**UNIVERSIDADE ESTADUAL DA PARAÍBA**
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**PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA**
**DOUTORADO EM ODONTOLOGIA**

**LARISSA RANGEL PEIXOTO**

# INFLUÊNCIA DE DIFERENTES TÉCNICAS DE CIMENTAÇÃO DE PINOS DE FIBRA DE VIDRO NA RESISTÊNCIA À FRATURA, DETECÇÃO DE TRINCAS E GERAÇÃO DE ARTEFATOS EM PRÉ-MOLARES UNIRRADICULARES

**CAMPINA GRANDE – PB**
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Tese apresentada ao Programa de Pós-Graduação em Odontologia da Universidade Estadual da Paraíba, como parte dos requisitos para obtenção do título de Doutor em Odontologia – Área de concentração em Clínica Odontológica.

**Orientadora:** Profª. Drª Daniela Pita de Melo

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## DEDICATÓRIA

A **minha família**, pelo carinho, companheirismo e exemplo de amor.

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Agradeço à Deus que sempre me guiou e foi o grande responsável por esta conquista. A defesa deste doutorado só foi possível pela Sua Eterna Graça!

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“*As coisas tangíveis tornam-se insensíveis à palma da mão. Mas as coisas findas, muito mais que lindas, essas ficarão*” (Carlos Drummond de Andrade)

# RESUMO

**Objetivos:** Avaliar a influência de diferentes técnicas de cimentação de pinos de fibra de vidro (PFV) na resistência à fratura radicular, potencial de detecção de trincas e geração de artefatos tomográficos e microtomográficos. **Metodologia:** Quarenta dentes pré-molares unirradiculares foram divididos aleatoriamente em quatro grupos (n = 10): FGA- PFV cimentado com cimento resinoso dual; FGCore- PFV cimentado com cimento resinoso dual com alto conteúdo de carga; MCFG- PFV com filamento metálico cimentado com cimento resinoso dual; AFG – PFV anatomizado cimentado com cimento resinoso dual. Cada dente foi submetido ao teste de resistência à fratura a 0,5mm/min em uma máquina universal de testes (ISTRON 3365 Machine). A amostra foi escaneada no Skyscan 1172 (Bruker, Kontich, Bélgica) para avaliar a morfologia inicial dos dentes e o padrão de fratura, utilizando os seguintes escores: (1) fratura do núcleo de preenchimento; (2) fratura radicular favorável; e (3) fratura radicular desfavorável. Além disso, foi realizada uma quantificação da porcentagem de artefatos gerados em imagens de Micro-Tomografia Computadorizada (Micro-TC). As imagens de Tomografia Computadorizada de Feixe Cônico (TCFC) foram adquiridas usando o CS 9000 3D (Kodak Dental Systems, Carestream Health, Rochester, NY, EUA). Cada dente foi escaneado sob quatro parâmetros de exposição: 74kV, 80kV, 85kV e 90kV. Os demais parâmetros foram fixados em 76 µm de tamanho de voxel, 5 cm x 3,75 cm de tamanho de FOV e 10 mA. Dois observadores avaliaram as imagens de TCFC para detecção de fratura radicular utilizando uma escala de confiança de 5 pontos e um escore de 4 pontos para a presença de artefatos. A análise de variância unidirecional (ANOVA) e o teste de Tukey foram utilizados para verificar os valores de resistência a fratura entre os grupos, enquanto o teste exato de Fisher foi usado para averiguar a associação entre o padrão de fratura e os grupos. A avaliação quantitativa de artefatos de Micro-TC foi analisada usando os testes de Kruskall Wallis e Mann Whitney. Os valores de sensibilidade, especificidade e área sob a curva ROC (AUC) foram calculados e comparados por análises de variância bidirecional (ANOVA two-way) e teste de Tukey. A interferência dos artefatos no diagnóstico de fratura radicular foi avaliada pelo teste do qui-quadrado. Os dados foram tratados estatisticamente ao nível de significância de 5% ($\alpha = 0,05$). **Resultados:** Os valores de resistência à fratura radicular variaram de 465,38 ± 127,29 N a 364,47 ± 78,64 N (p = 0,159). Não foi observada associação estatisticamente significante entre o padrão de fratura e as técnicas de cimentação de PFV (p = 0,276). A quantificação de artefatos de imagem de Micro-TC para todos os grupos apresentou menos de 10% de artefatos (p = 0,062). Não houve diferenças significativas entre os parâmetros de exposição para sensibilidade, especificidade e valores de AUC (p> 0,05). O grupo AFG apresentou maiores valores de sensibilidade, diferindo estatisticamente do FGCore e do MCFG (p = 0,037). Os valores de especificidade do MCFG diferiram estatisticamente do FGCore (p = 0,012), apresentando menores valores. O grupo MCFG apresentou maior porcentagem de artefatos do que os demais grupos estudados (p <0,001). **Conclusões:** As diferentes técnicas de cimentação de PFV não influenciaram na resistência à fratura, no padrão de fratura e na intensidade de artefatos de Micro-CT. Diferentes parâmetros de exposição não interferem na detecção de fraturas radiculares. A presença do filamento metálico no interior do PFV diminui os valores de especificidade de fratura radicular e aumentou a intensidade do artefato em imagens de TCFC.

**Palavras-Chaves:** Dente não vital; Pino de fibra de vidro; Tomografia Computadorizada de Feixe Cônico; Microtomografia por Raio-X; Artefatos

## ABSTRACT

**Objectives:** To evaluate the influence of different fiberglass post (FGP) cementation techniques on root fracture resistance, crack detection potential and generation of tomographic and microtomographic artifacts. **Methodology:** Forty single-rooted human premolars teeth were randomly divided into four groups (n=10): FGA- Fiberglass post cemented with dual-curing resin cement; FGCore- Fiberglass post cemented with dual-curing resin cement with high filler content; MCFG- Metal core fiberglass post cemented with dual-curing resin cement; AFG- Anatomical fiberglass post cemented with dual-curing resin cement. Each tooth was submitted to fracture resistance test at 0.5mm/min in a universal testing machine (ISTRON 3365 Machine). Then, all teeth were scanned on Skyscan 1172 to assess initial tooth morphology and fracture pattern using the following scores: (1) Fracture of the coronal composite resin; (2) Favorable root fracture; and (3) Unfavorable root fracture. In addition, a quantification of the percentage of artifacts generated in Computed Micro-Tomography (Micro-CT) images was performed. Cone-Beam Computed Tomography (CBCT) images were acquired using the CS 9000 3D (Kodak Dental Systems, Carestream Health, Rochester, NY, USA). Each tooth was scanned under four exposure parameters: 74kV, 80kV, 85kV and 90kV. The other parameters were set at 76 µm voxel size, 5 cm x 3.75 cm FOV size and 10 mA. Two observers assessed all CBCT images for root fracture detection using a 5-point confidence scale and a 4-point score for the presence of artifacts. One-way analysis of variance (ANOVA) and Tukey test were used to verify fracture resistance values between groups, while Fisher's exact test was used to verify the association between fracture pattern and groups. Quantitative evaluation of Micro-TC artifacts was analyzed using Kruskall Wallis and Mann Whitney tests. Sensitivity, specificity and area under the ROC curve (AUC) values were calculated and compared by two-way analyses of variance (ANOVA two-way) and Tukey's test Artifact interference on root fracture was assessed by chi-square test. Data were treated statistically at significance level of 5% (α=0.05). **Results:** Fracture resistance values varied from 465,38 ± 127,29 N to 364,47 ± 78,64 N (p=0.159). No association between the fracture pattern and fiberglass cementation techniques was observed (p=0.276). The quantification of Micro-CT image artifacts for all groups presented less than 10% of artifacts (p=0,062). There were no significant differences between the exposure parameters for sensitivity, specificity and AUC values (p>0.05). AFG presented higher sensitivity values, statistically differing from FGCore and MCFG (p=0.037). MCFG specificity values differed statistically from FGCore (p=0.012). MCFG presented higher percentage of moderate artifacts than the other studied groups (p=0.001). **Conclusions:** Fiberglass cementation techniques did not influence the resistance, fracture pattern, and Micro-CT artifact intensity. Different exposure parameters do not seem to interfere on root fracture detection. The presence of a metal core fiberglass post decreases root fracture detection specificity values and increases artifact intensity in CBCT images.

**Keywords:** Tooth, Nonvital; Cast, Fiberglass; Cone-Beam Computed Tomography; X-Ray Microtomography; Artifacts

## LISTA DE ILUSTRAÇÕES



**Artigo 1**

interest (VOI) image; b) Threshold quantification; c) Object volume (OV).

**Artigo 2**

**Figure 1.** Example of CBCT images in the sagittal, axial and coronal planes the studied fiberglass post cementation technique in all the studied exposure parameters.

## LISTA DE QUADROS

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## LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

ABO – Associação Brasileira de Odontologia

CTAn - *CT-analyser*

DICOM - *Digital Imaging and Communications in Medicine* (Imagem digital e comunicação em medicina)

FOV - Campo de visão (*Field of view*)

JAC - Junção amelocementária

kV – Quilovoltagem

LABIO - Laboratório Integrado de Biomateriais

LAMIB - Laboratório de Microscopia e Imagem Biológica

mA – Miliamperagem

µm – Micrômetro

mm – Milímetros

Micro – TC - Micro-Tomografia Computadorizada

NaCl - Cloreto de Sódio

PFV - Pino de fibra de vidro

TCFC - Tomografia Computadorizada de Feixe Cônico

UEPB - Universidade Estadual da Paraíba

UFPB - Universidade Federal da Paraíba

VOI - Volume de interesse (*Volume of Interest*)

VO - Volume do objeto (*Object volume*)

Nº - Número

% - Por cento; percentual de

º - Graus

## SUMÁRIO

## CONSIDERAÇÕES INICIAIS

O maior risco de fratura em dentes tratados endodonticamente está provavelmente relacionado à redução do tecido dental remanescente, pressões axiais exercidas durante o tratamento e redução da umidade (CHAUHAN et al., 2019; YASA et al., 2017; KAJAN; TAROMSARI, 2012). Em conjunto, esses aspectos tornam os dentes despolpados um problema frequente na clínica odontológica.

Após a realização do tratamento endodôntico, o dente necessita ser restaurado para recuperar sua forma, função e estética. Pelo fato de haver pouco remanescente coronário, geralmente, necessita-se da utilização de retentores intrarradiculares para reter a coroa artificial (CHUANG et al., 2010; JAYASENTHIL et al., 2016).

Diferentes tipos de retentores são utilizados nas restaurações intrarradiculares de dentes tratados endodonticamente (KURTHUKOTI et al., 2015; SCHIAVETTI et al., 2010). Dentre estes, os núcleos metálicos fundidos são tradicionalmente utilizados pelos cirurgiões dentistas. Porém, são mais rígidos e apresentam módulo de elasticidade superior ao substrato dentinário, provocando maiores tensões sobre a dentina e aumentando as chances de fratura radicular (DA SILVA et al., 2010; FIGUEIREDO et al., 2015; GARBIN et al., 2010; SANTOS et al., 2010).

Além de serem mais estéticos, os pinos de fibra de vidro (PFV) apresentam módulo de elasticidade e rigidez semelhantes à dentina, possuem cimentação adesiva, reduzida corrosão e toxicidade, assim como alta resistência à tração e à fadiga (ABDULJAWADET al., 2016; KIM et al., 2016; LAMICHHANE; XU; ZHANG, 2014). A utilização destes pinos reduz o risco de fratura vertical da raiz, uma vez que absorverem impactos e transmitem poucas tensões às estruturas dentárias remanescentes (GIOVANNI et al., 2009; KESWANI; MARIA; PUNGA, 2014; PENELAS et al., 2015; SANTOS-FILHO et al., 2014; WATANABE et al., 2012).

Um fator essencial para conferir longevidade e bom prognóstico de restaurações intrarradiculares em dentes tratados endodonticamente é a espessura do cimento. O uso de cimento resinoso como um agente de união pode ajudar a limitar infiltração e aumentar a retenção dos dispositivos intrarradiculares. Percebe-se que uma menor espessura de cimento confere melhor adesão do pino, menor formação de fendas e maior resistência à fratura (GOMES et al., 2014; PEDREIRA et al., 2016; SCHMAGE et al., 2009).

Uma vez que os PFV pré-fabricados não se assemelham totalmente à anatomia do canal radicular e adaptam-se de forma imprecisa a este, faz-se necessário utilizar quantidades excessivas de cimento resinoso para promover o preenchimento de espaço entre o remanescente dentário e o pino (MARCHI et al., 2008; MARCOS et al., 2016; MOOSAVI; MALEKNEJAD; KIMYAI, 2008; TEIXEIRA et al., 2008; TEIXEIRA; SILVA-SOUSA; SOUSA-NETO, 2009; ZOGHEIB et al., 2008). A adição da resina composta ao PFV melhora suas propriedades mecânicas e reduz a linha de cimento, uma vez que permite um melhor ajuste marginal às paredes da raiz e cria condições favoráveis à retenção (COSTA et al. 2012; GOMES et al., 2016).

Estudos demostraram que o uso de PFV anatomizados apresentou maior força de ligação, superior resistência à fratura, menor formação de fendas, redução dos níveis de estresse e desempenho superior comparado aos pinos não-anatomizados (BELLI et al., 2014; CLAVIJO et al., 2009; FARIA-E-SILVA et al., 2009; GOMES et al., 2014; MACEDO; FARIA E SILVA; MARTINS, 2010; SILVA et al., 2011).

No caso de insucesso do tratamento com retentores intrarradiculares, as fraturas radiculares são frequentemente encontradas. A presença de fraturas verticais da raiz reduz o prognóstico e pode levar à perda do dente. Dessa forma, sua identificação é desafiadora e exige combinação de sinais clínicos e radiográficos (HEKMATIAN et al., 2018).

Nas imagens periapicais intrabucais as estruturas dentárias são vistas em duas dimensões. A deficiência dessa técnica em detectar precisamente as fraturas indica a necessidade de uso de sistemas por imagem que permitam uma melhor resolução espacial. Nesse aspecto, a Tomografia Computadorizada de Feixe Cônico (TCFC) vem sendo utilizada, permitindo visualizar fraturas radiculares em diferentes planos (axial, sagital e coronal) e identificá-las com maior precisão (KIARUDI et al., 2015; NIKBIN et al. 2018; METSKA et al., 2012).

Apesar de inúmeras qualidades da TCFC, os artefatos de imagem, conceituados como qualquer distorção ou erro na imagem que não representa o objeto em estudo, estão frequentemente presentes, limitando a qualidade da imagem radiográfica (SCHULZE et al., 2011). Os artefatos tomográficos podem gerar linhas hipodensas, halos hipodensos e estrias hiperdensas. Os artefatos hipodensos geralmente ocorrem devido ao endurecimento do feixe, no qual apenas fótons de raios X de alta energia passam através do metal, enquanto os fótons de baixa energia são absorvidos. Dessa forma, o feixe resultante torna-se mais energético, resultando em halos e linhas escuras, que dificultam a visualização da área. As estrias hiperdensas ocorrem quando os fótons são bloqueados e o feixe resultante torna-se menos energético, formando áreas claras que, geralmente, ocorrem na periferia de materiais metálicos (KUTEKEN et al., 2015; BELEDELLI; SOUZA, 2012).

