SERVIÇO PÚBLICO FEDERAL
MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DE UBERLÂNDIA
FACULDADE DE ODONTOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

ANDRÉA DOLORES CORREIA MIRANDA VALDIVIA

Análise comparativa de comportamento *in vivo* e *in vitro* de protocolos de reabilitação de dentes tratados endodonticamente.

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

Uberlândia, Fevereiro de 2016

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Banca Examinadora:
Orientador: Prof. Dr. Carlos José Soares, UFU
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Ata da defesa de TESE DE DOUTORADO junto ao Programa de Pós-graduação em Odontologia Faculdade de Odontologia da Universidade Federal de Uberlândia.

Defesa de: Tese de Doutorado nº 011 - COPOD
Data: 12/02/2016
Discente: Andréa Dolores Correia Miranda Valdivia; Matrícula: (11213ODO002)
Título do Trabalho: Análise comparativa de comportamento *in vivo* e *in vitro* de protocolos de reabilitação de dentes tratados endodonticamente.
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Linha de pesquisa: Biomecânica aplica à Odontologia
Projeto de Pesquisa de vinculação: Biomecânica aplica à Odontologia

As **oito** horas do dia **doze de fevereiro do ano de 2016** no Anfiteatro Bloco 4L Anexo A, sala 23 Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em janeiro de 2016, assim composta: Professores Doutores: Alfredo Júlio Fernandes Neto (UFU); Veridiana Resende Novais Simamoto (UFU); Cesar Penazzo Lepri (UNIUBE); Roberto Sales e Pessoa (UNITRI); Carlos José Soares (UFU) orientador(a) do(a) candidato(a) **Andréa Dolores Correia Miranda Valdivia.**

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

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

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

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

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

Prof. Dr. Cesar Penazzo Lepri – UNIUBE

Prof. Dr. Roberto Sales e Pessoa – UNITRI

Prof. Dr. Alfredo Júlio Fernandes Neto – UFU

Profa. Dra. Veridiana Resende Novais Simamoto – UFU

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

DEDICATÓRIA

A Deus

Agradeço por tudo que acontece em nossas vidas, nunca sabemos o que Deus tem pra nos dar, mas Ele conhece nossos corações, nossos medos e nossas necessidades.

À minha família,

Especialmente ao meu filho Alejandro, o maior presente de Deus na minha vida e à minha avó Maria Dolores, pelas saudades eternas.

"Sem Deus não há vida, sem família não há base
e sem amigos não há mundo colorido."
(Verena)

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E a todas as pessoas que, de alguma forma, contribuíram para que essa etapa fosse vencida!

EPÍGRAFE

A lição do bambu chinês

Depois de plantada a semente deste incrível
arbusto, não se vê nada,
por aproximadamente 5 anos, exceto o lento
desabrochar de um diminuto broto,
a partir do bulbo.
Durante 5 anos, todo o crescimento é
subterrâneo, invisível a olho nu,
mas, uma maciça e fibrosa estrutura de raiz,
que se estende vertical
e horizontalmente pela terra está sendo construída.
Então no final do 5º ano, o bambu chinês,
cresce até atingir a altura de 25 metros.
Um escritor americano escreveu:
"Muitas coisas na vida pessoal e profissional
são iguais ao bambu chinês:
você trabalha, investe tempo, esforço, faz tudo
o que pode para nutrir seu crescimento,
e, às vezes não vê nada por semanas, meses, ou anos.
Mas se tiver paciência para continuar
trabalhando, persistindo e nutrindo,
o seu 5º ano chegará, e, com ele, virão um
crescimento e mudanças que você jamais
esperava...
O bambu chinês nos ensina que não devemos
facilmente desistir de nossos projetos,
de nossos sonhos... especialmente no nosso trabalho,
(que é sempre um grande projeto em nossas vidas)
E que devemos lembrar do bambu chinês,
para não desistirmos facilmente
diante das dificuldades que surgirão.
É preciso muita fibra para chegar às alturas e,
Ao mesmo tempo,
muita flexibilidade para se curvar ao chão."

(Autor desconhecido)

SUMÁRIO

RESUMO

RESUMO

A restauração de dentes tratados endodonticamente têm sido grande desafio para a odontologia restauradora. Geralmente, estes dentes apresentam estrutura coronária insuficiente para reter o material restaurador, sendo necessária a utilização de retentores intrarradiculares para viabilizar a reconstituição coronária. Este trabalho tem como objetivo geral analisar o efeito do protocolo restaurador de dente tratado endodonticamente por meio de avaliação comparativa *in vivo* e simultânea *in vitro*, empregando ensaios mecânicos e computacionais pelo método de elementos finitos. Visa ainda validar os ensaios computacionais e ensaios experimentais laboratoriais por meio de análise comparativa com parâmetros clínicos. Este estudo foi dividido em quatro objetivos específicos; ***objetivo específico 1:*** avaliar a influência do tratamento de superfície de pinos pré-fabricados na resistência de união de pino ao canal radicular, por meio de teste de micropush-out; ***objetivo específico 2:*** desenvolver e validar a geração de modelos tridimensionais específicos de paciente com incisivos centrais anteriores com diferente tamanho de férula, restaurados com pino de fibra de vidro e coroa em cerâmica pura CAD/CAM usando tomografia computadorizada Cone-beam (CT) e combinação de softwares específicos de elementos finitos; ***objetivo específico 3:*** avaliar a deformação antes e após ciclagem térmica e mecânica, resistência à fratura e padrão de falha de incisivos tratados endodonticamente restaurados com pino de fibra de vidro e coroa total em cerâmica pura CAD/CAM com e sem férula; ***objetivo específico 4:*** gerar síntese dos achados dos objetivos específicos 1, 2 e 3 compilados em um artigo de comunicação aos clínicos brasileiros cumprindo a função social da geração do conhecimento. Após análise dos resultados pode-se concluir que o tratamento de superfície com 24% de peróxido de hidrogênio por 1 minuto resultou em significativamente maior resistência de união na cimentação de pinos de fibra de vidro. A definição do protocolo de modelagem individualizada forneceu as etapas necessárias para a aplicação da metodologia em paciente. A distribuição de tensões mostrou que as tensões geradas no incisivo que não possui férula uniforme, foram maiores em comparação a incisivo com maior extensão de férula independentemente do método de carregamento. A manutenção de férula uniforme foi mais relevante do que maior extensão da férula em uma

região específica do preparo. A presença de férula evitou o descolamento do pino de fibra da dentina radicular após fadiga térmica e mecânica. O grupo sem férula apresentou maior deformação radicular após processo de envelhecimento. O grupo com férula apresentou maiores valores de resistência à fratura, baixa concentração de tensões na dentina radicular e menor índice de fraturas catastróficas. O uso de pino de fibra de vidro associado à coroa em cerâmica pura permitiu o restabelecimento da estética e funcionalidade biomecânica do dente tratado endodonticamente com intervenção periodontal voltada aos tecidos de revestimento que possibilitou um recontorno gengival adequado para realização dos procedimentos restauradores.

ABSTRACT

ABSTRACT

The restoration of endodontically treated teeth have been a challenge for restorative dentistry because usually the amount of remaining coronal dentin of these teeth are not enough to retain the restorative material, requiring the use of intra-radicular posts to provide retention for the core and restorative crown. This study aimed to evaluate the effect of rehabilitation protocols of endodontically treated teeth for the comparison of in vivo and simultaneous in vitro tests, employing mechanical tests and computational by finite element method; also aims to validate the computational and experimental testing laboratory through comparative analysis with clinical parameters. This study was divided into four specific objectives; ***specific objective 1:*** to evaluate the influence of the surface treatments of fiberglass posts on bond strength to root dentin using push-out test; ***specific objective 2:*** to develop protocol and validate the generation of three-dimensional patient specific model of anterior central incisors with different ferrule design restored with glass fiber post and CAD-CAM all-ceramic restoration using cone-beam computed tomography and specific software combination for finite elements analysis; ***specific objective 3:*** to evaluate the strain before and after thermo-mechanical fatigue aging, the fracture resistance and fracture mode of endodontically treated incisors restored using a fiberglass post and CAD/CAM all ceramic crown with and without ferrule; ***specific objective 4:*** generate manuscript that summarize the main findings of specific objective 1, 2 and 3 designated to Brazilian clinical fulfilling the social function of knowledge generation. After analyzing the results it can be concluded that the post surface treatment with 24% hydrogen peroxide for 1 min yielded significantly higher bond strength on the fiberglass posts cementation. The definition of protocol of individualized models provided the sequence necessary for the application of the methodology on patient, the stress distribution on evaluated teeth showed that stresses on left incisor, which had no-uniform ferrule were higher compared with the right incisor, regardless of the loading method. The maintenance of uniform ferrule was more relevant than localized higher ferrule. The ferrule presence prevented the post detaching maintain the root dentin strain after thermal-mechanical aging. The no ferrule group showed increase root dentin strain after aging process. The ferrule group had higher fracture resistance, lower stress concentration on root dentin and

less catastrophic fractures. The use of glass fiber post associated to the all ceramic crown allowed the restoration of biomechanics aesthetics and functionality of endodontically treated tooth with periodontal intervention in order to achieve a favorable condition for the restorative procedures.

INTRODUÇÃO E REFERENCIAL TEÓRICO

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Dentes tratados endodonticamente frequentemente requerem retentores intrarradiculares para realização de procedimentos restauradores, devido às grandes perdas de estrutura dental causada por cárie ou acessos endodônticos à cavidade pulpar (Bateman et al., 2003). O propósito dos retentores não é reforçar a estrutura, mas reter e estabilizar os materiais restauradores, uma vez que estes podem interferir na resistência mecânica do dente, aumentando o risco de dano da estrutura dental remanescente (Santos-Filho et al., 2008). Fatores relacionados ao retentor intrarradicular, tais como: comprimento, espessura, configuração e a composição podem influenciar na biomecânica destes dentes, alterando o padrão de distribuição de tensões (Barjau-Escribano et al., 2006), resistência à fratura (Barjau-Escribano et al., 2006; Santos-Filho et al., 2008; Silva et al., 2011) e deformação da estrutura remanescente (Santos-Filho et al., 2008; Silva et al., 2011). Assim nas últimas décadas, a introdução dos pinos de fibra de vidro surgiu como alternativa aos pinos metálicos (Bateman et al., 2003), já que os pinos de fibra apresentam módulo de elasticidade similar ao da dentina (Naumann et al., 2006), reduzindo a concentração de tensões nas interfaces, capacitando o complexo restaurador a mimetizar o comportamento biomecânico de dentes hígidos (Santos-Filho et al., 2008; Silva et al., 2011). Estudos utilizando o método de elementos finitos têm se mostrado como instrumento valioso na análise da distribuição de tensões nas restaurações de dentes anteriores. O fato dos pinos de fibra exibirem propriedades biomecânicas mais similares às da dentina que os pinos metálicos (Lanza et al., 2005), tem motivado pesquisadores ao estudo cada vez mais crescente dos retentores intrarradiculares com auxilio desta metodologia (Santos-Filho et al., 2014; Veríssimo et al., 2014).

Outro fator importante na resistência do dente tratado endodonticamente é o abraçamento de estrutura dental em torno do retentor intrarradicular, denominado efeito férula, este é obtido quando se tem a preservação de 1,5 a 2,0 mm de estrutura dentária em torno da região cervical do núcleo (Morgano, 1996; Morgano & Brackett,1999). A falta de porção coronária mais retentiva parece ser o fator de fragilização do complexo dente/restauração (Purton & Love, 1996). Quando não existe estrutura coronária suficiente para propiciar base de sustentação, as forças que incidem sobre o núcleo são direcionadas obliquamente, tornando a raiz mais susceptível à fratura (Pegoraro, 2000).

A existência de variedade de opções no tratamento reabilitador com retentores intrarradiculares geram dúvidas aos profissionais de qual o melhor planejamento reabilitador. Na cimentação de pinos no interior do canal, quer seja em raízes fragilizadas (Silva et al., 2011) ou não, altas tensões de contração são geradas durante o processo de polimerização do cimento resinoso (Ferrari et al., 2009, Pereira et al., 2015). O risco de fratura pode ser potencializado por falhas na interface adesiva entre o retentor e o material de cimentação e entre este e a dentina radicular. O fator de configuração cavitário (fator C), é altamente desfavorável no interior do canal, e parece contribuir com a formação de tensões de contração de polimerização na interface adesiva influenciando negativamente na qualidade de adesão, justificando a desunião do retentor como fator de falha clínica prevalente destes procedimentos restauradores (Jongsma et al., 2011).

Outro aspecto que pode contribuir para a ocorrência de falha de deslocamento do pino é a falta de completa polimerização do cimento resinoso (Pereira et al., 2015).Atualmente encontra-se a disposição do clínico pinos de fibra de vidro translúcidos, que prometem transmitir a luz até o terço apical das raízes, promovendo melhor polimerização do cimento e consequente melhora na resistência adesiva. Cimentos resinosos autoadesivos têm sido propostos para minimizar este aspecto pela simplificação do processo de cimentação adesiva (Aguiar et al., 2010). Entretanto, apesar das vantagens, falhas na adesão entre pino de fibra-cimento-dentina têm sido relatadas (de Souza Menezes et al., 2011), e estudos in vivo têm mostrado que a adesão nesta interface é crítica para o sucesso clínico deste tipo de restauração (Cagidiaco et al., 2007, Valdivia et al., 2014).

