta Grossa, report number 25/2011 and protocol number 18741/10. Twenty-four extracted human mandibular premolars were stored in distilled water at 4°C and used within 6 months after extraction (ISO/TS 11405).²³ The inclusion criteria included the following: absence of caries, root cracks, prior endodontic treatments, posts, crowns or severe root curvatures; and a root length of 14 ± 1 mm, measured from the cement-enamel junction (CEJ).

Specimen preparation

Endodontic treatment

Teeth were cross-sectioned immediately below the CEJ using a low-speed diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, USA). Endodontic access was made using a bur with a high-speed hand-piece and water spray. Working length was established by inserting a #10 Flexofile into each canal until it was visible at the apical foramen. The working length was determined by subtracting 1 mm from the canal length. A crown-down technique was used for instrumentation with Gates Glidden drills #2 to #4. Apical enlargement was performed to size 40 and .06 taper. Irrigation was performed after every change of instrument by alternating 1 mL of 1% NaOCl solution and 17% EDTA solution. Roots were dried with paper points (Dentsply Maillefer, Petrópolis, RJ, Brazil), filled with resin-based sealer (AH Plus, DeTrey, Dentsply, Konstanz, Germany) and gutta-percha points using the warm vertical condensation technique. The root access was temporarily filled with conventional

glass ionomer cement (Vitro Fil, DFL, Rio de Janeiro, RJ, Brazil). The roots were stored at 37°C in 100% humidity for a week.

Post space preparation and experimental groups

After one week, the roots were randomly divided into 3 groups (n=8), according to the preparation of post space: WeAd — well-adapted (low RCT), MoAd — moderately well-adapted (medium RCT), and PoAd — poorly adapted (high RCT).

For this purpose, the post spaces were prepared with drills of different diameters. In the WeAd and MoAd groups, the post spaces were prepared with a low-speed drill provided by the post manufacturer (Whitepost DC, FGM, Joinville, Santa Catarina, Brazil). In WeAd, a drill corresponding to the # 0.5 post was used, which had the same crown diameter as the post (1.4 mm), and in MoAd, the drill corresponding to the # 3 post with 2.0 mm crown diameter was used. In PoAd, the post spaces were prepared with a conical diamond bur # 4137 (KG Sorensen, Barueri, São Paulo, Brazil) with 2.6 mm crown diameter adapted at a low speed. We have used a conical diamond bur in this group because there is no other post drill with higher crown diameter available in the market. However, after root canal widening with the diamond bur, the drill corresponding to the #0.5 post was used in order to standardize the smear layer in the root dentin.

In all groups, the same brand of fiber glass post (cylindrical with tapered end [Whitepost DC # 0.5, FGM, Joinville, SC, Brasil]) with a crown diameter of 1.4 mm was cemented. The working length was 10 mm for all teeth, respecting the limit of the apical 4 mm of endodontic filling material. One bur was used for only 6 preparations.

After the post space preparations, the canals were irrigated with 10 mL of distilled water and dried with paper points. To ensure that there was no residual gutta-percha on the walls after post space preparation, a radiographic evaluation of each root was performed.

Post luting procedures

Before the cementation procedures, each fiber glass post was horizontally sectioned with a water-cooled diamond rotary cutting instrument so that a total length of 13 mm remained. Ten mm of the post length were cemented inside the root canal, while the remaining cervical 3 mm served as a guide to standardize the distance of the light curing device from the cervical root area.

The root canal walls were etched with 37% phosphoric acid gel (Total-Etch; Ivoclar-Vivadent, Schaan, Liechtenstein). The gel was introduced in the canal through a needle and washed after 15 s with an endodontic syringe. Excess water was removed from the post space by gently blowing air into it and using paper points, leaving the dentin slightly moist. After this, a specific microbrush (Excite DSC Endo microbrush, Ivoclar-Vivadent, Schaan, Liechtenstein) was used to apply two coats of the dual-cure two-step etch-and-rinse adhesive (Excite DSC, Ivoclar-Vivadent, Schaan, Liechtenstein) to the root canal. A paper point was used to absorb the excess adhesive solution. The base and catalyst components of the resin cement (Variolink II, Ivoclar-Vivadent, Schaan, Liechtenstein) were then mixed, and the resin cement was introduced into the root canal space with a Centrix syringe²⁸ (DFL, Rio de Janeiro, RJ, Brazil) before seating the fiber post. After the fiber post was seated, the excess resin cement was removed, and the remaining cement was light polymerized through the

post for 40 s with a LED light curing device (L.E. Demetron I/ Kerr Corporation, Orange, CA, USA) using a power density of 800 mW/cm². After the post luting procedures, the roots with cemented posts were covered with conventional glass ionomer cement (Vitro Fil, DFL, Rio de Janeiro, RJ, Brazil), and all samples were stored in water at 37°C for 1 week.

Sample Preparation

After this, the roots were placed in separate polyvinyl chloride (PVC) tubes and embedded in acrylic resin (Duralay, Reliance, Dental Mfg. Co., Worth, IL, USA). The portion of each root that contained the bonded fiber post was sectioned perpendicular to the long axis into six 1-mm thick slices. An Isomet 1000 (Buehler, Lake Bluff, IL, USA) saw was used under water cooling to create two cervical, two middle, and two apical slices. Subsequently, all specimens were observed with a light stereomicroscope at 10 X magnification in order to identify any artifacts caused by the sectioning procedure. If any defects were observed, the slices would be discarded.

Resin cement thickness (RCT) Evaluation

All of the slices were photographed with an optical microscope (Olympus, model BX 51, Olympus, Tokyo, Japan) at 100 X magnification. Each photograph was marked with an "X" that divided it into 4 segments, and measurements were taken perpendicular to the lines forming the "X". For each sample (slice), 4 measurements were taken at the 4 points of the "X". The mean RCT (µm) of each sample (slice) was calculated for statistical purposes. The RCT was measured using the UTHSCSA

ImageTool 3.0 software (Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, Texas, USA).

Evaluation of the length and width of the gap formed at the cement-dentin interface

Three slices of each tooth, one from each root third, were randomly selected for evaluating gap formation. Impressions of the slice surfaces were taken with additional silicone (Virtual, Ivoclar-Vivadent, Schaan, Liechtenstein) in order to create positive replicas in epoxy resin (Alpha Resiqualy, Curitiba, Brazil). Each replica was mounted on a metal stub and sputter-coated with 200 Å of gold-palladium in a Polaron SC7620 "Mini" sputter Coater (Quorum Technologies, Ltd., East Sussex, UK) for 5 min at a current of 10 mA. After this, each specimen was examined by scanning electron microscopy (SEM) (JSM 6360LV, Jeol, Ltd., Tokyo, Japan) at different magnifications (30 X to 2000 X) using 15 kV accelerating voltage.

Measurements were made of the entire length and width of the gaps, using UTHSCSA ImageTool 3.0 software (Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, Texas, USA). In each slice, the widest gap at the cement/dentin interface was measured (μm) by 2 different, calibrated operators. The length of the gap was expressed as a percentage of the total length of the bonded area. In both measurements, the values taken from the 3 slices from the same tooth were averaged for statistical purposes. If any disagreement occurred during evaluation, a consensus had to be obtained.

Each slice was also categorized as either having or not having bubbles/voids within the resin cement layer. This procedure was also performed by two evaluators who needed to reach a consensus in case of disagreements.

Push-out Test Evaluation

The coronal side of each slice was identified, and its thickness was measured with a Mitutoyo digital caliper (accuracy of 0.01 mm). The slices were also photographed on both sides with an optical microscope (Olympus, model BX 51, Olympus, Tokyo, Japan) at a 40 X magnification in order to calculate the coronal and apical diameters of the posts with the purpose of calculating their individual bonding areas. This measurement was also taken with the UTHSCSA ImageTool 3.0 software (Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, Texas, USA).

Each specimen (slice) was subjected to a push-out BS test using a universal loading device (AG-I, Shimadzu Autograph, Tokyo, Japan) at a crosshead speed of 0.5 mm/min. The load was applied in the apical-coronal direction until the post was dislodged. Care was taken to center the push-out pin on the center of the post surface without stressing the surrounding post space walls. With regard to the tapered design of the post, different sizes of punch pins were used, which matched the diameter of the post at the different root thirds being tested.

The maximum failure load was recorded in Newton (N) and converted into MPa by dividing the applied load by the bonded area (S_L). Two bonded areas were used for the calculation of the BS, the lateral surface of the fiber post area, and the

lateral surface of the root canal. For both calculations, the bonded area was the lateral surface of a truncated cone, and it was calculated by using the formula:

$$S_L = \pi(R + r)[(h^2 + (R - r)^2)^{0.5}]$$

Where $\pi = 3.14$, R = coronal post radius or root canal radius (coronal post + resin cement radius), r = apical post radius or apical root canal radius (post + resin cement radius), and h = root slice thickness.

Failure mode analysis

After push-out evaluation, the failure modes of all specimens were evaluated under a stereomicroscope (40 X magnification). Each debonded specimen was analyzed by two independent and calibrated operators. The failure modes were classified according to the following criteria: (1) adhesive failure between dentin and luting cement; (2) adhesive failure between luting cement and post; (3) cohesive failure within luting cement; (4) cohesive failure within the post; (5) cohesive failure within dentin; and (6) mixed failure. If any disagreement occurred between the evaluators, a consensus had to be obtained.

Statistical Analysis

The experimental unit for all properties evaluated was the root; therefore, all values obtained for a single root were averaged for statistical purposes. The data obtained of RCT, BS, length, and width of the gaps were statistically analyzed by one-way ANOVA and Tukey's test for pairwise comparisons at a level of significance of 5%. The two approaches used for the BS calculation were compared by paired t-tests at a level of significance of 5%.

The percentage of slices with bubbles/voids were evaluated by the chi-square test ($\alpha = 0.05$). Correlations between the RCT vs. BS, RCT vs. mean gap length, RCT vs. mean gap width, BS vs. mean gap length, and BS vs. mean gap width were evaluated using the Pearson product moment correlation test ($\alpha = 0.05$). Pair-wise comparisons of the failure modes were analyzed by utilizing Fisher's exact test ($\alpha = 0.05$). The Sigma Plot 11 software (Systat Software, San Jose, CA, USA) was used to statically purpose.

Results

None of the specimens presented artifacts caused by the sectioning procedure; therefore, none were discarded.

One-way ANOVA detected significant differences in the RCT ($p < 0.001$). The lowest RCT (μm) values were observed for WeAd, while the highest were observed for PoAd. MoAd showed an intermediate RCT value (Table 1).

As regards gap evaluation, statistical analysis revealed significant differences in the mean gap length and width ($p < 0.0001$). The highest mean gap length (%) and width (μm) were observed for the PoAd. The groups MoAd and WeAd were statistically similar (Table 1). A representative image of the RCT and gap widths for each group can be seen in Figure 1.

From the total of 24 slices evaluated in each group, 10 (42%), 14 (58%), and 24 (100%), respectively, for groups WeAd, MoAd, and PoAd showed gaps (chi-square test, $p = 0.0001$). Similarly, 14 (58%), 19 (79%), and 24 (100%), respectively, for groups WeAd, MoAd, and PoAd showed the presence of bubbles/voids within the resin cement (chi-square test, $p = 0.002$).

The use of post radius for the calculation of BS resulted in higher values than the use of root canal radius (Table 2). Significant differences in BS values were detected by one-way ANOVA, considering the post radius, ($p = 0.006$) as well as the root canal radius ($p < 0.0001$). Higher push-out BS values were observed for WeAd irrespectively of the way that the BS was calculated (Table 2). MoAd and PoAd were

statistically similar ($p > 0.05$) when the post radius was used for BS calculation; however, they differed when root canal radius was used (Table 2).

The analysis of the failure mode is shown in Table 3. No cohesive fracture in cement, post, and dentin or adhesive failure between the cement and post were observed in this investigation. Significantly more mixed failures occurred for all of the groups ($p < 0.02$), and no significant difference in the fracture pattern was observed among them ($p > 0.05$).

The Pearson product moment correlation test showed a moderate, negative, and significant correlation between RCT and BS ($r = -0.665$; $p = 0.0003$). A strong, positive, and significant correlation between the RCT and mean gap length ($r = 0.8274$; $p < 0.0001$) and RCT and mean gap width ($r = 0.8396$; $p < 0.0001$) was also detected (Figure 2). For all correlation tests, we employed the BS values calculated using the post radius.

A moderate, negative, and significant correlation between BS and mean gap length ($r = -0.4676$; $p = 0.0184$) was observed, whereas a negative, but non-significant, correlation between BS and mean gap width ($r = -0.3718$; $p = 0.0671$) was detected (Figure 2).

Discussion

Most of the studies that evaluate the bonding of fiber posts to root canal calculate the BS based on the lateral area of the fiber post.^{11,17,18,19,25,31,35,45,46} However, this study demonstrated that this procedure overestimated the BS values because debonding does not occur in the interface between the resin cement and the fiber post but, rather, between the cement and the root canal walls. Thus, it seems that the use of the lateral area of the root canal is the best method for the calculation of BS, as has been similarly done in a few previous studies.^{26,43}

The present study detected that all of the specimens from the PoAd group showed gap formation at the interface and bubbles/voids within the resin cement. Even in the well-adapted, a gap-free interface was not observed. This means that obtaining a perfect adhesion and the creation of a perfect monoblock system between the post, the resin cement, and dentin is an unreal expectation,⁴¹ one that cannot be accomplished in a clinical scenario. The high C-factor of the closed cavity in root canals (close to 200) led to higher polymerization stress, resulting in gaps at the adhesive interface,^{7,41} even under ideal conditions of adaptation.

It is known that an adverse chemical interaction between unpolymerized acidic monomers, (oxygen inhibition layer of the simplified adhesive) and the tertiary amine from the auto/dual-cured composite may occur.^{36,40} This might also have favored gap formation at the adhesive interface, as the two-step etch-and-rinse (ER) adhesive system (Excite DSC) was used with the dual-cure resin cement (Variolink II). Moreover, two-step ER systems have been shown to function as permeable membranes,^{39,40} allowing water movement across their structure even after polymerization,^{6,9} which

may adversely affect the bond of auto/dual-cured resin cements to the dentin surface.^{9,39}

However, the present investigation showed that the magnitude of gap formation and the resultant BS within the adhesive interface was dependent on the fiber post adaptation to the root canal, which led us to the rejection of both the first and second null hypotheses. According to Feilzer et al.,¹² the composite sample thickness affects stress distribution. This is accentuated in thin layers due to increased boundary restraints (C-factor), contributing to an inverse relationship between film thickness and shrinkage stress.^{2,3} However, although this means that a higher stress contraction is expected to occur under WeAd, some authors have shown that if the BS values to the tooth structure were sufficiently high, thin adhesive joints might enhance the BS of luted restorations.¹

Additionally, as demonstrated in the current study, thicker RCT contains more structural discontinuities, such as bubbles, cracks, or gaps; these are expected to produce stress concentration zones.²⁰ These zones are responsible for starting the fracture line and, therefore, reducing the BS of the fiber post to the root canals, as observed in the present investigation. We could not neglect mentioning that the appearance of bubbles and voids is also dependent on the cement application method.^{28,47,48} For instance, it was demonstrated that the use of the flexible root canal-shaped application aid as an elongation tip,^{47,48} as well as the Lentulo drill and Centrix syringe,²⁸ to insert the resin cement into the root canal was shown to improve the homogeneity of the resin cement layer. In the present study, the resin cement

was introduced into the root canal space with a Centrix syringe, as the elongation tip is designed to be used with the resin cement from the 3MESPE.

Another important aspect to be considered in the PoAd is that the increased amount of resin cement could have adversely affected the absorption of light and, hence, the polymerization reaction of the resin cement within its entire thickness. It is possible that sufficient light transmission did not occur through the post to sufficiently light polymerize the entire RCT in the MoAd and PoAd groups. Thus, the polymerization of resin cement in thicker layers may have relied only on the chemical activation produced by the self-cure component of the dual polymerization system. This resulted in the formation of resin cement with reduced mechanical properties, as well as BS to the root canal. Indeed, it has been demonstrated that dual-cure resin cements that polymerize only by chemical activation do not reach high levels of hardness, as do those polymerized under the dual conditions (light + chemical activation).¹⁴

Based on the aforementioned findings, one may assume that the RCT could be a determining factor in the clinical performance of FRC posts. This finding seems to predispose the restoration to debonding, as observed earlier in prospective and retrospective clinical studies.^{13,15}

The positive and significant correlation between gap length/width and RCT suggests that the increase in RCT significantly decreases the bonding integrity and BS of fiber posts to the root canals. However, to the extent of the authors' knowledge, the relationship between RCT and gap formation has not been investigated prior to this study.

On the other hand, the relationship between RCT and BS was already performed by earlier studies, which produced conflicting results.^{10,30,31,37} While the results of the present study are in agreement with the study of Schmager et al.,³⁷ other authors^{10,30,31} did not find any correlation between RCT and post retention or BS.