Os aparelhos de TCFC permitem uma variação de parâmetros de exposição, como o tamanho do voxel, campo de visão (FOV), quilivoltagem (kV), tempo de exposição e miliamperagem (mA) (AL-OKSHI et al., 2015, JONES et al., 2015). Esses ajustes podem modificar a qualidade da imagem, assim como a quantidade de radiação emitida ao paciente. Dessa forma, recomendam-se protocolos que permitam uma boa qualidade para o diagnóstico, com o mínimo de exposição à radiação possível (PINTO et al. 2017; FREITAS et al., 2019), considerando e respeitando o princípio ALARA (“as low as diagnostically acceptable" ou “tão baixo quanto razoavelmente possível”).

A kV é responsável pela movimentação dos elétrons dentro da ampola, estando relacionada com a penetração dos fótons nos tecidos, de modo que altos valores de kV garantem maior penetrabilidade. Este parece ser o principal parâmetro de energia que influencia a produção de artefatos (FREITAS et al., 2018).

Embora não seja utilizada *in vivo*, a Micro-Tomografia Computadorizada (Micro-TC) apresenta-se como outra modalidade que possibilita um diagnóstico eficaz das fraturas radiculares (HUANG et al., 2014). Trata-se de uma técnica precisa, nítida e com alto poder de resolução que permite a reconstrução, em três dimensões, da restauração dentária e de seus tecidos circundantes, sem comprometer a integridade da amostra (CARRERA et al., 2015).

Ainda não existe um consenso em relação à técnica e tipo de dispositivo ideal para a restauração dos dentes tratados endodonticamente. Deve-se buscar uma técnica restauradora que possa reestabelecer a estética e função, assim como conferir longevidade aos elementos dentais. Além disso, almeja-se evitar fracassos comuns, a exemplo das fraturas radiculares, que apresentam diagnóstico limitado. Devido aos questionamentos ainda presentes em relação à restauração de dentes despolpados, o presente estudo fornece informações acerca de diferentes técnicas de cimentação e confecção de PFV. Além disso, contribui para elucidação dos aspectos relacionados à detecção de fraturas e trincas de dentes tratados endodonticamente, mediante o uso de TCFC e Micro-TC.

Diante do exposto, o objetivo da pesquisa é avaliar a influência de diferentes técnicas de cimentação de PFV na resistência à fratura radicular, potencial de detecção de trincas e geração de artefatos tomográficos e microtomográficos em dentes pré-molares unirradiculares.

# 2 OBJETIVOS

## 2.1 Objetivo Geral

- Avaliar a influência de diferentes técnicas de cimentação de PFV na resistência à fratura, potencial de detecção de trincas e geração de artefatos tomográficos e micro-tomográficos em dentes pré-molares unirradiculares.

## 2.2 Objetivos Específicos

- Avaliar a resistência à fratura e o padrão de fratura de dentes tratados endodonticamente e reabilitados com diferentes técnicas de cimentação de PFV;
- Identificar a técnica de confecção e cimentação de retentores intrarradiculares que proporciona melhor diagnóstico de fraturas radiculares e menor geração de artefatos em imagens de TCFC;
- Analisar o parâmetro de exposição que proporciona melhor diagnóstico de fraturas radiculares e menor geração de artefatos em imagens de TCFC;
- Avaliar a interferência da produção de artefatos tomográficos no diagnóstico de fraturas radiculares;
- Verificar a geração de artefatos produzidos nas imagens obtidas por Micro-TC.

# 3 METODOLOGIA

## 3.1 Princípios éticos

O estudo foi aprovado pelo Comitê de Ética em Pesquisa da Universidade Estadual da Paraíba, em conformidade com a Resolução CNS nº 466/12 (CAAE: 65415617.0.0000.5187) (Anexo A).

## 3.2 Delineamento do estudo

O estudo consistiu em uma pesquisa experimental *in vitro*, do tipo analítico (HOCHMAN et al., 2005). Foi realizado um estudo de abordagem indutiva, com procedimento estatístico-comparativo e técnica de documentação direta.

## 3.3 Local da pesquisa

A pesquisa foi realizada no Laboratório de Prótese Dentária da Universidade Estadual da Paraíba – UEPB, no Laboratório Integrado de Biomateriais (LABIO) da Universidade Federal da Paraíba – UFPB e no Laboratório de Microscopia e Imagem Biológica (LAMIB) da UFPB. As imagens tomográficas foram adquiridas na Associação Brasileira de Odontologia - PB (ABO-PB).

## 3.4 Amostra

Quarenta dentes humanos pré-molares unirradiculares totalizaram a amostra deste estudo.

Como critérios de inclusão da amostra, os dentes deveriam possuir curvatura radicular máxima de ≤ 5, assim como dimensões semelhantes.

Os critérios de exclusão incluíram a presença de cálculos pulpares, tratamento endodôntico prévio, presença trincas e/ou fraturas radiculares pré-existentes, multiplicidade de canais, dentes com reabsorção radicular e com anomalias.

### 3.5 Caracterização da amostra

Os quarenta pré-molares unirradiculares foram divididos, aleatoriamente, em quatro grupos experimentais, cada qual com dez dentes (n=10), sendo eles:

FGA: Dentes tratados com pino de fibra de vidro (WhitePost DCE nº1, FGM, Joinville, SC, Brasil) + cimentação com cimento resinoso dual (Allcem, FGM, Joinville, SC, Brasil) + núcleo de preenchimento de resina composta (Filtek™ Z350, Restaurador Universal Filtek™ Z350, 3M ESPE, Maplewood, EUA);

FGCore: Dentes tratados com pino de fibra de vidro (WhitePost DCE nº 1, FGM) + núcleo de preenchimento e cimentação com cimento resinoso dual com alto conteúdo de carga (Allcem Core, FGM, Joinville, SC, Brasil);

MCFG: Dentes tratados com pino de fibra de vidro (Reforpost nº 1, Angelus, Londrina, PR, Brasil) + cimentação com cimento resinoso dual + núcleo de preenchimento de resina composta;

AFG: Dentes tratados com pino de fibra de vidro (WhitePost DCE nº 0,5, FGM) anatomizado com resina composta + cimentação com cimento resinoso dual + núcleo de preenchimento de resina composta.

### 3.6 Preparo dos dentes

Os dentes foram submetidos à raspagem e alisamento radicular (Trinity Odontologia, São Paulo, SP, Brasil). Em seguida, os mesmos foram inseridos separadamente em tubos de polipropileno tipo Eppendorf (Micro Test Tubes 3810X standard - Eppendorf do Brasil Ltda, São Paulo, SP, Brasil), permanecendo hidratados em solução salina de NaCl 0,9% (ADV, Nova Odessa, São Paulo, Brasil), exceto durante sua manipulação.

A espessura de dentina radicular remanescente foi mensurada com um paquímetro digital, com a finalidade de padronizar as amostras. Dessa forma, foram descartados os dentes que não se enquadraram em um limite de 20% a partir da média de espessura dentinária.

As coroas de todos os dentes foram seccionadas no limite da junção amelocementária (JAC). Para isto, foi utilizado um disco de carborundum (KG Sorensen, Zenith Dental ApS, Agerskov, Dinamarca) acoplado a um micromotor elétrico (LB 100, Beltec, Araraquara, SP, Brasil).

O tratamento endodôntico foi realizado com o auxílio do sistema rotatório Reciproc R50 (VDW, Munique, Alemanha) (Figura 1). Após a instrumentação do canal radicular, os dentes foram obturados pela técnica de Compactação Termomecânica (PacMac 45.04 de 21 mm, SybronEndo Dental Specialties, Glendora, CA, EUA) (Figura 2). Utilizou-se um cone de guta-percha (Reciproc R50, VDW, München, Alemanha) de tamanho e conicidade idênticos ao instrumento utilizado no preparo mecânico, pincelado com cimento Sealer 26 (Dentsply, Rio de Janeiro, Brasil) e inserido no comprimento real de trabalho (CRT). Por fim, a massa plástica foi compactada verticalmente com calcador frio (Figura 2).

Logo após, foram desobturados 2/3 do comprimento do canal utilizando uma broca Largo Peeso nº 1 (Dentsply/Maillefer, Brasil) e a quantidade de material restante da guta-percha no canal foi observada através de uma radiografia periapical.

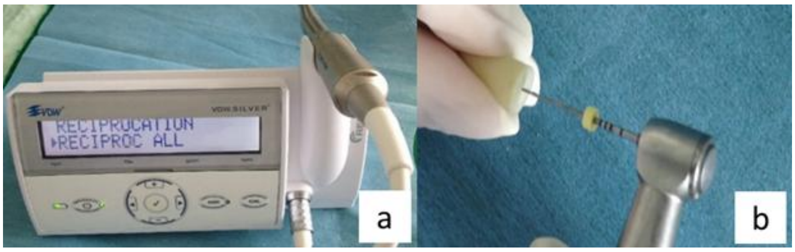



**Figura 1.** (a) Instrumentação com sistema Reciproc R50; (b) Posicionamento da lima.

**FONTE:** Pesquisador.

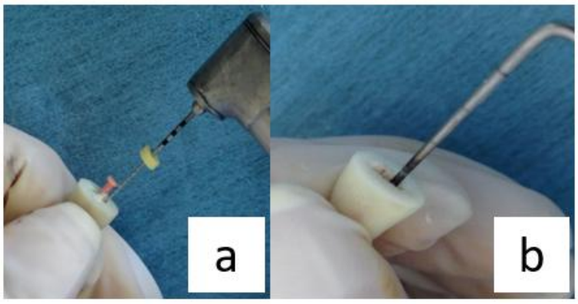



**Figura 2.** (a) Termocompactação - Inserção da PacMac ao lado do cone; (b) Compactação vertical.

**FONTE:** Pesquisador.

Todos os protocolos de preparo e cimentação dos pinos foram realizados segundo as recomendações do fabricante. Para o grupo FGA (Whitepost DCE nº1, FGM, Joinville, Brasil), o pino foi inicialmente limpo com álcool 70% e preparado com gel de ácido fosfórico (Condac 37, FGM, Joinville, Santa Catarina, Brasil), Silano Prosil (FGM, Joinville, Santa Catarina, Brasil) e sistema adesivo fotopolimerizável (Ambar , FGM, Joinville, Santa Catarina, Brasil). O canal radicular recebeu tratamento prévio com gel de ácido fosfórico (Condac 37) e sistema adesivo fotopolimerizável (Ambar). O cimento resinoso dual (AllCem, FGM, Joinville, SC, Brasil) foi inserido no conduto com auxílio de uma broca lentulo 25mm

(Dentsply/Maillefer, Brasil) e o pino foi assentado até sua adaptação no canal radicular. Por fim, procedeu-se com a fotopolimerização do cimento pela superfície e através do pino (Figura 3).

O grupo FGCore (Whitepost DCE nº1, FGM, Joinville, Brasil) seguiu os procedimentos descritos anteriormente, entretanto o cimento resinoso dual com alto conteúdo de carga (Allcem Core, FGM, Joinville, Santa Catarina, Brasil) foi utilizado para cimentação do pino (Figura 4).

Para o grupo MCFG (Reforpost nº1, Angelus, Londrina, Paraná, Brasil) o pino foi inicialmente limpo com álcool 70% e preparado com Silano Prosil e aplicação do sistema adesivo autopolimerizável (Catalisador, Fusion-Duralink, Angelus, Londrina, Paraná, Brasil). O canal radicular recebeu tratamento com gel de ácido fosfórico (Condac 37) e sistema adesivo autocondicionante (Primer e adesivo químico catalisador Fusion-Duralink, Angelus, Londrina, Paraná, Brasil). O cimento resinoso dual AllCem foi inserido no conduto com auxílio de uma broca lentulo 25mm (Dentsply/Maillefer, Brasil) e o pino foi assentado até sua adaptação no canal radicular (Figura 5).

No grupo AFG, o pino (Whitepost DCE nº 0,5, FGM, Joinville, Brasil) foi anatomizado com resina composta (Filtek ™ Z350 XT) para melhor adaptação no canal radicular. Inicialmente, o pino foi limpo com álcool 70% e condicionado com gel de ácido fosfórico (Condac 37) por 40 segundos, seguido por lavagem e secagem. Posteriormente, o pino foi revestido com silano Prosil e o sistema adesivo fotopolimerizável (Ambar) foi aplicado e fotopolimerizado por 20 segundos. Logo após, o pino foi coberto com uma porção de resina composta e o conjunto (pino e resina) foi inserido no canal, previamente lubrificado com um gel lubrificante hidrossolúvel (ENDO-PTC, F&A, São Paulo, Brasil). O excesso de resina na porção cervical foi removido e o conjunto foi polimerizado por 20 segundos. Com o pino anatomizado fora do conduto, procedeu-se a fotopolimerização adicional por 20 segundos em cada superfície. O canal radicular recebeu tratamento com gel de ácido fosfórico (Condac 37) e sistema adesivo fotopolimerizável (Ambar). Após a remoção de áreas retentivas, o PFV anatomizado foi cimentado no interior do canal radicular com o cimento resinoso dual AllCem (Figura 6).

Os núcleos de preenchimento dos grupos FGA, MCFG e AFG foram confeccionados em resina composta (Filtek ™ Z350), sendo as dimensões padronizadas com o auxílio de uma matriz de uma matriz de acetato (Bio-Art, São Paulo, Brazil) compatível com o preparo (Figura 7). No grupo FGCore, o cimento resinoso dual Allcem Core foi utilizado para confecção do núcleo de preenchimento.