Dessa forma, a fim de melhorar a resistência de união entre o pino de fibra e o cimento resinoso, são propostos tratamentos de superfície para remoção da resina epóxica superficial e exposição das fibras dos pinos, para aumentar a união química e micromecânica (Monticelli et al., 2006). Estes procedimentos podem ser divididos, segundo Monticelli et al. (2008), em três categorias: (1) tratamentos de superfície com substâncias para otimizar a união química, como a silanização, ou silanização e aplicação de adesivo; (2)

asperização da superfície para aumentar a retenção micro-mecânica, por meio do condicionamento ácido, jateamento ou silicatização; ou (3) associação das duas técnicas anteriores. Comparando-se estas técnicas de tratamento de superfície, o condicionamento com peróxido de hidrogênio é o que tem apresentado melhores resultados, pois além de ser eficiente, apresenta facilidade técnica de utilização (Monticelli et al., 2008), promove dissolução parcial da matriz de resina epóxica (Monticelli et al., 2008) e não causa danos as fibras do pino (Monticelli et al., 2006; Valdivia et al., 2014).

O estabelecimento de associação de metodologias que visam analisar parâmetros distintos, porém complementares se faz necessário em avaliações in vitro para aproximar a detecção de falhas mais próximo da realidade. O emprego de processo de envelhecimento que caracteriza a fadiga das estruturas envolvidas por meio de ciclos térmicos e mecânicos possibilitam a simulação de alguns desafios verificados em ambiente clínico aos quais materiais restauradores e substratos dentários são expostos (Silva et al., 2011). Os ensaios mecânicos destrutivos são importantes meios de análise do comportamento do dente e de diferentes materiais (Soares et al., 2006), no entanto, torna-se necessária a associação com metodologias não-destrutivas, como ensaio de extensometria (Santos-Filho et al., 2008; Veríssimo et al., 2014) ou computacionais como método de elementos finitos (Soares, 2003; Magne, 2007; Magne & Oganesyan, 2009; Santos-Filho et al., 2014; Veríssimo et al., 2014), favorecendo análise biomecânica sequencial e detalhada do comportamento da amostra. Por conseguinte, parece que na biomecânica um bom caminho é o emprego da associação com metodologias que se completem que possam ser retroalimentadas e que acabem envolvendo menores investimentos e com respostas mais próximas àquelas que se conseguem com os experimentos in vivo. A associação com metodologias computacionais como o método de elementos finitos (MEF) constitui mais um importante aliado na caracterização deste processo de comportamento das estruturas dentais.

Contudo, tanto os ensaios experimentais necessitam de validação como os modelos de elementos finitos necessitam ser confirmados e validados por meio de análises laboratoriais. Rotineiramente os estudos que envolvem MEF, trabalham com processo de simplificação de amostras simulando genericamente um modelo que represente o comportamento do grupo de estruturas biológicas estudadas. Pensar nesta extrapolação para modelos geometricamente similares é perfeitamente pertinente, contudo a análise de estruturas biológicas de geometrias altamente variadas ainda se pauta consideravelmente na análise da variabilidade por meio de utilização de diversas amostras para que os valores médios representem mais adequadamente o comportamento biomecânico. Inicia-se na análise biomecânica a necessidade de ampliação de amostras biológicas para que resultados provenientes de diferentes modelos possam prever melhor estes aspectos. Diante deste horizonte, nada mais válido que a associação de análise clínica prospectiva com a simulação simultânea destas estruturas em modelos computacionais e ainda experimentais para que este ciclo investigativo possa ser retroalimentado e retrovalidado.

Considerando que dentes tratados endodonticamente apresentam maior potencial de falhas nos procedimentos restauradores, podendo gerar falhas estruturais em todo o complexo dente-restauração, parece pertinente analisar comparativamente o comportamento *in vivo* e *in vitro* de protocolos de reabilitação de dentes tratados endodonticamente. Ao obter tais resultados, espera-se responder a questionamento clínico, de forma crítica e embasada cientificamente, para que o número de falhas e perdas após tratamentos tão complexos possam ser reduzidas.

OBJETIVOS

2. OBJETIVOS

Objetivo Geral

Este projeto visa de forma sequencial e progressiva analisar o efeito do protocolo restaurador de dente tratado endodonticamente por meio de avaliação comparativa in vivo e simultânea in vitro, empregando ensaios mecânicos e computacionais pelo método de elementos finitos. Visa ainda validar os ensaios computacionais e ensaios experimentais laboratoriais por meio de análise comparativa com parâmetros clínicos.

Objetivos específicos

Objetivo específico 1

Capítulo 1 - *Effect of Surface Treatment of Fiberglass Posts on Bond Strength to Root Dentin*

O objetivo deste estudo foi avaliar a influência do tratamento de superfície de pinos pré-fabricados na resistência de união de pino ao canal radicular, por meio de teste de micropush-out.

Objetivo específico 2

Capítulo 2 - *Patient specific finite element analysis of fiber post and ferrule design*

O objetivo deste estudo foi desenvolver e validar a geração de modelos tridimensionais específicos de paciente com incisivos centrais anteriores com diferente tamanho de férula, restaurados com pino de fibra de vidro e coroa em cerâmica pura CAD/CAM usando tomografia computadorizada Cone-beam (CT) e combinação de softwares específicos de elementos finitos.

Objetivo específico 3

Capítulo 3 – *Biomechanical effect of ferrule presence on incisor teeth restored with fiberglass post and CAD/CAM ceramic crown after thermal cycling and fatigue loading*

O objetivo deste estudo foi avaliar a deformação antes e após ciclagem térmica e mecânica, resistência à fratura e padrão de falha de incisivos tratados endodonticamente restaurados com pino de fibra de vidro e coroa total em cerâmica pura CAD/CAM com e sem férula.

Objetivo específico 4

Capítulo 4 - ***Reabilitação estética do sorriso com uso de pino de fibra de vidro associado à coroa cerâmica CAD/CAM - Aspectos clínicos e biomecânicos.***

O objetivo deste trabalho foi gerar síntese dos achados dos objetivos específicos 1, 2, e 3 compilados em um artigo de comunicação aos clínicos brasileiros cumprindo a função social da geração do conhecimento.

CAPÍTULOS

3. CAPÍTULOS

3.1 CAPÍTULO 1

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Effect of surface treatment of fiberglass posts on bond strength to root dentine

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Effect of Surface Treatment of Fiberglass Posts on Bond Strength to Root Dentin

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This study evaluated the influence of the surface treatments of fiberglass posts on bond strength to root dentin using push-out test. Forty bovine incisor roots were endodontically treated. The surface of the fiberglass posts (Exacto #2, Angelus) were treated using 4 different protocols (n=10): Control - 70% ethanol for 1 min; 37% phosphoric acid for 1 min; 10% hydrofluoric acid for 1 min; and 24% hydrogen peroxide for 1 min. After a silane coupling agent was applied for 1 min and all posts were cemented using self-adhesive resin cement (RelyX Unicem, 3M-ESPE). The roots were sectioned and two 1-mm-thick slices were obtained from each third: cervical, middle and apical. The specimens were subjected to the push-out test with a crosshead speed of 0.5 mm/min. Data were analyzed by repeated measures ANOVA followed by Tukey's HSD tests (α=0.05). The surface treatment (p<0.001) and root third region (p=0.007) factors were significant. The retention to root canal was affected by surface treatment type. The post surface treatment with 24% hydrogen peroxide for 1 min yielded significantly higher bond strength when the fiberglass posts were cemented with RelyX Unicem.

Key words: surface treatments, fiberglass posts, push-out test, self-adhesive resin cement.

Introduction

Fiberglass posts are a viable alternative for restoration of endodontically treated teeth (1-3) and their retention with composite restorations depends on the quality of the bond established at different interfaces (4). The most frequent cause of failure is debonding of a post restoration to the root canal (5,6). Therefore, in order to improve the bond strength between the post and the resin cement, surface pre-treatment procedures for posts have been investigated (2,7).

Surface treatment is a common method for improving the adhesion properties of a material, by facilitating chemical and micro-mechanical retention between different constituents (8). These procedures fall into three categories: 1) chemical bonding between a composite and post (silane coating); 2) surface roughening (sandblasting and etching); or 3) combination of micromechanical and chemical components by using the two above-mentioned methods (4).

Silane coupling agent is a hybrid organic-inorganic compound that can mediate adhesion between inorganic and organic matrices through intrinsic dual reactivity capability to increase surface wettability, creating a chemical bridge with OH-covered substrates, such as glass (4,8). A chemical bond may be achieved between the core resin matrix and the exposed glass fibers of the post at the interface level (9,10). However, the interfacial strength is still relatively low because of the absence of chemical union between the methacrylate-based resin composites and the epoxy resin matrix of fiber posts (11).

Hydrofluoric acid in combination with a silane-coupling agent is often employed to enhance the bond strength between composite resins and feldspathic ceramics (12,13). Because silica and quartz present in fiber posts are comparable in chemical structure with ceramic materials, hydrofluoric acid has recently been proposed for etching fiberglass posts (2). It is intended to create a rough pattern on the surface, which allows for micromechanical interlocking with the resin cement and composite (4). On the other hand, the treatment using hydrogen peroxide (HP) dissolves the epoxy resin matrix, exposing the surface of fibers to silanization (2,7,14,15). The spaces between fibers provide additional sites for micromechanical retention of the resin composites (10,11). Etching with phosphoric acid is also employed as a fiberglass surface treatment indicated by manufacturers; however, they recommend this substance as a cleaning agent (16).

The aim of this study was to evaluate the influence of different surface treatments of fiberglass post on their bond strength to root canal, using a push-out test. A delayed photo-activation protocol was used for the self-adhesive resin cement to allow for analyzing the adhesion of the posts to the root canal walls, excluding interferences of the cement-dentin interface and enabling a better chemical and photo-polymerization of resin cement. The morphological aspects of the fibers and the post-surface characteristics following the different pretreatments were also observed using scanning electron microscopy (SEM).

The hypothesis generated is that push-out bond strength of fiberglass post to root dentine is not affected by different post surface treatments.

Material and Methods

Forty bovine incisors with similar dimensions had their coronal portion removed to obtain 15-mm-long roots. Canals were instrumented with Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), irrigated with 1.0% NaOCl and saline and filled with gutta-percha cones (Dentsply Ind. e Com. Ltda., Petrópolis, RJ, Brazil) and calcium hydroxide-based endodontic sealer (Sealer 26 Dentsply Ind. e Com. Ltda.). Post spaces were prepared to a depth of 10 mm using a heated instrument (GP heater; Dentsply Maillefer) to remove gutta-percha, and a specific drill system (Exacto #2, Angelus, Londrina, PR, Brazil).

The roots were randomly divided in 4 groups according to the surface treatment (n=10) of the opaque and cylindrical/conical fiberglass posts (Exacto; Angelus, size 2, with 1.5 mm in diameter and 17.0 mm in length): Control - the post surfaces were cleaned with 70% ethanol according to the manufacturer's recommendation over the post surface using a microbrush for 1 min, dried for 1 min and the silane coupling agent (Silano, Angelus) was applied and allowed to evaporate for 1 min; PA37% group, the post surface was etched with 37% phosphoric acid (Condac 37, FGM, Joinville, SC, Brazil) for 1 min, followed by rising with water for 1 min and drying. Next, a silane coupling agent was applied for 1 min; HF group, the post surface was etched with 10% hydrofluoric acid gel (Condac Porcelana, FGM) applied over the post surface for 1 min followed by rising and drying. The silane agent was then applied on the post surface for 1 min allowing solvent evaporation; HP group, the fiber post was immersed in 24% HP solution placed in Eppendorf tubes for 1 min followed by rising and drying. Afterwards, the silane was applied for 1 min.

All posts were cemented to the root canal using self-adhesive resin cement (RelyX Unicem, 3M ESPE, St Paul, MN, USA) according to the manufacturers' instructions by hand mixing the predisposed cement portions in a mix-pad for 20 s until reaching material homogeneity and inserted into the root canal with size 40 stainless steel K-files (Dentsply Maillefer). The posts were coated with the resin cement and seated under finger pressure. Five minutes after insertion, photo-activation was performed through the coronal portion of the root at the buccal, lingual, and coronal faces for 40 s, a total of 120 s light exposure. The photo-activation procedures were performed using a light-curing unit with 800 mW/Cm^2 intensity (XL3000, 3M-ESPE).