This lack of consensus suggests that other factors besides the degree of mismatch between the fiber post and the root canals may play a role in BS. This may lead one to speculate that either the resin cement itself or the adhesive system might have been the weak link at the adhesive interfaces; therefore, the effect of RCT was minor and not detected in the previous studies.^{10,30,31} The fact that laboratory studies^{16,35,43} reported low BS values when testing the resin cement used in the Perez et al.³¹ study strengthens this hypothesis. Additionally, the adhesive system employed by Perdigão et al.³⁰ has shown poor performance in clinical studies.^{34,44}

Finally, we should not overlook the study's limitations. The test specimen crowns were not totally restored, and no thermal cycling or mechanical stressing was applied. These factors may limit the direct application of the study results to clinical conditions. Another limitation is that only one resin cement and adhesive system was employed to investigate the research question. As resin cements and adhesive systems differ in their chemical and mechanical properties, the generalizability of the results of the present study when compared to other materials available in the market should be completed with caution.

This study showed that the fitting of the fiber post to the root canal may be a clinical problem, and alternative methods should be studied to avoid such issues, which would thereby reduce the RCT under clinical conditions in order to minimize gap formation and maximize fiber post retention in root canals.

Conclusions

Within the limitations of this *in vitro* study, it was demonstrated that the push-out bond strength of fiber posts in oversized dowel spaces cemented with the tested resin cement decreased significantly when compared with that of precise fitting posts, most likely due to increased gap formation. It is advisable to prepare post spaces that allow for the chosen fiber post to fit into the space as accurately as possible.

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References

1. Alster D, Feilzer AJ, De Gee AJ, Davidson CL. Tensile strength of thin resin composite layers as a function of layer thickness. *J Dent Res* 1995;74:1745-1748.
2. Alster D, Feilzer AJ, de Gee AJ, Davidson CL. Polymerization contraction stress in thin resin layers as a function of layer thickness. *Dent Mater* 1997;13:146-150.
3. Alster D, Venhoven BAM, Feilzer AJ, Davidson CL. Influence of compliance of the substrate materials on polymerization contraction stress in thin resin layers. *Biomaterials* 1997;18:337-341.
4. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. *J Dent* 1999;27:275-278.
5. Baba NZ, Goodacre CJ, Daher T. Restoration of endodontically treated teeth: the seven keys to success. *Gen Dent* 2009;57:596-603.
6. Bonfante EA, Pegoraro LF, de Goes MF, Carvalho RM. SEM observation of the bond integrity of fiber-reinforced composite posts cemented into root canals. *Dent Mater* 2008;24:483-491.
7. Bouillaguet S, Troesch S, Wataha JC, Krejci I, Meyer JM, Pashley DH. Microtensile bond strength between adhesive cements and root canal dentin. *Dent Mater* 2003;19:199-205.
8. Braem M, Lambrechts P, Van Doren V, Vanherle G. The impact of composite structure on its elastic response. *J Dent Res* 1986;65:648-653.
9. Chersoni S, Acquaviva GL, Prati C, Ferrari M, Grandini S, Pashley DH, et al. In vivo fluid movement through dentin adhesives in endodontically treated teeth. *J Dent Res* 2005;84:223-227.
10. D'Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. *J Prosthet Dent* 2007;98:193-198.
11. D'Arcangelo C, D'Amario M, Vadini M, Zazzeroni S, De Angelis F, Caputi S. An evaluation of luting agent application technique effect on fibre post retention. *J Dent* 2008;36:235-240.
12. Feilzer AJ, de Gee AJ, Davidson CL. Increased wall-to-wall curing contraction in thin bonded resin layers. *J Dent Res* 1989;68:48-50.

13. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. *Am J Dent* 2000;13:9B-13B.
14. Fonseca RG, Cruz CA, Adabo GL. The influence of chemical activation on hardness of dual-curing resin cements. *Braz Oral Res* 2004;18:228-232.
15. Fredriksson M, Astbäck J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber-reinforced epoxy resin posts. *J Prosthet Dent* 1998;80:151-157.
16. Galhano G, de Melo RM, Valandro LF, Bottino MA. Comparison of resin push-out strength to root dentin of bovine- and human-teeth. *Indian J Dent* 2009;20:332-336.
17. Giachetti L, Grandini S, Calamai P, Fantini G, Russo DS. Translucent fiber post cementation using light- and dual-curing adhesive techniques and a self-adhesive material: push-out test. *J Dent* 2009;37:638-642.
18. Gomes GM, Gomes OM, Reis A, Gomes JC, Loguercio AD, Calixto AL. Regional bond strengths to root canal dentin of fiber posts luted with three cementation systems. *Braz Dent J* 2011;22:460-467.
19. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. *Eur J Oral Sci* 2004;112:353-361.
20. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. SEM evaluation of the cement layer thickness after luting two different posts. *J Adhes Dent* 2005;7:235-240.
21. Hayashi M, Ebisu S. Key factors in achieving firm adhesion in post-core restorations. *Jap Dent Sci Rev* 2008;44:22-28.
22. Hornbrook DS, Hastings JH. Use of bondable reinforcement fiber for post and core build-up in an endodontically treated tooth: maximizing strength and aesthetics. *Pract Periodontics Aesthet Dent* 1995;7:33-42.
23. International Standardization for Organization. Guidance on testing of adhesion to tooth structure. Geneva, Switzerland: 2003; CD TR 11405.
24. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canals posts. *Dent Mater* 2004;20:29-36.

25. Manicardi CA, Versiani MA, Saquy PC, Pécora JD, de Sousa-Neto MD. Influence of filling materials on the bonding interface of thin-walled roots reinforced with resin and quartz fiber posts. *J Endod* 2011;37:531-537.
26. Marques de Melo R, Bottino MA, Galvão RK, Soboyejo WO. Bond strengths, degree of conversion of the cement and molecular structure of the adhesive-dentine joint in fibre post restorations. *J Dent* 2012;40:286-294.
27. Martelli H Jr, Pellizzer EP, Rosa BT, Lopes MB, Gonini A Jr. Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fibre posts. *Int Endod J* 2008;41:685-692.
28. Michida SM, Souza RO, Bottino MA, Valandro LF. Cementation of fiber post: influence of the cement insertion techniques on the bond strength of the fiber post-root dentin and the quality of the cement layer. *Minerva Stomatol* 2010;59:633-636.
29. Morgano SM, Rodrigues AH, Sabrosa CE. Restoration of endodontically treated teeth. *Dent Clin North Am* 2004;48:397-416.
30. Perdigão J, Gomes G, Augusto V. The effect of dowel space on the bond strengths of fiber posts. *J Prosthodont* 2007;16:154-164.
31. Perez BE, Barbosa SH, Melo RM, Zamboni SC, Ozcan M, Valandro LF, et al. Does the thickness of the resin cement affect the bond strength of a fiber post to the root dentin? *Int J Prosthodont* 2006;19:606-609.
32. Peutzfeldt A, Asmussen E. Modulus of resilience as predictor for clinical wear of restorative resins. *Dent Mater* 1992;8:146-148.
33. Qualtrough AJ, Manocci F. Tooth-colored post systems: a review. *Oper Dent* 2003;28:86-91.
34. Reis A, Loguercio AD. A 36-month clinical evaluation of ethanol/water and acetone-based etch-and-rinse adhesives in non-carious cervical lesions. *Oper Dent* 2009;34:384-391.
35. Sadek FT, Goracci C, Monticelli F, Grandini S, Cury AH, Tay F, et al. Immediate and 24-hour evaluation of the interfacial strengths of fiber posts. *J Endod* 2006;32:1174-1177.
36. Sanares AM, Itthagarun A, King NM, Tay FR, Pashley DH. Adverse surface interactions between one-bottle light-cured adhesives and chemical-cured composites. *Dent Mater* 2001;17:542-556.

37. Schmage P, Pfeiffer P, Pinto E, Platzer U, Nergiz I. Influence of oversized dowel space preparation on the bond strengths of FRC posts. *Oper Dent* 2009;34:93-101.
38. Schmitter M, Rammelsberg P, Lenz J, Scheuber S, Schweizerhof K, Rues S. Teeth restored using fiber-reinforced posts: in vitro fracture tests and finite element analysis. *Acta Biomater* 2010;6:3747-3754.
39. Tay FR, Pashley DH, Suh BI, Carvalho RM, Itthagarun A. Single-step adhesives are permeable membranes. *J Dent* 2002;30:371-382.
40. Tay FR, Pashley DH, Yiu CK, Sanarens AM, Wei SH. Factors contributing to the incompatibility between simplified-step adhesives and chemically-cured or dual-cured composites. Part I. Single-step self-etching adhesive. *J Adhes Dent* 2003;5:27-40.
41. Tay FR, Loushine RJ, Lambrechts P, Weller RN, Pashley DH. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. *J Endod* 2005;31:584-589.
42. Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. *J Endod* 2007;33:391-398.
43. Valandro LF, Baldissara P, Galhano GA, Melo RM, Mallmann A, Scotti R, et al. Effect of mechanical cycling on the push-out bond strength of fiber posts adhesively bonded to human root dentin. *Oper Dent* 2007;32:579-588.
44. van Dijken JW. Clinical evaluation of three adhesive systems in class V non-carious lesions. *Dent Mater* 2000;16:285-291.
45. Vano M, Cury AH, Goracci C, Chieffi N, Gabriele M, Tay FR, et al. Retention of fiber posts cemented at different time intervals in canals obturated using an epoxy resin sealer. *J Dent* 2008;36:801-807.
46. Wang VJ, Chen YM, Yip KH, Smales RJ, Meng QF, Chen L. Effect of two fiber post types and two luting cement systems on regional post retention using the push-out test. *Dent Mater* 2008;24:372-377.
47. Watzke R, Blunck U, Frankenberger R, Naumann M. Interface homogeneity of adhesively luted glass fiber posts. *Dent Mater* 2008;24:1512-1517.
48. Watzke R, Frankenberger R, Naumann M. Probability of interface imperfections within SEM cross-sections of adhesively luted GFP. *Dent Mater* 2009;25:1256-1263.

49. Zicari F, Couthino E, De Munck J, Poitevin A, Scotti R, Naert I, et al. Bonding effectiveness and sealing ability of fiber-post bonding. *Dent Mater* 2008;24:967-977.
50. Zogheib LV, Pereira JR, do Valle AL, de Oliveira JA, Pegoraro LF. Fracture resistance of weakened roots restored with composite resin and glass fiber post. *Braz Dent J* 2008;19:329-33.

FIGURES

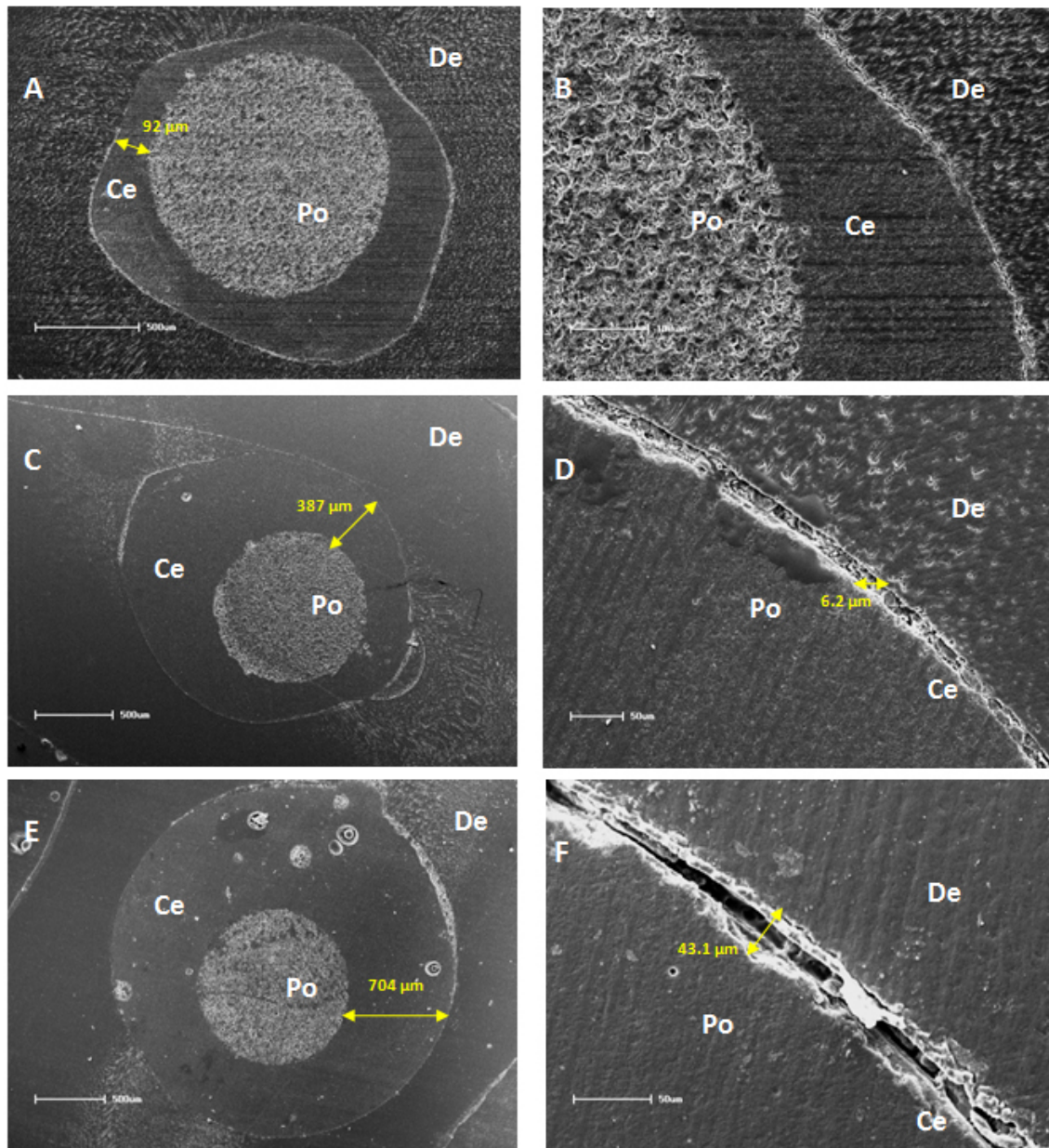


Figure 1 - Scanning electron micrographs of representative resin cement thickness (double arrow in A, C and E) and gaps width (line in D and F) formed in the cement-dentin interface for each group (A,B –WeAd; C,D – MoAd; E,F – PoAd). No gaps were found in B (WeAd). De - dentin; Po - post; Ce - cement.

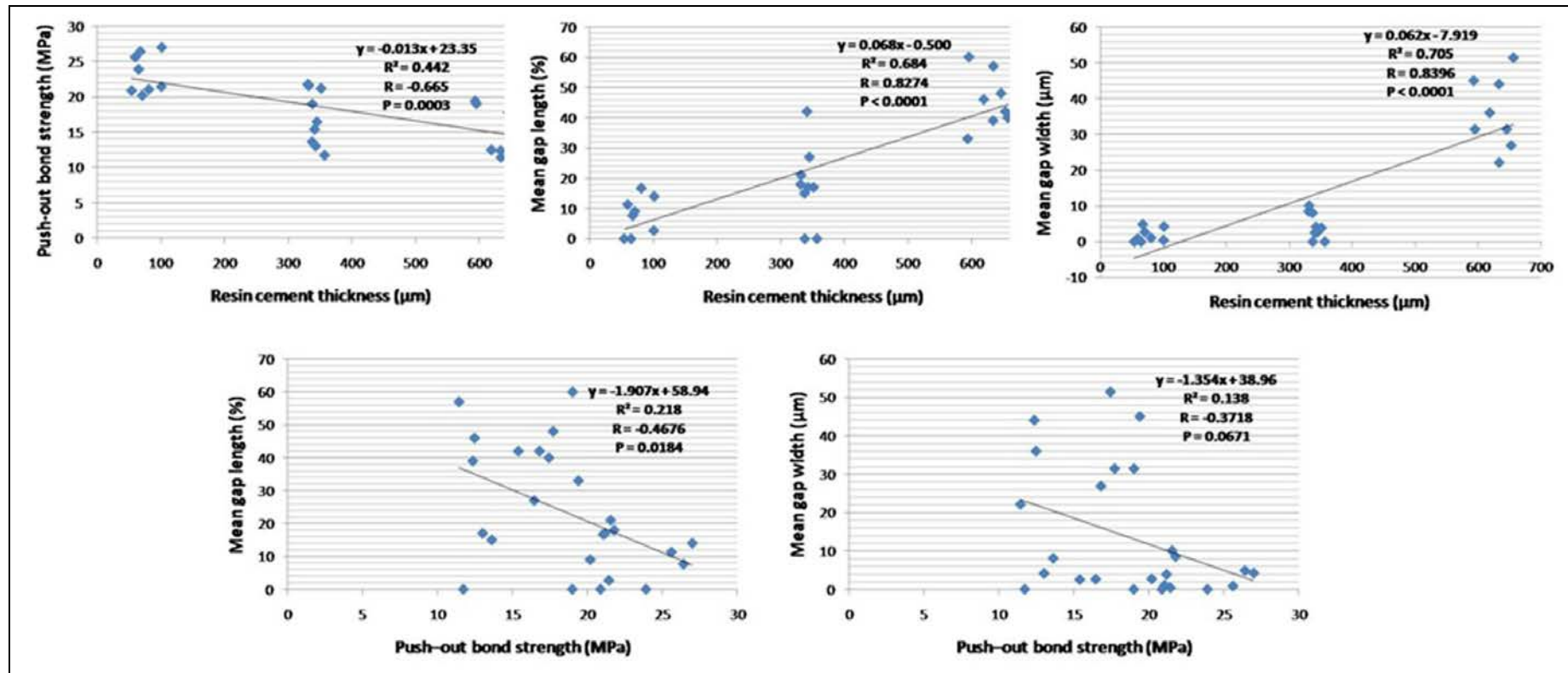


Figure 2 – Significant linear correlations between the properties evaluated in this study.