**Figura 3**. Sequência do tratamento da superfície do pino, do conduto radicular e cimentação do PFV do grupo FGA.

**FONTE:** Pesquisador.

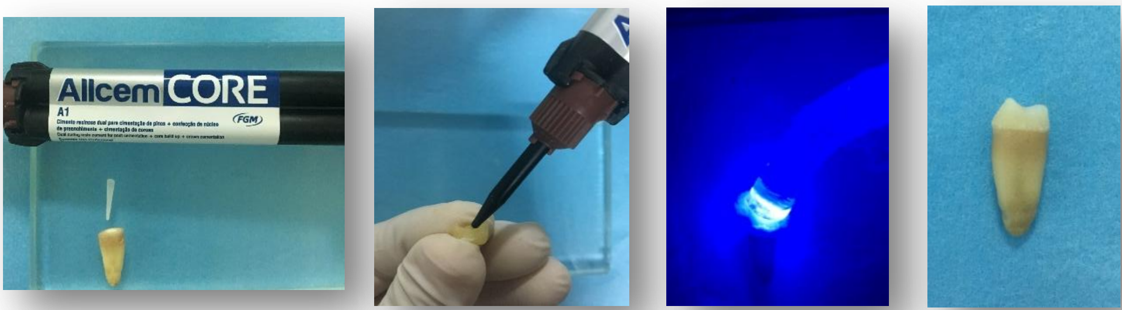



**Figura 4**. Sequência da cimentação do PFV do grupo FGCore.

**FONTE:** Pesquisador.


**Figura 5**. Sequência do tratamento da superfície do pino, do conduto radicular e cimentação do PFV do grupo MCFG.

**FONTE:** Pesquisador.


**Figura 6**. Sequência da cimentação do PFV do grupo AFG.

**FONTE:** Pesquisador.

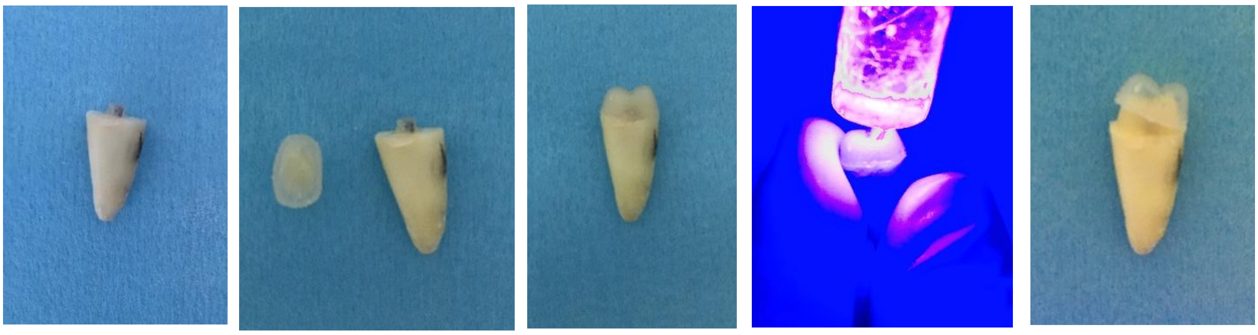


**Figura 7**. Matriz de acetato usada para confeccionar os núcleos de preenchimento.

**FONTE:** Pesquisador.

### 3.7 Indução da fratura

Os dentes foram envolvidos com material de impressão de poliéster (Impregum F, 3M-Espe, Seefeld, Alemanha) para reproduzir o ligamento periodontal e foram montados individualmente em frascos acrílicos do tipo J7 (35 x 22 mm), contendo resina acrílica (Vipi flash, VIPI, São Paulo, Brasil).

Os dentes foram fixados a um delineador, pelo núcleo de preenchimento, através de cera pegajosa. Para simular a distância do espaço biológico, a superfície radicular foi imersa nos tubos até a marcação de 3 mm da margem cervical, permanecendo estática até a polimerização total da resina acrílica (Figura 8).

Para a realização do ensaio de resistência à fratura, foi utilizado um suporte de madeira com angulação de 22,5º. O conjunto foi fixado na plataforma metálica do aparelho, de forma que não houvesse movimentação durante o procedimento.

A amostra foi induzida à fratura utilizando uma máquina de ensaio universal (ISTRON 3365 Machine), posicionando-se uma ponta metálica de extremidade esférica sobre o núcleo de preenchimento (22,5°) com velocidade de 0,5 mm/min (Figura 9).

**Figura 8.** Fixação do dente nos tubos acrílicos contendo resina acrílica.

**FONTE:** Pesquisador.

**Figura 9.** Indução à fratura na máquina de ensaio universal (ISTRON 3365 Machine)**.**

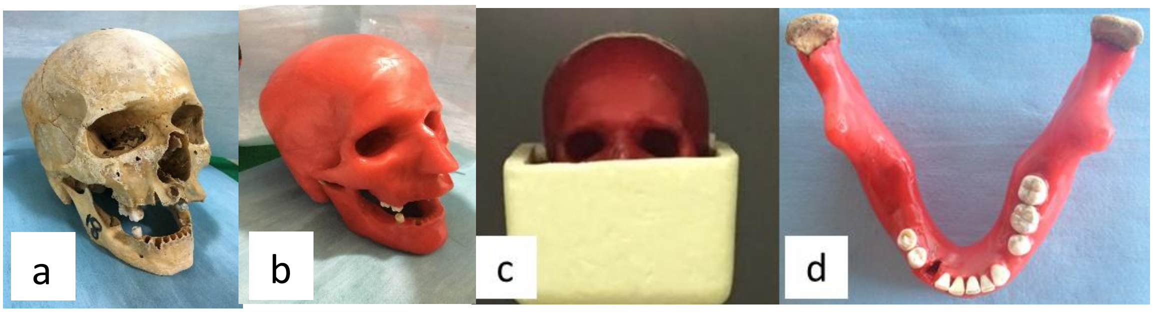
**FONTE:** Pesquisador.

### 3.8 Preparo do crânio e mandíbula

Inicialmente, o crânio foi recoberto com uma camada de 5 mm de espessura de cera rosa nº 7 (Figura 10). Os dentes também foram envolvidos em uma fina camada de cera rosa nº 7, no intuito de simular o espaço do ligamento periodontal.

O conjunto crânio/mandíbula foi colocado numa caixa de isopor retangular contendo água para simular uma situação clínica. Outros dentes, sem restaurações metálicas, foram posicionados nos alvéolos inicialmente vazios para simular a arcada de um paciente semidentado (Figura 10) (adaptado de PINTO et al., 2016).

Apesar da amostra ser toda representada por pré-molares, o alvéolo do canino inferior direito foi o que conseguiu receber os dentes de forma que todos pudessem ficar posicionados no nível da base do osso alveolar.




(a) Aspecto inicial do crânio; (b) aspecto final do crânio encerado; (c) conjunto crânio/mandíbula dentro da caixa de isopor com água; (d) aspecto final da mandíbula semi-dentada.

**FONTE:** Pesquisador.

### 3.9 Aquisição das imagens tomográficas

Antes e após a fratura dos dentes, imagens tomográficas dos dentes foram adquiridas pelo aparelho CS 9000 3D (Kodak Dental Systems, a Carestream Health, Rochester, NY, EUA) (Figura 11).

Cada dente foi escaneado sob 4 parâmetros de exposição: 74kV, 80kV, 85kV e 90kV. Os demais parâmetros foram fixados em 76 µm de tamanho de voxel, 5 cm x 3,75 cm de tamanho de FOV e 10 mA. O conjunto de dados resultante foi exportado como arquivos Digital Imaging and Communication em Medicina (DICOM) e salvo com um código anônimo.

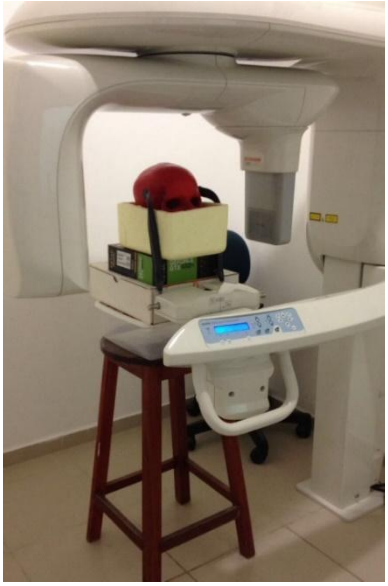


**Figura 11.** Escaneamento no tomógrafo Carestream (KODAK CS 9000).

**FONTE:** Pesquisador.

### 3.10 Calibração e análise da detecção de fraturas e artefatos nas imagens tomográficas

Foi realizada uma calibração dos avaliadores para verificar a presença de artefatos nas imagens (realizado nas imagens anteriores ao ensaio de fratura) e analisar a existência ou não das fraturas radiculares (realizado nas imagens após a indução de fratura). Para isto, dois radiologistas odontológicos com mais de cinco anos de experiência receberam uma sessão de treinamentos verbais e práticos antes das avaliações.

Os volumes foram visualizados usando o software de imagem CS 3D (Carestream Dental Rochester-NY, EUA) em um Dell Inspiron 14 série 5000 (Dell Inc., Eldorado do Sul, Brasil), com uma tela de 14 polegadas em uma sala com iluminação e temperatura controladas. Ajustes para configurações de zoom, brilho e contraste foram deixados ao critério de cada observador. Um número limitado de 16 volumes foi avaliado por dia.

Os examinadores registraram suas observações estabelecendo escores para o diagnóstico de fratura (Quadro 01), assim como para observar a quantidade dos artefatos formados em imagens de TCFC e a influência destes no diagnóstico da fratura (Quadro 02).

**Quadro 01:** Critérios de diagnóstico de fratura.

| | |
|---|---|
| **1** | Definitivamente ausente |
| **2** | Provavelmente não apresenta fratura radicular |
| **3** | Inseguro: não há como afirmar presença de fratura |
| **4** | Provavelmente apresenta fratura radicular |
| **5** | Definitivamente apresenta fratura radicular |

**FONTE**: Quadro elaborado pela pesquisadora.

**Quadro 02:** Critérios de grau de interferência dos artefatos nas imagens de TCFC.

| | |
|---|---|
| **0** | **Ausente** (sem a formação de artefatos) |
| **1** | **Leve** (artefato está presente, mas não interfere no diagnóstico de fratura) |
| **2** | **Moderado** (artefato está presente moderadamente e pode interferir no diagnóstico de fratura) |
| **3** | **Grave** (artefato grave está presente e definitivamente interfere no diagnóstico da fratura) |

### 3.11 Aquisição das imagens microtomográficas

Os dentes foram escaneados de forma individualizada, antes e após o ensaio de fratura, no microtomógrafo SkyScan 1172 (Bruker, Kontich, Belgium), utilizando o protocolo de escaneamento com os seguintes parâmetros: 100 kVp, 100 µA, filtro de 0.5 Al, 27 µm tamanho de voxel, 0.4˚ de rotation step, 2 frame e giro de 360˚ (Figura 12).

A reconstrução das imagens foi executada no software NRecon (Bruker, Kontich, Belgium) com a aplicação das seguintes correções de artefato: 2 de redução de ruído (smoothing) e 6 de redução de artefato em anel (ring artifact). O reposicionamento do volume dos dentes em posição padrão foi realizada no software Dataviewer (Bruker, Kontich, Belgium), anteriormente a realização das análises.

As imagens de micro-TC adquiridas antes do ensaio de fratura identificaram a morfologia inicial dos dentes, assim como foram utilizadas para realizar a análise quantitativa de artefatos gerados em micro-TC. As imagens adquiridas após a indução da fratura foram usadas para avaliar a presença e o padrão de fratura.

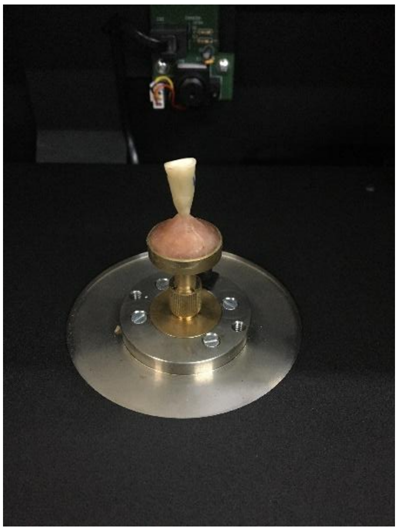


**Figura 12.** Escaneamento no microtomógrafo SkyScan 1172 (Bruker, Kontich, Belgium).
**FONTE:** Pesquisador.

### 3.12 Classificação do padrão de fratura

Com relação ao padrão de fratura radicular, as fraturas foram classificadas em: (1) Fratura do núcleo de preenchimento; (2) Fratura radicular favorável ou não catastrófica – até 3mm da JCE, ou seja, acima da margem óssea; (3) Fratura radicular desfavorável ou catastrófica - >3mm da JCE, ou seja, abaixo da margem óssea ou com presença de fratura vertical.

### 3.13 Análise microtomográfica

Para a análise da presença ou ausência das fraturas, o software Dataviewer (Bruker, Kontich, Belgium) foi escolhido, de modo que as três reconstruções (axial, coronal e sagital) foram exploradas com a possível aplicação da ferramenta de zoom. Pelo fato de as fraturas serem facilmente visualizadas, apenas um avaliador experiente realizou essa etapa de avaliação.

Para a classificação do padrão das fraturas, o mesmo avaliador usou o software CTAn (Bruker, Kontich, Belgium), tendo em vista que este software expõe a altura de cada corte visualizado em milímetros.

Para a análise quantitativa dos artefatos, foram usadas ferramentas avançadas do software CTAn. O volume de interesse (VOI) foi definido entre a margem cervical e a porção mais apical do PFV. A seleção dos tons de cinza compatíveis com artefatos ao redor dos retentores intrarradiculares foi obtida dentro do limiar de threshold de 50 a 70, sendo usado para definir o volume do objeto (VO) (Figuras 13a e b). Após a seleção da faixa de artefatos, a ferramenta de quantificação de volume foi aplicada (Figura 13c) e os resultados foram tabulados para posterior análise. A porcentagem de artefatos detectados nas imagens foi calculada pela razão entre o volume do objeto e o volume de interesse (VO / VOI × 100).

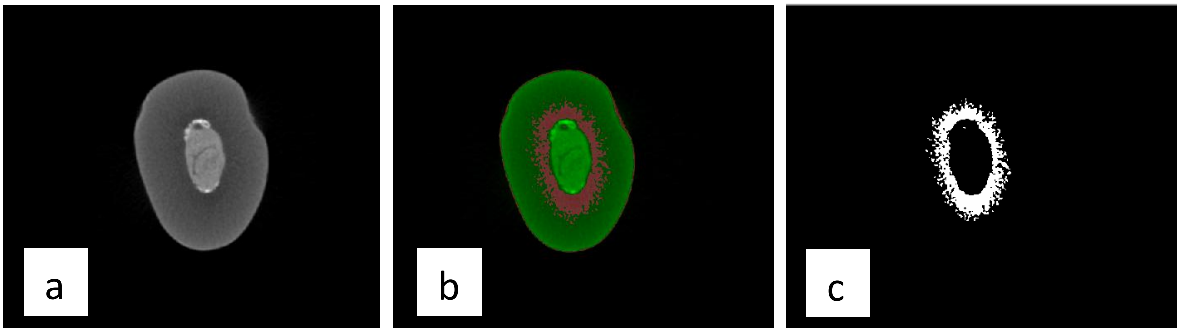



**Figura 13.** Análise quantitativa de artefatos no software CTAn: (a) Imagem do volume de interesse (VOI); (b) Quantificação de threshold; (c) Volume do objeto (VO).

**FONTE:** Pesquisador.

### 3.14 Estudo piloto

Foi realizado um estudo piloto para teste das metodologias e técnicas utilizadas.

### 3.15 Análise estatística

Os valores de resistência a fratura apresentaram distribuição normal. Diante disso, optou-se por realizar o teste de análise de variância a um fator (ANOVA 1-way), com pós-teste de Tukey.

O Teste exato de Fisher foi utilizado para verificar associações entre o padrão de fratura e o tipo de material.

Os valores quantitativos de artefatos gerados em micro-CT não apresentaram distribuição normal. Portanto, os dados foram analisados pelos testes de Kruskall Wallis e Mann Whitney.

O coeficiente Kappa interobservador foi utilizado para a detecção de fraturas radiculares. Os valores de sensibilidade, especificidade e área sob a curva ROC (AUC) foram calculados e comparados por análises de variância bidirecional (two-way ANOVA) e teste de Tukey. A interferência dos artefatos tomográficos no diagnóstico de fratura radicular foi avaliada pela estatística descritiva e o teste do qui-quadrado.