Push-Out Test

After storing for 24 h in distilled water at 37 °C, the roots were sectioned transversally into six slices with a low-speed diamond blade (Isomet 1000, Buehler, Lake Bluff, IL, USA) under water cooling. Two 1 mm thick slices were obtained from the cervical, middle and apical third regions. After measuring the thickness with a digital caliper (Mitutoyo, São Paulo, SP, Brazil), each specimen was marked on its coronal surface with an indelible marker, and the diameter of top and bottom surfaces of post was measured using an optical microscope under 40× magnification (Mitutoyo TM-500). The specimen was positioned on a universal testing machine (EMIC DL 2000I; São José dos Pinhais, Paraná, Brazil) in such a way that the load applicator tip coincided with the metal base orifice, and then submitted to compression loading in on apex to crown direction at a speed of 0.5 mm/min, until failure by displacement of the post. The bonding strength values were calculated using the equation (17):

$$\text{Area} = \pi (R_1 + R_2) \sqrt{R_1 - R_2)^2 + h^2}$$

where π is the constant 3.14, R_1 is the top post radius, R_2 is the bottom post radius, h is the specimen thickness in mm.

To determine the failure mode, all specimens tested were air dried and analyzed under a confocal laser scanning microscope (LSM510, Carl Zeiss Laser Scanning Systems, Oberkochen, Germany). The failure modes were evaluated using a classification system modified from Castellan et al. (18): (I) Adhesive failure between post and luting cement; (II) Adhesive failure between dentin and luting cement; (III) Cohesive failure in cement; (IV) Cohesive failure in dentine; and (V) Mixed failure.

Specimens tested were mounted on aluminum stubs, sputter coated with gold (Bal-Tec SCD 050; Balzers, Liechtenstein) and examined with a scanning electron microscope (SEM; LEO 435 VP; LEO Electron Microscopy Ltd., Cambridge, UK). SEM images were obtained at different magnifications to illustrate the failure modes and the effect of the different surface treatments on the morphological aspects of the fiberglass post surface.

Statistical Analysis

The bond strength data were tested for normal distribution (Shapiro-Wilk, $p<0.05$) and equality of variances (Levene's test, $p<0.05$). Data were analyzed by repeated-measured ANOVA to evaluate the effect of the study factor (surface treatment) with the repetition defined as the third regions; followed by the Tukey's Honestly Significant Difference (HSD) test at a 5% level of significance.

Results

The mean and standard deviations of the bond strengths for the post surface treatments measured in each root region are shown in Table 1. The results of the repeated measures ANOVA revealed that the surface treatment ($p<0.001$) and root third region ($p=0.007$) factors were significant. The Tukey's HSD test showed that the HP group had a significantly higher bond strength than the other surface treatments. The post-surface treatment with ethanol 70% (control), PA37% and HF had similar bond strength. The push-out bond strength of the fiberglass cemented with RelyX Unicem was significantly higher in the cervical than in middle and apical regions.

Confocal observation demonstrated the distribution of the failure modes for each experimental group in Table 2. All samples were classified according to the failure pattern. The cohesive failures in cement (Fig. 1C) were more prevalent in the control and HF groups and the adhesive failures between dentin and luting cement (Fig. 1B) were more prevalent in the PA37% and HP groups. Adhesive failures between post and luting cement (Fig. 1A) were more prevalent in PA37% group when compared to the others groups. Cohesive failures in dentin (Fig. 1D) were not seen in HP group and mixed failures (Fig. 1E) were observed in the PA37% and HP groups.

Representative specimens of the investigated pretreatment procedures are shown in Figure 2. SEM observation revealed that the post surface etched with ethanol (Fig. 2A) and phosphoric acid (Fig. 2B) was not modified. An aggressive attack on the epoxy matrix and fiberglass was observed by SEM evaluation on the surfaces etched with hydrofluoric acid (Fig. 2C). This technique produced substantial damage to the fiberglass and affected the integrity of the post. Treatment with HP exposed more superficial fibers and caused surface dissolution of the epoxy resin matrix to a greater depth (Fig. 2D). It also was observed that fibers were not damaged by the etching treatment.

Table 1. Mean push-out bond strength values (S.D.) in MPa

Surface treatment	Region			
	Cervical	Middle	Apical	Pooled average
24% hydrogen peroxide	19.9 (4.8)	16.7 (4.7)	15.8 (4.4)	17.5 (2.2)[A]
10% hydrofluoric acid	14.0 (5.2)	11.4 (5.5)	10.8 (2.8)	12.1 (1.7)[B]
37% phosphoric acid	11.6 (6.3)	10.2 (6.5)	10.1 (4.5)	10.6 (0.8)[B]
70% ethanol (control)	11.8 (3.8)	9.9 (4.9)	9.8 (6.2)	10.5 (1.1)[B]
Pooled average	14.3 (3.9)[a]	12.1 (3.2)[b]	11.6 (2.8)[b]	

Different letters indicate statistically significant difference verified by the Tukey's test ($p<0.05$). Uppercase letter is used to compare surface treatment (in columns), and lowercase letters is used to compare root region (in rows).

Table 2. Failure mode distribution in the groups

Surface treatment	Failure modes				
	I	II	III	IV	V
70% ethanol (control)	7 (12%)	20 (33%)	30 (50%)	3 (5%)	-
37% phosphoric acid	12 (20%)	24 (40%)	19 (32%)	3 (5%)	2 (3%)
10% hydrofluoric acid	6 (10%)	18 (30%)	34 (57%)	2 (3%)	-
24% hydrogen peroxide	6 (10%)	30 (50%)	20 (33%)	-	4 (7%)
Total	31 (13%)	92 (38%)	103 (43%)	8 (4%)	6 (2%)

I, Adhesive failure between post and luting cement; II, Adhesive failure between dentin and luting cement; III, Cohesive failure in cement; IV, Cohesive failure in dentin; and V, Mixed failure.

Discussion

The tested hypothesis was rejected; the bond strength of glass fiber posts to root canal was affected by the different post surface treatments. The bond strength of fiberglass post to root canal was significantly higher when the 24% HP surface treatment was used compared with the other surface treatments, 70% ethanol, 37% phosphoric acid and 10% hydrofluoric acid.

The push-out test has been considered the most appropriate method to assess the adhesion of luted posts to root canal dentin (19). The push-out test involves the use of an indenter to push a small fiber diameter into a specimen with a thickness of approximately 1 mm, which allows a more uniform distribution of the load applied throughout the bonded interface (19). Nevertheless, the pin diameter, specimen thickness, and elastic modulus of the filling material all have effects on the push-out bond strength results (20).

Resin-based adhesive luting materials are widely used for the fixation of posts, and currently all the resin cements are based upon the use of either an etch-and-rinse or of a self-etch adhesive, along with a low-viscosity resin composite. This multistep application procedure is complex and somewhat technique-sensitive, which could compromise the bonding effectiveness. Self-adhesive resin cements were introduced in 2001 to simplify luting procedures and are have been a good option to fix fiberglass post due to their bonding performance and low viscosity eliminating the need for pretreatment of tooth. The manufacturer to be based upon acid monomers that demineralize and infiltrate the tooth substrate, resulting in micromechanical retention, claims the adhesive proprieties. Secondary reactions have been suggested to provide chemical adhesion to hydroxyapatite. A recent systematic review on the role of resin cement on bond strength of glass-fiber posts seems to suggest that the use of self-adhesive resin cement, especially with RelyX Unicem, could improve the retention of fiberglass posts in root canals (21).

The results obtained in this study for bond strength showed significantly higher values in the cervical region than in the middle and apical regions for all groups. It could attributed to the presence of smear layer, generated during endodontic treatment and post space preparation, which are deposited on the root canal walls. The presence of such a layer impairs a proper contact between the acidic methacrylates of self-adhesive resin cements and the underlying dentin during adhesive procedures, interfering with its bond strength to dentin (22). A previous study reported that self-adhesive cements presented a limited decalcification/infiltration for into the underlying dentin and that no hybrid layer and/or resin tag formation was detectable at the interfaces bonded with self-adhesive cements (23). Moreover, light curing provides higher bond strengths to dentin than self curing mainly when the light source is closer to the composite material (24).

The use of ethanol has been recommended by the manufacturers to clean the post surface to remove any kind of organic contamination and/or particles adhered to the post, which could impair the bond strength to luting agent improving the potential of the interaction with resin-based

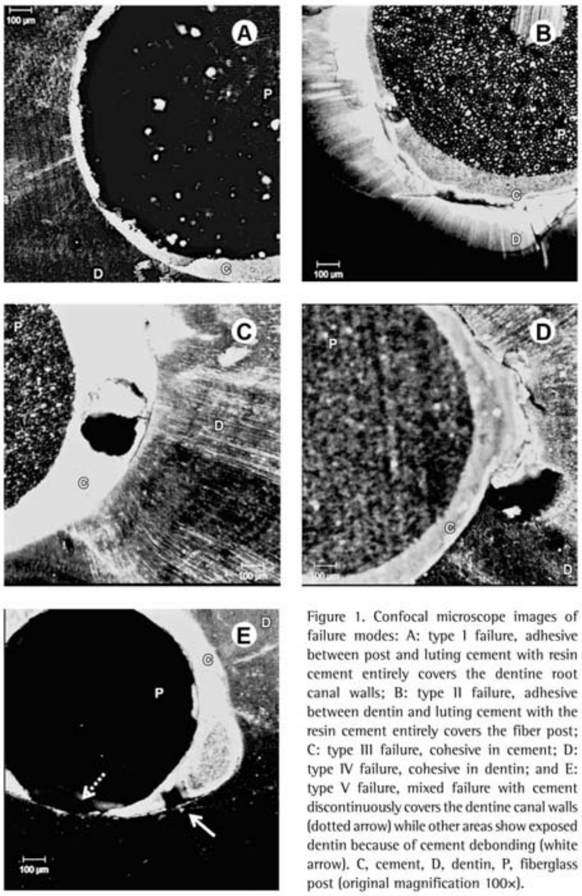

Figure 1. Confocal microscope images of failure modes: A: type I failure, adhesive between post and luting cement with resin cement entirely covers the dentine root canal walls; B: type II failure, adhesive between dentin and luting cement with the resin cement entirely covers the fiber post; C: type III failure, cohesive in cement; D: type IV failure, cohesive in dentin; and E: type V failure, mixed failure with cement discontinuously covers the dentine canal walls (dotted arrow) while other areas show exposed dentin because of cement debonding (white arrow). C, cement, D, dentin, P, fiberglass post (original magnification 100×).

materials. In this research, ethanol was used as a control group. The results of this study showed that this treatment resulted in similar bond strength of the phosphoric acid and hydrofluoric acid groups. SEM observation revealed that the post surface etched phosphoric acid was not modified by maintenance the same pattern of ethanol group. The roughness of the post surface produced by the phosphoric acid may have been insufficient to attain strong mechanical interlocking between the cement and the post surface.

On the other hand, the SEM analysis revealed cracking of the fibers, as well as on underlining treated epoxy resin, when hydrofluoric acid was used (Fig. 2C). This technique produced substantial damage to the glass fibers, which affected the integrity of the post, probably due to the extremely corrosive effect of hydrofluoric acid on the glass phase (1,12).

Using HP over the post surface has also demonstrated mechanical-chemical bonding of resin-based material to the fiber post (7,11). The etching effect of HP is based on oxidation of the post surface, thus breaking epoxy resin bonds. A recent study (15) comparing 24% and 35% HP showed that higher concentration results in higher oxidizing effect, and improved the bond strength for 35% regardless of application or immersion mode; however immersion for 24% resulted in higher values on bond strength. In this study, 24% HP was able to remove a superficial layer of epoxy resin, exposing the larger surface area of fibers to silanization (Fig. 2D) with no damaging generated on the fiber network when this product is applied at 1 min (2,7,11). This explains the results in which higher values were found when coupling this treatment protocol was applied. When the surface of the post was etched with 24% HP, probably a more reactive surface was generated for better retention of the post and resin cement.

Silane coupling agents mainly exert their function by bonding chemically to the posts and core material and improving surface wettability (1,10). With the removal of the superficial layer of epoxy resin via surface treatment as previously showed in this study, more exposed fibers in terms of surface area are available for reacting with the silane molecules (1,2,9,11). In this study, silane was applied in all samples after the specific surface treatment of each group. It is likely that their application improved the bond strength, mainly when the 24% HP was used, showing both chemical and micromechanical interaction.