Table 1 – Means and standard deviations of resin cement thickness (μm), gap length (%), and gap width (μm) for the experimental groups (*).

Experimental Groups	Resin Cement Thickness (μm)	Gap Length (%)	Gap Width (μm)
Well adapted	75.2 $\pm$ 17.9 a	7.4 $\pm$ 6.7 a	1.4 $\pm$ 1.8 a
Moderately well adapted	341.9 $\pm$ 8.5 b	17.0 $\pm$ 13.4 a	4.1 $\pm$ 3.9 a
Poorly adapted	628.9 $\pm$ 24.4 c	45.5 $\pm$ 9.3 b	35.5 $\pm$ 9.9 b

* Comparisons are valid only for columns. Similar lowercase letters indicate statistically similar means ($p > 0.05$).

Table 2 – Means and standard deviations of push-out bond strength (MPa) for the experimental groups (*) using the different methods for calculation of the bonded area.

Experimental Groups	Bond strength (MPa)	
	Post radius	Root canal radius
Well adapted	23.3 ± 2.8 aA	20.2 ± 2.2 aA
Moderately well adapted	17.1 ± 3.9 bA	10.0 ± 2.0 bB
Poorly adapted	15.8 ± 3.2 bA	7.3 ± 1.4 cB

* Lowercase letters indicate the comparisons within each column. Uppercase letters indicate the comparison within each row. Identical letters indicate statistically similar means ($p > 0.05$).

Table 3 - Distribution of the failure mode among the different experimental groups (*)

Experimental Groups	Adhesive Dentin- Cement	Adhesive Cement-Post	Cohesive in Cement	Cohesive in Post	Cohesive in Dentin	Mixed
Well adapted	16	0	0	0	0	32
Moderately well adapte	19	0	0	0	0	29
Poorly adapted	14	0	0	0	0	34

() No cohesive failure in cement, post and dentin or adhesive failure between cement and the post were observed. Significantly more mixed failures occurred for all the groups*

4.2 Artigo **Evaluation of different restorative techniques for filling flared roots: fracture resistance and bond strength after mechanical fatigue** submetido para avaliação na revista *Journal of Adhesive Dentistry*.

COVER LETTER

Dear Editor,

We, Giovana Mongruel Gomes, Osnara Maria Mongruel Gomes, João Carlos Gomes, Alessandro Dourado Loguercio, Abraham Lincoln Calixto and Alessandra Reis, are pleased to submit the enclosed manuscript: **Evaluation of different restorative techniques for filling flared roots: fracture resistance and bond strength after mechanical fatigue** as an original article for publication in the *Journal of Adhesive Dentistry*. This manuscript is entirely original, and it is not under review elsewhere. There is no overlap with other manuscripts that are in review.

We, authors, take the responsibility for the contents of the manuscript, including review and approval of this version, and satisfy the requirements for authorship. There are no relevant financial conflicts of interest.

As you will see in the introduction section, some previous studies have also investigated the same issue. However, no earlier study has cemented a metal-free crown on flared root canals and submitted it to mechanical fatigue before comparison of restorative techniques for cementation of fiber posts. This seems to be of paramount importance since fatigue is one of most important factors that lead to restorative treatment failure. Apart from that, all reported techniques were evaluated in a single experiment. No other study has done this before. The advantage of this is that it increases the power of comparison between different protocols. Altogether we

believe the results of this study can provide clinicians with the best level of in vitro evidence related to the issue under investigation.

We would highly appreciate to have our study published in such a high quality journal as *Journal of Adhesive Dentistry*.

Yours sincerely,

Giovana Mongruel Gomes

Journal of Adhesive Dentistry

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TITLE PAGE**Evaluation of different restorative techniques for filling flared roots: fracture resistance and bond strength after mechanical fatigue**

Giovana Mongruel Gomes¹ [DDS, MS], Osnara Maria Mongruel Gomes² [DDS, MS, PhD], João Carlos Gomes² [DDS, MS, PhD], Alessandro Dourado Loguercio² [DDS, MS, PhD], Abraham Lincoln Calixto² [DDS, MS, PhD], Alessandra Reis² [DDS, PhD].

¹ Professor and PhD student. Department of Restorative Dentistry, School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

² Professors. Department of Restorative Dentistry. School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

Authors address:

Universidade Estadual de Ponta Grossa
Avenida Carlos Cavalcanti 4748 – Uvaranas, Ponta Grossa, Paraná, Brazil
84030-900

Corresponding author:

Giovana Mongruel Gomes
Rua Engenheiro Schamber 452, ap 21 Ponta Grossa, Paraná, Brazil
84010-340
Telephone: 00554232226560 Fax: 00554232247351
Email: giomongruel@gmail.com

Keywords: Bond strength; fiber posts; fracture resistance; resin cements; root dentin; weakened roots.

Evaluation of different restorative techniques for filling flared roots: fracture resistance and bond strength after mechanical fatigue

Abstract

Purpose: To evaluate the fracture resistance (FR) and bond strength (BS) of flared roots restored with different restorative techniques for fiber posts cementation after mechanical fatigue (MF). **Materials and Methods:** The root canals of 84 single-rooted premolars were endodontically treated and prepared in order to simulate an oversized root canal, except for the positive control group (PC), in which a prefabricated fiber post (PFP) with the diameter compatible with the conduit was cemented. In the other oversized root canals, alternative restorative techniques for filling root canals were tested: NC - negative control (PFP with a smaller diameter than of the root canal), PA - PFP + accessory posts, RR – root reinforcement with composite resin, DAP – direct anatomical post and IAP – indirect anatomical post. After the luting procedures (Excite® DSC and Variolink® II), indirect composite crowns were cemented on composite resin cores and the specimens were submitted to MF (1.2×10^6 cycles, 40 N). From each group 8 specimens were subjected to the push-out BS test and the others 6 specimens to the FR test. For both tests the data were subjected to ANOVA and Scheffe's tests ($\alpha=0.05$). **Results:** In relation to the FR all the alternative techniques showed intermediate performance being similar to both control groups; in relation to the BS, only the groups DAP and IAP were similar to the well-adapted condition (PC group). **Conclusion:** The use of DAP and IAP should be the first choice for fiber post cementation in oversized root canals.

Keywords: Bond strength; fiber posts; fracture resistance; resin cements; root dentin, weakened roots.

Clinical relevance: When clinicians cannot lute a well-adapted fiber post to the root canal, the direct and indirect anatomic posts seem to be an interesting alternative technique for restoring these teeth.

Introduction

Teeth submitted to endodontic treatment usually have extensive loss of dental structure and require the use of intra-radicular retainers and filling cores to hold the final restoration.⁴⁵ The main advantage of glass fiber posts is the similar modulus of elasticity in comparison to that of dentin, which favors better stress distribution in the root structure^{15,34,38} and reduces the risk of root fractures.^{6,43}

As pointed out by Perdigão et al.,³¹ one of the clinically relevant problems dentists face when restoring endodontically treated teeth is the mismatch between root canal and post diameters. There are root canals that exhibit extensive tissue destruction resulting from carious lesions, previous restoration with excessive post and core diameters, endodontic over-instrumentation, incomplete physiological root formation due to traumatic impacts, internal resorption, developmental anomalies, or even oval shape.^{2,27}

Bonding prefabricated glass fiber post to flared roots results in thick resin cement layers. Compared with thin layers, thicker layers have an increased likelihood of presenting structural discontinuities, which leads to stress concentration zones¹⁴ that start the fracture line, which reduces the bond strength of the fiber post to the root canals.^{10,37}

In an aim to minimize the mismatch between flared root canals and glass fiber posts, several techniques are proposed. Some authors suggest the restoration of the root canal with composite resin^{22,36,46} to reduce its canal width. Others indicate the direct anatomical fiber post through anatomical shaping of the prefabricated fiber posts with a composite resin into the root canal.^{5,8,13,24} The preparation of indirect anatomical posts on impressions of the root canals has also been proposed to avoid

the production of a new interface in the direct approach (fiber post-composite resin) that may be subjected to failures.⁵ The use of accessory posts is another suggested technique to fill in the mismatch around the main glass fiber post and the root canal.^{5,26}

Studies evaluating the effectiveness of these techniques for restoration of flared roots are controversial,^{5,11,25,39,46,47} and methodologically different, making their comparison difficult. Additionally, to the extent of our knowledge, the few available studies do not mimic clinical conditions;^{5,11,25,26,43,47} i.e., roots are neither restored with a indirect composite restoration nor subjected to a fatigue cycling test.

Therefore, the aim of this study was to evaluate the fracture resistance and bond strength of posts to flared roots restored with different restorative techniques for fiber posts cementation after mechanical fatigue. Two null hypotheses were tested: 1) there are no differences in the fracture resistance and failure mode between flared roots reconstructed with the different restorative techniques, and (2) there are no differences in the push-out bond strength of posts to dentin for the different restorative techniques for filling flared roots.

Materials and Methods

Eighty-four extracted human mandibular premolars were stored in distilled water at 4 °C and used within 6 months after extraction.¹⁸ To be included in the study sample, teeth should be sound, without root cracks and severe root curvatures and not submitted to previous endodontic. Additionally teeth should have a root length of 14 ± 1 mm, measured from the cement-enamel junction (CEJ).

Specimen preparation

Endodontic treatment

Teeth were transversally sectioned 2 mm above the CEJ using a low-speed diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, USA). Endodontic access was made using a tapered fissure bur with a high-speed handpiece and water spray. Working length was established by inserting a #10 Flexofile into each canal until it was visible at the apical foramen. One millimeter was subtracted from this length to establish the working length. A crown-down technique was used for instrumentation with Gates Glidden drills #2 to #4. Apical enlargement was performed to size 40 and .06 taper. Irrigation was performed after every change of instrument by alternating 1 mL of 1% NaOCl solution and 17% EDTA solution. Roots were dried with paper points (Dentsply Maillefer, Petrópolis, RJ, Brazil), filled with resin-based sealer (AH Plus, DeTrey, Dentsply, Konstanz, Germany) and tapered gutta-percha points using the warm vertical condensation technique. The root access was temporarily filled with conventional glass ionomer cement (Vitro Fil, DFL, Rio de Janeiro, RJ, Brazil). The roots were stored at 37 °C in 100% humidity for a week.

Post space preparation

After one week the post spaces of 14 teeth were prepared to receive a glass fiber post #0.5 at low speed (Whitepost DC # 0.5, FGM, Joinville, SC, Brazil), with a crown diameter of 1.4 mm. This group was considered the positive control group (PC). In this group, a perfect adaptation of the post into the conduit was simulated, so the corresponding drill of the #0.5 post was used for canal preparation.

The root canals of the remaining 70 teeth were enlarged with a conical diamond bur #4137 (KG Sorensen, Barueri, SP, Brazil) with 2.6 mm crown diameter adapted at low speed. After root canal widening, the canal walls were prepared slightly with the drill corresponding to the #0.5 post at low speed (Whitepost DC, FGM) in order to standardize the smear layer. After the post space preparations, the canals were irrigated with 10 mL of distilled water and dried with paper points. The working length was 12 mm for all teeth, respecting the apical limit of 4 mm for the endodontic filling material. One bur was used for only six preparations.

Experimental groups

A total of 6 experimental conditions (n=14 for each one) were tested as follows (Figure 1 and Figure 2). The detailed composition and batch number of the materials employed are listed in Table 1.

1. Positive control group (n=14): Prefabricated glass fiber posts #0.5 size, with a diameter compatible to the root canal, were cemented into the roots, simulating an ideal adaptation of the post (Figure 2A).

2. *Negative control group* (n=14): The same prefabricated glass fiber posts were cemented in the flared root canals, simulating an inadequate adaptation of the post (Figure 2B).

3. *Accessory posts group* (n=14): After placement of the main prefabricated fiber post #0.5 on the center of the canal, two accessory glass fiber posts (Reforpin # 1, with a coronal diameter of 1.1, Angelus, Londrina, PR, Brazil) were inserted during cementation (Figure 2C).

4. *Root reinforcement with composite resin* (n=14): Root dentin walls were etched with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) for 15 s, followed by water rinsing and drying with paper points. The two-step etch-and-rinse bonding agent (Tetric N-Bond, Ivoclar-Vivadent) was applied on the entire canal surface in two coats as recommended by the manufacturer. After solvent evaporation, the adhesive was light-cured by positioning the tip of the light-curing unit at the canal entrance for 10 s. A flowable composite resin (Tetric N-Flow, Ivoclar-Vivadent) was applied in order to fill in the root canal from the apex to the cervical portion to avoid the formation of air pockets. After this, the prefabricated glass fiber post #0.5 was lubricated with the hydrosoluble gel (KY, Johnson & Johnson, São José dos Campos, SP, Brazil) and was inserted into the canal. The fiber post was subsequently removed from the conduit and inserted into the resin mass along the whole post space extension. After removal of the excess resin, the tip of the light-curing unit was placed over the post and the flowable resin light-cured for 20 s. The fiber post was dislodged from the canal again, leaving the space ready for cementation of the prefabricated fiber post. Without the post, the flowable resin was additionally light-

cured for 20 s. After it, copious water rinsing was done to remove the lubricant gel from the root canals and the fiber posts, and the post spaces were slightly re-prepared with the drill corresponding to the # 0.5 post (Figure 2D).

5. Direct anatomical post group (n=14): The glass fiber post #0.5 was conditioned with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) for 15 s, followed by rinsing and drying. Then, the fiber post was coated with a layer of the silane coupling agent (Prosil, FGM) for 1 min, and the surface was dried by gently air drying (5 s). The two-step etch-and-rinse adhesive system (Tetric N-Bond, Ivoclar-Vivadent) was applied in two coats, followed by solvent evaporation and finally light-cured for 10 s. The fiber posts were covered with a nanohybrid composite resin (Tetric N-Ceram, Ivoclar-Vivadent), and the set (fiber post + composite resin) was inserted into the canal, previously lubricated with a hydrosoluble gel (KY, Johnson & Johnson).

This set was removed and replaced twice and the cervical excess resin composite was removed. The composite resin was light-cured for 20 s with the post inside the conduit. The relined fiber post was then removed and the composite resin was additionally light-cured for 20 s in each of the buccal, lingual, mesio and distal surfaces in order to completely polymerize the relining resin. The anatomic post was tried in again, in order to ensure adequate adaptation. The root canals and the relined fiber posts were then rinsed abundantly with water to remove the lubricant gel (Figure 2E).

6. Indirect anatomical post group (n=14): For this group, the Fibrex-Lab system (Angelus, Londrina, PR, Brazil) was used. Initially impressions of the root canal were

made with acrylic resin (Duralay, Reliance, Worth, IL, USA). The impressions were lubricated and covered with hot glue (Angelus) following the manufacturer's instructions. After the glue cooled, the impressions were removed and replicas of the root canals were obtained. Medium unidirectional glass fibers (Fibrex-lab, Angelus) with the respective flowable resin from the kit were inserted into the replica. The flowable resin was light-cured for 5 min according to the manufacturer's instructions. Then, the indirect anatomical post was removed from the replica (Figure 2F).

Post luting procedures

Before the cementation procedures, each glass fiber post was horizontally sectioned with a water-cooled diamond rotary cutting instrument, so that a total length of 15 mm remained. The fiber posts as well as the accessory posts were cleaned with 70% alcohol for 5 s. Twelve millimeters of the post length were cemented inside the root canal, while the remaining cervical 3 mm served as a guide to standardize the distance of the light-curing device from the cervical root region.

The root canal walls of all roots were etched with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein). The gel was introduced in the canal through a needle, and rinsed after 15 s with water spray. Excess water was removed from the post space by gently blowing air into it, and using paper points, leaving the dentin slightly moist. After this, an Excite DSC Endo microbrush (Ivoclar-Vivadent, Schaan, Liechtenstein) was used to apply two coats of the dual-cure two-step etch-and-rinse adhesive to the root canal. A paper point was used to absorb the excess adhesive solution. The base and catalyst components of Variolink II (Ivoclar-Vivadent, Schaan, Liechtenstein) were then mixed, and the resin cement was

introduced into the root canal space with a Centrix syringe (DFL, Rio de Janeiro, RJ, Brazil) before seating the fiber post. After the fiber post was seated, the excess resin cement was removed, and the remaining cement was light-cured through the post for 40 s.

After the post luting procedures, cores were built-up with a nanohybrid composite resin (Tetric N-Ceram, Ivoclar-Vivadent, Schaan, Liechtenstein). An incremental technique was used to insert the composite resin, and each 2-mm increment was light-cured for 20 s. All light-curing procedures were performed with a LED light-curing device (Radii Plus, SDI Limited, Victoria, Australia) using a power density of 1500 mW/cm².