Adotou-se um índice de significância de 5%.

# 4 RESULTADOS

## 4.1 Artigo 1

Title: Assessment of resistance to fracture, fracture pattern and intensity of artifact of different fiberglass posts' – a Micro-CT study

Será submetido ao periódico "Dental Materials", qualis A1 para Odontologia.

# Assessment of resistance to fracture, fracture pattern and intensity of artifact of different fiberglass posts' – a Micro-CT study

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**ABSTRACT**

***Objetives:*** To assess the resistance, fracture pattern and artifact intensity on Micro-CT images of teeth restored with fiberglass posts using different cementation techniques. ***Methods:*** Forty single-rooted human premolars teeth were randomly divided into four groups (n=10): 1- Fiberglass post cemented with dual-curing resin cement; 2- Fiberglass post cemented with dual-curing resin cement with high filler content; 3- Metal core fiberglass post cemented with dual-curing resin cement; 4- Anatomical fiberglass post cemented with dual-curing resin cement. The sample was scanned on micro-CT scanner to assess its initial morphology and the percentage of micro-CT artifacts. Each tooth was submitted to fracture resistance test at 0.5mm/min in a universal testing machine. Then, all teeth were scanned on Skyscan 1172 to determine fracture pattern, using the following scores: (1) Fracture of the coronal composite resin; (2) Favorable root fracture; and (3) Unfavorable root fracture. One-way analysis of variance (ANOVA) and Tukey test were used for statistical analysis. Fisher's exact test was used to verify the association between fracture pattern and fiberglass post groups. Quantitative evaluation of Micro-CT artifacts was analyzed using Kruskall Wallis and Mann Whitney tests. ***Results:*** Fracture resistance values varied from 465,38 ± 127,29 N to 364,47 ± 78,64 N (p=0.159). No association between the fracture pattern and fiberglass cementation techniques was observed (p=0.276). The quantification of Micro-CT image artifacts for all groups presented less than 10% of artifacts (p=0,062). ***Conclusion:*** Fiberglass cementation techniques did not influence the resistance, fracture pattern, and Micro-CT artifact intensity. Fiberglass posts tend to present favorable factures. Micro-CT artifacts do not impair root fracture detection.


***Keywords*:** Tooth, Nonvital; X-Ray Microtomography; Artifacts

## 1. Introduction

Endodontically treated teeth are considered susceptible to fracture due to loss of dentin tissue, root canal instrumentation and moisture reduction [1,2]. Therefore, choosing the best treatment to restore teeth with extensive loss of coronal structure becomes a challenge for clinicians [3]. Intracanal posts are indicated to retain prosthetic crowns and help distributing occlusal stress along the tooth structure to increase root canal therapy success [4,5].

Teeth restored with metal cast posts tend to present a high number of vertical root fractures due to its high modulus of elasticity which distributes and concentrates the stress in the apical third of the root [6, 7]. The use of intracanal posts with similar modulus of elasticity to dentin, such as fiberglass posts, creates homogeneous stress distribution and reduces the incidence of vertical root fractures [8, 9].

Resin cements have generally been recommended for fiberglass post cementation [10]. Given that prefabricated fiberglass posts do not completely resemble the root canal anatomy and are inaccurately adapted to the root canal, it is necessary to use excessive amounts of resin cement to promote the complete filling of the space between the remaining tooth canal and the prefabricated fiberglass post [11-13]. Fiberglass post anatomization with resinous compound technique has been indicated to restore root canals. In this technique, a smaller amount of resin cement is applied, increasing the bond strength between the post and the root canal and minimizing the risk of dental fractures.

Micro-Computerized Tomography (Micro-CT) is not indicated for *in vivo* studies, it is an effective image modality for in *vitro* studies and root fracture detection [14]. For *in vitro* applications, Micro-CT is considered the gold standard image modality that allows a precise the reconstruction in three dimensions of the dental restoration and its surrounding tissues without compromising the integrity of the sample [15, 16]. Despite Micro-CT advantages, it presents image artifacts i.e. any distortion or error in the image that does not represent the object being studied [17].

There is yet no consensus regarding the technique and type of post that is ideal for the restoration of endodontically treated teeth, even considering the disseminated use of fiberglass posts. A restorative technique should be sought that can restore aesthetics and function, as well as provide longevity to the tooth. An ideal material and technique should avoid common failures, such as root fractures. This study aimed to assess different fiberglass posts' fracture resistance, fracture pattern and artifact intensity using Micro-CT.

## 2. Material and methods

This in vitro experimental study was approved by the Ethics and Research Committee of the first author's institution (protocol number: 65415617.0.0000.5187) and follows the Helsinki Declaration.

### 2.1. Sample preparation

The sample was composed of forty single-rooted human teeth (premolars), extracted for therapeutic reasons. As inclusion criteria, all teeth should have a maximum root curvature of ≤5° and similar dimensions. The sample was inspected by transillumination for the absence of root fractures. All teeth were also radiographed on photostimulated plates (Digora Optime, Soredex, Tuusula, Finland) to exclude those with pulp stones, internal and/or external root resorption, previous endodontic treatment, multiple root canals, root canal obliteration, root fractures or any other anomaly.

After cleaning and disinfection protocols, all crowns were removed at the cementoenamel junction and root canals were prepared to a standard size using the Reciproc R50 system (VDW, München, Germany). Then, a thermo-mechanical compacted root filling was placed using endodontic cement Sealer 26 (Dentsply, Rio de Janeiro, Brazil) and PacMac 21 mm, size 45, .04 taper (SybronEndo Dental Specialties, Glendora, CA, USA). For posterior post preparation and fitting, gutta-percha of the roots' coronal two-thirds were removed using size 1 Piezo drills (Peeso Long Drill no 1, Dentsply Sirona Endodontics, Ballaigues, Switzerland).

The sample was divided into four groups, each containing ten teeth: 1- Fiberglass post (WhitePost DCE size nº 1, FGM, Joinville, SC, Brazil) cemented with dual-curing resin cement (Allcem, FGM, Joinville, SC, Brasil) (FGA); 2 - Fiberglass post (WhitePost DCE size nº 1, FGM, Joinville, SC, Brazil) cemented with dual-curing resin cement with high filler content (AllcemCore, FGM, Joinville, SC, Brazil) (FGCore). 3- Metal core fiberglass post (Reforpost size nº 1, Angelus, Londrina, PR. Brazil) cemented with dual-curing resin cement (Allcem, MCFG); 4- Anatomical fiberglass post (WhitePost DCE size nº 0,5, FGM, Joinville, SC, Brazil) + composite resin (Filtek™ Z350, 3M ESPE, Maplewood, EUA) cemented with dual-curing resin cement (AFG).

All fiberglass posts were prepared according to manufacturer's recommendations. FGA was prepared using phosphoric acid gel treatment (Condac 37, FGM, Joinville, Santa

Catarina, Brazil), Prosil Silane (FGM, Joinville, Santa Catarina, Brazil) and light-curing adhesive system (Ambar, FGM, Joinville, Santa Catarina, Brazil). This group was then cemented using dual cement AllCem.

FGCore followed procedures described previously; however, for this group the dual resin cement Allcem Core was used for cementation of the post.

MCFG (Reforpost, Angelus, Londrina, Paraná, Brazil) was prepared using Prosil Silane and self-curing adhesive system (Fusion-Duralink, Angelus, Londrina, Paraná, Brazil). This group was then cemented using dual cement AllCem.

AFG (Whitepost FGM, Joinville, Brazil) was prepared to better fit the root canal anatomy reinforced by Filtek™ Z350 XT (3M, Maplewood, EUA) composite resin. The fiberglass posts were prepared by phosphoric acid gel conditioning (Condac 37), Prosil Silane and light-curing adhesive system (Ambar). The fiberglass post was covered with compound resin and then introduced into the root canal, previously soaked with water-soluble lubricating gel (ENDO-PTC, F&A, São Paulo, Brazil). The anatomized post received additional photopolymerization for 20 seconds. The AFG set was then cemented using dual cement AllCem.

The root canals were prepared for post cementation using phosphoric acid gel treatment (Condac 37) and light-curing adhesive system (Ambar), for FGA, FGCore and AFG; and self-etching (Primer and Chemical Fusion-Duralink Catalyst Adhesive, Angelus, Londrina, Paraná, Brazil) for the MCFG group.

The coronal composite resin portion (filling nuclei) (Filtek™ Z350) of each post was standardized using an acetate matrix (Bio-Art, São Paulo, Brazil), except for the FGCore group, which had their coronal portion composed with AllCem Core dual cement. Digital periapical radiographic images were obtained to validate the fiberglass posts.

Micro-CT images were acquired prior to the fracture induction for artifact quantification and after fracture induction for assessment of root fracture and pattern analysis.

### 2.2.Fracture Induction

Each tooth root was covered with polyether printing material to reproduce the periodontal ligament, (Impregum F, 3M-Espe, Seefeld, Germany). The teeth were mounted, individually, in 35 x 22 mm acrylic tubes filled with acrylic resin (Vipi flash, VIPI, São Paulo, Brazil). In order to simulate the biological space, teeth were mounted into acrylic resin by leaving 3 mm from the cervical margin. The sample remained fixed until the acrylic resin was totally polymerized.

Fracture induction was achieved by using an Instron machine (INSTRON 3365, Instron Corporation, Canton, MA, USA). The fracture was performed by a spherical metal tip positioned on the coronal composite resin portion of the tooth with a 22.5° angulation and 0.5 mm/min speed. When the fracture occurred, the machine stopped, to avoid fragments displacement.

### 2.3.Micro-CT Image Acquisition

Micro-CT images acquired after fracture induction were used as gold standard to determine the presence and pattern of the root fractures.

Each tooth was individually scanned on the SkyScan 1172 (Bruker, Kontich, Belgium). The exposure parameters protocol was set at 100 kVp, 100 µA, 0.5 Al filter, 27 µm voxel size, 0.4˚ rotation step, 2 frame and 360˚ rotation. Image reconstruction was done using NRecon (Bruker, Kontich, Belgium) with the following artifact correction applications: 2 smoothing noise reduction and 6 ring artifact reduction.

Tooth volume pattern repositioning was done using Dataviewer (Bruker, Kontich, Belgium), before image analyses.

### 2.4.Micro-CT fracture pattern analysis

Dataviewer software was used to assess fracture presence. Fracture pattern was assessed using CTAn (Bruker, Kontich, Belgium), with all three planes (axial, coronal and sagittal) explored using zooming tool.

An experienced observer assessed all Micro-CT images for fracture detection. Fracture pattern was classified as: (1) Fracture of the coronal composite resin; (2) Favorable or non catastrophic root fracture - within the 3mm from the cervical margin, therefore, above the bone margin; and (3) Unfavorable or catastrophic root fracture - more than 3mm from the cervical margin - vertical root fracture or fracture bellow the bone margin (Fig.1).

## 2.5.Micro-CT Artifact Analysis

A volume of interest (VOI) was defined between the cervical margin and the most apical portion of the fiberglass post for quantitative analysis,. The artifact was quantified within the threshold between 50 and 70 of the grey scale and this was used to define object volume (OV) (Fig. 2).

The percentage of artifact detected within images was calculated by the ratio between object volume and volume of interest (OV/VOI × 100).

## 2.6.Data Analysis

Fracture resistance values presented normal distribution; therefore, ANOVA 1-way analysis of variance and Tukey test were used for statistical purpose. Fisher's exact test was used to verify the association between root fracture pattern and fiberglass post groups. Micro-CT quantitative artifact values showed non normal distribution; therefore, data were analyzed using Kruskal Wallis and Mann Whitney tests. Significance was set at 5%.

## 3. Results

Fracture resistance mean values are shown on Table 1. There were no statistically significant differences between fiberglass post cementation technique groups for fracture resistance (p=0.159). Furthermore, the cementation technique did not influence the fracture pattern (p= 0.276) (Table 2).

Quantitative evaluation of Micro-CT artifacts is shown in Table 3. All groups presented similar median percentages, varying between 8.12 and 3.92 (p=0.062).

## 4. Discussion

The aim of this study was to assess root fracture resistance, root fracture pattern and artifact intensity using Micro-CT images of endodontically treated teeth restored with different fiberglass post cementation techniques. Although the fracture resistance did not vary significantly among groups, greater number of unfavorable root fracture was found for FGCore and AFG groups. The presence of image artifacts on Micro-CT images was not greater than 10% according to the results of this study, which may not compromise clinical diagnostic of fractures.

The rehabilitation of endodontically treated teeth with great loss of coronary structure is still a challenge in Dentistry, since the prognosis of these teeth depends not only on the success of the endodontic treatment, but also on the type of restoration. In addition, the remaining dental structure is too weak to withstand occlusal stress, which can lead to root fracture [2, 3, 18].

Dental fracture occurs when the applied forces exceed the tensile strength of the dentin, since the capacity of this structure for plastic deformation is reduced [19].

Although the use of the anatomical fiberglass post increases the adaptation of the post to the root canal walls and decreases the thickness of the resinous cement [20], this study showed that the fracture strength of teeth treated with anatomized posts was not statistically superior to the non-anatomized fiberglass post groups. These findings corroborate with those of Costa et al. [21]; however, disagree with Belli et al. [22], Gomes et al. [23] and Silva et al. [24] studies, which stated that post anatomization using composite resin improved the fracture resistance of weakened roots compared to non-anatomized direct post cementation.

The analysis of fracture pattern showed a higher prevalence of favorable fractures in all tested groups, corroborating previous studies [25-27]. This may be due to the modulus of elasticity similar to dentin and provide a homogeneous distribution of the occlusal stress [8, 9, 28]. The use of fiberglass posts avoids catastrophic failures such as root fractures in the middle or apical portion of the root, which usually occur in materials with high modulus of elasticity, such as casted metal posts [6, 7, 25]. This is an important clinical finding, since favorable fractures allow the preservation of the dental element, without the need of dental extraction. Thus, the use of posts with physical properties similar to the lost tooth structure is of fundamental importance in cases of fragile roots.

The material used to build the coronal portion also plays a key role in the resistance of the treatment. The FGCore group used AllCem Core cement as a cementing and filling nuclei material. The manufacturer claims that its bulk content provides excellent physical and mechanical properties and allows the construction of the coronal core to serve as a safe support for future prosthetic restoration. This study’s fracture resistance results showed that there was no significant difference when comparing fiberglass posts cemented and reconstructed with AllCem Core dual cement and the groups that had the coronal core made with composite resin and cemented with AllCem resin cement.

Dual resin cement was used to restore all fiberglass posts in this study. Previous studies show that the composition of these cements, which combines photoactivation with chemical polymerization, provides bond strength, wear resistance and compressive strength superior to other cementation materials [10]. However, like all restorative material, dual resin cement also presents some inconveniences, such as the need to control moisture at the time of cementation and to perform an adequate photopolymerization to achieve a successful treatment [29].