Confocal microscopy was used and appears to be a noteworthy alternative for the evaluation of the bond failure pattern in loaded specimens, since it is less time-consuming and does not require any preparation of samples. In the present study, the failure modes of tested samples showed a wider variation. Failure modes were primarily cohesive failures in cement (43%). When mechanical

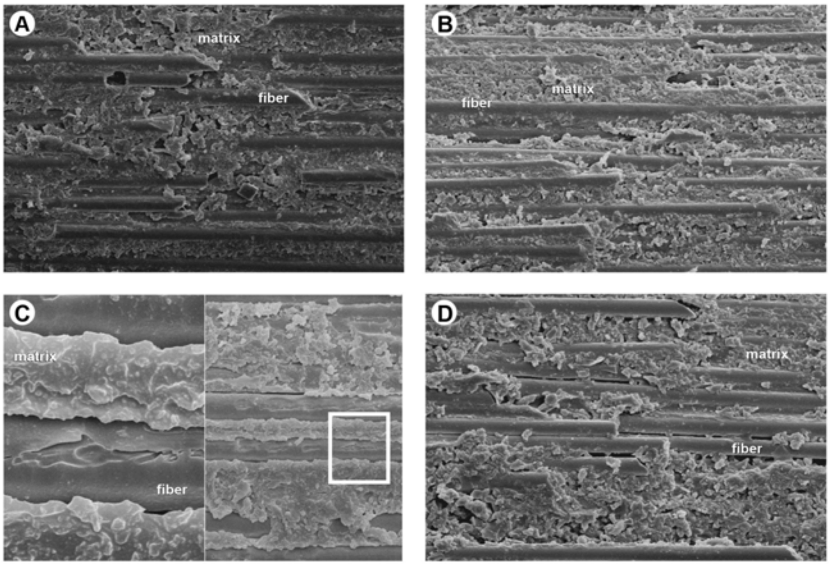

Figure 2. SEM micrograph of fiberglass post surface etched with 70% ethanol (A), 37% phosphoric acid (B), 10% hydrofluoric acid (C) and 24% hydrogen peroxide (D). The white square in image "C" shows areas with damaged fibers caused by the hydrofluoric acid action (original magnification 250×).

treatment is not effective, failure tends to occur along the interfaces, but when chemical bonding is involved, the failure often occurs cohesively through the cement itself (25). The second most frequent type was adhesive failure between dentin and luting cement (38%), which could be explained by smear layer presence that can affect the bond strength. The higher adhesive failure mode at the post-resin cement interface was observed in the ethanol (12%) and phosphoric acid groups (20%), in which lower bond strength values were found. This failure mode (I) was 13% compared within the groups, which could be attributed to the fact that this study used a delayed photo-activation protocol after 5 min, which could result in a lower shrinkage of resin cement and a higher bond strength between the structures.

This study presents some limitations such as lack of mechanical or thermal cycling and limited number of surface treatment protocols. Clinical trials are necessary to validate the results of this investigation, as well as the evaluation of the stress distribution using finite element analysis. However, fiberglass post is now the best option to restore root treated teeth that need additional retention, and the use of the adequate post surface treatment to improve the post retention should be a clinical challenge. The use of 24% HP appeared as a very promising post surface treatment for this strategy.

Considering the methodology applied and the limitations of this *in vitro* study, it can be concluded that the use of treatment surface on fiber post is important to improve the post-cement-dentin interaction. The application of 24% HP enhanced significantly the interfacial bond strength between fiber posts and root dentin. Additionally, bond strength to root was significantly higher in the cervical region than in middle and apical regions, irrespective of post surface treatment with the use of a self-adhesive resin cement.

Resumo

Este estudo avaliou a influência de tratamentos de superfície de pinos de fibra de vidro na resistência de união à dentina radicular por meio do teste de push-out. Quarenta raízes de incisivos bovinos foram submetidas a tratamento endodôntico. A superfície dos pinos de fibra de vidro (Exacto #2, Angelus) foram tratadas com 4 protocolos diferentes (n=10): Controle - 70 % de etanol durante 1 min; 37 % de ácido fosfórico durante 1 min, 10% de ácido fluorídrico durante 1 min e 24 % de peróxido de hidrogênio durante 1 min. Depois foi aplicado agente de união silano por 1 min e todos os pinos foram cimentados com cimento resinoso auto-adesivo (RelyX Unicem, 3M- ESPE). As raízes foram seccionadas e foram obtidas duas fatias de 1 mm de espessura em cada terço: cervical, médio e apical. Os espécimes foram submetidos ao teste de push-out com uma velocidade de 0.5 mm/min. Os dados foram analisados pelo teste ANOVA com medidas repetidas, seguido pelo teste de Tukey HSD (α=0,05). Os fatores tratamento de superfície ($p<0,001$) e região do terço radicular ($p=0,007$) foram significantes; no entanto, a interação entre os dois fatores não foi significante ($p=0,827$). A retenção ao canal radicular foi afetada pelo tipo de tratamento de superfície. O tratamento de superfície com 24% de peróxido de hidrogênio por 1 min rendeu significativamente maior resistência de união quando os pinos de fibra de vidro foram cimentados com RelyX Unicem.

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CAPÍTULOS

3.2 CAPÍTULO 2

Artigo a ser enviado para publicação no periódico Journal of Dental Research

Patient specific finite element analysis of fiber post and ferrule design

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Patient specific finite element analysis of fiber post and ferrule design

Abstract

Biomechanical effect of ferrule on anterior endodontic treated teeth has been evaluated using clinical trials, in vitro tests and finite element analysis. No studies have been performed using patient specific model with real no-uniform ferrule and no-linear antagonist biting load with clinical validation. Patient with both upper central incisors with different ferrule design that received endodontic treatment and restoration using fiber post, composite core and CAD-CAM di-silicate ceramic crowns, was selected. The bite force was measured for each central incisor and for both incisors. Strain-gauge was attached on buccal surface of both teeth to record tooth strain during bite force recording. A cone beam tomography was used to scan the teeth and the projection data were exported using the DICOM files for Mimics and 3-Matic (Materialise) and Patran (MSC) softwares for finite element patient specific model generation of the anterior maxilla with both central incisor and mandibular incisors. The bite loading was simulated in 3 methods: M1, nodal point load using individual force clinically measured (55N for right incisor; 100N for left incisor); M2, nodal load using the force measure for both teeth (155N); M3, non-linear contact load by the antagonist teeth (155N). The mechanical properties were obtained from the literature. Modified von Mises equivalent stress was used for stress evaluation. Stresses on left incisor, which had no-uniform ferrule were higher compared with the right incisor, regardless of the loading method. The bone level influence the stress distribution, higher bone limit to cavosurface preparation resulted in higher stress concentration. The stress in the roots and fiber posts for M1 and M2 models were higher than those for M3 model. Simulate loading using antagonist result in lower stresses, being more realistic compared with clinical success of fiber post. The maintenance of uniform ferrule was more relevant than localized higher ferrule.

1. Introduction

The restoration of severely damaged, endodontically treated teeth commonly requires post and core restorations for retention purposes (Bateman *et al.,* 2003; Silva *et al.,* 2010). The correct choice of the post system used for teeth rehabilitation and the ferrule effect are crucial for treatment prognosis (Stankiewicz and Wilson, 2002). Fiber posts have been used clinically as an alternative to metal posts in the restoration of endodontically treated teeth (Ferrari *et al.,* 2007; Goracci and Ferrari, 2011; Soares *et al.,* 2012). The amount of coronal and root dentin remains after root canal instrumentation and post space preparation are correlated with the fracture resistance and plays an important role in the longevity of the tooth and restoration (Ichim *et al.,* 2006; Silva *et al.,* 2010, Veríssimo *et al.,* 2014). A recent meta-analysis suggested that coronal wall absence might increase the risk of fiber post-core restoration failure, while the role of ferrule effect is still not entirely understood (Yang *et al.,* 2015). Others studies reported that the presence of uniform ferrule surrounding remaining tooth structure enhanced fracture resistance and increase the long term success of post-endodontic of anterior teeth (Silva *et al.,* 2010; Soares *et al.,* 2012).

Numerous finite element studies have linked the ferrule effect on biomechanics behavior of anterior endodontic treated teeth with various factors such as remaining dentin thickness (Coelho *et al.,* 2009; Santos Filho *et al.,* 2014), different ferrule height and configuration (Ichim *et al.,* 2006; Roscoe *et al.,* 2013; Juloski *et al.,* 2014; Zhang *et al.,* 2015). However all these studies have used the FEA models are created using general data of the anterior teeth, with the standardization of the ferrule design to isolate the effect of the specific factor. Other simplification on finite element analysis of fiber post is the nodal static load or time dependent gradually increased load application (Roscoe *et al.,* 2013; Juloski *et al.,* 2014).

Nowadays, computed tomographic scan data, allows the efficient generation of sophisticated 3D models (Xin *et al.,* 2013; Pessoa *et al.,* 2014). Those models can address a wider range of questions than earlier models. Using standard triangle language (STL) and identification of the tooth structure remaining and restorative materials by radiodensity levels produce more realist models with specific conditions of the patients (Pessoa *et al.,* 2014). Some conditions are inherently nonlinear, such as nonlinear material responses (e.g., rate-dependent properties or viscoelasticity, plastic deformation), time-dependent boundary conditions, load application or geometric instabilities

(Adams and Askenazi, 1999; Soares *et al.,* 2012). Nonlinear solutions require more computational interactions to converge to a final solution, being more costly in terms of computation and time. However, the nonlinear FEA is more powerful tool to predict stress within structures in comparison with conventional linear static models (Soares *et al.,* 2012). No FEA studies of endodontic treated teeth restored with fiber post have been performed yet, on the author's knowledge, using patient specific model that represent real no-uniform ferrule presence and nonlinear antagonist bite load application and followed by clinical validation.

Use of strain-gauge methods for finite element analysis validation on in vitro studies is usual and determines more accuracy on two-way (Bicalho *et al.* 2014, Santos Filho *et al.,* 2014). Patient validation has been nowadays used to reproduce clinical conditions on finite element validation (Juloski *et al.,* 2014). The validation and data correlation of FEA patient specific analysis might represent a powerful strategy for combination of clinical trials and finite element analysis to predict the clinical failures. Therefore the aim of this study was to develop protocol and validate the generation of three-dimensional patient specific model of anterior central incisors with different ferrule design restored with glass fiber post and CAD-CAM all-ceramic restoration using cone-beam computed tomography and specific software combination for finite elements analysis.

2. Materials and Methods

2.1. Patient rehabilitation

The subject included in this study was recruited from the Dental Hospital from Federal University of Uberlandia. This study had the approval of the Ethic Committee (#144.423/2012). The patient presented two upper central incisors with necessity of periodontal surgery, endodontic treatment and fiber post, composite core and all-ceramic crowns rehabilitation.

After periodontal surgery that recovery biological width, conservative endodontic access was performed and the root canals were instrumented with a size 80 master apical file (K-file; Dentsply, Maillefer, Ballaigues, Switzerland). Canals were rinsed with 1.0% sodium hypochlorite (Cloro Rio 1.0%, São José do Rio Preto, SP, Brazil), physiological saline and filled with gutta percha

(Dentsply, Petrópolis, Rio de Janeiro, Brazil) and calcium hydroxide-based endodontic sealer (Sealer 26, Dentsply) (Valdivia et al., 2012). Root canals were prepared using dedicated drill for conic smooth glass fiber posts (ExactoTranslucido no. 3, Angelus) with 1.0mm on apical and 2.0mm on cervical limit. The posts were immersed in 24% hydrogen peroxide (H_2O_2, Dinâmica, SP, Brazil) followed by silane coupling agent (Silano, Angelus) application for 1 minute (Valdivia et al., 2012). The posts were luted with self-adhesive resin cement (RelyXUnicem 2; 3M ESPE, St Paul, Minn). After 5 minutes, the resin cement was light activated on each surface for 40 seconds with an LED unit (Radii-Cal; SDI, Bayswater, Australia). The coronal tooth remaining was etched using 37% phosphoric acid (Cond AC 37, FGM, Joinville, SC, Brazil) for 15s and the etch-and-rinse 3 steps adhesive system (Scotchbond Multi-Purpose; 3M ESPE) was used, following the manufacturer's instructions.

The composite resin cores were built incrementally using Tetric Ceram composite resin (Ivoclar/Vivadent, Ellwangen, Germany), light activating each increment for 40 seconds using an LED unit (Radii-Cal; SDI). Complete crown coverage preparations featuring 1.5 mm of axial reduction and 6 degrees of axial convergence of the walls were performed with diamond rotary burs (KG Sorensen, Barueri, SP, Brazil). Impression of the tooth preparation was taken using polyvinylsiloxane material (Express™ VPS; 3M ESPE). Lithium di-silicate glass-ceramic CAD/CAM system (e.max IPS CAD, Ivoclar/Vivadent, Ellwangen, Germany) was used for all-ceramic crowns. The internal surfaces of ceramic crowns the restorations were etched with 10% hydrofluoric acid for 20 seconds (Cond AC Porcelana, FGM) followed by silane application for 1 min. Ceramic crowns were luted using self-adhesive resin cement (RelyXUnicem 2, 3M ESPE), light activating after 5 minutes for 40 seconds on each surface using an LED unit (Radii-Cal; SDI).