Indirect composite crowns cementation

The coronal preparation of the composite cores to receive a full indirect composite crown was performed by means of #2135 and #3098MF diamond burs (KG Sorensen, Barueri, SP, Brazil) in a high-speed handpiece under water cooling. All roots received ferrule in the coronal ending with 2.0 mm height, 1.2 mm depth and 1.5 mm occlusal reduction. The axial and occlusal-axial angles were rounded. The cervical finish line was continuous, defined, and clear. After preparation, the composite cores were finished and polished with Sof-Lex aluminum oxide discs (3M-ESPE, St Paul, MN, USA).

Impressions of the prepared specimens were taken with addition silicone (Virtual, Ivoclar-Vivadent, Schaan, Liechtenstein) and complete indirect composite crowns were fabricated with the restorative system SR Adoro (Ivoclar-Vivadent, Schaan, Liechtenstein) reinforced with fibers (Fibrex-Lab Coronal, Angelus, Londrina,

PR, Brazil) according to the manufacturer's recommendations. After testing and adjustment, the crowns were adhesively cemented on the cores with Excite DSC and Variolink II, following the same protocol described for fiber post cementation.

Periodontal ligament simulation

To reproduce the clinical situation and to provide a more accurate assessment of human root fracture strength, the methodology of the present study included tooth embedding in acrylic resin (Duralay, Reliance, Worth, IL, USA) and periodontal ligament simulation using a polyether impression material (Impregum™ Soft, 3M ESPE, St Paul, MN, USA), according to the method described by Soares et al. 2005.⁴⁰

Initially, root surfaces were dipped into melted wax (Horus, Herpo Produtos Dentários, Petrópolis, RJ, Brazil) up to 2 mm below the CEJ, resulting in a 0.2 to 0.3 mm thick wax layer. Then, the roots were embedded in acrylic resin using polyvinyl chloride (PVC) cylinders (25 mm diameter x 40 mm high) as molds. The resin was mixed according to the manufacturer's instructions and inserted in the PVC cylinder immediately after mixing. After resin polymerization, the teeth were removed from the PVC cylinders, and the wax was removed from the root surface and resin cylinder "sockets" using warm water. The resin cylinders were filled with the polyether impression material⁴⁰ using a molding syringe. The roots were reinserted into their respective cylinder "sockets" and excess impression material was removed with a #12 scalpel blade. Therefore, the polyether filled the space previously occupied by wax, thus providing a standardized simulated periodontal ligament with a thickness of approximately 0.2 to 0.3 mm.

Mechanical Fatigue

All specimens were subjected to 1.2×10^6 cycles of mechanical fatigue in a controlled chewing simulator (Elquip, São Carlos, SP, Brazil), which simulates approximately 5 years of clinical service.^{29,33} The samples were placed at the base of a testing machine material fatigue at an angle of 90° in relation to the horizontal plane and were subjected to repetitive impacts directed on the occlusal surface of the crown. The applied force was 40 N at a frequency of 2 Hz. During the cycles, the samples were kept at 37°C in 100% humidity.

Fracture strength test

Six specimens per group were subjected to a compressive load at a crosshead speed of 0.5 mm/min until fracture.^{39,43,47} To carry out the fracture resistance testing, a stainless-steel metal device was made containing a sloping plane of 30° in relation to the base with a cylindrical concavity at the center of this plane where the specimens were inserted. Thus, the samples were submitted to a compressive loading in a universal testing machine (AG-I, Shimadzu Autograph, Tokyo, Japan) at an angle of 150° in relation to the long axis of the roots. The compressive load was applied in the buccal cusp (working cusp) of the crowns, and it was automatically discontinued when the restorative system failed (dislocation or fracture of the crown, or the coronal portion or root fracture). The values were recorded in Newton.

After testing, all roots were removed from the cylinder "sockets" and the fracture modes were classified as reparable (would allow repair) or irreparable (non-restorable) in accordance with the degree of dental structure destruction: 1) reparable (displacement of the crown, post fracture, or root fracture above the root

cervical level that would allow a new restoration) and 2) irreparable (fracture below the root cervical third, vertical or oblique fracture, or horizontal fracture in the middle and apical thirds which condemn the tooth to extraction).^{23,47}

Push-out bond strength test

The 8 remaining roots from each group (n=8) were subjected to the push-out test. For this purpose, the indirect composite crowns cemented on these teeth were sectioned and discarded, and the portion of each root that contained the bonded fiber post was serially sectioned perpendicular to the long axis into six 1-mm thick slices. An Isomet 1000 (Buehler) saw was used under water cooling to produce six slices. Subsequently, all specimens were observed with a light stereomicroscope at 10 X magnification (Olympus, model BX 51, Olympus, Tokyo, Japan) to detect any artifacts caused by the sectioning procedure. If any defects were observed the slices would be discarded.

The coronal side of each slice was identified and its thickness measured with a Mitutoyo digital caliper (accuracy of 0.01 mm). The slices were also photographed on both sides, with an optical microscope (Olympus) at a 40 X magnification in order to measure the internal coronal and apical diameters of the root canal walls, with the purpose of calculating their individual bonding area. This measurement was taken with UTHSCSA ImageTool 3.0 software (Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, Texas, USA).

Each slice was subjected to a push-out BS test using a universal loading device (Shimadzu) at a crosshead speed of 0.5 mm/min with the load applied in the apical-coronal direction until the post was dislodged. Care was taken to center the push-out

pin on the center of the post surface, without stressing the surrounding post space walls. With regard to the tapered design of the post, different sizes of punch pins, which matched the diameter of the root canal at the different root thirds being tested, were used.

The maximum failure load was recorded in Newton (N) and converted into MPa by dividing the applied load by the bonded area (S_L). As the bonded area was the lateral surface of a truncated cone, it was calculated by the formula:

$$S_L = \pi(R + r)[(h^2 + (R - r)^2)^{0.5}]$$

Where $\pi = 3.14$, R = internal coronal radius of the root canal, r = internal apical radius of the root canal, and h = root slice thickness.

Statistical Analysis

The experimental unit for all properties evaluated was the root, therefore all values obtained for a single root were averaged for statistical purposes. The data from push-out and fracture resistance were statistically analyzed by one-way ANOVA and Scheffe's post hoc tests at a level of significance of 5%. The failure modes of the groups were statistically analyzed by Fisher's exact test ($\alpha = 0.05$).

Results

A good adaptation of the fiber post to the root canal was observed in all techniques, except from the negative control and the accessory post group, where a thick resin cement layer is easily distinguished (Figure 3).

All specimens remained intact after 1.2×10^6 cycles of dynamic loading. The means of the fracture failure strengths and their respective standard deviations (N) are presented in Table 2. A statistically significant effect was detected by one-way ANOVA ($p = 0.0129$). The positive control group showed the highest fracture strength and the negative control showed the lowest ($p < 0.05$). All other techniques showed intermediate performance similar to both control groups.

One-way ANOVA also detected statistical differences among groups for the push-out test (one-way ANOVA, $p < 0.001$). The highest bond strength mean was observed for the positive control group and the lowest mean for the negative control group ($p < 0.05$). Only the direct anatomical post and indirect anatomical post groups showed BS values similar to the well-adapted condition (positive control group). The use of an accessory post had an intermediate performance, being statistically similar to direct and indirect anatomical posts and root reinforcement with composite resin groups ($p > 0.05$).

Table 3 shows the distribution of the failure mode among the different experimental groups after the fracture resistance test. No significant difference was observed among them (Fisher's exact test, $p > 0.05$). The majority of the fractures in this study were repairable (91.6%). Representative images of repairable and irreparable fractures can be seen in Figure 4.

Discussion

Although previous studies have already investigated techniques for cementation of fiber posts in root flared canals,^{5,11,13,24,25,26,47} most of these studies did not simulate at least one out of three important clinical features, recreated in this study protocol: final restoration of the root, simulation of the periodontal ligament, and mechanical aging.

In a clinical scenario, the core and post are always covered by a final restoration to improve the integrity of endodontically treated teeth²¹ and to maximize the fracture resistance of the roots.^{16,28,41} The presence of the periodontal ligament and tooth supporting structures partially absorb the masticatory loads and therefore studies that did not simulate them may obtain unreliable load values, which may affect the mode of failure of the specimens⁴⁰ and the group comparisons.

Post-retained restorations are subjected to repetitive ordinary chewing forces over time as well as other environmental challenging factors.¹⁷ This explains why most post-retained restorations do not fail by static compressive loads, but by fatigue stress.¹⁷ Thus, mechanical aging is essential to resemble closely the clinical conditions to which post-retained restorations are prone to.

One of the purposes of all tested techniques herein tested is to reduce the resin cement thickness and consequently the polymerization stress at the cement/dentin and cement/post interfaces.³ This stress induces structural discontinuities^{10,14} and stress concentration zones¹⁴ that are responsible for starting the fracture line and reducing the bond strength of the fiber post to the root canals.¹⁴

Except from the negative control group and accessory post group, all other techniques employed a thin resin cement layer during cementation. Therefore, the differences among the techniques and the positive control group cannot be solely explained by the thickness of the resin cement layer. Other factors may also be involved in the retention of the post to the root canals.

Both direct and indirect anatomical post techniques showed bond strength values similar to the positive control group, which are in agreement with previous studies.^{8,24} In the direct anatomical post technique, the fiber post is relined into the root canal, replacing the resin cement by the composite resin,¹³ which has better mechanical and physical properties. This technique is relatively easy: only a few additional steps are required to lute a conventional fiber post. Similarly to the direct anatomical post group, the individual post fabricated in the indirect technique may also have superior mechanical properties,⁵ although this technique has the disadvantage of being more time-consuming and expensive due to the need for a laboratory step.¹³

The high retention values³⁰ and pull-out bond strength²⁴ of the direct and indirect anatomical post techniques can also be attributed to the high hydraulic pressure they put on the cement against the dentin walls, resulting in better contact between the cement/post set and dentin.^{4,8} This pressure reduces blister formation in the cement,⁴ eliminating sources of flaw-initiating sites; increases the number of tubules filled with the resin cement⁴⁴ due to better penetration of resin into demineralized dentin; and results in a more uniform hybrid layer, with greater resin tags and adhesive lateral branches.

Previous studies^{20,39} reported that the placement of accessory posts significantly increased the fracture resistance of over-flared roots and this was also partially observed in this study. However, in terms of bond strength, no significant enhancement was observed in this study. The thickness of the cement layer in the accessory posts group was not as thin as in the other groups because a large number of empty spaces still exist between the accessory posts and the root walls (Figure 3C). Thus, the likelihood of the resin cement layer presenting large lacunae or bubbles is high,¹⁴ reducing the cohesive strength of the resin cement and the bond strength to dentin. The large volume of cement inserted in the root canal in this technique may also induce high polymerization shrinkage stresses at the adhesive interface, favoring debonding at low forces.

The poor behavior of the resin reinforcement group was not expected since a previous study¹¹ reported an increase in root fracture strength after restoration of root canal with composite resins. Composite resin absorbs and distributes forces in a more uniform manner, which may increase fracture resistance and improve the prognosis of post-retained restorations.^{9,22} However, the difficulties in providing an adequate curing at the deepest regions of the canal wall might have affected the material properties⁴⁸ and its bonding to the adhesive layer. A translucent post can assist in curing the deepest layers of resin, but light-transmitting posts alone may not be sufficient to allow adequate composite resin polymerization within the canal space.³⁵ Therefore, the inferior curing of the composite resin can be responsible for the low bond strength values reported in this study and the low fracture resistance of the reinforced root in other published papers.^{25,46,47}

In general, most of the fracture patterns observed in this study, even in the negative control group, were repairable, confirming earlier findings.^{13,26,39,43,47} Due to the similar elastic modulus of the resin cement, dentin, glass fiber posts, and composite resin,^{1,19,32} this monoblock acts as a shock absorber, which increases tooth strength.⁶ Moreover, glass fiber posts are flexible; this property prevents the propagation of microcracks, favoring the distribution of the load to the cervical root third and along the periodontal support.⁷

The fracture resistance test used in this study was not sensitive enough to rank the different techniques. The test allowed us to conclude that the positive control group, which had the thickest root dentin structure, showed a higher fracture resistance than the negative control group. This was somewhat expected due to fact that the fracture resistance of endodontically treated teeth seems to be directly proportional to the amount of remaining dentin structure.^{25,42,46} During normal occlusal function, dentin exhibits considerable plastic deformation, resisting varying degrees and angles of load. If the dentin canal walls are thin, they may flex more during loading and this may reduce the stability of the metal-free crown over the cemented fiber post. Consequently, the restorative complex may fracture at reduced loads, which may explain the resistance of the negative control group. Thus, the maintenance of healthy radicular dentin is more important than the root reconstruction protocol in terms of fracture resistance.

In summary, clinicians should attempt to keep as much dentin structure as possible, since the positive control group was the one that exhibited the highest bond strength and fracture resistance results. The close contact between the fiber

post and the root canals allows better transference of the load, minimizes stress concentration, and enhances the sliding friction between the bonding substrates.¹² However, if this is not possible, direct and indirect anatomic posts seem to be the best technique for restoring flared root canals.

Clinical extrapolation of the results must be done judiciously and prudently since not all conditions of the oral environment can be simulated. Clinically, the forces generated by masticatory activities occur in several directions instead of a single direction, as performed in the in vitro compressive fracture strength tests. Further controlled clinical trials should be conducted to evaluate the long-term performance of these techniques in a clinical scenario.

Conclusions

Within the limitations of this in vitro study, it was demonstrated that the direct and indirect anatomic posts seem to be the best technique for restoring flared root canals, as the resulting bond strength and fracture resistance were comparable with a well-adapted situation.

Acknowledgements

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References

1. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. *J Dent* 1999;27:275-278.
2. Baba NZ, Goodacre CJ, Daher T. Restoration of endodontically treated teeth: the seven keys to success. *Gen Dent* 2009;57:596-603.
3. Braga RR, Boaro LC, Kuroe T, Azevedo CL, Singer JM. Influence of cavity dimensions and their derivatives (volume and "C" factor) on shrinkage stress development and microleakage of composite restorations. *Dent Mater* 2006;22:818-823.
4. Chieffi N, Chersoni S, Papacchini F, Vano M, Goracci C, Davidson CL, et al. The effect of application sustained seating pressure on adhesive luting procedure. *Dent Mater* 2007;23:159-166.
5. Clavijo VG, Reis JM, Kabbach W, Faria e Silva AL, Oliveira Junior OB, Andrade MF. Fracture strength of flared bovine roots restored with different intraradicular posts. *J Appl Oral Sci* 2009;17:574-578.
6. Coelho CS, Biffi JC, Silva GR, Abrahão A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. *Dent Mater J* 2009;28:671-678.
7. Eskitascioglu G, Belli S, Kalkan M. Evaluation of two post core systems using two different methods (fracture strength test and finite elemental stress analysis). *J Endod* 2002;28:629-633.
8. Faria-e-Silva AL, Pedrosa-Filho Cde F, Menezes Mde S, Silveira DM, Martins LR. Effect of relining on fiber post retention to root canal. *J Appl Oral Sci* 2009;17:600-604.
9. Godder B, Zhukovsky L, Bivona PL, Epelboym D. Rehabilitation of thin-walled roots with light-activated composite resin: a case report. *Compendium* 1994;15:54-57.
10. Gomes GM, Rezende EC, Gomes OM, Gomes JC, Loguercio AD, Reis A. Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin. *J Adhes Dent* *in press*.
11. Gonçalves LA, Vansan LP, Paulino SM, Sousa Neto MD. Fracture resistance of weakened roots restored with a transilluminating post and adhesive restorative materials. *J Prosthet Dent* 2006;96:339-344.

12. Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M. The contribution of friction to the dislocation resistance of bonded fiber posts. *J Endod* 2005;31:608-612.
13. Grandini S, Sapio S, Simonetti M. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. *J Adhes Dent* 2003;5:243-247.
14. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. SEM evaluation of the cement layer thickness after luting two different posts. *J Adhes Dent* 2005;7:235-240.
15. Hayashi M, Ebisu S. Key factors in achieving firm adhesion in post-core restorations. *Jap Dent Sci Rev* 2008;44:22-28.
16. Hu S, Osada T, Shimizu T, Warita K, Kawawa T. Resistance to cyclic fatigue and fracture of structurally compromised root restored with different post and core restorations. *Dent Mater J* 2005;24:225-231.
17. Huysmans MC, Peters MC, Van der Varst PG, Plasschaert AJ. Failure behavior of fatigue-tested post and cores. *Int Endod J* 1993;26:294-300.
18. International Standardization for Organization. Guidance on testing of adhesion to tooth structure. Geneva, Switzerland: 2003; CD TR 11405.
19. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canals posts. *Dent Mater* 2004;20:29-36.
20. Li Q, Xu B, Wang Y, Cai Y. Effects of auxiliary fiber posts on endodontically treated teeth with flared canals. *Oper Dent* 2011;36:380-389.
21. Libman WJ, Nicholls JL. Load fatigue of teeth restored with cast posts and cores and complete crowns. *Int J Prosthodont* 1995;8:155-161.
22. Lui JL. Composite resin reinforcement of flared canals using light-transmitting plastic posts. *Quintessence Int* 1994;25:313-319.
23. Maccari PC, Cosme DC, Oshima HM, Burnett LH Jr, Shinkai RS. Fracture strength of endodontically treated teeth with flared root canals and restored with different post systems. *J Esthet Restor Dent* 2007;19:30-36.
24. Macedo VC, Faria e Silva AL, Martins LRM. Effect of cement type, relining procedure, and length of cementation on pull-out bond strength of fiber posts. *J Endod* 2010;36:1543-1546.