In the present study, the height of the ferrule was not considered, since all the teeth were cut at the cementoenamel junction in order to characterize a sample with great loss of the remaining dental structure. However, previous studies have stated that the height of the ferrule (at least 2mm) has been pointed as an element that contributes to the greater resistance to tooth fracture [28, 30-32]. The absence of ferule within this study's sample aimed to reproduce a more challenging condition, in addition to blinding the Micro-CT examiner to the studied teeth groups when assessing root fracture presence and pattern).

In CBCT images, when there are high density materials within the volume, several artifacts are generated, impairing image quality for diagnostic purposes [33, 34]. Micro-CT is a non-destructive image modality that allows a comprehensive visualization of the spatial organization of the specimen structures, as well as a quantitative analysis obtained from a 3D model software. In addition, artifacts, such as ring and beam artifacts, can be corrected or reduced using the NRecon software, which was also used in this study [15, 16,35,36]. Due to these factors, only 3.92% to 8.21% of artifacts were measured in the Micro-CT images of this study, not interfering in the diagnosis of fractures and corroborating on the validation of Micro-CT as a gold standard method for root fracture detection for *in vitro* studies.

Some limitations of the present study were in vitro nature of the study, which cannot fully replicate the complex oral conditions. In addition, the effect of the presence of ferrule was not tested. Furthermore, studies using other fiberglass cementation techniques groups and teeth restored with metallic cast posts, as well as *in vivo* tests should be performed.

## 5. Conclusion

There were no significant differences for root fracture resistance and root fracture pattern between the studied fiberglass posts. Teeth restored with fiberglass posts, independent of the cementation technique of choice, tend to present favorable fractures; therefore, allowing the use of dental remnant for a new restoration and increasing the life span of endodontically treated teeth. Micro CT images generates few artifacts and not impair root fracture detection.

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# Appendices

## Table A.1

**Table 1-** Fracture resistance values according to different cementation techniques.

| Groups | Mean Fracture Resistance (N) (Standard Deviation) |
|---|---|
| FGA | 438.60 (111.33) |
| FGCore | 364.47 (78.64) |
| MCFG | 438.68 (79.62) |
| AFG | 465.38 (127.29) |

One-way Analysis of Variance (p=0.159)

**Table A.2**

**Table 2 -** Fracture pattern frequency according to different cementation techniques.

| **Group** | **Fracture of the coronal composite resin part** | | **Favorable or non catastrophic root fracture** | | **Unfavorable or catastrophic root fracture** | |
|---|---|---|---|---|---|---|
| | N | % | n | % | n | % |
| FGA | 8 | 80.0 | 1 | 10.0 | 1 | 10.0 |
| FGCore | 1 | 10.0 | 5 | 50.0 | 4 | 40.0 |
| MCFG | 5 | 50.0 | 4 | 40.0 | 1 | 10.0 |
| AFG | 4 | 40.0 | 3 | 30.0 | 3 | 30.0 |

Fisher exact test (p-value = 0.081)

**Table A.3**

**Table 3 -** Quantitative evaluation of Micro-CT artifacts according to different fiberglass post cementation techniques. Percentage of Object volume represents the percentage of the image affected by the presence of artifacts.

| Group | Volume of Interest (VOI) (in $mm^3$) | | | Object Volume (OV) (in $mm^3$) | | | Percent of Object Volume (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Median | 95.0% Lower CL for Median | 95.0% Upper CL for Median | Median | 95.0% Lower CL for Median | 95.0% Upper CL for Median | Median | 95.0% Lower CL for Median | 95.0% Upper CL for Median |
| **FGA** | 221.13 | 204.66 | 330.88 | 19.48 | 9.69 | 28.80 | 7.69 **A** | 5.03 | 10.01 |
| **FGCore** | 172.04 | 143.05 | 191.39 | 6.12 | 5.10 | 9.27 | 3.92 **A** | 2.83 | 5.15 |
| **MCFG** | 184.64 | 168.88 | 203.10 | 9.20 | 7.51 | 11.86 | 4.64 **A** | 4.02 | 6.59 |
| **AFG** | 206.82 | 186.55 | 230.77 | 18.60 | 6.68 | 23.44 | 8.12 **A** | 5.18 | 9.71 |
| **p-value*** | | | | | | | **0.062** | | |

Kruskal-Wallis and Mann-Whitney testes ($p<0.05$). Different uppercase letters indicate statistically significant differences.

**Fig.A.4**

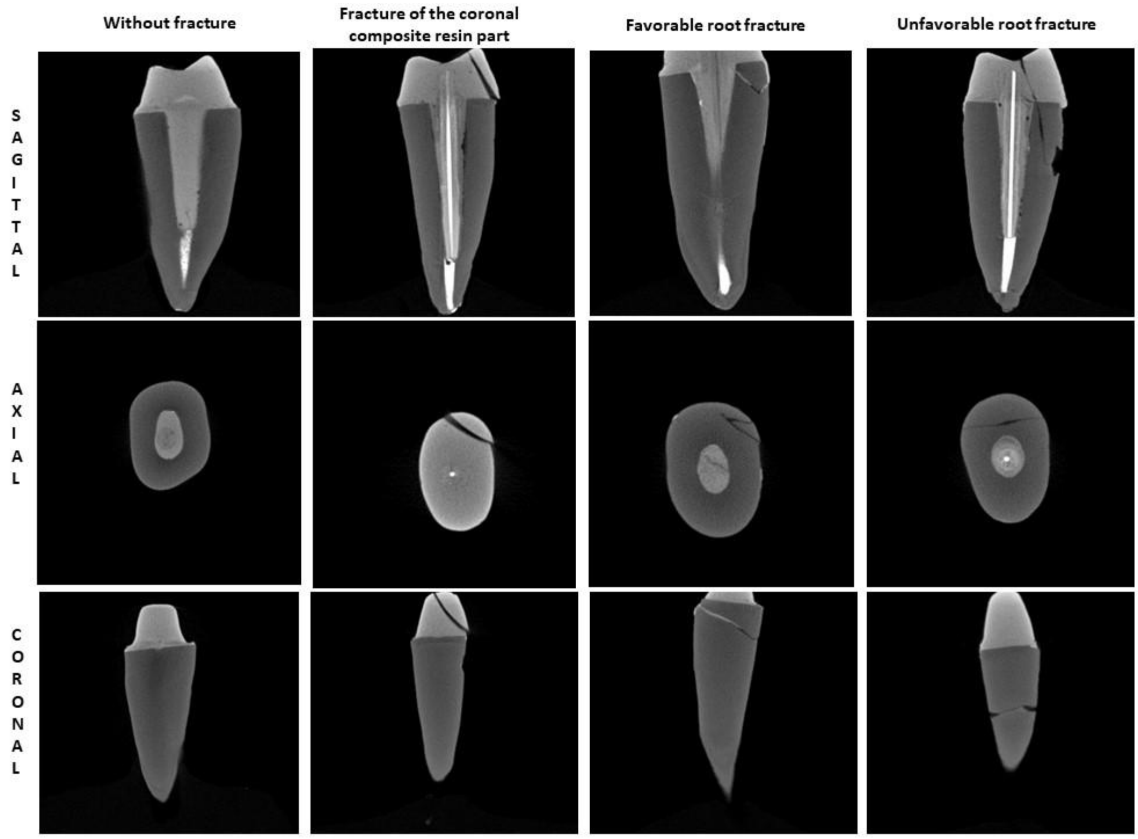


**Fig 1.** Micro-CT images showing the fracture pattern analysis in the three planes (sagittal, axial and coronal): Without fracture; Fracture of the coronal composite resin part; Favorable root fracture and Unfavorable root fracture.

**Fig.A.5**

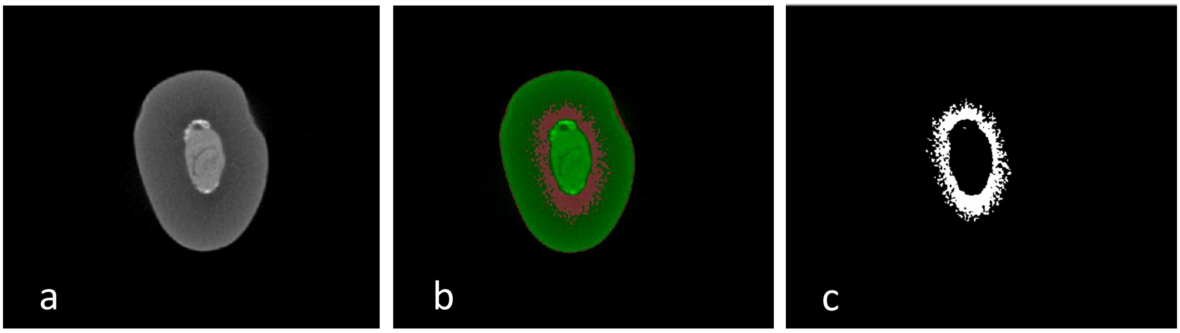


**Fig 2.** Quantitative analysis of artifacts in CTAn software: a) Volume of interest (VOI) image; b) Threshold quantification; c) Object volume (OV).

## 4.2 Artigo 2

Title: The Effect of Different Posts and Fiberglass Cementation Techniques and exposure parameters on the Detection of Root Fractures in CBCT images

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**The Effect of Different Posts and Fiberglass Cementation Techniques and exposure parameters on the Detection of Root Fractures in CBCT images**

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Running Title: Fiberglass post root fracture on CBCT

Key Words: Artifacts, cone-beam computed tomography, fiberglass

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**ABSTRACT**

**Aim:** To assess the effect of different posts and fiberglass cementation techniques and CBCT exposure parameters on the detection of root fractures and artifact intensity. Methodology: Thirty single-rooted human teeth were randomly divided into three groups (n=10): Fiberglass post cemented with dual-curing resin cement with high filler content (FGCore); Metal core fiberglass post cemented with dual-curing resin cement (MCFG); and Anatomical fiberglass post cemented with dual-curing resin cement (AFG). CBCT scans were acquired using CS 9000 3D. Each tooth was imaged under 4 exposure parameters: 74kV, 80kV, 85kV and 90kV. Others parameters were set at 76µm voxel size, 5 cm x 3.75 cm FOV size and 10 mA. CBCT scans were acquired before and after root fractured induction. Each tooth was submitted to fracture resistance test at 0.5mm/min in a universal testing machine. Micro-CT images were used as gold standard to determine the presence of root fractures. Two observers assessed all CBCT images for root fracture detection using a 5-point confidence scale and a 4-point score for the presence of artifacts. Sensitivity, specificity and area under the ROC curve (AUC) values were calculated and compared by two-way analyses of variance (ANOVA two-way) and Tukey's test. Artifact interference on root fracture was assessed by chi-square test. Data were treated statistically at significance level of 5% ($\alpha=0.05$). **Results:** There were no significant differences between the exposure parameters for sensitivity, specificity and AUC values ($p>0.05$). AFG presented higher sensitivity values, statistically differing from FGCore and MCFG ($p=0.037$). MCFG specificity values differed statistically from FGCore ($p=0.012$). MCFG presented higher percentage of moderate artifacts than the other studied groups ($p=0.001$). **Conclusions:** Different exposure parameters do not seem to interfere on root fracture detection. The presence of a metal core fiberglass post decreases root fracture detection specificity values and increases artifact intensity.

**Introduction**

Endodontically treated teeth present significant differences in their physical and mechanical properties when compared with vital teeth. The lack of moisture due to pulp removal contributes to a decrease on tooth's resilience and increases its fracture susceptibility (Chauhan *et al.* 2019). The use of intracanal posts can increase endodontically treated teeth's fracture resistance. These posts act by distributing the torsional forces within the root dentin along the root length, promoting retention for the final restoration (Sulaiman *et al.* 2018).

Fiberglass posts have led to a major advance in aesthetic restorations and their biomechanical properties (high flexural strength and similar modulus of elasticity to dentin) minimize the transmission of tensions within root walls and reduce the possibility of root fractures (Chauhan *et al.* 2019). Resin cements are well established materials for fiberglass post cementation, since their adhesiveness and lack of solubility guarantee the integrity of the adhesive interface. In addition, these cements can bind to both dentin and restorative materials, exhibiting greater initial adhesion strength than water-based cements (Pereira *et al.* 2013).

For the treatment of large or enlarged root canals, one of the proposed techniques is the use of anatomical fiberglass post. This technique is done by modeling the root canal with composite resin associated with a prefabricated fiberglass post. The addition of the resin to the fiberglass post improves its mechanical properties and reduces the cement line, since it allows a better marginal adjustment to the walls of the root and creates conditions favorable to post retention (Costa *et al.* 2012).

Root fracture reduces dental prognosis and can lead to inflammation, followed by bone resorption, granulation tissue formation and, in severe cases, root extraction. The detection of root fractures is challenging and requires a combination of clinical and radiographic signs (Hekmatian *et al.* 2018).

Root fracture diagnosis is usually based on radiographic images; however, the central ray of the X-ray beam does not always pass through the plane of the fracture, especially in fractures that run obliquely along the long axis of the tooth. Therefore, the overlap of surrounding anatomical structures makes the visualization of the fracture even more difficult (Chang *et al.* 2016, Armata *et al.* 2018). The inability to visualize root fractures in conventional radiographs highlights the need to use a more advanced modality of imaging diagnosis, such as cone beam computed tomography (CBCT) (Nikbin *et al*. 2018). However, CBCT image quality is impaired by image artifacts, which can be defined as any distortion or error in the image that is unrelated to the object being studied (Schulze *et al.* 2011, Freitas *et al.* 2019). Chang *et al.* (2016), Nikbin *et al.* (2018), Yamamoto-Silva *et al.* (2018) affirm that image artifacts are frequently present in CBCT images impairing image quality for diagnosis.

CBCT scanners exposure parameters adjustments may reduce artifact intensity. Kilovoltage (kV) is considered the main energetic parameter to interfere on artifact intensity (Freitas *et al.* 2018). When adjusting exposure parameters to reduce artifacts, it is important to consider radiation dose. High dose exposure parameters used to reduce artifacts are not justified (Freitas *et al.* 2019); thus, low exposure protocols without loss of diagnostic quality are recommended to minimize X-ray biological effects (Pinto *et al.* 2017, Freitas *et al.* 2019). Therefore, this study aimed to assess the effect of different fiberglass cementation techniques and CBCT exposure parameters on the detection of root fractures and artifact intensity.

## Material and Methods

This in vitro experimental study was approved by the Ethics and Research Committee of the first author's institution (protocol number: 65415617.0.0000.5187) and follows the Helsinki Declaration.

### Sample preparation

The sample was composed of thirty single-rooted human teeth (premolars), extracted for therapeutic reasons. As inclusion criteria, all teeth should have a maximum root curvature of $\leq 5°$ and similar dimensions. The sample was inspected by transillumination for the absence of root fractures. Teeth was also radiographed on photostimulated plates (Digora Optime, Soredex, Tuusula, Finland) to exclude those with pulp stones, internal and/or external root resorption, previous endodontic treatment, multiple root canals, root canal obliteration, root fractures or any other anomaly.