2.2. Strain and bite force intraoral measurement

For the strain measurements, one strain-gauge (PA-06-060CC-350-LEN; Excel Sensores, Embú, SP, Brazil) was attached on buccal face of the restored teeth. The strain-gauges were attached on the crown facial surfaces parallel to the long axes using adhesive system, and were connected to a data acquisition device (ADS0500IP; Lynx Tecnologia Eletrônica, SP, Brazil). A control specimen was used to compensate for local environment temperature fluctuations due to electrical gauge resistance. Strain data were recorded on a computer that performed the signal transformation and data analysis (AqDados 7.02 and AqAnalysis; Lynx, SP, Brazil). At the same time of strain measurement the bite force in Newtons (N) was measured postoperatively for each restored tooth isolated and both teeth at the same time (Gnatodinamômetro Digital Especial Kratos, Brazil). The load recording was repeated for 5 times and the mean values were: for the right incisor had 55.2 ± 5.1N, for the left incisor had 102.8± 7.3N and for both teeth biting had 155± 9.5N. These biting forces values were used for finite element model input (Fig. 1).

2.3. Cone-Beam images acquisition

After the rehabilitation, the patient was positioned on cone beam tomography (i-CAT GXCB-500™ Imaging Sciences International, Hatfield, Pennsylvania) with the median sagittal plane perpendicular to the horizontal plane, and the occlusal plane parallel to the horizontal plane, was used to scan the samples at a voxel dimension of 0.125 mm. A total of 704 slices was provided with 23 seconds of acquisition and the exposure parameters were 120 kV, 3.0 to 7.0 mA. The projection data were exported using the DICOM (Digital Imaging and Communication in Medicine) file format (Fig. 2).

2.4. 3D Finite element model generation

The images were reconstructed using the methodology explained by Jaecques et al 2004. The different hard tissues visible on the scans were identified using an interactive medical image control system (MIMICS 16.0, Materialise, Leuven, Belgium). Extended visualization and segmentation of the different structures were accomplished based on image density thresholding. Each resulting mask of bone, periodontal ligament, ceramic crown, dentin, resin core, fiber glass post, gutta percha and resin cement were then converted into a 3-D file (STL, bilinear, and interplane interpolation algorithm) using the Mimics STL+ module. Because of the aspect ratio and connectivity of the triangles in the native STLs, these files are inappropriate for use in FEA. Reducing the number of triangles and simultaneously improving the quality of the triangles while maintaining the geometry is automatically achieved with the Remesh component present in Mimics software.

Then, an advanced STL design and meshing software (3-Matic 8.0; Materialise, Leuven, Bélgica) was used to simulate the forms of treatment used in the teeth samples. The treatment of each STL was held separately followed by the merging of all parts in a single STL file called the assembly. The definitive assembly was then remeshed using the 3-matic REMESH component. Self-intersecting curves was maintained and the tolerance variation from the original data will be specified (quality of triangles does not mean tolerance variation from the original data). As in Mimics Remesh, the quality is defined as a measure of triangle height/base ratio so that the file can be imported in the FEA software package without generating errors.

The STL models were imported to MSC.Patran® 2010r2 (MSC.Software, MSC software, Santa Ana, CA, USA) and meshed. Tetrahedral elements were used to ensure smooth contact at the interfaces. The volumetric meshes of bone and all model components were therefore generated based on the optmized surface's standard triangulated language (STL) descriptions (Pessoa et al., 2010). During meshing process of the bone solid model, the entire volume that is contained within the outer bone surface is meshed. This means that the mesh consists of tetrahedral elements located in either cortical or trabecular bone. To discriminate between both tissues, different elastic properties can be assigned, based on the grey values in the CT images (Jaecques et al. 2004, Pessoa et al. 2010). In this way, the information in the CT images may be used not only to extract the patient's bone geometry and but also to assign patient-specific bone mechanical properties. After that, the volumetric meshes were imported in a FEA software package (MSC.Marc/MSC.Mentat, MSC.Software, Santa Ana, CA) for the attribution of material properties to the other model components (i.e. ceramic, composite resin, dentin, resin cement, glass fiber post and periodontal ligament). The values of the Young's modulus and Poisson's ratio for the materials and structures were adopted from the literature and are summarized in Table 1. Glass fiber post was considered as an orthotropic material (Table 2).

For simulating the interface between model components, bonded contact was assumed. In this configuration no relative motion could occur at model components interfaces. The nodes on the base of the bone structure were rigidly fixed in the x, y- and z-directions. Three loading conditions were simulated: M1, nodal point load using individual force clinically measured (55N for right incisor; 100N for left incisor); M2, nodal load using the mean force measure for both teeth (155N); M3, non-linear contact load by the antagonist teeth (155N). The load for M1 and M2, had a coronal-apical direction and an inclination of 135 degrees in relation to the tooth longitudinal axis The analysis and post-processing were performed for each model by means of the MSC.MARC/ Mentat® 2010r3 software (MSC.Software). Stress were analyzed using modified von Mises equivalent stresses, which integrate all stress components into one stress equivalent value. The compressive and tensile strength ratio used to calculate modified von mises stresses are summarized on Table I and Table II.

3. Results

The modified von Mises stress distributions for dentin structure, fiber post and resin cement are summarized on Fig. 3. Since the highest stresses were found in the root dentin and fiber post, the stresses were evaluated in these structures. Stresses on the root dentin and fiber post for left central incisor were higher compared with the right central incisor, regardless of the shape (Fig. 3). The higher stress concentration was located on distal region of left incisor, where was measured smaller ferrule. The bone level influence the stress distribution, higher distance from the bone limit to cavosurface preparation resulted in higher stress concentration (Fig. 3). The stress distributions in the roots and fiber posts for models with individual load for each incisor and mean point load were higher than those of antagonist non-linear loading (Fig. 3).

4. Discussion

The aim of this study was to evaluate the hypothesis that the patient specific finite element analysis of endodontic treated upper incisors with different ferrule design restored with glass fiber post/composite core/CAD-CAM ceramic crown could demonstrate that ferrule uniformity is more important than ferrule height. Additionally was to evaluated that the simulation of loading application using nonlinear contact load of antagonist teeth result in lower stress concentration on root dentin than nodal loading application.

When loads are applied to a structure, structural strains (deformation) and stresses are generated. This is normal, and is how a structure performs its structural function. However if such stresses become excessive and exceed the elastic limit, structural failure may result (Soares *et al.,* 2012). Stresses represent how masticatory forces are transferred through a tooth structure (Versluis and Tantbirojn, 2011). These stresses cannot be measured directly, and for failure in complex structures it is not easy to understand why and when a failure process is initiated, and how we can optimize the strength and longevity of restorative procedures. The relationship between stress and strain is expressed in constitutive equations that may be numerical calculated by using finite element. This study focused on the pre-processing phase of finite element, more specifically on model generation and boundary conditions, represented by loading method simulation. To simulate the masticatory forces, this study used point loads and by means of a simulated opposing incisal of the antagonist tooth. A point load application resulted in high stress concentrations around the loaded nodes, creating unrealistic stress concentrations. (Soares *et al.,* 2012). The point load applications for M1 and M2 used in this study were gradually increased in 10 increments, which represent a more realist simplification than total load applied on point load on just one increment. However, the non-linear contact method, represented by antagonist teeth loading, resulted in lower stress concentration on the root dentin, demonstrating that higher levels of stress concentration observed in several studies maybe are overestimated. (Roscoe *et al.,* 2013; Santos Filho *et al.,* 2014) In reality, a masticatory contact force is likely to be distributed across certain contact areas on lingual surface of the upper anterior teeth. Contact areas move depending on stiffness and thus deformation of both opposing teeth.

The stress analysis confirmed that the ferrule design plays important rule on the stress concentration on glass fiber post and mainly on the root dentin. It was also confirmed that the ferrule uniformity is more important aspect, even if the ferrule has smaller height. The ferrule of right central incisor is much more uniform and has approximately 1.6±0.2mm in height. On the other hand, the ferrule of left central incisor is higher in medial (3.5mm) and decrease drastically to no ferrule on distal (0.3mm). The absence of ferrule on proximal region resulted in higher stress concentration on root dentin and also into the root canal. The most of the in vitro study have simulate the ferrule on buccal and lingual region, however the fracture line observed is always oblique connecting the proximal area at the cavosurface angle with buccal region at the bone support level. This is worse for maxillary central incisors, which are exposed to repeated oblique stresses due to their position in the dental arch (Arunpraditkul *et al.,* 2009). Overall, it appeared that preserving a ferrule is beneficial to increase the fracture resistance of endodontically treated teeth (Zicari *et al.,* 2013; Soares *et al.,* 2012). Based on the results of this study, for clinical trial is recommended to record the ferrule dimension at least on 4 regions: buccal, medial, lingual and distal. With these data is possible to correlate the future failure with more realist effect of ferrule presence and configuration. Other aspect that contribute on the stress concentration on proximal region of right incisor is the thickness of the root dentin on cervical area (1.06mm –right incisor; 1.83- left incisor). The weakened root resulted in high levels of tensile stress inside the root canal (Santos Filho *et al.,* 2014)

The occlusal stability is mandatory factor for longevity of tooth restoration. The use of glass fiber post placed in incisors or canines had a failure rate about three times higher than that of restorations placed in premolars or molars (Naumann *et al.,* 2012; Soares *et al.,* 2012). These findings may be explained by the higher horizontal forces causing tensile stress on anterior teeth, compared with a more perpendicular compressive force vector for posterior teeth (Schmitter *et al.,* 2007, Naumann *et al.,* 2012). The intensity of the stress concentration observed on the root dentin when was simulated different loading intensity on both central incisors, demonstrated that load level related directly to the stress concentration. Based on the results of this study, stable and homogeneously occlusal contact during protrusive masticatory movement result in more homogeneous stress distribution, reducing the failure possibility of anterior endodontic restored teeth.

Other aspect that should be emphasized in this study is the effect of the bone height level on the stress distribution. The small reduction on the bone support observed on right incisor comparing to the left central incisor reflected on higher stress concentration on the root dentin. When anterior teeth is loaded, lower bone support tends to result in tendency of intrusion and normally is coupled with an enhanced flexural tendency, changing the stress distribution, and probably increasing the total displacement. (Roscoe *et al.,* 2013)

The inherent problem with three-dimensional finite element models is that the geometrical input needs to be generated (Cattaneo *et al.,* 2001). The computed tomography scanning method describe in this study was able to generate for the first time the endodontic treated teeth restored with fiber post accurate patient specific models as demonstrated with models for studies that use bone structures and implant studies (Cattaneo *et al.,* 2001; Pessoa *et al.,* 2010, Pessoa *et al.,* 2014). The method developed still requires some manual input especially when applied, as in this case, the materials with very similar radiodensity like fiber post, resin cement, root dentin. This study showed a the association of clinical trials with patient specific finite element analysis that may be used for more powerful biomechanical analysis of endodontic treated teeth restored with fiber post. An in-depth understanding of the biomechanical environment of patient-specific restored tooth can be gained through the use of FEA. This increase in knowledge of stress/strain distributions and magnitudes within a specific rehabilitation systems and surrounding jawbone may give support for the optimization of the restoration designs and protocols of materials usage, as a function of the parameters beneficial to treatment long-term sucess, thereby decreasing the risks of failure. Moreover, the possibility of prediction of failure aspects in a given rehabilitation would allow to antecipate and avoid that it really happen.

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Table I – Mechanical isotropic properties, poisson's ratio, tensile and compressive strength for all Materials.

Mterials/ Structures	Elastic Modulus (MPa)	Poisson's ratio	Tensile Strength (MPa)	Compressive Strength (MPa)	References
Ceramic	96000	0.31	271.0	360.0	Dong et al., 2003
Dentin	18600	0.31	98.7	297.0	Rees et al., 1994
Composite resin	17000	0.28	45.5	277.0	Soares et al., 2013
Periodontal Ligament	50	0.45	-	**a-**	Rees et al., 1994
Gutta Percha	0.69	0.45	-	-	Ko et al., 1992
Cortical Bone	13700	0.30	-	-	Ko el al., 1992
Cancellous Bone	1370	0.30	-	-	Ko el al., 1992
Resin Cement	9100	0.30	-	-	Pereira et al., 2015

Table II. Orthotropic properties, tensile Strength and Compressive Strength of the glass-fiber post.