25. Marchi GM, Paulillo LA, Pimenta LA, De Lima FA. Effect of different filling materials in combination with intraradicular posts on the resistance to fracture of weakened roots. *J Oral Rehabil* 2003;30:623-629.
26. Martelli H Jr, Pellizzer EP, Rosa BT, Lopes MB, Gonini A Jr. Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fibre posts. *Int Endod J* 2008;41:685-692.
27. Morgano SM, Rodrigues AH, Sabrosa CE. Restoration of endodontically treated teeth. *Dent Clin North Am* 2004;48:397-416.
28. Naumann M, Preuss A, Frankenberger R. Reinforcement effect of adhesively luted fiber reinforced composite versus titanium posts. *Dent Mater* 2007;23:138-144.
29. Naumann M, Sterzenbach G, Rosentritt M, Beuer F, Frankenberger R. In vitro performance of self-adhesive resin cements for post-and-core build-ups: Influence of chewing simulation or 1-year storage in 0.5% chloramine solution. *Acta Biomater* 2010;6:4389-4395.
30. Patierno JM, Rueggeberg FA, Anderson RW, Weller RN, Pashley DH. Push-out strength and SEM evaluation of resin composite bonded to internal cervical dentin. *Endod Dent Traumatol* 1996;12:227-236.
31. Perdigão J, Gomes G, Augusto V. The effect of dowel space on the bond strengths of fiber posts. *J Prosthodont* 2007;16:154-164.
32. Peutzfeldt A, Asmussen E. Modulus of resilience as predictor for clinical wear of restorative resins. *Dent Mater* 1992;8:146-148.
33. Pontius O, Hutter JW. Survival rate fracture strength of incisors restored with different post and core systems and endodontically treated incisors without coronoradicular reinforcement. *J Endod* 2002;28:710-715.
34. Qualtrough AJ, Manocci F. Tooth-colored post systems: a review. *Oper Dent* 2003;28:86-91.
35. Roberts HW, Leonard DL, Vandewalle KS, Cohen ME, Charlton DG. The effect of a translucent post on resin composite depth of cure. *Dent Mater* 2004;20:617-622.
36. Saupe WA, Gluskin AH, Radke RA. A comparative study of fracture resistance between morphological dowel and cores and a resin-reinforced dowel system in the intraradicular restoration of structurally compromised roots. *Quintessence Int* 1996;27:483-491.

37. Schmage P, Pfeiffer P, Pinto E, Platzer U, Nergiz I. Influence of oversized dowel space preparation on the bond strengths of FRC posts. *Oper Dent* 2009;34:93-101.
38. Schmitter M, Rammelsberg P, Lenz J, Scheuber S, Schweizerhof K, Rues S. Teeth restored using fiber-reinforced posts: in vitro fracture tests and finite element analysis. *Acta Biomat* 2010;6:3747-3754.
39. Silva GR, Santos-Filho PC, Simamoto-Júnior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. *Braz Dent J* 2011;22:230-237.
40. Soares CJ, Pizi EC, Fonseca RB, Martins LR. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. *Braz Oral Res* 2005;19:11-16.
41. Tan PL, Aquilino AS, Gratton DG, Stanford CM, Tan SC, Johnson WT, et al. In vitro fracture resistance of endodontically treated incisors with varying ferrule heights and configurations. *J Prosthet Dent* 2005;93:331-336.
42. Tjan AHL, Whang SB. Resistance to root fracture of dowel channels with various thickness of buccal dentin walls. *J Prosthet Dent* 1985;53:496-500.
43. Torabi K, Fattahi F. Fracture resistance of endodontically treated teeth restored by different FRC posts: an in vitro study. *Indian J Dent Res* 2009;20:282-287.
44. Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. *Dent Mater* 2002;18:495-502.
45. Zicari F, Couthino E, De Munck J, Poitevin A, Scotti R, Naert I, et al. Bonding effectiveness and sealing ability of fiber-post bonding. *Dent Mater* 2008;24:967-977.
46. Zogheib LV, Pereira JR, do Valle AL, de Oliveira JA, Pegoraro LF. Fracture resistance of weakened roots restored with composite resin and glass fiber post. *Braz Dent J* 2008;19:329-333.
47. Zogheib LV, Saavedra Gde S, Cardoso PE, Valera MC, Araújo MA. Resistance to compression of weakened roots subjected to different root reconstruction protocols. *J Appl Oral Sci* 2011;19:648-654.
48. Yoldas O, Alaçam T. Microhardness of composites in simulated root canals cured with light transmitting posts and glass-fiber reinforced composite posts. *J Endod* 2005;31:104-106.

TABLES

Table 1 – Composition, classification and batch number of the materials.

Material / Manufacture	Classification	Composition	Batch number
Total-Etch / Ivoclar Vivadent	Etching conditioning	Contains phosphoric acid (37 wt.% in water), thickening agent and colour pigments.	P56449
Excite [®] DSC / Ivoclar Vivadent	Adhesive system (dual-curing)	Excite [®] DSC contains HEMA, dimethacrylates, phosphonic acid acrylate, highly dispersed silicon dioxide, initiators and stabilizers in an alcohol solution. The Excite [®] DSC Brush is coated with initiators.	N01061
Tetric [®] N-Bond / Ivoclar Vivadent	Adhesive system (light-curing)	Contains phosphoric acid acrylate, HEMA, Bis-GMA, urethane dimethacrylate, ethanol, film-form agent, catalysts and stabilizers.	N64295
Tetric [®] N-Flow /	Composite resin	Contains 36 wt.% dimethacrylates (including	N74353

Ivoclar Vivadent	(light-curing)	TEGDMA), 63 wt.% fillers (barium glass, ytterbium trifluoride, highly dispersed silica and mixed oxide) and 1 wt.% catalysts, stabilizers and pigments. The total content of inorganic fillers is 39 vol.%. The particle size of inorganic fillers is between 40 and 3000 nm.	
Tetric® N-Ceram / Ivoclar Vivadent	Composite resin (light-curing)	Consists of dimethacrylates (19-20 wt.%). The fillers contain barium glass, ytterbium trifluoride, mixed oxide and copolymers (80-81 wt.%). Additives, catalysts, stabilizers and pigments are additional contents (< 1 wt.%). The total content of inorganic fillers is 55-vol.%. The particle size of inorganic fillers is between 40 and 3000 nm.	L54096
Variolink® II / Ivoclar Vivadent	Resin cement (dual-curing)	The monomer matrix is composed of Bis-GMA, urethane dimethacrylate, and triethylene glycol dimethacrylate. The inorganic fillers are barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, and spheroid mixed oxide. Additional contents: catalysts, stabilizers, and pigments. The particle size is 0.04 – 3.0 µm. The mean particle size is 0.7 µm.	N44255

Table 2 – Means and standard deviations of the fracture strength (N) and push-out bond strength (MPa) for the different experimental groups as well as the statistical significance *.

Experimental Groups	Fracture strength (n=6 for each group)	Bond strength (n=8 for each group)
Positive Control	1194.9 ± 269.0 a	12.0 ± 1.5 a
Negative control	815.3 ± 114.3 b	3.7 ± 1.2 c
Accessory posts	1076.5 ± 209.0 a,b	8.0 ± 1.5 b
Root reinforcement	1013.4 ± 195 a,b	6.3 ± 1.2 b,c
Direct anatomical post	882.9 ± 112.4 a,b	8.8 ± 2.5 a,b
Indirect anatomical post	1156.5 ± 229.4 a,b	8.8 ± 2.3 a,b

* Comparisons are valid only within the same column. Similar lowercase letters indicate statistically similar means ($p > 0.05$).

Table 3- Number of specimens distributed according to the different fracture modes and the overall percentage of repairable and irreparable failures.

GROUPS	REPAIRABLE FAILURES (%)			IRREPARABLE FAILURES (%)		
	Crown displacement	Post fracture	Above the root cervical third	Bellow the root cervical third	Vertical or oblique root fracture	Horizontal root fracture (middle and apical thirds)
Positive control	5		1			
Negative control	3		2		1	
Accessory posts	5		1			
Root reinforcement with composite resin	4				2	
Direct anatomical post	5	1				
Indirect anatomical post	4	1	1			
Total (%)	72.2%	5.6%	13.9%	0%	8.3%	0%
Overall (%)	91.7%			8.3%		

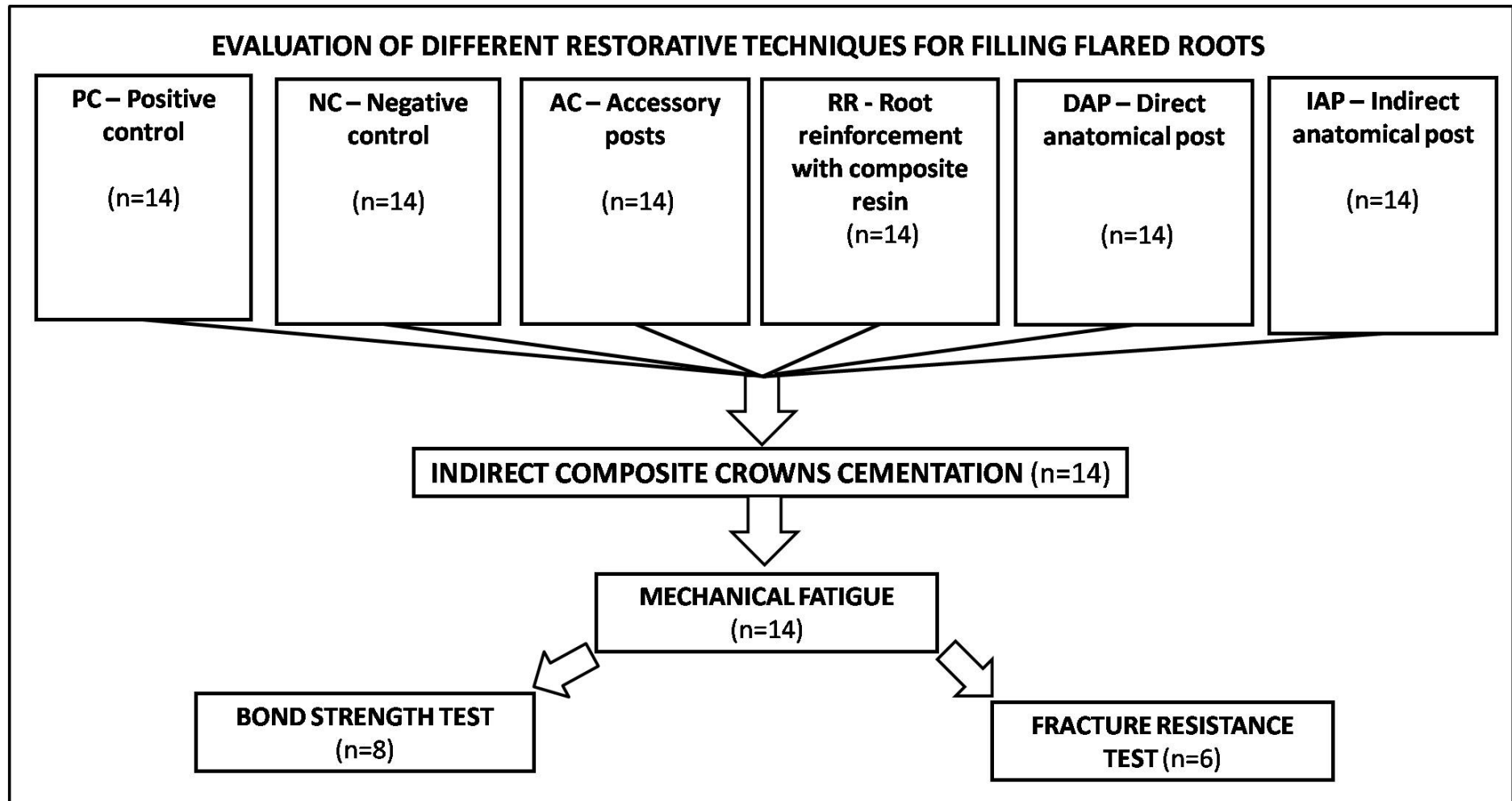


Figure 1 – Experimental flow-chart.

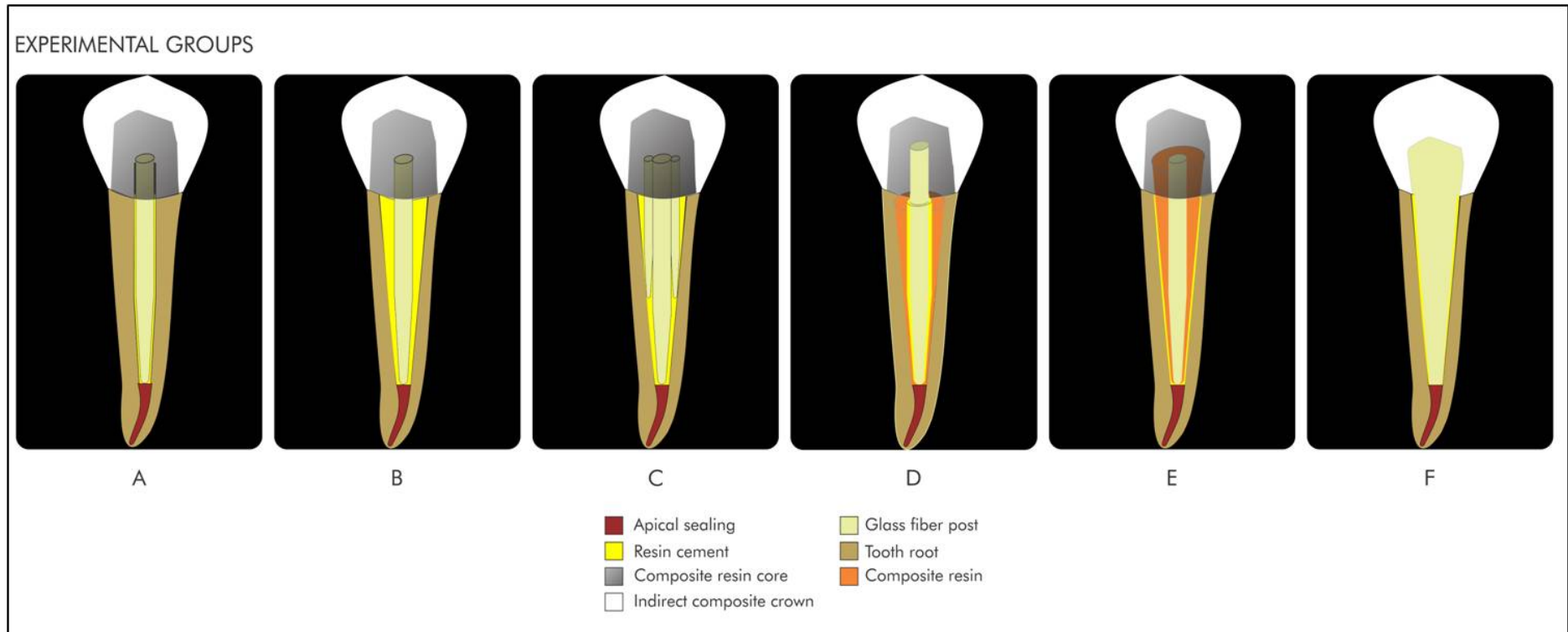


Figure 2 – Schematic illustration of the experimental groups. A - Positive control group, B - Negative control group, C - Accessory posts group, D - Root reinforcement with composite resin, E - Direct anatomical post group, F - Indirect anatomical post group.