After cleaning and disinfection protocols, all crowns were removed at the cementoenamel junction and root canals were prepared to a standard size using the Reciproc R50 system (VDW, München, Germany). Then, a thermo-mechanically compacted root filling was placed using endodontic cement Sealer 26 (Dentsply, Rio de Janeiro, Brazil) and PacMac 21 mm, size 45, .04 taper (SybronEndo Dental Specialties, Glendora, CA, USA). For posterior post preparation and fitting, gutta-percha of the roots' coronal two-thirds were removed using size 1 Piezo drills (Peeso Long Drill no 1, Dentsply Sirona Endodontics, Ballaigues, Switzerland).

The sample was divided into four groups, each containing ten teeth: 1 - Fiberglass post (WhitePost DCE size nº 1, FGM, Joinville, SC, Brazil) cemented dual-curing resin cement with high filler content (FGCore) (AllcemCore, FGM, Joinville, SC, Brazil) (FGCore). 2- Metal core fiberglass post (Reforpost size nº 1, Angelus, Londrina, PR. Brazil) cemented with dual-curing resin cement (Allcem, MCFG); 3- Anatomical fiberglass post (WhitePost DCE size nº 0,5, FGM, Joinville, SC, Brazil) + composite resin (Filtek™ Z350, 3M ESPE, Maplewood, EUA) cemented with dual-curing resin cement (AFG).

All fiberglass posts were prepared according to manufacturer's recommendations. FGCore was prepared using phosphoric acid gel treatment (Condac 37, FGM, Joinville, Santa Catarina, Brazil), Prosil Silane (FGM, Joinville, Santa Catarina, Brazil) and light-curing adhesive system (Ambar, FGM, Joinville, Santa Catarina, Brazil). This group was then cemented using dual cement AllCem Core.

MCFG (Reforpost, Angelus, Londrina, Paraná, Brazil) was prepared using Prosil Silane and self-curing adhesive system (Fusion-Duralink, Angelus, Londrina, Paraná, Brazil). This group was then cemented using dual cement AllCem.

AFG (Whitepost FGM, Joinville, Brazil) was prepared to better fit the root canal anatomy reinforced by Filtek™ Z350 XT composite resin. The fiberglass posts were prepared by phosphoric acid gel conditioning (Condac 37), Prosil Silane and light-curing adhesive system (Ambar). The fiberglass post was covered with compound resin and then introduced into the root canal, previously soaked with water-soluble lubricating gel (ENDO-PTC, F&A, São Paulo, Brazil). The anatomized post received additional photopolymerization for 20 seconds. The AFG set was then cemented using dual cement AllCem.

The root canals were prepared for post cementation using phosphoric acid gel treatment (Condac 37) and light-curing adhesive system (Ambar), for FGCore and AFG; and Self-etching (Primer and Chemical Fusion-Duralink Catalyst Adhesive, Angelus, Londrina, Paraná, Brazil) for the MCFG group.

The coronal composite resin part (filling nuclei) (Filtek™ Z350) of each post was standardized using an acetate matrix (Bio-Art, São Paulo, Brazil), except for the FGCore group, which had their coronal portion composed with AllCem Core dual cement. Digital periapical radiographic images were obtained to validate the fiberglass posts.

The root canals were prepared for post cementation using phosphoric acid gel treatment (Condac 37, FGM, Joinville, Santa Catarina, Brazil) and light-curing adhesive system (Ambar, FGM, Joinville, Santa Catarina, Brazil), for FGA, FGCore and AFG; and Self-etching (Primer and Chemical Fusion-Duralink Catalyst Adhesive, Angelus, Londrina, Paraná, Brazil) for the MCFG group.

The coronal composite resin part (Filtek™ Z350) of each post was standardized using an acetate matrix (Bio-Art, São Paulo, Brazil), except for the AFGCore group, which had their coronal portion composed with AllCem Core dual cement. Digital periapical radiographic images were obtained to validate the fiberglass posts.

CBCT images of all studied teeth were acquired before and after root fractured induction.

**CBCT Image Acquisition**

Each premolar was coated with a 0.2-mm layer of wax and placed in an empty maxillary right canine socket of a partially dentate dry human skull. The skull was also coated with a 5-mm-thick wax to simulate the interference of soft tissues on the CBCT scans. The skull was then placed in a foam box filled with water to simulate soft tissue coverage.

CBCT scans were acquired using CS 9000 3D (Kodak Dental Systems, Carestream Health, Rochester, NY, EUA). Each tooth was imaged under 4 exposure parameters: 74kV, 80kV, 85kV and 90kV. Exposure parameters were set at 76µm voxel size, 5 cm x 3.75 cm FOV size and 10 mA (Fig 1).

The resulting dataset was exported as Digital Imaging and Communication in Medicine (DICOM) files and saved with an anonymized code.

**Fracture Induction**

Each tooth root was covered with polyether printing material (Impregum F, 3M-Espe, Seefeld, Germany) to reproduce the periodontal ligament. The teeth were mounted, individually, in 35 x 22 mm acrylic tubes filled with acrylic resin (Vipi flash, VIPI, São Paulo, Brazil). In order to simulate the biological space, teeth were mounted into acrylic resin by leaving 3 mm from the cervical margin. The sample remained fixed until the acrylic resin was totally polymerized.

Fracture induction was done using an Instron machine (INSTRON 3365, Instron Corporation, Canton, MA, USA). The fracture was performed by a spherical metal tip positioned on the coronal composite resin part of the tooth with a 22.5° angulation and 0.5

mm/min speed. When the fracture occurred, the machine stopped, which avoided fragments displacement.

After fracture induction, the sample was scanned on the CS 9000 3Dusing the same parameters described before, to obtain CBCT scans of the fractured teeth. A total of 320 CBCT volumes (40 teeth, 4 exposure parameters, 2 scans) were acquired.

**Micro-CT Image Acquisition**

Micro-CT images were used as gold-standard to determine the presence of the root fractures.

Each tooth was individually scanned on the SkyScan 1172 (Bruker, Kontich, Belgium). The exposure parameters protocol was set at 100 kVp, 100 µA, 0.5 Al filter, 27 µm voxel size, 0.4˚ rotation step, 2 frame and 360˚ rotation. Image reconstruction was done using NRecon (Bruker, Kontich, Belgium) with the following artifact correction applications: 2 smoothing noise reduction and 6 ring artifact reduction.

Tooth volume pattern repositioning was done using Dataviewer (Bruker, Kontich, Belgium), before image analyses.

**CBCT Analyses**

Prior to all examination sessions, verbal and practical instructions and calibration tests were performed.

Two observers (Oral and Maxillofacial Radiologists) assessed all CBCT images for root fracture detection using a 5-point confidence scale for root fracture detection (1- Absent, 2- Probably absent, 3- Unsure, 4- Probably present and 5- Present) and a 4-point score for the presence of artifacts: 0- absent; 1- mild – artefact was present, but did not interfere on VRF diagnosis; 2- moderate – artefact was present and might interfere on VRF diagnosis; 3- severe – artefact was present and definitely interfered on VRF diagnosis).

The volumes were visualized using CS 3D imaging software (Carestream Dental Rochester-NY, EUA) on a Dell Inspiron 14 5000 series (Dell Inc., Eldorado do Sul, Brazil), with a 15 inches screen in a room with controlled illumination and temperature. Adjustments for zoom, brightness and contrast settings were left to the discretion of each observer. A limited of 16 volumes were evaluated per day.

### Data Analyses

Kappa inter-observer coefficient was used for root fracture detection. The sensitivity, specificity and area under the ROC curve (AUC) values were calculated and compared by two-way analyses of variance (two-way ANOVA) and Tukey's test. Artifact interference on root fracture was assessed by descriptive statistics and Chi-square test to assess artifact score association with the observers' root fracture detection answers. Data were treated statistically by adopting a significance level of 5% ($\alpha=0.05$).

## Results

Kappa inter-observer coefficient for root fracture detection was 0.542.

There were no significant differences between the exposure parameters for sensitivity, specificity and AUC values (p=0,99) (Table 01).

AFG presented higher sensitivity values, statistically differing from FGCore and MCFG (p=0.037). MCFG specificity values differed statistically from FGCore (p=0.012) (Table 01).

Table 2 shows expresses the distribution of the reported scores for the generation of artifacts according to different fiberglass post cementation groups and the studied exposure parameters. MCFG presented higher percentage of moderate artifacts than the other studied groups (p=0.001). For all studied exposure parameters groups, the presence of moderate artifact intensity was higher than absence and mild artifact intensity (p=0.042).

## Discussion

Root fractures are common findings of endodontically treated teeth; therefore, the precise diagnosis of these fractures is important to evaluate the prognosis and the maintenance of the tooth in the oral cavity. Maxillary and mandibular premolars and the mesial root of the mandibular molars are more susceptible to root fractures (Tamse *et al.* 1998, Miyagaki et al. 2013). In addition, 90% of root fractured teeth present gutta-percha filling, whereas approximately 61.7% of presents intracanal post restoration (Edlund *et al*. 2011).

CBCT scans have demonstrated a superior efficacy in the diagnosis of root fractures compared to the periapical radiography (Valizadeh *et al*. 2011, da Silveira *et al*. 2013), presenting 68% to 99% accuracy values (Corbella et al., 2014). However, CBCT root fractures detection can be impaired by the presence high atomic number materials within the root canal, such as gutta-percha and metal posts (Costa *et al*. 2011, Wang *et al*. 2011, Khedmat *et al*. 2012, Junqueira *et al*. 2013, Patel *et al*. 2013).

Intracanal filling techniques should be designed to reduce image artifacts and improve root fracture detection, as the prognosis of the endodontic-prosthetic treatment is linked to the obturation of root canals as well as post restoration (Gillen *et al*., 2011). Intracanal materials may interfere on root fractures detection, especially metal posts which are associated with root fracture diagnosis impairment, presenting lower accuracy and sensitivity values than fiberglass posts. Metal posts present higher artifact intensity than fiberglass posts (Neves *et al*. 2014, Ferreira *et al*. 2015, de Rezende Barbosa *et al*. 2016, Pinto *et al.* 2017).

Although fiberglass posts present better results on root fracture detection and artifact intensity than gutta-percha and metal posts (Pinto *et al*. 2017), one can only indicate fiberglass posts when a minimum 2mm remaining teeth is present for ferrule effect. Although the preparation of teeth to receive metal posts increases the risk of root fracture, metal posts are still indicated when the remaining crown is less than 2mm (Santos Pantaleón *et al*. 2019, Bachhi *et al.* 2019). Different cementation techniques may expand fiberglass post indication to more severally damaged teeth and studies on that matter are still needed to improve teeth prognosis.

Metal core fiberglass posts presented lower specificity values and a higher percentage of moderate artifacts than conventional fiberglass posts. According to Lima *et al*. 2019, metal core fiberglass posts may interfere in the formation of hypodense artifacts when compared to conventional fiberglass posts, in accordance to this study. Streak artifact formation due to high density intracanal materials is responsible for a reduction in specificity (Talwar *et al.* 2016), as high-density dental materials attenuate more x-ray and promote higher artifact intensity, leading to greater diagnosis impairment (de Rezende Barbosa *et al*. 2016, Pinto *et al*. 2016, Codari *et al*. 2017, Freitas *et al*. 2019).

The anatomical fiberglass post cementation technique seems to improve root fracture detection and presents lower artifact intensity than other cementation techniques.

CBCT scanner manufacturers usually indicate exposure parameter protocols to achieve high-quality images. However, higher exposure parameter protocols lead to higher exposure doses. According to previous studies (Chindasombatjareon *et al.* 2011, Bamba *et al.* 2013, Bezerra *et al*. 2015), higher tube voltage is associated with lower artifact intensity. In this study, higher tube voltage protocols did not decrease the observers’ perception of artifact intensity and did not interfere on root fracture detection; therefore, lower dose protocols are recommended for root fracture detection (Pinto *et al*. 2017, Rabelo *et al*. 2017, Freitas *et al*. 2019). Dose optimization by choosing minimal dose exposure parameters that permit high-quality image achievement (Pinto *et al*. 2017, Freitas *et al*. 2019), considering the “as low as reasonably achievable" (ALARA), "as low as diagnostically acceptable" (ALADA) and “as low as diagnostically acceptable, indication-oriented and patient-specific” (ALADAIP) principles (Jaju & Jaju 2015, Oenning *et al*. 2019).

Some limitations of the study included the fact that it was performed in a wax-coated skull, in which the soft tissues were simulated using wax, water and a foam box, not representing the total mass of all the structures positioned inside and outside the FOV. Clinical parameters such as probing depth, mobility, bone loss and sensitivity during mastication were not evaluated, since it was an *in vitro* study. In addition, only a subjective analysis was performed for the presence of artifacts. Quantitative studies of artifacts with different exposure parameters and different CBCT scanners should be performed to better understand the diagnosis of root fractures using CBCT images.

**Conclusion**

The presence of a metal core fiberglass post decreases root fracture specificity values and increases artifact intensity. Anatomical fiberglass posts may improve root fracture detection and are an alternative to conventional fiberglass post cementation techniques. Different exposure parameters do not seem to interfere on root fracture detection.