Properties*	**Glass-fiber post**	**Tensile Strength (MPa)**	**Compressive Strength (MPa)**
EX (MPa)	37000	40	250
EY (MPa)	9500		
EZ (MPa)	9500		
ηXY	0.34		
ηYZ	0.27		
ηXZ	0.34		
Gxy (MPa)	3544.8		
Gxz (MPa)	1456.7		
Gxz (MPa)	3544.8		

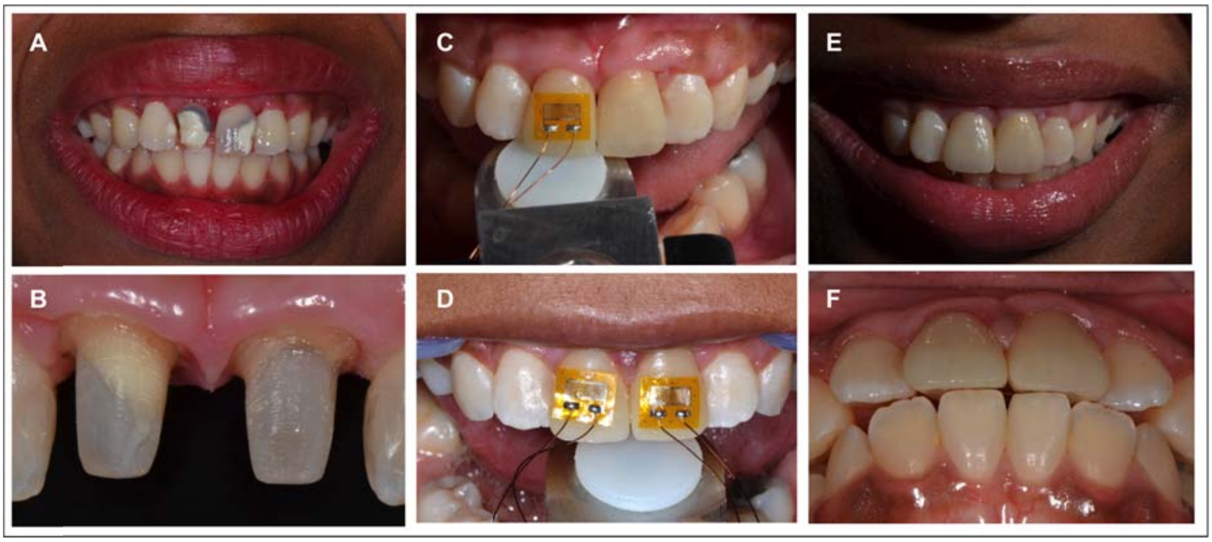
*Veríssimo et al. 2014.

Figure Legends

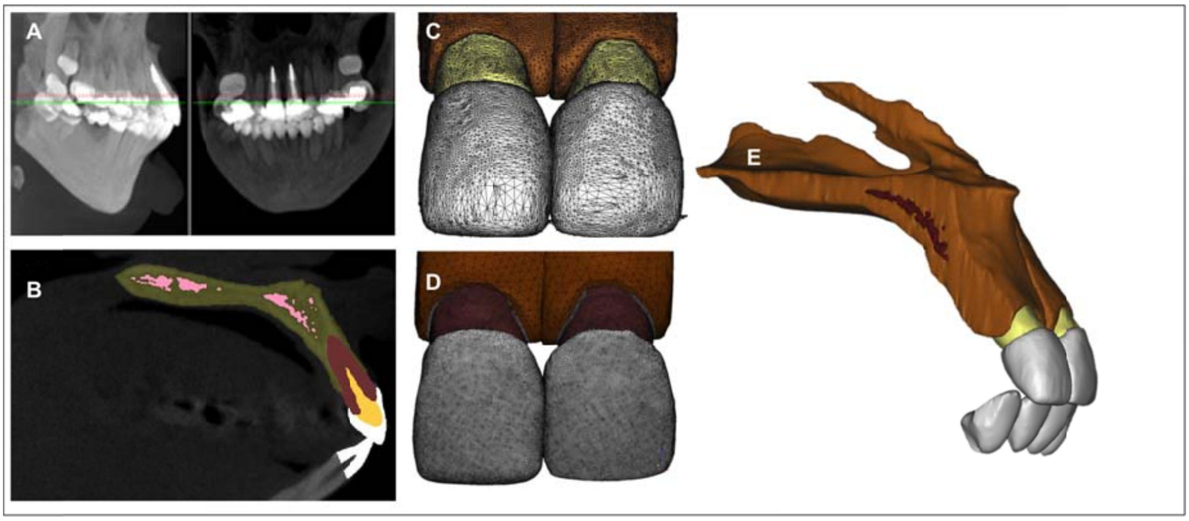
Figure 1. Rehabilitated patient; A. initial conditions of several dental structure loss; B. tooth preparation of glass fiber post/composite core; C. strain-gauge measurement and bite force recording for isolated tooth; D. strain-gauge measurement and bite force recording for both teeth together; E. Final rehabilitation; F. Initial contact of antagonist teeth during protrusive jaw movement.

Figure 2. Finite element model generation; A. cone beam computerized tomography; B. structures and materials segmentation on Mimics software; C. STL. mesh with no organized triangles; D. final mesh created on 3-Matic and Patran softwares; E. Final patient specific model.

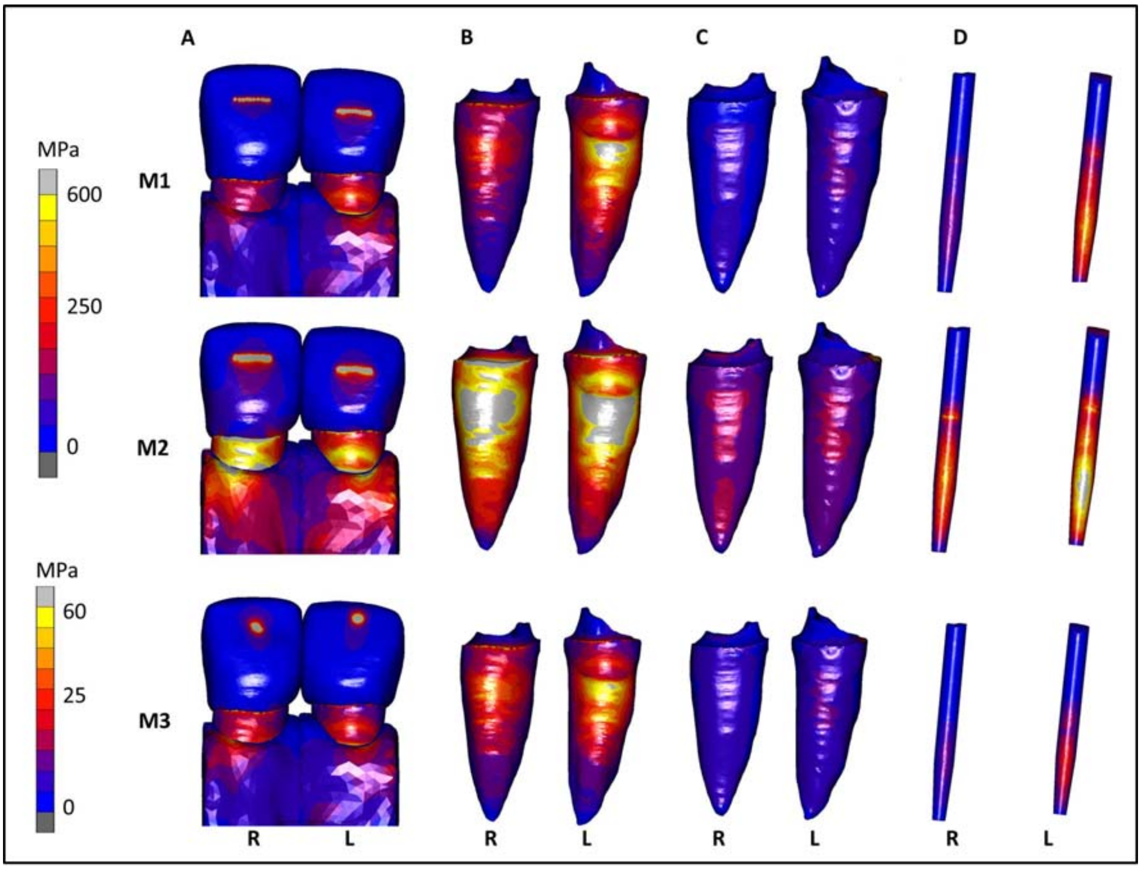
Figure 3. Modified von Mises stress results; M1. Individualized tooth level load by point load application model; M2. Mean of both teeth load by point load application model Mean bite load; M3. Antagonist load application model; A. Crown contact stress concentration; B. Stress distribution on lingual surface of root dentin; C. Stress distribution on buccal surface of root dentin; D. Stress distribution on glass fiber post.



Initial conditions of several dental structure loss; B. tooth preparation of glass fiber post/composite core; C. strain-gauge measurement and bite force recording for isolated tooth; D. strain-gauge measurement and bite force recording for both teeth together; E. Final rehabilitation; F. Initial contact of antagonist teeth during protrusive jaw movement.



Cone beam computerized tomography; B. structures and materials segmentation on Mimics software; C. STL. mesh with no organized triangles; D. final mesh created on 3-Matic and Patran softwares; E. Final patient specific model.



M1. Individualized tooth level load by point load application model; M2. Mean of both teeth load by point load application model Mean bite load; M3. Antagonist load application model; A. Crown contact stress concentration; B. Stress distribution on lingual surface of root dentin; C. Stress distribution on bucal surfaces of root dentin; D. Stress distribution on glass fiber post (R:Right Incisor; L: Left Incisor).

CAPÍTULOS

3.3 CAPÍTULO 3

Artigo a ser enviado para publicação no periódico Journal of Dentistry

Title: Biomechanical effect of ferrule presence on incisor teeth restored with fiberglass post and CAD/CAM ceramic crown after thermal cycling and fatigue loading.

Short title: Biomechanical behavior of endodontic treated teeth

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Biomechanical effect of ferrule presence on incisor teeth restored with fiberglass post and CAD/CAM ceramic crown after thermal cycling and fatigue loading.

ABSTRACT

Objectives. To evaluate the biomechanics of endodontically treated incisors restored with fiberglass post and CAD-CAM ceramic crown with and without ferrule after thermal and mechanical aging.

Methods. Twenty bovine incisors were divided into two groups (n=10): Fe, with ferrule of 2 mm and NFe, without ferrule. The teeth were endodontic treated and restored with fiberglass post (Exacto 3), composite core (Tetric Ceram), and CAD-CAM lithium disilicate ceramic crown (IPS e.max CAD). The specimens were subjected to 20,000 thermo-cycles and 2,400,000 simulated chewing cycles. Ceramic crown and root dentin strains (μS) were measured using strain-gauges (n=10) during 100N loading before and after thermal and mechanical aging, and at fracture load. Specimens were subsequently loaded to fracture (N). Stress distribution was analyzed using 3D finite element models created by micro-CT (n=3). Strain data were analyzed by two-way ANOVA and Tukey HSD tests, fracture resistance was analyzed using *t*-Student and fracture mode using Chi-square test (α=0.05).

Results. After aging NFe had higher root dentin deformation than Fe. Fe had higher fracture resistance than NFe. Fe had fracture involving ceramic crown or associated with core. NFe had more root dentin fracture and post debonding. The NFe had lower ration fracture resistance/root strain than Fe. The stress levels on root dentin and fiberglass were lower for Fe.

Conclusions. Fe prevented the post detaching maintain the root dentin strain after thermal-mechanical aging. The NFe increased root dentin strain after aging process. Fe had higher fracture resistance, lower stress concentration on root dentin and less catastrophic fractures.

Clinical Significance. Tooth structure remaining of endodontically treated teeth, expressed by ferrule presence, preserve the integrity between restorative procedures and root dentin reducing the strain values and increasing the fracture resistance. Ferrule presence is crucial for a favorable prognosis of endodontically treated teeth.

Keywords. Fiber post, ferrule, ceramic, strain-gauge test, fracture resistance, finite element analysis, thermal cycling, fatigue.

1. **Introduction**

Endodontically treated teeth commonly requires post and core restorations for retention purposes.[1,2] Posts associated with all ceramic crowns are an option for teeth with a severe loss of coronal structure.[3] Several materials and techniques had been advocated for restoring endodontic treated teeth; for example lithium disilicate crowns CAD/CAM system have shown a good clinical performance.[4] The correct choice of the post system and the ferrule effect are crucial for treatment prognosis.[5] Fiberglass posts have been used clinically as an alternative to metal posts in the restoration of endodontically treated teeth.[6-8] The major advantage of fiberglass posts is their similar elastic modulus to dentin,[9] which may lead to a better distribution of the occlusal loads along the root.[10,11] Failures in post-retained crowns generally occur in the maxillary anterior region, where horizontal forces are greater than in other areas.[12]

The amount of coronal and root dentin remains after root canal instrumentation and post space preparation correlated with the fracture resistance and plays an important role in the biomechanical behavior of endodontic treated teeth restored with fiber post.[2,3] A recent meta-analysis suggested that coronal wall absence might increase the risk of fiber post-core restoration failure, while the role of ferrule effect is still not entirely understood.[13] Others studies reported that the presence of uniform ferrule surrounding remaining tooth structure enhanced fracture resistance and increase the fracture resistance,[2] and increase the long term success of post-endodontic of anterior teeth.[8]

Failure of endodontic restored teeth is result of the interaction between multiple mechanical properties and interactions between restorative materials.[14] To evaluate biomechanical behavior and the failure process of restored endodontically treated teeth, destructive mechanical tests serve as important means of analyzing of the tooth under high-intensity loads. [11]

However, this method does not provide enough information about the internal structural behavior of the complex tooth restoration against loading. Therefore, it is necessary to combine nondestructive methods such as the strain gauge methods for complete biomechanical analysis.[2,3,11,15] The strain measured during the nondestructive tests in this study can be regarded as an indication of the repetitive deformation that roots undergo during functioning, resulting in such structural fatigue.[16] To approximate the in vitro test to the clinical failures of restores tooth the artificial aging, of specimens using cyclic mechanical loading and thermal cycling represent the ideal in vitro design for a study reproducing the physiological functions of the oral environment.[17] Generally, the artificial aging of dental materials is indicated because it accelerates the degradation process, which causes a significant decrease in the mechanical properties.[18,19]

The aim of this study was to evaluate the strain before and after thermo-mechanical fatigue aging, the fracture resistance and fracture mode of endodontically treated incisors restored using a fiberglass post and CAD/CAM all ceramic crown with and without ferrule. The null hypothesis tested was that biomechanical behavior would not be affected by the amount of remaining coronal dentin.