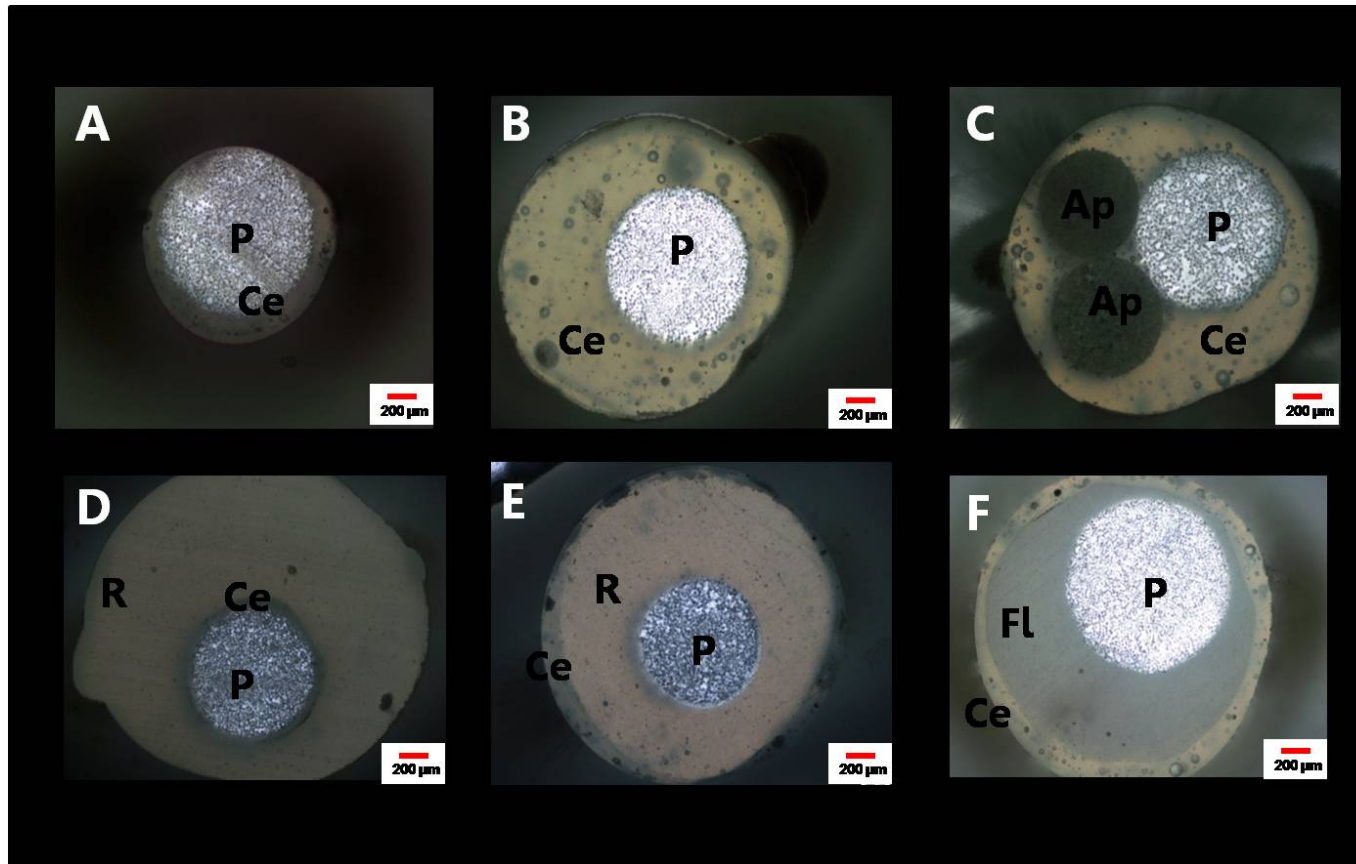


Figure 3 - Adaptation of the fiber post to the root canal in the different groups. A - Positive control group, B - Negative control group, C - Accessory posts group, D - Root reinforcement with composite resin, E - Direct anatomical post group, F - Indirect anatomical post group. *P* - post; *Ce* - resin cement; *Ap* - accessory posts; *R* - composite resin; *Fl* - fibrex-lab system.

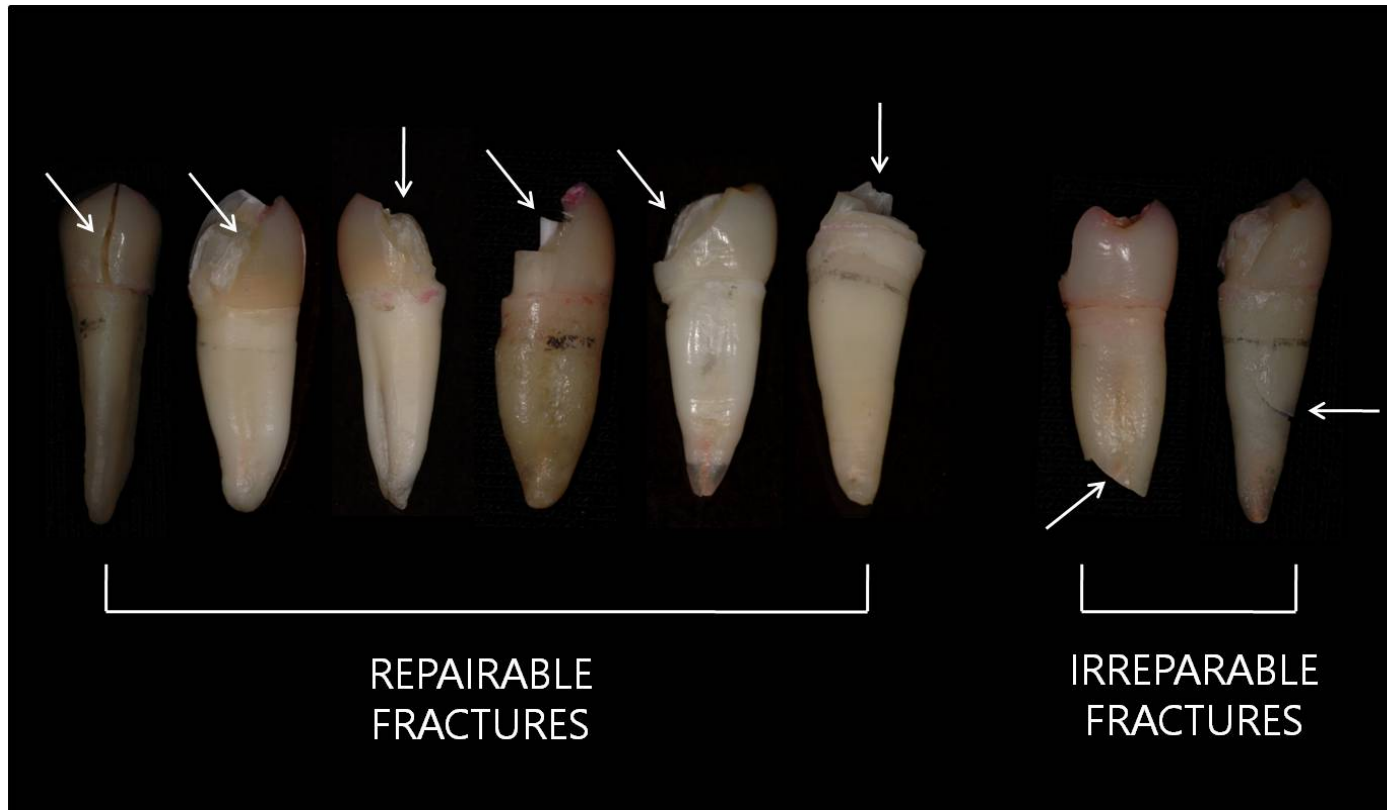


Figure 4 - Representative images of repairable and irreparable fractures.

4.3 Artigo **Use of a direct anatomic post in a flared root canal: a case report** submetido para avaliação na revista *Journal of Esthetic and Restorative Dentistry*.

COVER LETTER

Dear Editor,

We, Giovana Mongruel Gomes, Raphael Vieira Monte Alto, Gustavo Oliveira dos Santos, Cheung Ka Fai, Osnara Maria Mongruel Gomes, João Carlos Gomes, Alessandro Dourado Loguercio and Alessandra Reis, are pleased to submit the enclosed manuscript: **Use of a direct anatomic post in a flared root canal: a case report** as an original article for publication in the *Journal of Esthetic and Restorative Dentistry*. This manuscript is entirely original, and it is not under review elsewhere. There is no overlap with other manuscripts that are in review.

We, authors, take the responsibility for the contents of the manuscript, including review and approval of this version, and satisfy the requirements for authorship. There are no relevant financial conflicts of interest.

We would highly appreciate to have our study published in such a high quality journal as *Journal of Esthetic and Restorative Dentistry*.

Yours sincerely,

Giovana Mongruel Gomes

Journal of Esthetic and Restorative Dentistry



Use of a direct anatomic post in a flared root canal: a case report

Journal:	<i>Journal of Esthetic and Restorative Dentistry</i>
Manuscript ID:	Draft
Wiley - Manuscript type:	Clinical Article
Keywords:	Fiber post, Resin cement, Flared root
Abstract:	The following case report describes the rehabilitation of a flared root canal using a direct anatomic post (a resin composite combined to a prefabricated glass fiber post) associated with metal-free ceramic restoration. The report presents the clinical protocol for the fabrication of the cores, which provide an intimate fit to the remaining root and mechanical properties similar to those of dental structure, being an alternative to the conventional metal cores.

TITLE PAGE

Use of a direct anatomic post in a flared root canal: a case report

Giovana Mongrue! Gomes¹ [DDS, MS], Raphael Vieira Monte Alto² [DDS, MS, PhD], Gustavo Oliveira dos Santos² [DDS, MS, PhD], Cheung Ka Fai³ [DDS, MS], Osnara Maria Mongrue! Gomes⁴ [DDS, MS, PhD], João Carlos Gomes⁴ [DDS, MS, PhD], Alessandro Dourado Loguercio⁴ [DDS, MS, PhD], Alessandra Reis⁴ [DDS, PhD].

¹ PhD student. Department of Restorative Dentistry, School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

² Professors. Department of General Clinical. School of Dentistry, Federal University Fluminense. Rio de Janeiro, RJ, Brazil.

³ Master student. Department of General Clinical. School of Dentistry, Federal University Fluminense. Rio de Janeiro, RJ, Brazil.

⁴ Professors. Department of Restorative Dentistry. School of Dentistry, State University of Ponta Grossa. Ponta Grossa, Paraná, Brazil.

Authors address:

Universidade Estadual de Ponta Grossa
Avenida Carlos Cavalcanti 4748 – Uvaranas, Ponta Grossa, Paraná, Brazil
84030-900

Corresponding author:

Giovana Mongrue! Gomes
Rua Engenheiro Schamber 452, ap 21 Ponta Grossa, Paraná, Brazil
84010-340
Telephone: 00554232226560 Fax: 00554232247351
Email: giomongrue!@gmail.com

Keywords: anatomic post; composite resin; fiber post; flared root; resin cement.

Use of a direct anatomic post in a flared root canal: a case report

Abstract

The following case report describes the rehabilitation of a flared root canal using a direct anatomic post (a resin composite combined to a prefabricated glass fiber post) associated with metal-free ceramic restoration. The report presents the clinical protocol for the fabrication of the cores, which provide an intimate fit to the remaining root and mechanical properties similar to those of dental structure, being an alternative to the conventional metal cores.

Clinical significance: When clinicians cannot lute a well-adapted fiber post to the root canal, the direct anatomic posts seem to be an interesting alternative technique for restoring these teeth.

Keywords: anatomic post; composite resin; fiber post; flared root; resin cement.

INTRODUCTION

Teeth submitted to endodontic treatment usually have extensive loss of dental structure and require the use of intra-radicular retainers and filling cores to hold the final restoration.¹ Glass fiber posts have the advantage of presenting a modulus of elasticity similar to dentin, which favors better stress distribution in the dental structure²⁻⁴ and reduces the risk of root fractures.^{5,6}

The mismatch between the root canal space and post diameters is a clinically relevant concern, as reported by Perdigão et al. 2007.⁷ Wide root canals can be the result of carious lesions, previous restorations with excessive post and core diameters, endodontic over-instrumentation, incomplete physiological root formation, internal resorption, developmental anomalies, or even oval-shaped root canals.^{8,9}

Clinical situations of this nature make the restorative procedure difficult. Although cast metal cores can be made in order to adapt well to the remaining root structure, they can produce a wedging action under masticatory forces, resulting in root fractures and condemning the tooth to extraction.¹⁰ Prefabricated fiber posts do not resemble the individual root canal anatomy and adapt inaccurately, thereby obliging the operator to employ excessive amounts of resin cement to replace lost structure.¹¹ Thicker resin cement layers have structural discontinuities, which lead to stress concentration zones¹² and reduce the bond strength of the fiber post to the root canals.^{13,14}

In this way, several techniques have been suggested to restore weakened root canals, and among them, there is the technique of anatomical shaping of

prefabricated fiber posts with a composite resin into the root canal.¹⁵ This technique provides a close adaptation of the post to the conduit, reduces the resin cement thickness, and, therefore, improves the mechanical and retentive properties of these anatomic posts.¹⁴⁻¹⁸

As laboratory results have reported good results with this technique,¹⁶⁻¹⁹ the aim of this clinical case is to describe the anatomical shaping of a prefabricated post (direct anatomical post) and highlight the important clinical steps involved in the success of this clinical protocol in the case of flared root canals, as well as to promote a discussion comparing the advantages of this technique with those of other techniques suggested to restore weakened root canals.

CASE REPORT

A 30-year-old, female patient sought specialized dentistry treatment, her chief complaint being the esthetic appearance of the upper central incisor (tooth #21). Under clinical examination, we diagnosed the presence of a wide and faulty composite resin restoration (Figures 1-2). After radiographic analysis, endodontic re-treatment was recommended due to the presence of a periapical lesion. The proposed treatment plan was to manufacture an all-ceramic crown after cementation of a direct anatomic post. An initial impression with addition silicone (Express XT, 3M ESPE, St. Paul, MN, USA) was done to prepare stone models, diagnostic wax-up, and mock-up to make the procedure more predictable.²⁰

Initially, largo drills were used for gutta-percha removal of the root canal. After gutta-percha removal, the corresponding drill of the Exacto #3 post (Ângelus, Londrina, PR, Brazil) was used for canal preparation (Figure 3). In this same visit, the post was anatomically characterized with composite resin for better adaptation into the root canal and retention of the indirect crown.

For this procedure, the conduit was initially lubricated with a hydrosoluble gel (KY, Johnson & Johnson, São José dos Campos, SP, Brazil) (Figure 4). A glass fiber post # 3 was conditioned with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) for 15 s, followed by rinsing and drying. The fiber post was coated with a layer of the silane coupling agent (Silane, Ângelus) for 1 min, and the surface was dried by gently air drying (5 s). The two-step etch-and-rinse adhesive system (Tetric N-Bond, Ivoclar-Vivadent) was applied in two coats, followed by solvent evaporation and finally light curing for 10 s. The fiber post was covered with a

nanohybrid composite resin (Tetric N-Ceram, Ivoclar-Vivadent) (Figure 5), and the set (fiber post + composite resin) was inserted into the canal (Figure 6), previously lubricated with a hydrosoluble gel.

This set was removed and replaced twice, and the cervical excess resin composite was removed. The composite resin was light-cured for 20 s with the post inside the conduit (Figure 7). The relined fiber post was then removed (Figure 8), and the composite resin was additionally light-cured for 20 s in each of the buccal, lingual, mesio, and distal surfaces to completely polymerize the relining resin. All light-curing procedures were performed with an LED light-curing device (Radii Plus, SDI Limited, Victoria, Australia) using a power density of 1500 mW/cm².

After removal of the retentive areas (Figure 9), the direct anatomic post was inserted again, to ensure adequate adaptation. The set was inserted into the canal, and a fiber core (Reforcore, Ângelus) was selected (Figure 10) to aid in the core build-up with a nanohybrid composite resin (Tetric N-Ceram, Ivoclar-Vivadent) (Figure 11). An incremental technique was used to place the composite resin, and each 2-mm increment was light-cured for 20 s.

After that, a coronal preparation of the composite core was prepared to receive an all-ceramic crown. This preparation followed the retention and stability principles, and it was performed by means of #1014, #2135, #3098 MF, and #3168 diamond burs (KG Sorensen, Barueri, SP, Brazil) in a high-speed handpiece under water cooling. The preparation resulted in a ferrule at the coronal end measuring 2.0 mm in height and 1.2 mm in depth, having a 1.5 to 2.0-mm occlusal reduction and 1.0 to 1.5-mm buccal and palatal reductions. All angles were rounded, and the

cervical finish line was continuous, defined, and clear. After preparation, the composite core was finished and polished with Sof-Lex aluminum oxide discs (3M-ESPE, St Paul, MN, USA) (Figure 12). The post was removed (Figure 13), and the root canal and the relined fiber post was rinsed abundantly with water/air to remove the lubricant gel.

The post was conditioned with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent) for 15 s. A self-adhesive resin cement (RelyX U200, 3M ESPE) was introduced into the root canal space with an intra-canal mix tip and was also added on the post surface. After the fiber post seating (Figure 14), the excess resin cement was removed (Figure 15), and the remaining cement was light-cured through the post for 40 s. Finally, a temporary restoration was cemented (Figure 16).

In the next session, an impression of the prepared crown was taken with addition silicone (Express XT, 3M ESPE) and sent to a prosthesis laboratory. The all-ceramic crown was fabricated with the IPS e-max System (Ivoclar-Vivadent). After testing and adjustments, the internal area of the crown was conditioned with hydrofluoric acid (IPS Etching Gel, Ivoclar-Vivadent) for 20 s, washed with an air-water spray for 1 min, and cleaned with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent) for 30 s.