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**Tables**

**Table 01.** Two-way analysis of variance for sensitivity, specificity and AUC for the studied fiberglass cementation techniques and exposure parameters groups.

| **Group** | **kV** | **AUC** | **Sensitivity** | **Specificity** |
|---|---|---|---|---|
| FGCore | 74 | 0.66 A | 0.55 B | 0.77 A |
| | 80 | 0.70 A | 0.44 B | 0.95 A |
| | 85 | 0.68 A | 0.50 B | 0.86 A |
| | 90 | 0.71 A | 0.61 B | 0.82 A |
| MCFG | 74 | 0.74 A | 0.83 B | 0.64 B |
| | 80 | 0.62 A | 0.67 B | 0.57 B |
| | 85 | 0.57 A | 0.50 B | 0.63 B |
| | 90 | 0.70 A | 0.83 B | 0.57 B |
| AFG | 74 | 0,73 A | 0.80 A | 0.67 AB |
| | 80 | 0.78 A | 0.90 A | 0.67 AB |
| | 85 | 0.78 A | 0.80 A | 0.77 AB |
| | 90 | 0.88 A | 1.00 A | 0.77 AB |

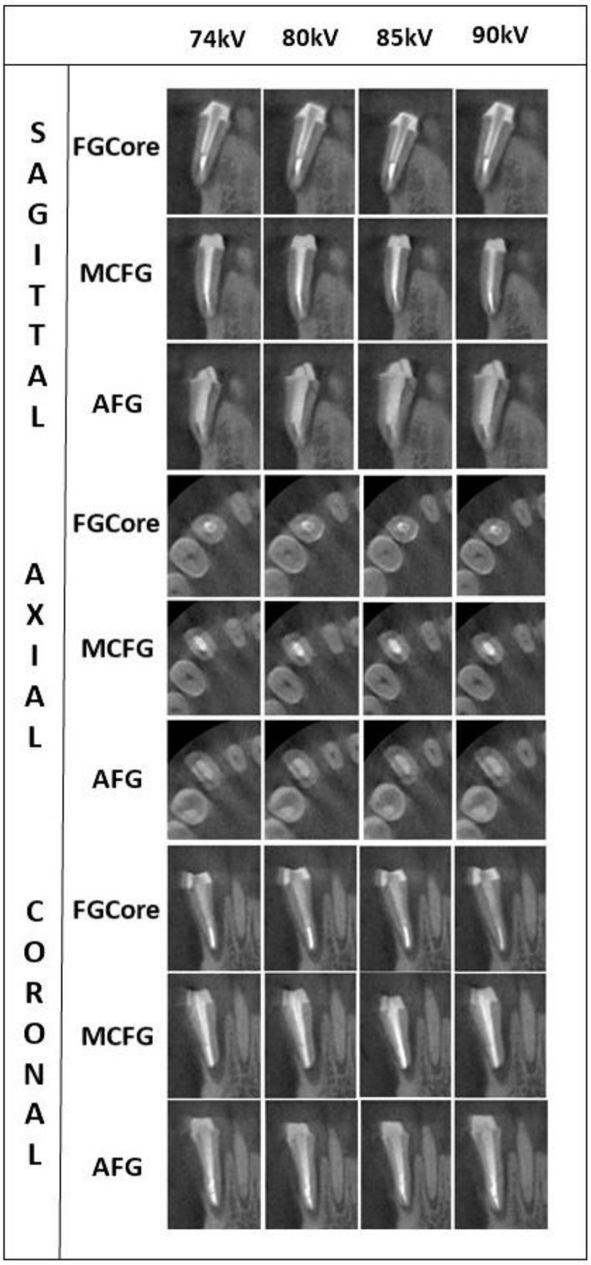
Different uppercase letters show differences among groups ($p<0.05$)

**Table 02.** Distribution of the reported artifact intensity scores according to the studied fiberglass post cementation groups and exposure parameters.

| | Absence n (%) | Light n (%) | Moderate n (%) | Total n (%) |
|---|---|---|---|---|
| **Groups** | | | | |
| FGCore | 19 (11.9) | 59 (36.9) | 82 (51.2) | 160 (100.0) |
| MCFG | 0 (0.0) | 20 (12.0) | 140 (87.5) | 160 (100.0) |
| AFG | 25 (15.6) | 88 (55.0) | 47 (29.4) | 160 (100.0) |
| p-value | p=0,001 | | | |
| **Kv** | | | | |
| 74 | 4 (3.3) | 47 (39.2) | 69 (57.5) | 120 (100.0) |
| 80 | 13 (10.8) | 43 (35.8) | 64 (53.3) | 120 (100.0) |
| 85 | 16 (13.3) | 30 (25.0) | 74 (61.7) | 120 (100.0) |
| 90 | 11 (9.2) | 47 (39.2) | 62 (51.7) | 120 (100.0) |
| p-value | p=0.042 | | | |

Chi-square Test

**Figure**


74kV
80kV
85kV
90kV
SAGITTAL
AXIAL
CORONAL
FGCore
MCFG
AFG
FGCore
MCFG
AFG
FGCore
MCFG
AFG

## Figure Legends

**Figure 1.** Example of CBCT images in the sagittal, axial and coronal planes of the studied fiberglass post cementation technique in all the studied exposure parameters.

# 5 CONSIDERAÇÕES FINAIS

A partir da análise dos resultados encontrados, pode-se concluir que:

- A técnica de confecção e cimentação de PFV não influenciou na resistência, no padrão de fratura e na presença de artefatos microtomográficos;
- PFV tendem a apresentar fraturas favoráveis;
- Os artefatos gerados em imagens de Micro-TC não prejudicam a detecção de fraturas radiculares;
- A presença do filamento metálico no interior do PFV diminui os valores de especificidade de fratura radicular e aumenta a intensidade do artefato em imagens de TCFC;
- PFVs anatomizados podem melhorar a detecção de fraturas radiculares e são uma alternativa às técnicas convencionais de confecção e cimentação de PFV;
- Diferentes parâmetros de exposição não interferem na detecção de fraturas radiculares.

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# ANEXOS

# ANEXOS

## ANEXO A – Parecer do CEP

UNIVERSIDADE ESTADUAL DA PARAÍBA - PRÓ-REITORIA DE PÓS-GRADUAÇÃO E

Plataforma Brasil

**PARECER CONSUBSTANCIADO DO CEP**

**DADOS DO PROJETO DE PESQUISA**

**Título da Pesquisa:** INFLUÊNCIA DE DIFERENTES RETENTORES INTRARRADICULARES NA RESISTÊNCIA À FRATURA, DETECÇÃO DE TRINCAS E GERAÇÃO DE ARTEFATOS TOMOGRÁFICOS EM PRÉ-MOLARES UNIRRADICULARES

**Pesquisador:** Larissa Rangel Peixoto

**Área Temática:**

**Versão:** 1

**CAAE:** 65415617.0.0000.5187

**Instituição Proponente:** UNIVERSIDADE ESTADUAL DA PARAÍBA

**Patrocinador Principal:** Financiamento Próprio

**DADOS DO PARECER**

**Número do Parecer:** 2.045.369

**Apresentação do Projeto:**

Projeto encaminhado em sua versão física e eletrônica para análise, a Plataforma Brasil/Comitê de Ética em Pesquisa da Universidade Estadual da Paraíba, com fins à obtenção de parecer favorável para inicio de elaboração e desenvolvimento do Trabalho de Conclusão do Curso de Pós-Graduação, nível Doutorado em Odontologia/UEPB. Justificam os pesquisadores responsáveis: "A restauração de dentes tratados endodonticamente e com grande perda da estrutura coronária ainda é um desafio na Odontologia. As mudanças na arquitetura dentária fazem com que a coroa clínica dificilmente suporte o estresse oclusal funcional, podendo ocasionar fratura radicular. Nesse sentido, a utilização de pinos e núcleos intrarradiculares é capaz de promover uma melhora na estrutura sobre a qual a restauração coronária será retida. As fraturas radiculares são comuns em dentes tratados endodonticamente. Nesse sentido, o diagnóstico de uma fratura de raiz mostra-se importante para avaliar o prognóstico e determinar o tratamento apropriado para o dente. Ainda não existe um consenso em relação à técnica e tipo de dispositivo ideal para a restauração dos dentes despolpados. Deve-se buscar uma técnica restauradora que possa reestabelecer a estética e função, assim como conferir longevidade dos elementos dentais. Além disso, almeija-se evitar fracassos comuns, a exemplo das fraturas radiculares, que apresentam diagnóstico limitado. Devido aos questionamentos ainda presentes em relação à restauração de

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**Anexo B – Normas da revista Dental Materials**

## Preparation

**Peer review**

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***Use of word processing software***

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To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

**Article structure**

***Subdivision - numbered sections***

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

***Introduction***

This must be presented in a structured format, covering the following subjects, although actual subheadings should not be included:
• succinct statements of the issue in question;
• the essence of existing knowledge and understanding pertinent to the issue (reference);
• the aims and objectives of the research being reported relating the research to dentistry, where not obvious.

***Materials and methods***

• describe the procedures and analytical techniques.
• only cite references to published methods.
• include at least general composition details and batch numbers for all materials.
• identify names and sources of all commercial products e.g.
"The composite (Silar, 3M Co., St. Paul, MN, USA)..."
"... an Au-Pd alloy (Estheticor Opal, Cendres et Metaux, Switzerland)."
• specify statistical significance test methods.

***Results***

• refer to appropriate tables and figures.
• refrain from subjective comments.
• make no reference to previous literature.
• report statistical findings.

***Discussion***

• explain and interpret data.
• state implications of the results, relate to composition.
• indicate limitations of findings.
• relate to other relevant research.

***Conclusion (if included)***

• must NOT repeat Results or Discussion
• must concisely state inference, significance, or consequences

***Appendices***

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

**Essential title page information**

• ***Title.*** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
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• ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

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Highlights are mandatory for this journal. They consist of a short collection of bullet points that convey the core findings of the article and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). You can view example Highlights on our information site.

**Abstract (structured format)**

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• subheadings should appear in the text of the abstract as follows: Objectives, Methods, Results, Significance. (For Systematic Reviews: Objectives, Data, Sources, Study selection, Conclusions). The Results section may incorporate small tabulations of data, normally 3 rows maximum.

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See https://www.elsevier.com/highlights for examples.

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Up to 10 keywords should be supplied e.g. dental material, composite resin, adhesion.

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***Acknowledgements***

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List funding sources in this standard way to facilitate compliance to funder's requirements:
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If no funding has been provided for the research, please include the following sentence:
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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If you are submitting an article prepared with Microsoft Word containing embedded math equations then please read this (related support information).

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**ANEXO C – Normas da Revista International Endodontic Journal**

**Author Guidelines**

**Content of Author Guidelines**: 1. General, 2. Ethical Guidelines, 3. Manuscript Submission Procedure, 4. Manuscript Types Accepted, 5. Manuscript Format and Structure, 6. After Acceptance

**Useful Websites**: **Submission Site**, **Articles published in *International Endodontic Journal***, **Author Services**, **Wiley's Ethical Guidelines**, **Guidelines for Figures**
The journal to which you are submitting your manuscript employs a plagiarism detection system. By submitting your manuscript to this journal you accept that your manuscript may be screened for plagiarism against previously published works.

1. **GENERAL**

*International Endodontic Journal* publishes original scientific articles, reviews, clinical articles and case reports in the field of Endodontology; the branch of dental sciences dealing with health, injuries to and diseases of the pulp and periradicular region, and their relationship with systemic well-being and health. Original scientific articles are published in the areas of biomedical science, applied materials science, bioengineering, epidemiology and social science relevant to endodontic disease and its management, and to the restoration of root-treated teeth. In addition, review articles, reports of clinical cases, book reviews, summaries and abstracts of scientific meetings and news items are accepted.
Please read the instructions below carefully for details on the submission of manuscripts, the journal's requirements and standards as well as information concerning the procedure after a manuscript has been accepted for publication in *International Endodontic Journal*. Authors are encouraged to visit **Wiley Author Services** for further information on the preparation and submission of articles and figures.

**2. ETHICAL GUIDELINES**
*International Endodontic Journal* adheres to the below ethical guidelines for publication and research.

**2.1. Authorship and Acknowledgements**

Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Journal.
*International Endodontic Journal* adheres to the definition of authorship set up by The International Committee of Medical Journal Editors (ICMJE). According to the ICMJE, authorship criteria should be based on 1) substantial contributions to conception and design of, or acquisiation of data or analysis and interpretation of data, 2) drafting the article or revising it critically for important intellectual content and 3) final approval of the version to be published. Authors should meet conditions 1, 2 and 3.

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

**2.2. Ethical Approvals**

Experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association **Declaration of Helsinki** (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.
When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.
All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study. The authors MUST upload a copy of the ethical approval letter when submitting their manuscript and a separate English translation. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

**2.3 Clinical Trials**

The International Endodontic Journal asks that authors submitting manuscripts reporting from a clinical trial to register the trials in any of the following public clinical trials registries: **www.clinicaltrials.gov**, **https://www.clinicaltrialsregister.eu/**, **http://isrctn.org/**. Other primary registries if named in the WHO network will also be considered acceptable. The clinical trial registration number and name of the trial register should be included in the Acknowledgements at the submission stage.
2.3.1 Randomised control clinical trials
Randomised control clinical trials should be reported using the guidelines available at **www.consort-statement.org**. A CONSORT checklist and flow diagram (as a Figure) should also be included in the submission material.
2.3.2 Epidemiological observational trials
Submitting authors of epidemiological human observations studies are required to review and submit a 'strengthening the reporting of observational studies in Epidemiology' (STROBE) checklist and statement. Compliance with this should be detailed in the materials and methods section. (**www.strobe-statement.org**)

**2.4 Systematic Reviews**

Authors submitting a systematic review should register the protocol in a readily-accessible source at the time of project inception (e.g. PROSPERO database, previously published review protocol in journal). The protocol registration number, name of the database or journal reference should be provided in the 'Acknowledgements' at the submission stage. Systematic review should be reported using the PRISMA guidelines (**http://www.prisma-statement.org/**). A PRISMA checklist and flow diagram (as a Figure) should also be included in the submission material.

**2.5 DNA Sequences and Crystallographic Structure Determinations**

Papers reporting protein or DNA sequences and crystallographic structure determinations will not be accepted without a Genbank or Brookhaven accession number, respectively. Other supporting data sets must be made available on the publication date from the authors directly.

**2.6 Conflict of Interest and Source of Funding**

*International Endodontic Journal* requires that all authors (both the corresponding author and co-authors) disclose any potential sources of conflict of interest. Any interest or relationship, financial or otherwise that might be perceived as influencing an author's objectivity is considered a potential source of conflict of interest. These must be disclosed when directly relevant or indirectly related to the work that the authors describe in their manuscript. Potential sources of conflict of interest include but are not limited to patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. If authors are unsure whether a past or present affiliation or relationship should be disclosed in the manuscript, please contact the editorial office at **iejeditor@cardiff.ac.uk**. The existence of a conflict of interest does not preclude publication in this journal.
The above policies are in accordance with the Uniform Requirements for Manuscripts Submitted to Biomedical Journals produced by the International Committee of Medical Journal Editors (**http://www.icmje.org/**).
It is the responsibility of the corresponding author to have all authors of a manuscript fill out a conflict of interest disclosure form, and to upload all forms individually (do not combine the forms into one file) together with the manuscript on submission. The disclosure statement should be included under Acknowledgements. Please find the form below:

**Conflict of Interest Disclosure Form**

**2.7 Appeal of Decision**

The decision on a paper is final and cannot be appealed.

**2.8 Permissions**

If all or parts of previously published illustrations are used, permission must be obtained from the copyright holder concerned. It is the author's responsibility to obtain these in writing and provide copies to the Publishers.

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If your paper is accepted, the author identified as the formal corresponding author for the paper will receive an email prompting them to login into Author Services; where via the Wiley Author Licensing Service (WALS) they will be able to complete the license agreement on behalf of all authors on the paper. Your article cannot be published until this has been done.

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**2.9 OnlineOpen**

OnlineOpen is available to authors of primary research articles who wish to make their article available to non-subscribers on publication, or whose funding agency requires grantees to archive the final version of their article. With OnlineOpen, the author, the author's funding agency, or the author's institution pays a fee to ensure that the article is made available to non-subscribers upon publication via Wiley Online Library, as well as deposited in the funding agency's preferred archive. For the full list of terms and conditions, see
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Prior to acceptance there is no requirement to inform an Editorial Office that you intend to publish your paper OnlineOpen if you do not wish to. All OnlineOpen articles are treated in the same way as any other article. They go through the journal's standard peer-review process and will be accepted or rejected based on their own merit.

**3. MANUSCRIPT SUBMISSION PROCEDURE**
Manuscripts should be submitted electronically via the online submission site **http://mc.manuscriptcentral.com/iej**. The use of an online submission and peer review site enables immediate distribution of manuscripts and consequentially speeds up the review process. It also allows authors to track the status of their own manuscripts. Complete instructions for submitting a paper is available online and below. Further assistance can be obtained from **iejeditor@cardiff.ac.uk**.