2. Materials and Methods

2.1. Specimen Preparation

Twenty bovine incisors were selected for this study. The selected incisors had similar dimensions (coronal volume within 10% of the average), roots without curvature, were free of cracks or defects. All external debris was removed with a hand scaler, and the teeth were stored in distilled water at 37°C. The anatomic crowns of all teeth were sectioned perpendicular to the long axis, using a water-cooled diamond disk (no. 7020; KG Sorensen, Barueri, São Paulo, Brazil), up to 15.0 mm from the apical limit in the specimens with ferrule (n=10; Fe group, Fig.1A), and up to 13.0 mm from the apical limit in the specimens without ferrule (n=10; NFe group, Fig.1B). The mean dimensions of bovine roots was similar to human maxillary central incisors.[2] The dimension Root canals were instrumented to the full extension using no. 2 and 3 Gates-

Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland). A no. 4 Gates-Glidden drill (Dentsply Malleifer) was used in the cervical and middle thirds of the root canal. Canals were rinsed with 1.0% sodium hypochlorite (Miyako do Brasil, Guarulhos, São Paulo, Brazil) and physiological saline (Avante Pharma, Belo Horizonte, Minas Gerais, Brazil), dried with paper points, and obturated with gutta-percha (Dentsply) and calcium hydroxide-based cement (Sealer 26, Dentsply).[20] The specimens of the Fe group were prepared with a diamond rotary cutting instrument (no. 3215; KG Sorensen, Barueri, SP, Brazil) creating a 2.0-mm-high circular ferrule with rounded cervical ending. Post space was obtained initially with a heated instrument (M-Series Hand Pluggers; Dentsply Maillefer), and the residual gutta-percha was then removed with Gates-Glidden drills, standardizing the post space at 8.0 mm for the group without ferrule and 10.0 mm for the group with ferrule, preserving 5.0 mm of gutta-percha at the apex. Next, root canals were enlarged with a 1.0- to 1.6-mm-diameter conical drill (Exacto drill no. 3, Angelus Science and Technology, Londrina, Paraná, Brazil) to 8.0 mm for the group with no ferrule and 10.0 mm for the group with ferrule, generating standardized post space for the fiberglass post.[2]

The roots were embedded in polystyrene resin (AM 190 resin; AeroJet, Santo Amaro, São Paulo, Brazil). Roots with no ferrule were embedded 2.0 mm below, and roots with ferrule, 4.0 mm below the cervical limit. The periodontal ligament was simulated using polyether impression material (Impregum Soft; 3M ESPE, St. Paul, Minn, USA). [21] To accomplish this, root surfaces were dipped into molten wax up to 2.0 mm apically from the cervical limit for groups without a ferrule and 4.0 mm for groups with a ferrule. The resulting wax layer was 0.2 to 0.3 mm thick. A radiographic film with a centralized circular opening (IBF, Rio de Janeiro, Rio de Janeiro, Brazil) was used to stabilize the teeth for the embedding procedure. The roots were placed with the cervical limit facing down into the opening in a wooden board, leaving the root in a vertical position perpendicular to the supporting radiographic film. Then, a plastic cylinder (PVC; Tigre, Joinville, Santa Catarina, Brazil), 20.0 mm in height and 22.0 mm in diameter, was placed over the root and fixed in position with cyanoacrylate resin adhesive (Super Bonder; Loctite, Itapeví, Sao Paulo, Brazil) and wax. The self-curing polystyrene resin (AM 190 resin; AeroJet, Piracicava, SP, Brazil) was manipulated according to manufacturer’s instructions and inserted into the cylinder. After polystyrene resin polymerization, the roots were removed from the cylinder, and the wax was removed from both the root surface and cylinder. Impression material (Impregum Soft; 3M ESPE) was placed into the resin cylinders, the roots were reinserted, and the excess polyether material was removed with a scalpel blade.[15]

2.2.Post and core and crown fabrication

Prefabricated fiberglass posts (Exacto Translucido No. 3; Angelus, Londrina, Brazil) with 1.4-mm and 0.9-mm diameters in the coronal and apical portions, respectively, were cleaned with a 70% alcohol solution (Miyako do Brasil) then, the post were immersed in 24% hydrogen peroxide (H2O2, Dinâmica, SP, Brasil) for 1 minute followed by rising and drying.[15] Afterwards, the one-bottle silane coupling agent (Silano; Angelus Science and Technology) was applied for 1 minute.

For post cementation, post spaces were rinsed with 0.9% saline solution (Indústria Farmacêutica Basa, Caxias do Sul, RS, Brazil), and dried with paper points (Denstply). All posts were cemented with self-adhesive resin cement (RelyX U200; 3M ESPE) and was manipulated according to manufacturer's instructions, introduced into the canal The cementation process was standardized with a 500-g load applied to the specimens for 5 minutes and at every luting step.[2] Excess cement was removed after 1 minute. After 5 minutes,[22] the resin cement was light polymerized on each surface of the specimens (buccal, palatal, incisal) for 40 seconds with 1200 mW cm^{-2} (Radii-Cal; SDI, Bayswater, Australia).[15] Composite core was fabricated using 2-mm increments of composite resin (Tetric Ceram, Ivoclar Vivadent, Liechtenstein) in association with etch-and-rising adhesive system (Scotchbond Multi-Purpose, 3M-ESPE). Each increment was light activated for 40 seconds with LED curing unit. All ceramic crown preparations featuring 1.5 mm of axial reduction and 6 degrees of axial convergence of the walls were performed with a tapered rounded-end diamond rotary cutting instrument (no. 4138; KG Sorensen). Diamond cutting instruments were discarded after every fifth preparation. Cavity preparations were finished with an extra-fine-grit diamond rotary cutting instrument (No. 3145FF; KG Sorensen).

Specimens were restored with CAD-CAM all ceramic crowns. Each sample was scanning using the CEREC 3D software (Sirona Dental Systems, Bensheim, Germany) and milled out of lithium disilicate glass ceramic block (IPS e.max CAD, size I12, Ivoclar Vivadent) according to the manufacturer's instructions. The internal restoration surface was etched with 10% hydrofluoric acid (Condac Porcelana, FGM, Joinville, SC, Brazil) for 20 seconds followed by rising and drying. The silane agent (Silano, Ângelus, Londrina, Paraná, Brazil) was then applied for 1 minute. [23] Ceramic crowns were cemented using self-adhesive resin cement (RelyX U200; 3M ESPE) following the same protocol described for post fixation.

2.3. Strain measurement test

The specimens were submitted to the strain-gauge test before and after artificial aging. To measure the tooth deformation, 2 strain gauges with grade of 1mmX1mm (PA-06-038AA-120-LEN; Excel Sensores, Embú, São Paulo, Brazil) were placed to the root surface 2.0mm below the crown limit, one satin-gauge was placed on the buccal surface (Fig. 1C), parallel to the long axis, and the other on the lingual surface (Fig. 1D).[11] One strain gauge with grade of 4mmX2mm (PA-06-060CC-350-LEN; Excel Sensores) was attached to the buccal surface of the ceramic crown (Fig. 1C). The strain gauges were bonded with a cyanoacrylate resin adhesive (Super Bonder; Loctite) and connected to a data acquisition device (ADS0500IP; Lynx, São Paulo, São Paulo, Brazil). In addition, a control specimen, with 3 strain gauges attached but not subjected to loading, was mounted adjacent to the tested tooth to compensate for temperature fluctuations due to gauge electrical resistance or local environment.[2,3,11]

The specimens with strain gauges were subjected to a nondestructive ramp-load from 0 to 100 N using a mechanical testing machine (EMIC DL2000; EMIC, São José dos Pinhais, Paraná, Brazil) before and after artificial aging. The load was applied using 0.5 mm/min crosshead speed at 45-degree angle the long axis of the tooth (Fig. 1E).[2,11] Data were recorded on a computer that performed the signal transformation and data analysis (AqDados 7.02 and AqAnalysis; Lynx).

2.4. Thermocycling and Fatigue loading

Thermal variations were induced in a thermal cycling machine (Thermo-cycler, Willytech, Munich, Germany) between two water baths of 5 ^{o}C and 55 ^{o}C with a dwell time of 30 seconds each temperature. All specimens were subjected during 20,000 cycles. After first 10,000 thermal aging cycles, the specimens were submitted to a fatigue load of 1,200,000. Then more 10,000 thermal aging cycles and 2,400,000 cycles were performed. The fatigue loading was performed under water irrigation using a chewing simulator with sliding movement (Willytech, Munich, Germany), simulating 10 years of clinical function.[24] Load was applied at 45^{o} at a frequency of 1.6 Hz. A sinusoidal load of 0-50N was applied with stainless-steel ball-shaped stylus in the lingual surface of the ceramic crown (Fig. 1F).[25,26] Failures under fatigue loading were recording during test by integrated LVDT displacement sensors, which able to detect displacement of 100µm and connected to a PC-software.

2.5. Strain during fracture procedure (CSt-Fr), fracture resistance and fracture mode

All specimens were loaded to fracture using the same compressive loading design as used during the strain gauge tests. The force required (N) to cause fracture was recorded by a 500-Kn load-cell hardwired to software (TESC; EMIC), which detected any sudden load drop in its load-cell during the compression tests. Strains were also recorded at failure load (St-Fr) (Fig. 1G).
The fracture mode of each specimen was assigned to one of five categories: (I) post debonding without ceramic crown or root dentin fracture; (II) cohesive fracture of ceramic crown only; (III) cohesive fracture of ceramic crown with core involved; (IV) fracture with root involvement in cervical third that can be restored in association with periodontal surgery; (V) root fracture in the middle or apical third, which require extraction of the tooth. The samples were evaluated after fracture resistance test for crack presence, helping to determine the fracture mode (29). The images of the sample were captured at ×1.5 magnification under standardized conditions (Nikon D60 and Nikkor 105 mm macro lens, Chiyoda, Tokyo, Japan) using transillumination LED light (Photonita, P1050, Florianópolis, SC, Brazil), with the optic fiber illuminator positioned on the incisal surface of the tooth. Fractured specimens were mounted on aluminum stubs,

sputter coated with gold (Bal-Tec SCD 050; Balzers, Liechtenstein) and examined under a scanning electron microscope (EVO MA 10, CARL ZEIZ, Germany). SEM images were obtained at different magnifications to illustrate the failure modes.

2.6. *Residual stress calculation-finite element analysis*

The 3D finite element models were generated using 3 samples randomly selected for each group (Fe and NFe). The samples were scanned micro-CT (Model 1172, Brucker Skyscan, Kontich, Belgium).[27] The equipment was adjusted to scan the whole tooth, with a beam accelerating voltage of 100kV, X-ray beam current of 100μ□A, filter material Al+Cu, image pixe size of 10μm, resolution of 2000 x 1048, rotation step of 0.7^{o} obtaining 4 frames, which resulted in 2340 slices. Using NRecon® software were selected 780 slices tooth structure, applying artifact correction parameters of Smoothing 2 and ring 5.

The DICOM files obtained of MicroCT were identified using an interactive medical image control system (MIMICS 16.0, Materialise, Leuven, Belgium). The segmentation of the dental structures and restorative materials were accomplished based on the image density thresholding. The masks of dentin, resin cement, gutta-percha, fiberglass post, composite resin and ceramic were converted into a 3-D file (STL, bilinear, and interplane interpolation algorithm) using the Mimics STL. The aspect ratio and connectivity of the triangles in the native STLs resulted in an inappropriate model for FEA use. Therefore, the remesh component present in Mimics software was carried out to reduce the number of triangles and simultaneously improve the quality of the triangles while maintaining the geometry. In addition, an advanced STL design and meshing software (3-Matic 8.0; Materialise, Leuven, Bélgica) was used to create the resin cylinder and simulated periodontal ligament. The treatment of each STL was held separately followed by the merging of all parts in a single STL file called assembly. The final assembly was then re-meshed using the 3-matic REMESH component. Self-intersecting curves were maintained and the tolerance variation from the original data was specified (quality of triangles does not mean tolerance variation from the original data). As in Mimics Remesh the quality is defined as a measure of triangle height/base ratio so that the file can be imported in the FEA software package without producing errors.