Before the crown cementation procedure, the surfaces of the prepared tooth were etched with 37% phosphoric acid gel (Total Etch, Ivoclar-Vivadent) and rinsed after 15 s with an air-water spray. Excess water was removed by gently blowing air, leaving the dentin slightly moist. After this, a dual adhesive system (Excite DSC, Ivoclar-Vivadent) was applied in two coats to the prepared tooth surfaces. Gently

blowing air was used to absorb the excess adhesive solution, and it was light-cured for 10 s. The base and catalyst components of Variolink II (Ivoclar-Vivadent) were then mixed, and the resin cement was introduced into the indirect crown. After the crown was seated, the excess resin cement was removed, and the remaining cement was light-cured through the indirect crown for 40 s in each of the buccal, lingual, mesio, distal and occlusal surfaces. After it, the cervical endings of the crown and the gingival health was checked; the excess cement was also removed with a #12 scalpel blade for better hygiene and prevention of biofilm retention in the cervical region.

The outcome of the restorative procedure after 7 days can be seen in Figure 17.

DISCUSSION

The present case was suitable for the preparation of a direct anatomic post. Due to the endodontic re-treatment, the tooth had a flared root canal with thin radicular dentin. Introducing a conventional fiber post into the canal required either force to round off the canal walls or a thick layer of luting cement to fill up the spaces between the loosely fitting post and the canal walls. This would have subjected the restoration and tooth to adhesive failure and/or post debonding.²¹ Thus, using a post well-fitted to the canal shape allows the use of a thin uniform layer of cement that increases retention.^{14,15}

Some authors suggest the restoration of flared root canals with composite resin to reduce canal width.²²⁻²⁵ However, the difficulties in providing an adequate curing at the deepest regions of the canal wall may affect the material properties²⁶ and its bonding to the adhesive layer. This does not occur with the direct anatomic post, as the composite resin attached to the fiber post is firstly cured inside the root canal, but it can also be cured further before the luting procedures.

Another suggested protocol is the use of accessory posts to fill in the mismatch around the main glass fiber post and the root canal.^{16,27} Contrary to expectations, the thickness of the cement layer is not reduced significantly, as empty spaces still remain between the accessory posts and the root walls. Thus, the likelihood of the resin cement layer presenting large lacunae or bubbles is high,¹² reducing the adhesive performance of this technique.

In the direct anatomical post technique, as performed in this case report, the fiber post is relined into the root canal, replacing the resin cement by composite

resin,¹⁵ which has better mechanical and physical properties.¹⁴⁻¹⁸ This technique is relatively easy: only a few additional steps are required to lute a conventional fiber post. Indirect anatomic posts were claimed to have superior mechanical properties,¹⁶ but they have the disadvantage of being more time-consuming and expensive to fabricate due to the need for a laboratory step.

By performing a direct anatomic post technique, a direct restoration can be performed on the individualized post in only one clinical visit, without laboratory involvement. Additionally, when a prosthetic restoration was planned, as in this case report, it was possible to immediately build up and prepare a resin composite core on the direct anatomic post.

The good performance of the anatomical post techniques in laboratory studies¹⁶⁻¹⁹ can be attributed to the high hydraulic pressure they put on the cement against the dentin walls, resulting in better contact between the cement/post set and the dentin.^{17,28} This pressure reduces blister formation in the cement,²⁸ eliminating sources of flaw-initiating sites; increases the number of tubules filled with the resin cement²⁹ due to better penetration of resin into demineralized dentin; and results in a more uniform hybrid layer, with greater resin tags and adhesive lateral branches.

Some clinical steps in the protocol deserve discussion. Several studies suggest the application of silane coupling agents on fiber posts to enhance adhesion to composite resins.^{30,31} Silane solutions can be described as hybrid organic–inorganic compounds that are able to promote adhesion between organic and inorganic matrices due to an intrinsic dual reactivity.³² This is the reason for the fiber post in

the present case report being coated with a layer of the silane coupling agent before modeling with composite resin.

However, this is not consensual in the literature. Opinions differ on the efficiency of post silanization. There are other authors who claim that the use of silane may be useless³³ to improve the bonding of the post with polymeric materials. This means that further laboratory studies still need to be conducted in order to elucidate whether or not better resin bonding of the post with the composite resin is in fact reached; otherwise, this clinical step could be suppressed, making the procedure simpler.

In this case report, the anatomical shaping of the prefabricated fiber posts was performed with a nanohybrid composite resin (Tetric N-Ceram, Ivoclar-Vivadent). This composite is a light-cured, radiopaque nanohybrid composite based on nano-optimized technology, being universally used in restorative procedures. In accordance with de Moraes et al. 2009,³⁴ nanohybrid resins generally present similar or slightly better properties than those of microhybrid materials, thus accounting for the choice for the present treatment.

Another source of variability of this technique is the kind of resin cement employed to lute the set into the root canal. In the present clinical case, we employed the self-adhesive cement RelyX U200. This material does not require rinsing, solving the problem of substrate moisture control, especially in the root canal, and thus simplifies the clinical procedure. The high bond strength values observed for self-adhesive cements in several studies³⁵⁻³⁹ can be attributed to the chemical interaction between monomer acidic phosphate groups and dentin/enamel hydroxyapatite⁴⁰ and

to the material's low shrinkage,^{41,42} leading to better intimate contact of the resin cement with the root canal walls and higher frictional resistance.⁴³ Additionally, this type of cement (self-adhesive) seems to be less sensitive to the operator's skills³⁹ and root region,³⁷ which is an additional advantage over other conventional adhesive systems.³⁹ However, the role of the resin cement material on the performance of this technique should be the focus of future investigations.

To finalize the clinical case, a composite resin build-up was performed for further cementation of an indirect ceramic restoration. The restorative protocol herein employed preserved the tooth structure, returned the tooth function, and improved esthetics. Given the great tendency to prepare esthetic metal-free restorations, the use of anatomical posts tends to offer a solution when facing flared root canals in daily practice.

CONCLUSION

The use of direct anatomical posts in flared root canals is a practical, low-cost, and fast technique that can be applied in direct and indirect esthetic restorations.

REFERENCES

1. Zicari F, Couthino E, De Munck J, et al. Bonding effectiveness and sealing ability of fiber-post bonding. *Dent Mater* 2008;24:967-77.
2. Qualtrough AJ, Manocci F. Tooth-colored post systems: a review. *Oper Dent* 2003;28:86-91.
3. Hayashi M, Ebisu S. Key factors in achieving firm adhesion in post-core restorations. *Jap Dent Sci Rev* 2008;44:22-8.
4. Schmitter M, Rammelsberg P, Lenz J, et al. Teeth restored using fiber-reinforced posts: in vitro fracture tests and finite element analysis. *Acta Biomater* 2010;6:3747-54.
5. Coelho CS, Biffi JC, Silva GR, et al. Finite element analysis of weakened roots restored with composite resin and posts. *Dent Mater J* 2009;28:671-8.
6. Torabi K, Fattahi F. Fracture resistance of endodontically treated teeth restored by different FRC posts: an in vitro study. *Indian J Dent Res* 2009;20:282-7.
7. Perdigão J, Gomes G, Augusto V. The effect of dowel space on the bond strengths of fiber posts. *J Prosthodont* 2007;16:154-64.
8. Morgano SM, Rodrigues AH, Sabrosa CE. Restoration of endodontically treated teeth. *Dent Clin North Am* 2004;48:397-416.
9. Baba NZ, Goodacre CJ, Daher T. Restoration of endodontically treated teeth: the seven keys to success. *Gen Dent* 2009;57:596-603.
10. Heydecke G, Butz F, Strub JR. Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in-vitro study. *J Dent* 2001;29:427-33.
11. Hornbrook DS, Hastings JH. Use of bondable reinforcement fiber for post and core build-up in an endodontically treated tooth: maximizing strength and aesthetics. *Pract Periodontics Aesthet Dent* 1995;7:33-42.
12. Grandini S, Goracci C, Monticelli F, et al. SEM evaluation of the cement layer thickness after luting two different posts. *J Adhes Dent* 2005;7:235-40.

13. Schmage P, Pfeiffer P, Pinto E, et al. Influence of oversized dowel space preparation on the bond strengths of FRC posts. *Oper Dent* 2009;34:93-101.
14. Gomes GM, Rezende EC, Gomes OM, et al. Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin. *J Adhes Dent* *in press*.
15. Grandini S, Sapio S, Simonetti M. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. *J Adhes Dent* 2003;5:243-7.
16. Clavijo VG, Reis JM, Kabbach W, et al. Fracture strength of flared bovine roots restored with different intraradicular posts. *J Appl Oral Sci* 2009;17:574-8.
17. Faria-e-Silva AL, Pedrosa-Filho Cde F, Menezes Mde S, et al. Effect of relining on fiber post retention to root canal. *J Appl Oral Sci* 2009;17:600-4.
18. Macedo VC, Faria e Silva AL, Martins LRM. Effect of cement type, relining procedure, and length of cementation on pull-out bond strength of fiber posts. *J Endod* 2010;36:1543-6.
19. Silva GR, Santos-Filho PC, Simamoto-Júnior PC, et al. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. *Braz Dent J* 2011;230-7.
20. Viana PC, Correia A, Neves M, et al. Soft tissue waxup and mock-up as key factors in a treatment plan: case presentation. *Eur J Esthet Dent* 2012;7:310-23.
21. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber post. *Am J Dent* 2000;13:9B-13B.
22. Lui JL. Composite resin reinforcement of flared canals using light-transmitting plastic posts. *Quintessence Int* 1994;25:313-9.
23. Saupe WA, Gluskin AH, Radke RA. A comparative study of fracture resistance between morphological dowel and cores and a resin-reinforced dowel system in the intraradicular restoration of structurally compromised roots. *Quintessence Int* 1996;27:483-91.
24. Gonçalves LA, Vansan LP, Paulino SM, Sousa Neto MD. Fracture resistance of weakened roots restored with a transilluminating post and adhesive restorative materials. *J Prosthet Dent* 2006;96:339-44.

25. Zogheib LV, Pereira JR, do Valle AL, et al. Fracture resistance of weakened roots restored with composite resin and glass fiber post. *Braz Dent J* 2008;19:329-33.
26. Yoldas O, Alaçam T. Microhardness of composites in simulated root canals cured with light transmitting posts and glass-fiber reinforced composite posts. *J Endod* 2005;31:104-6.
27. Martelli H Jr, Pellizzer EP, Rosa BT, et al. Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fibre posts. *Int Endod J* 2008;41:685-92.
28. Chieffi N, Chersoni S, Papacchini F, et al. The effect of application sustained seating pressure on adhesive luting procedure. *Dent Mater* 2007;23:159-66.
29. Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. *Dent Mater* 2002;18:495-502.
30. Aksornmuang J, Foxton RM, Nakajima M, Tagami J. Microtensile bond strength of a dual-cure resin core material to glass and quartz fibre posts. *J Dent* 2004;32:443-50.
31. Goracci C, Raffaelli O, Monticelli F, et al. The adhesion between prefabricated FRC posts and composite resin cores: Microtensile bond strength with and without post- silanization. *Dent Mater* 2005;21:437-44
32. Matinlinna JP, Lassila LV, Ozcan M, et al. An introduction to silanes and their clinical applications in dentistry. *Int J Prosthodont* 2004;17:155-64.
33. Perdigão J, Gomes G, Lee IK. The effect of silane on the bond strengths of fiber posts. *Dent Mater* 2006;22:752-8.
34. de Moraes RR, Gonçalves Lde S, Lancellotti AC, et al. Nanohybrid resin composites: nanofiller loaded materials or traditional microhybrid resins? *Oper Dent* 2009;34:551-7.
35. Zicari F, Couthino E, De Munck J, et al. Bonding effectiveness and sealing ability of fiber-post bonding. *Dent Mater* 2008;24:967-77.
36. Amaral M, Santini MF, Wandscher V, et al. An in vitro comparison of different cementation strategies on the pull-out strength of a glass fiber post. *Oper Dent* 2009;34:443-51.

37. Gomes GM, Gomes OM, Reis A, et al. Regional bond strengths to root canal dentin of fiber posts luted with three cementation systems. *Braz Dent J* 2011;22:460-7.
38. Leme AA, Coutinho M, Insaurralde AF, et al. The influence of time and cement type on push-out bond strength of fiber posts to root dentin. *Oper Dent* 2011;36:643-8.
39. Gomes GM, Gomes OM, Reis A, et al. Effect of operator experience on the outcome of fiber post cementation with different resin cements. *Oper Dent* 2012 Dec 5. [Epub ahead of print].
40. Radovic I, Monticelli F, Goracci C, et al. Self-adhesive resin cements: a literature review. *J Adhes Dent* 2008;10:251-8.
41. Spinell T, Schedle A, Watts DC. Polymerization shrinkage kinetics of dimethacrylate resin-cements. *Dent Mater* 2009;25:1058-66.
42. Kitzmüller K, Graf A, Watts D, Schedle A. Setting kinetics and shrinkage of self-adhesive resin cements depend on cure-mode and temperature. *Dent Mater* 2011;27:544-51.
43. Goracci C, Fabianelli A, Sadek FT, et al. The contribution of friction to the dislocation resistance of bonded fiber posts *J Endod* 2005;31:608-12.

FIGURES

Figure 1 – Initial smile.



Figure 2 - One can notice the presence of a fractured provisional restoration of direct composite resin on tooth 21.



Figure 3 – After removal the crown, root canal preparation with the corresponding drill of the fiber post were selected.



Figure 4 - The conduit being lubricated with a hydrosoluble gel.



Figure 5 – After appropriate superficial treatment, the fiber post was covered with a nanohybrid composite resin.



Figure 6 - The set (fiber post + composite resin) being inserted into the canal.



Figure 7 - The composite resin being light-cured through the post.



Figure 8 - The relined fiber post being removed from the conduit.



Figure 9 – Removal of the retentive areas of the direct anatomic post.



Figure 10 - Core build-up with a direct fiber core and a nanohybrid composite resin.



Figure 11 - Direct core build-up.



Figure 12 - Coronal preparation of the direct core after finishing and polishing.



Figure 13 – The direct anatomic post ready to be cemented.



Figure 14 - The cementation of the anatomic post.



Figure 15 - The excess resin cement being removed.



Figure 16 - A temporary restoration cemented on the direct core.



Figure 17 - The outcome of the restorative procedures.

5 DISCUSSÃO

No primeiro experimento desse trabalho foi avaliada a influência da adaptação de pinos e conseqüentemente da espessura de cimento resinoso no desempenho de pinos de fibra de vidro cimentados no canal radicular. Observou-se que a adaptação do pino foi capaz de influenciar na adesão intrarradicular; uma vez que quanto maior a espessura do cimento resinoso, menor foi a resistência de união e maior a formação de *gaps* na interface cimento resinoso/dentina radicular.

Nossos resultados vão de acordo com os de Grandini et al.¹⁸ 2005. Segundo os autores quando camadas espessas de cimento são empregadas, a deformação resultante da contração de polimerização pode gerar maior tensão de polimerização nas interfaces cimento/dentina e cimento/pino, induzindo descontinuidades estruturais, tais como bolhas, espaços ou fendas, resultando em zonas de concentração de estresse. Essas zonas são responsáveis por iniciar uma linha de fratura e, conseqüentemente, reduzem a performance adesiva desses pinos ao canal radicular; o que foi observado no presente estudo. Isto foi observado mesmo na situação que simulou uma adaptação ideal do pino, o que denota que uma interface livre de *gaps* não foi observada. Assim a obtenção de uma adesão perfeita e a criação de um sistema monobloco entre o pino, o cimento resinoso e a dentina radicular (Tay et al.⁷ 2007) é uma expectativa irreal, a qual não é atingida num cenário clínico.

Maiores *gaps*, no entanto, foram observados nos grupos que simularam uma adaptação inadequada dos pinos, além da presença de bolhas na camada de cimento resinoso. Além disto, a maior quantidade de cimento resinoso na situação da adaptação inadequada dos pinos pode ter afetado a absorção de luz e, por conseguinte, a reação de polimerização do cimento na sua espessura total no interior do canal radicular. Isto pode ter sido o fator responsável pela menor resistência de união dos pinos aos canais radiculares sobre-alargados em comparação com a situação de pinos justapostos aos canais radiculares.

Com base nos achados acima mencionados, supõe-se que a espessura de cimento resinoso pode ser sim um fator determinante no desempenho clínico de pinos de fibra de vidro, sendo que quanto maior a espessura, maior a chance de seu

descolamento. Apesar da espessura ideal de cimento ainda ser desconhecida, estudos clínicos prospectivos e retrospectivos já indicam que uma maior frequência de descolamento ocorre quando a espessura do cimento é maior (Fredriksson et al.²¹ 1998, Ferrari et al.²² 2000).

Portanto, sugere-se preparar canais radiculares que permitam a escolha do pino que se ajuste ao espaço preparado com a maior precisão possível. Infelizmente, essa situação de adaptação ideal dos pinos muitas vezes não é atingida clinicamente, uma vez que há canais radiculares que exibem amplo alargamento (Morgano et al.¹⁴ 2004, Baba et al.¹⁵ 2009) e como esses pinos de fibras são pré-fabricados, nem sempre se adaptam intimamente ao canal radicular. Assim, a restauração dessas raízes enfraquecidas representa ainda um desafio para os cirurgiões-dentistas. Dessa forma, algumas alternativas para reduzir a espessura de cimento resinoso durante a cimentação de pinos de fibra têm sido sugeridas.