**3.1. Getting Started**

• Launch your web browser (supported browsers include Internet Explorer 5.5 or higher, Safari 1.2.4, or Firefox 1.0.4 or higher) and go to the journal's online Submission

Site: **http://mc.manuscriptcentral.com/iej**
• Log-in, or if you are a new user, click on 'register here'.
• If you are registering as a new user.
- After clicking on 'register here', enter your name and e-mail information and click 'Next'. Your e-mail information is very important.
- Enter your institution and address information as appropriate, and then click 'Next.'
- Enter a user ID and password of your choice (we recommend using your e-mail address as your user ID), and then select your areas of expertise. Click 'Finish'.
• If you are registered, but have forgotten your log in details, please enter your e-mail address under 'Password Help'. The system will send you an automatic user ID and a new temporary password.
• Log-in and select 'Author Centre '

**3.2. Submitting Your Manuscript**

• After you have logged into your 'Author Centre', submit your manuscript by clicking on the submission link under 'Author Resources'.
• Enter data and answer questions as appropriate. You may copy and paste directly from your manuscript and you may upload your pre-prepared covering letter.
• Click the 'Next' button on each screen to save your work and advance to the next screen.
• You are required to upload your files.
- Click on the 'Browse' button and locate the file on your computer.
- Select the designation of each file in the drop down next to the Browse button.
- When you have selected all files you wish to upload, click the 'Upload Files' button.
• Review your submission (in HTML and PDF format) before completing your submission by sending it to the Journal. Click the 'Submit' button when you are finished reviewing.

**3.3. Manuscript Files Accepted**

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rft) files (not write-protected) plus separate figure files. GIF, JPEG, PICT or Bitmap files are acceptable for submission, but only high-resolution TIF or EPS files are suitable for printing. The files will be automatically converted to HTML and PDF on upload and will be used for the review process. The text file must contain the abstract, main text, references, tables, and figure legends, but no embedded figures or Title page. The Title page should be uploaded as a separate file. In the main text, please reference figures as for instance 'Figure 1', 'Figure 2' etc to match the tag name you choose for the individual figure files uploaded. Manuscripts should be formatted as described in the Author Guidelines below.

**3.4. Blinded Review**

Manuscript that do not conform to the general aims and scope of the journal will be returned immediately without review. All other manuscripts will be reviewed by experts in the field (generally two referees). International Endodontic Journal aims to forward referees´ comments and to inform the corresponding author of the result of the review process. Manuscripts will be considered for fast-track publication under special circumstances after consultation with the Editor.
International Endodontic Journal uses double blinded review. The names of the reviewers will thus not be disclosed to the author submitting a paper and the name(s) of the author(s) will not be disclosed to the reviewers.

To allow double blinded review, please submit (upload) your main manuscript and title page as separate files.
Please upload:
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• Figure files under the file designation 'figures'
• The title page and Acknowledgements where applicable, should be uploaded under the file designation 'title page'
All documents uploaded under the file designation 'title page' will not be viewable in the html and pdf format you are asked to review in the end of the submission process. The files viewable in the html and pdf format are the files available to the reviewer in the review process.

### 3.5. Suspension of Submission Mid-way in the Submission Process

You may suspend a submission at any phase before clicking the 'Submit' button and save it to submit later. The manuscript can then be located under 'Unsubmitted Manuscripts' and you can click on 'Continue Submission' to continue your submission when you choose to.

### 3.6. E-mail Confirmation of Submission

After submission you will receive an e-mail to confirm receipt of your manuscript. If you do not receive the confirmation e-mail after 24 hours, please check your e-mail address carefully in the system. If the e-mail address is correct please contact your IT department. The error may be caused by some sort of spam filtering on your e-mail server. Also, the e-mails should be received if the IT department adds our e-mail server (uranus.scholarone.com) to their whitelist.

### 3.7. Manuscript Status

You can access ScholarOne Manuscripts any time to check your 'Author Centre' for the status of your manuscript. The Journal will inform you by e-mail once a decision has been made.

### 3.8. Submission of Revised Manuscripts

To submit a revised manuscript, locate your manuscript under 'Manuscripts with Decisions' and click on 'Submit a Revision'. Please remember to delete any old files uploaded when you upload your revised manuscript.

## 4. MANUSCRIPT TYPES ACCEPTED

**Original Scientific Articles**: must describe significant and original experimental observations and provide sufficient detail so that the observations can be critically evaluated and, if necessary, repeated. Original Scientific Articles must conform to the highest international standards in the field.

**Review Articles**: are accepted for their broad general interest; all are refereed by experts in the field who are asked to comment on issues such as timeliness, general interest and balanced treatment of controversies, as well as on scientific accuracy. Reviews should generally include a clearly defined search strategy and take a broad view of the field rather than merely summarizing the authors´ own previous work. Extensive or unbalanced citation of the authors´ own publications is discouraged.

**Clinical Articles**: are suited to describe significant improvements in clinical practice such as the report of a novel technique, a breakthrough in technology or practical approaches to recognised clinical challenges. They should conform to the highest scientific and clinical practice standards.

**Case Reports**: illustrating unusual and clinically relevant observations are acceptable but they must be of sufficiently high quality to be considered worthy of publication in the Journal. On rare occasions, completed cases displaying non-obvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

**Supporting Information**: *International Endodontic Journal* encourages submission of adjuncts to printed papers via the supporting information website (see submission of supporting information below). It is encouraged that authors wishing to describe novel procedures or illustrate cases more fully with figures and/or video may wish to utilise this facility.

**Letters to the Editor:** are also acceptable.

**Meeting Reports:** are also acceptable.

## 5. MANUSCRIPT FORMAT AND STRUCTURE

### 5.1. Format

**Language**: The language of publication is English. It is preferred that manuscript is professionally edited. A list of independent suppliers of editing services can be found at **http://authorservices.wiley.com/bauthor/english_language.asp**. All services are paid for and arranged by the author, and use of one of these services does not guarantee acceptance or preference for publication

**Presentation**: Authors should pay special attention to the presentation of their research findings or clinical reports so that they may be communicated clearly. Technical jargon should be avoided as much as possible and clearly explained where its use is unavoidable. Abbreviations should also be kept to a minimum, particularly those that are not standard. The background and hypotheses underlying the study, as well as its main conclusions, should be clearly explained. Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

**Abbreviations**: International Endodontic Journal adheres to the conventions outlined in Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors. When non-standard terms appearing 3 or more times in the manuscript are to be abbreviated, they should be written out completely in the text when first used with the abbreviation in parenthesis.

### 5.2. Structure

All manuscripts submitted to *International Endodontic Journal* should include Title Page, Abstract, Main Text, References and Acknowledgements, Tables, Figures and Figure Legends as appropriate

**Title Page**: The title page should bear: (i) Title, which should be concise as well as descriptive; (ii) Initial(s) and last (family) name of each author; (iii) Name and address of department, hospital or institution to which work should be attributed; (iv) Running title (no more than 30 letters and spaces); (v) No more than six keywords (in alphabetical order); (vi) Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence.

**Abstract for Original Scientific Articles** should be no more than 350 words giving details of what was done using the following structure:
• **Aim**: Give a clear statement of the main aim of the study and the main hypothesis tested, if any.
• **Methodology**: Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.
• **Results**: Give the main results of the study, including the outcome of any statistical analysis.
• **Conclusions**: State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

**Abstract for Systematic Review Articles** should be no more than 350 words giving details of what was done using the following structure where applicable:

• **Background**: Provide a brief introduction of the subject and why it is important.
• **Aim**: Give a clear statement of the main aim of the study and the main hypothesis tested, if any.
• **Data sources**: Describe the databases searched.
• **Study eligibility criteria, participants, and interventions**: Briefly describe the methods adopted including exclusion/inclusion criteria.
• **Study appraisal and synthesis methods**: Describe bias, study type and quality
• **Results**: Give the main results of the review, including the outcome of any statistical meta-analysis.
• **Limitations**: Highlight problems with the current review end research area
• **Conclusions and implications of key findings**: State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

**Abstract for Review Articles (narrative)**

The Abstract should be unstructured and no more than 350 words.

**Abstract for Case Reports** should be no more than 350 words using the following structure:
• **Aim**: Give a clear statement of the main aim of the report and the clinical problem which is addressed.
• **Summary**: Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and analysis if any.
• **Key learning points**: Provide up to 5 short, bullet-pointed statements to highlight the key messages of the report. All points must be fully justified by material presented in the report.

**Abstract for Clinical Articles** should be no more than 350 words using the following structure:
• **Aim:** Give a clear statement of the main aim of the report and the clinical problem which is addressed.
• **Methodology:** Describe the methods adopted.
• **Results:** Give the main results of the study.
• **Conclusions:** State the primary conclusions of the study.

**Main Text of Original Scientific Article** should include Introduction, Materials and Methods, Results, Discussion and Conclusion

**Introduction**: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.

**Material and Methods**: must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.
***(i) Clinical Trials*** should be reported using the CONSORT guidelines available at **www.consort-statement.org**. A **CONSORT checklist** and flow diagram (as a Figure) should also be included in the submission material.
***(ii) Experimental Subjects***: experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association **Declaration of Helsinki** (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.

When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.
All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.
***(iii) Suppliers***: Suppliers of materials should be named and their location (Company, town/city, state, country) included.

**Results**: should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.

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

**Conclusion**: should contain a summary of the findings.

**Main Text of Review Articles** should be divided into Introduction, Review and Conclusions. The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical sub-sections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

**Main Text of Clinical Reports and Clinical Articles** should be divided into Introduction, Report, Discussion and Conclusion,. They should be well illustrated with clinical images, radiographs, diagrams and, where appropriate, supporting tables and graphs. However, all illustrations must be of the highest quality

**Acknowledgements**: *International Endodontic Journal* requires that all sources of institutional, private and corporate financial support for the work within the manuscript must be fully acknowledged, and any potential conflicts of interest noted. Grant or contribution numbers may be acknowledged, and principal grant holders should be listed. Acknowledgments should be brief and should not include thanks to anonymous referees and editors. See also above under Ethical Guidelines.

**5.3. References**

It is the policy of the Journal to encourage reference to the original papers rather than to literature reviews. Authors should therefore keep citations of reviews to the absolute minimum.

We recommend the use of a tool such as **EndNote** or **Reference Manager** for reference management and formatting. The EndNote reference style can be obtained upon request to the editorial office (**iejeditor@cardiff.ac.uk**). Reference Manager reference styles can be searched for here: **www.refman.com/support/rmstyles.asp**
**In the text**: single or double authors should be acknowledged together with the year of publication, e.g. (Pitt Ford & Roberts 1990). If more than two authors the first author followed by *et al.* is sufficient, e.g. (Tobias *et al.* 1991). If more than 1 paper is cited the references should be in year order and separated by "," e.g. (Pitt Ford & Roberts 1990, Tobias *et al*. 1991).
**Reference list**: All references should be brought together at the end of the paper in alphabetical order and should be in the following form.
(i) Names and initials of up to six authors. When there are seven or more, list the first three and add *et al.*
(ii)Year of publication in parentheses
(iii) Full title of paper followed by a full stop (.)
(iv) Title of journal in full (in italics)
(v) Volume number (bold) followed by a comma (,)
(vi) First and last pages

Examples of correct forms of reference follow:

***Standard journal article***

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

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

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

***Books and other monographs***

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

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

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

***Agency publication***
Ranofsky AL (1978) Surgical Operations in Short-Stay Hospitals: United States-1975. DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.8

***Dissertation or thesis***
Saunders EM (1988) In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis). Dundee, UK: University of Dundee.
***URLs***
Full reference details must be given along with the URL, i.e. authorship, year, title of document/report and URL.  If this information is not available, the reference should be removed and only the web address cited in the text.
Smith A (1999) Select committee report into social care in the community [WWW document]. URL http://www.dhss.gov.uk/reports/report015285.html
[accessed on 7 November 2003]

**5.4. Tables, Figures and Figure Legends**

**Tables**: Tables should be double-spaced with no vertical rulings, with a single bold ruling beneath the column titles. Units of measurements must be included in the column title.

**Figures**: All figures should be planned to fit within either 1 column width (8.0 cm), 1.5 column widths (13.0 cm) or 2 column widths (17.0 cm), and must be suitable for photocopy reproduction from the printed version of the manuscript. Lettering on figures should be in a clear, sans serif typeface (e.g. Helvetica); if possible, the same typeface should be used for all figures in a paper. After reduction for publication, upper-case text and numbers should be at least 1.5-2.0 mm high (10 point Helvetica). After reduction, symbols should be at least 2.0-3.0 mm high (10 point). All half-tone photographs should be submitted at final reproduction size. In general, multi-part figures should be arranged as they would appear in the final version. Reduction to the scale that will be used on the page is not necessary, but any special requirements (such as the separation distance of stereo pairs) should be clearly specified. Unnecessary figures and parts (panels) of figures should be avoided: data presented in small tables or histograms, for instance, can generally be stated briefly in the text instead. Figures should not contain more than one panel unless the parts are logically connected; each panel of a multipart figure should be sized so that the whole figure can be reduced by the same amount and reproduced on the printed page at the smallest size at which essential details are visible. Figures should be on a white background, and should avoid excessive boxing, unnecessary colour, shading and/or decorative effects (e.g. 3-dimensional skyscraper histograms) and highly pixelated computer drawings. The vertical axis of histograms should not be truncated to exaggerate small differences. The line spacing should be wide enough to remain clear on reduction to the minimum acceptable printed size.
Figures divided into parts should be labelled with a lower-case, boldface, roman letter, a, b, and so on, in the same typesize as used elsewhere in the figure. Lettering in figures should be in lower-case type, with the first letter capitalized. Units should have a single space between the number and the unit, and follow SI nomenclature or the nomenclature common to a particular field. Thousands should be separated by a thin space (1 000). Unusual units or abbreviations should be spelled out in full or defined in the legend. Scale bars should be used rather than magnification factors, with the length of the bar defined in the legend rather than on the bar itself. In general, visual cues (on the figures themselves) are preferred to verbal explanations in the legend (e.g. broken line, open red triangles etc.)

**Figure legends**: Figure legends should begin with a brief title for the whole figure and continue with a short description of each panel and the symbols used; they should not contain any details of methods.
**Permissions**: If all or part of previously published illustrations are to be used, permission must be obtained from the copyright holder concerned. This is the responsibilty of the authors before submission.

**Preparation of Electronic Figures for Publication:** Although low quality images are adequate for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit EPS (lineart) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented programmes. Scans (TIFF only) should have a resolution of 300 dpi (halftone) or 600 to 1200 dpi (line drawings) in relation to the reproduction size (see below). EPS files should be saved with fonts embedded (and with a TIFF preview if possible). For scanned images, the scanning resolution (at final image size) should be as follows to ensure good reproduction: lineart: >600 dpi; half-tones (including gel photographs): >300 dpi; figures containing both halftone and line images: >600 dpi.

Further information can be obtained at Wiley Blackwell's guidelines for figures: **http:/authorservices.wiley.com/bauthor/illustration.asp.**

Check your electronic artwork before submitting it: **http://authorservices.wiley.com/bauthor/eachecklist.asp**.

**5.5. Supporting Information**

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