No segundo experimento desse trabalho diferentes técnicas foram testadas por meio de testes de resistência de união e resistência à fratura, após os dentes terem sido submetidos à fadiga mecânica, como a técnica do pino anatômico direto (Grandini et al.²⁸ 2003, Clavijo et al.²⁹ 2009, Faria e Silva et al.³⁰ 2009, Macedo et al.³¹ 2010) e indireto (Clavijo et al.²⁹ 2009), dos pinos de fibra acessórios (Martelli et al.³² 2008, Clavijo et al.²⁹ 2009) e do reforço radicular com resina composta (Lui²³ 1994, Saupe et al.²⁴ 1996, Zogheib et al.¹⁶ 2008); todavia, pesquisas demonstrando a eficácia dessas técnicas alternativas apresentam resultados controversos e são escassas na literatura, além de empregarem diferentes metodologias dificultando a comparação das mesmas (Marchi et al.³³ 2003, Gonçalves et al.³⁴ 2006, Zogheib et al.¹⁶ 2008, Clavijo et al.²⁹ 2009, Silva et al.³⁵ 2011, Zogheib et al.³⁶ 2011). Para comparação de tais técnicas, no presente estudo foram simuladas três importantes características que mimetizam as reais condições clínicas aos que os dentes estão sujeitos na cavidade oral, como restauração final da raiz, simulação do ligamento periodontal e envelhecimento mecânico dos espécimes. Infelizmente, a grande maioria dos estudos disponíveis na literatura não mimetiza tais condições (Marchi et al.³³ 2003, Gonçalves et al.³⁴ 2006, Martelli et al.³² 2008, Clavijo et al.²⁹ 2009, Torabi et al.¹² 2009, Zogheib et al.³⁶ 2011), limitando, portanto, seus resultados.

Foi demonstrado nesse estudo que a resistência à fratura de dentes tratados endodonticamente foi diretamente proporcional à quantidade de dentina remanescente (Tjan et al.⁴² 1985, Marchi et al.³³ 2003, Zogheib et al.¹⁶ 2008). Assim, a manutenção de uma dentina radicular saudável demonstrou ser mais importante do que o protocolo de reconstrução da raiz fragilizada, em termos de resistência à fratura.

Ao analisar ambos os testes de resistência de união e resistência à fratura, observou-se que, entre as técnicas restauradoras alternativas testadas, os melhores resultados foram para os pinos anatômicos diretos e indiretos. Uma explicação para o bom desempenho desses pinos seria de que além de diminuir a espessura de cimento resinoso nos canais radiculares, esse tipo de tratamento exerce uma maior pressão de assentamento sobre o cimento contra as paredes dentinárias, resultando em melhor contato entre o conjunto cimento-pino e dentina radicular (Chieffi et al.⁴³ 2007, Faria-e-Silva et al.³⁰ 2009). Esta pressão reduz ainda a formação de bolhas no cimento (Chieffi et al.⁴³ 2007), eliminando fontes locais de início de falhas de adesão, além de aumentar o número de túbulos dentinários preenchidos pelo cimento resinoso (Vichi et al.⁴⁴ 2002). Assim, com essa melhor penetração de cimento pela dentina desmineralizada, uma camada híbrida mais uniforme é formada, com maiores prolongamentos de resina e ramificações laterais de adesivo, fatores estes que, segundo Patierno et al.⁴⁵ 1996, poderiam determinar maiores valores de retenção.

Apesar de estudos anteriores (Silva et al.³⁵ 2011, Li et al.⁴⁶ 2011) demonstrarem valores superiores de resistência à fratura para pinos acessórios, no presente estudo, essa situação não foi capaz de atingir valores de resistência de união semelhantes ao grupo controle positivo, o qual simulou a adaptação ideal dos pinos ao canal radicular. A probabilidade da camada de cimento resinoso nesse grupo apresentar bolhas é elevada (Grandini et al.¹⁸ 2005), uma vez que um grande número de espaços vazios ainda existem entre os pinos acessórios e as paredes do canal radicular; reduzindo, assim, a resistência de coesão do cimento e a resistência de união à dentina.

O pior comportamento observado para o grupo de reforço radicular com resina composta pode estar relacionado às dificuldades de uma polimerização adequada nas regiões mais profundas do canal radicular, o que pode ter afetado as propriedades dos materiais (Yoldas et al.⁴⁷ 2005), prejudicando sua adesão. Na tentativa de evitar essa situação de polimerização deficiente, foi utilizado no presente estudo um pino de fibra de vidro translúcido, o qual supostamente auxiliaria na polimerização das camadas mais profundas de resina; mas somente a transmissão de luz pelo pino, por si só, não foi suficiente para permitir uma polimerização adequada da resina composta dentro do canal radicular (Roberts et al.²⁶ 2004). Portanto, a polimerização deficiente da resina pode ter sido a responsável pelos baixos valores de resistência de união relatado neste estudo e de resistência à fratura em outros (Marchi et al.³³ 2003, Zogheib et al.¹⁶ 2008, Zogheib et al.³⁶ 2011).

Outra questão que merece destaque nesse segundo experimento é a predominância do padrão de fratura favorável observado em todos os grupos após o teste de resistência à fratura, devido ao biomimetismo observado entre os materiais restauradores aqui testados e a dentina radicular (Tay, Pashley⁷ 2007), o que favorece uma distribuição de tensões mais uniforme à estrutura radicular (Qualtrough, Manocci⁸ 2003, Hayashi, Ebisu⁹ 2008, Schmitter et al.¹⁰ 2010), reduzindo assim o risco de fraturas radiculares (Coelho et al.¹¹ 2009, Torabi et al.¹² 2009); tornando segura a utilização de todas as técnicas alternativas aqui avaliadas.

Em síntese, os cirurgiões-dentistas devem tentar manter o máximo de estrutura dentinária possível previamente à cimentação de um pino, uma vez que o grupo controle positivo foi o que apresentou os maiores resultados de resistência de união e resistência à fratura. No entanto, quando essa situação não for possível, pinos anatômicos diretos e indiretos foram as melhores técnicas para restauração de canais radiculares excessivamente alargados no presente estudo.

6 CONSIDERAÇÕES FINAIS

Os resultados deste estudo evidenciaram que a adaptação do pino ao conduto radicular influencia significativamente a retenção dos mesmos nos condutos radiculares. Quanto mais justa a adaptação dos pinos de fibra de vidro ao canal radicular, menor é a formação de *gaps* entre o cimento e as paredes do conduto radicular o que aumenta o prognóstico da retenção dos mesmos.

Infelizmente na ausência desta condição ideal, o uso de pinos anatômicos diretos e indiretos pode ser a primeira escolha do clínico para tratamento de canais excessivamente alargados. Estas técnicas apresentaram resultados semelhantes, em termos de resistência de união e resistência à fratura, ao do grupo que simulou adaptação ideal do pino ao conduto radicular.

No entanto, cabe salientar as limitações do presente estudo. Todos os procedimentos foram realizados por um único operador calibrado e com ampla experiência clínica e acadêmica. Assim, estudos que avaliem o efeito da experiência do operador e da variabilidade da técnica podem contribuir para o melhor entendimento do tema. Apesar de bem delineado, o estudo é laboratorial e somente ensaios clínicos randomizados podem fornecer evidências definitivas sobre a melhor técnica para uso clínico.

REFERÊNCIAS*

1. Zicari F, Couthino E, De Munck J, Poitevin A, Scotti R, Naert I, Van Meerbeek B. Bonding effectiveness and sealing ability of fiber-post bonding. *Dent Mater.* 2008 Jul;24(7):967-77.
2. Braem M, Lambrechts P, Van Doren V, Vanherle G. The impact of composite structure on its elastic response. *J Dent Res.* 1986 May;65(5):648-53.
3. Peutzfeldt A, Asmussen E. Modulus of resilience as predictor for clinical wear of restorative resins. *Dent Mater.* 1992 May;8(3):146-8.
4. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. *J Dent.* 1999 May;27(4):275-8.
5. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canals posts. *Dent Mater.* 2004 Jan;20(1):29-36.
6. Fares NH, Filho HN, Pacheco IB, Coutinho KQ, Nagem HD. Resistência flexural e módulo de elasticidade da resina composta. *Rev de Clín Pesq Odontol.* 2005 Set;2(1):53-5.
7. Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. *J Endod.* 2007 Apr;33(4):391-8.
8. Qualtrough AJ, Manocci F. Tooth-colored post systems: a review. *Oper Dent.* 2003 Jan-Feb;28(1):86-91.
9. Hayashi M, Ebisu S. Key factors in achieving firm adhesion in post-core restorations. *Jap Dent Sci Rev.* 2008 Jul;44(1):22-8.
10. Schmitter M, Rammelsberg P, Lenz J, Scheuber S, Schweizerhof K, Rues S. Teeth restored using fiber-reinforced posts: in vitro fracture tests and finite element analysis. *Acta Biomater.* 2010 Sep;6(9):3747-54.
11. Coelho CS, Biffi JC, Silva GR, Abrahão A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. *Dent Mater J.* 2009 Nov;28(6):671-8.
12. Torabi K, Fattahi F. Fracture resistance of endodontically treated teeth restored by different FRC posts: an in vitro study. *Indian J Dent Res.* 2009 Jul-Sep;20(3):282-7.
13. Foxton RM, Nakajima M, Tagami J, Miura H. Bonding of photo and dual-cure adhesives to root canal dentin. *Oper Dent.* 2003 Sep-Oct;28(5):543-51.

* De acordo com a norma do Programa de Pós-graduação em Odontologia Stricto-sensu da UEPG, baseada no modelo Vancouver. Abreviaturas dos periódicos em conformidade com o *Medline*.

14. Morgano SM, Rodrigues AH, Sabrosa CE. Restoration of endodontically treated teeth. *Dent Clin North Am*. 2004 Apr;48(2):397-416.
15. Baba NZ, Goodacre CJ, Daher T. Restoration of endodontically treated teeth: the seven keys to success. *Gen Dent*. 2009 Nov-Dec;57(6):596-603.
16. Zogheib LV, Pereira JR, do Valle AL, de Oliveira JA, Pegoraro LF. Fracture resistance of weakened roots restored with composite resin and glass fiber post. *Braz Dent J*. 2008;19(4):329-33.
17. Hornbrook DS, Hastings JH. Use of bondable reinforcement fiber for post and core build-up in an endodontically treated tooth: maximizing strength and aesthetics. *Pract Periodontics Aesthet Dent*. 1995 Jun-Jul;7(5):33-42.
18. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. SEM evaluation of the cement layer thickness after luting two different posts. *J Adhes Dent*. 2005 Autumn;7(3):235-40.
19. Perez BE, Barbosa SH, Melo RM, Zamboni SC, Ozcan M, Valandro LF, Bottino MA. Does the thickness of the resin cement affect the bond strength of a fiber post to the root dentin? *Int J Prosthodont*. 2006 Nov-Dec;19(6):606-9.
20. D'Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. *J Prosthet Dent*. 2007 Sep;98(3):193-8.
21. Fredriksson M, Astbäck J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber-reinforced epoxy resin posts. *J Prosthet Dent*. 1998 Aug;80(2):151-7.
22. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. *Am J Dent*. 2000 May;13(Spec No):9B-13B.
23. Lui JL. Composite resin reinforcement of flared canals using light-transmitting plastic posts. *Quintessence Int*. 1994 May;25(5):313-9.
24. Saupe WA, Gluskin AH, Radke RA. A comparative study of fracture resistance between morphological dowel and cores and a resin-reinforced dowel system in the intraradicular restoration of structurally compromised roots. *Quintessence Int*. 1996 July;27(7):483-91.
25. Lui JL. Depth of composite polymerization within simulated root canals using light-transmitting posts. *Oper Dent*. 1994 Sep-Oct;19(5):165-8.
26. Roberts HW, Leonard DL, Vandewalle KS, Cohen ME, Charlton DG. The effect of a translucent post on resin composite depth of cure. *Dent Mater*. 2004 Sep;20(7):617-22.
27. Faria e Silva AL, Arias VG, Soares LE, Martin AA, Martins LR. Influence of fiber-post translucency on the degree of conversion of a dual-cured resin cement. *J Endod*. 2007 Mar;33(3):303-5.

28. Grandini S, Sapio S, Simonetti M. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. *J Adhes Dent*. 2003 Fall;5(3):243-7.
29. Clavijo VG, Reis JM, Kabbach W, Faria e Silva AL, Oliveira Junior OB, Andrade MF. Fracture strength of flared bovine roots restored with different intraradicular posts. *J Appl Oral Sci*. 2009 Nov-Dec;17(6):574-8
30. Faria e Silva AL, Pedrosa-Filho Cde F, Menezes Mde S, Silveira DM, Martins LR. Effect of relining on fiber post retention to root canal. *J Appl Oral Sci*. 2009 Nov-Dec;17(6):600-4.
31. Macedo VC, Faria e Silva AL, Martins LRM. Effect of cement type, relining procedure, and length of cementation on pull-out bond strength of fiber posts. *J Endod*. 2010 Sep;36(9):1543-6.
32. Martelli H Jr, Pellizzer EP, Rosa BT, Lopes MB, Gonini A Jr. Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fibre posts. *Int Endod J*. 2008 Aug;41(8):685-92.
33. Marchi GM, Paulillo LA, Pimenta LA, De Lima FA. Effect of different filling materials in combination with intraradicular posts on the resistance to fracture of weakened roots. *J Oral Rehabil*. 2003 Jun;30(6):623-9.
34. Goncalves LA, Vansan LP, Paulino SM, Sousa Neto MD. Fracture resistance of weakened roots restored with a transilluminating post and adhesive restorative materials. *J Prosthet Dent*. 2006 Nov;96(5):339-44.
35. Silva GR, Santos-Filho PC, Simamoto-Júnior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. *Braz Dent J*. 2011;22(3):230-7.
36. Zogheib LV, Saavedra Gde S, Cardoso PE, Valera MC, Araújo MA. Resistance to compression of weakened roots subjected to different root reconstruction protocols. *J Appl Oral Sci*. 2011Nov-Dec;19(6):648-54.
37. International Standardization for Organization. Guidance on testing of adhesion to tooth structure. Geneve, Switzerland: 2003; CD TR 11405.
38. Soares CJ, Pizi EC, Fonseca RB, Martins LR. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. *Braz Oral Res*. 2005 Jan-Mar;19(1):11-6.
39. Pontius O, Hutter JW. Survival rate fracture strength of incisors restored with different post and core systems and endodontically treated incisors without coronoradicular reinforcement. *J Endod*. 2002 Oct;28(10):710-5.
40. Naumann M, Sterzenbach G, Rosentritt M, Beuer F, Frankenberger R. In vitro performance of self-adhesive resin cements for post-and-core build-ups: Influence of chewing simulation or 1-year storage in 0.5% chloramine solution. *Acta Biomater*. 2010 Nov;6(11):4389-95.

41. Maccari PC, Cosme DC, Oshima HM, Burnett LH Jr, Shinkai RS. Fracture strength of endodontically treated teeth with flared root canals and restored with different post systems. *J Esthet Restor Dent* 2007;19(1):30-6.
42. Tjan AHL, Whang SB. Resistance to root fracture of dowel channels with various thickness of buccal dentin walls. *J Prosthet Dent* 1985 Apr;53(4):496-500.
43. Chieffi N, Chersoni S, Papacchini F, Vano M, Goracci C, Davidson CL, Tay FR, Ferrari M. The effect of application sustained seating pressure on adhesive luting procedure. *Dent Mater* 2007 Feb;23(2):159-64.
44. Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. *Dent Mater* 2002 Nov;18(7):495-502.
45. Patierno JM, Rueggeberg FA, Anderson RW, Weller RN, Pashley DH. Push-out strength and SEM evaluation of resin composite bonded to internal cervical dentin. *Endod Dent Traumatol* 1996 Oct;12(5):227-36.
46. Li Q, Xu B, Wang Y, Cai Y. Effects of auxiliary fiber posts on endodontically treated teeth with flared canals. *Oper Dent* 2011 Jul-Aug;36(4):380-9.
47. Yoldas O, Alaçam T. Microhardness of composites in simulated root canals cured with light transmitting posts and glass-fiber reinforced composite posts. *J Endod* 2005 Feb;31(2):104-6.

ANEXO A

Aprovação do projeto pela Comissão de Ética em Pesquisa da
Universidade Estadual de Ponta Grossa. COEP - UEPG



PARECER Nº 25/2011
Protocolo: 18741/10

No dia 31 de março de 2011, a Comissão de Ética em Pesquisa, **APROVOU** o protocolo de pesquisa intitulado **"Avaliação de técnicas restauradoras para preenchimento de canais radiculares excessivamente alargados"** de responsabilidade da pesquisadora Alessandra Reis.

Conforme Resolução CNS 196/96, solicitamos que sejam apresentados a esta Comissão, relatórios sobre andamento da pesquisa, conforme modelo (<http://www.uepg.br/coep/>).
Data para entrega do relatório parcial: 31 de março de 2012.

Data para entrega do relatório Final: 31 de março de 2013.

Ponta Grossa, 01 de abril de 2011.

UNIVERSIDADE ESTADUAL DE PONTA GROSSA
COMISSÃO DE ÉTICA EM PESQUISA - COEP



Prof. Dr. Ulisses Coelho
Coordenador