As a specific approach for better model generation, the STL models were imported to MSC.Patran® 2010r2 (MSC.Software, MSC software, Santa Ana, CA, USA) and meshed. Tetrahedral elements were used to ensure smooth contact at all the models interfaces. The volumetric meshes of all models components were therefore created based on the optimized surface's standard triangulated language (STL) descriptions. After that, meshes were imported in a FEA software package (MSC.Marc/MSC.Mentat, MSC.Software, Santa Ana, CA) for the attribution of material properties to the other model components (i.e. bone, periodontal ligament, enamel, dentin, resin cement, gutta-percha, fiberglass post and resin composite). The elastic moduli of the restorative materials and dental structure are shown in Table 1 and Table 2. To simulate the interface among model components, precisely bonded contacts were held. The nodes on the base of the bone model structure were rigidly fixed in the x, y- and z-directions, to simulate the experimental set-up test. The loading conditions were simulated with nodal point load using individual force experimentally tested (100N applied at 45^o on lingual surface of the crown). The load application had a coronal-apical direction in relation to the tooth longitudinal axis. The assessment and post-processing were performed for each model using equivalent von Mises stresses by means of the MSC.MARC/ Mentat® 2010r3 software (MSC.Software).

3. Results

3.1. Fatigue loading

Only one NFe specimen failed during fatigue loading because of post debonding after 1,200,000 cycles. All the other specimens survived after 2,400,000 fatigue cycles.

3.2. Tooth structure and ceramic strain

The values of ceramic crown, buccal root surface and lingual root surface strains (µS) during the simulation of 100N loading before and after are shown in Table 3. The ceramic crown had lower deformation than root dentin irrespective of ferrule presence. For ceramic crown deformation, no difference was found between FE and NFE groups irrespective of aging presence. The buccal root dentin had higher deformation than lingual root dentin, irrespective of ferrule and aging presence. The NFe group had similar root dentin deformation than Fe group before aging, however after aging NFe group had higher root dentin deformation than Fe group, irrespective of dentin location. The aging process had no effect on root dentin strain for Fe group, irrespective of dentin location. However, The aging process increased significantly the root dentin strain for NFe group, irrespective of dentin location.

The values of ceramic crown, buccal root surface and lingual root surface strains (μS) and at the maximum fracture loading are shown in Table 4. The ceramic crown had lower deformation than root dentin irrespective of ferrule presence. The dentin deformation on buccal surface was always higher than on lingual surface. For ceramic crown deformation, no difference was found between FE and NFE. The NFe group had similar root buccal dentin deformation than Fe group. However the Fe had higher root lingual dentin deformation than NFe group.

3.3. Fracture resistance

The mean fracture resistance (N) and standard deviation values are shown in Table 5. Test t-Student showed that Fe had higher resistance to fracture than NFe.

Fracture mode distribution is presented in Table 5. Chi-square test showed significant difference between Fe and NFe ($P = 0.004$). Fe group tend to produce fracture involving ceramic crown isolate or with core fracture. NFe had more fracture involving root dentin and post debonding. Typical fracture modes for Fe and NFe obtained with transillumination method are shown on (Fig. 2). SEM analyses showed that ceramic crown fractures (Fig. 3A) and composite resin core fractures (Fig. 3B) are always accompanied by crown dentin detaching. The fracture involving cervical dentin demonstrated that dentin continued to be adhered to ceramic crown, and are located on the cervical third of the root (Fig. 3C). SEM images of post-detached samples demonstrated several amount of the bubbles and voids on the resin cement (Fig 3D).

The ratio between the maximum resistance and root dentin deformation at fracture moment is shown in Table 5. The NFe had lower ration fracture resistance/root strain than Fe groups ($P < 0.001$).

3.4. Finite element analysis

The von Mises stress distributions are summarized on Fig. 4, 5 and 6. The stress level on ceramic crown surface was lower than on root dentin and similar for all models (Fig. 4). The higher stress concentration was located on external surface of the root dentin (Fig. 5). The stress located on lingual root dentin surface was higher than on buccal root dentin. The higher stress concentration is located at the root dentin on NFe group interface with ceramic crown and composite core (Fig. 6). The stress distribution by Maximum Principal Stress for both groups are shown on Figure 7.

4. Discussion

The aim of this study was to evaluate the hypothesis that the presence of ferrule on anterior endodontic treated incisor restored with glass fiber post/composite core/CAD-CAM ceramic crown influence the biomechanical performance, expressed by crown and root dentin strains, fracture resistance, fracture mode and stress distribution. The results of the present study confirmed that the presence of ferrule maintain the integrity among restorative materials and root dentin with no increasing of root deformation after aging, reduced the stress concentration at root dentin, increased the fracture resistance and reduced the root fracture of endodontically treated incisors restored using a fiberglass post. Therefore the null hypothesis was rejected.

This study used bovine incisors instead human incisors. Bovine dentin is often used for in vitro tests, and is generally considered similar to human dentin in composition, properties and geometric root configuration.[28,29] The higher availability of bovine teeth made it possible to standardize the sample size and shape.[11,20] Standardization was essential for obtaining comparable results because deformation and fracture load depend on geometry. The dimensions and geometry of the selected bovine root dentin had similar dimensions of upper human incisor teeth. In this investigation, a force of 100 N was chosen for chewing simulation on tooth remaining strain and stress analysis because physiological biting forces during eating were found to be between 20 and 160 N. [30,31] The periodontal ligament with elastomeric material and embedment of the root using polystyrene resin with similar elastic modulus to bone tissue determined more similarity between in vitro experiment design and oral environment. [31] The combination of the methodologies using destructive and nondestructive methods on the same sample, like strain-gauge measurement and fracture resistance and fracture mode analysis permit the sequential understanding of the failure process. Measuring the deformation before fracture may contribute to a better understanding of the entire fracture process, from initiation to ultimate rupture. [16] However, stress is not possible to determine experimentally, being necessary to use the finite element analysis with simulation parameters in more realistic conditions. [32]

During oral function, teeth are subjected to dynamic masticatory and thermal loading. This subcritical loading may lead to a slow process of incremental structural degradation, often referred to as “fatigue”.[33] In this study, the specimens were subjected to 20,000 thermal cycles and 2,400,000 mechanical cycles to simulate a 10-year clinical service prior to the tests for the purpose of aging the samples.[15,24-26,34,35] Only one no ferrule group specimen failed during fatigue loading because of post debonding after 1,200,000 cycles, this kind of failure is the most common clinical failure in patients [8]. However, these are easily solved with a new cementation, prolonging the function for a long time.[6,8]

The current results show that the strain gauges attached to the buccal and palatal surfaces could detect differences between groups.[2,15] It has been demonstrated that when a single-root tooth is subjected to load applied to the long axis of the tooth, the greatest compressive and tensile stress occur at the lingual or buccal root surface of the coronal third of the root. [36,37] The strain values obtained in this study before and after aging demonstrated that ferrule presence is important for stress/strain transferring from the crown to the root dentin. The absence of ferrule increased significantly the strain values after aging, however when the ferrule is presented the strain values continue stable.

Measuring the deformation preceding fracture may contribute to a better understanding of the entire fracture process, from initiation to ultimate rupture. The strain gauges were attached near sites where fractures were expected to start.[2,15] Ceramics have high elastic moduli and low strain capacity, therefore, they tend to concentrate stress inside the body of the restoration.[38] The stiffness of the lithium glass ceramic may explain the lower strain values observed on buccal surface of the crown. Additionally the finite element models demonstrated that the stress concentration on the labial surface of the loaded incisor is insignificant when compared with the stress located on inner surface and at the proximal surface. For future studies, the position of the strain gauge on ceramic crown should be guided by stress analysis This finding may explain the higher fracture modes for Fe group, since the load for fracture this group was higher and the stress cannot be relieved by deformation,[39] material fracture occurs before stresses could be transferred to the tooth.

The failure for fracture is a direct consequence of the stress and strain magnitude and distribution. The teeth with no ferrule resulted in significantly lower fracture resistance than teeth with ferrule. The absence of ferrule increase stress at the root dentin/resin cement/fiberglass post interfaces. Theoretically, the initial interface debonding occurs when either the normal stress exceeds the tensile strength or the tangential stress overtakes the shear bond strength. [40] The fiberglass post are involved typically with this condition, and if the post detaching, while remaining in the root canal, the risk-of-fracture index in the root increase significantly. [41] Consequently the root dentin strain increased after thermal and mechanical aging, probably because the interfaces between restorative materials and root dentin presented detaching. Therefore the lower fracture resistance of the teeth without ferrule is a consequence of the both aspects, more root dentin stress and strain and more detaching sites on the interfaces. Similar results were observed for several other studies,[2,3,11,14,42] however the present study demonstrate clearly, using thermal mechanical aging process in association with strain-gauge test that demonstrate root dentin strain and specific finite element models that expressed the stress distribution, the principles that ferrule play to protect the endodontic treated teeth restored with fiberglass post. The limitations of this study include the in vitro conditions, which could not completely replicate clinical conditions. Clinical studies analyzing the dimension e configuration of ferrule in anterior teeth are important to confirm the present study results.

5. Conclusion

The ferrule presence contributed with the preventing of fiberglass post detaching to root dentin and restorative materials, maintain the same level of the root dentin strain after thermal-mechanical aging. The absence of ferrule resulted in increased level of root dentin strain after aging process. Incisors teeth with 2.0 mm of ferrule restored with CAD/CAM ceramic crown resulted in higher fracture resistance, lower stress concentration on root dentin and less fracture modes that involved root failure when compared with incisors without ferrule.

Acknowledgements

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Table 1. Elastic modulus (MPa) and Vickers Hardness (N/mm^2) of restorative materials and tooth structures.

Filling technique	Elastic Modulus (MPa)	Poisson's Ratio	Tensile Strength (MPa)	Compressive Strength (MPa)	Reference
Dentin	18600	0.31	98.7	297.0	[43]
Composite resin	17000	0.28	45.5	277.0	[44]
Lithium disilicate ceramic	96000	0.31	271.0	360.0	[45]
Polystyrene resin	13500	0.31			[46]
Gutta-percha	0.69	0.45			[47]
Resin cement	9100	0.30			[22]
Polyether	50	0.45			[46]

Table 2. Orthotropic properties, tensile Strength and Compressive Strength of the glass-fiber post. [3]

Properties	Glass-fiber post	Tensile Strength (MPa)	Compressive Strength (MPa)
EX (MPa)	37000	40	250
EY (MPa)	9500		
EZ (MPa)	9500		
ηXY	0.34		
ηYZ	0.27		
ηXZ	0.34		
Gxy (MPa)	3544.8		
Gxz (MPa)	1456.7		
Gxz (MPa)	3544.8		

Table 3. Root dentin strain (μS) measured by strain gauges (n = 10) before and after aging at 100N loading.

Aging	**Ceramic Crown**		**Buccal root surface**		**Lingual root surface**	
	Fe	**NFe**	**Fe**	**NFe**	**Fe**	**NFe**
Before	13.8 (5.4) Aa	12.8 (5.2) Aa	437.8 (178.1) Aa	611.1 (282.8) Aa	221.4 (81.7) Aa	236.7 (59.7
After	13.4 (4.0) Aa	16.8 (3.1) Aa	554.0 (233.8) Aa	1248.0 (282.8) Bb	311.8 (159.0) Aa	516.2 (195. Bb

Different uppercase letters indicate significant differences in aging. Different lower case letters indi significant difference for the dental remaining within of each strain mode (P<.05)

Table 4. Root dentin strain (μS) measured by strain gauges (n = 10) at fracture load.

Strain location	Fe	NFe
Ceramic Crown	150.1 (32.6) ^{Aa}	135.1 (31.1) ^{Aa}
Lingual root surface	2681.5 (1442.1) ^{Bb}	1506.2 (1323.7) ^{Ab}
Buccal root surface	5781.2 (2515.5) ^{Ac}	6433.9 (1996.3) ^{Ac}

Different uppercase letters indicate significant differences in strain location. Different lower case letters indicate significant difference for the dental remaining within of each strain mode (P<.05)

Table 5. Fracture resistance (N), mode of fracture and the ratio between root dentin deformation/fracture resistance measured by axial compression test (n = 10).

Groups	n	Fracture resistance (N)	Fracture mode					Ratio between Strain/Fracture resistance	
			I	II	III	IV	V	Buccal root surface	Lingual root surface
With Ferrule	10	1099.6 (214.8) ^{A}	0	4	5	1	0	0.19	0.41 ^{A}
Without Ferrule	10	675.3 (113.8) ^{B}	4	0	1	5	0	0.10	0.44 ^{B}

Different letters indicate significant difference between the dental remaining for fracture resistance (p<0.05).

LEGENDS

Fig. 1. A, NFe cavity preparation; B, Fe cavity preparation; C, 4.0X2.0mm strain gauge attached at buccal ceramic crown and 1.0X1.0mm strain gauge attached at coronal cervical limit on buccal root surface; D 1.0X1.0mm strain gauge attached at coronal cervical limit on palatal root surface; E, strain measurement at 100N loading simulating occlusion loading; F, mechanical cycling aging; G, strain measurement at fracture loading .

Fig. 2. Fracture modes prevalent for NFe group: A, type I, post debonding; B, type IV, root fracture in cervical third; and for Fe group: C, type III cohesive fracture restoration with core involved; D, type II, cohesive fracture restoration.

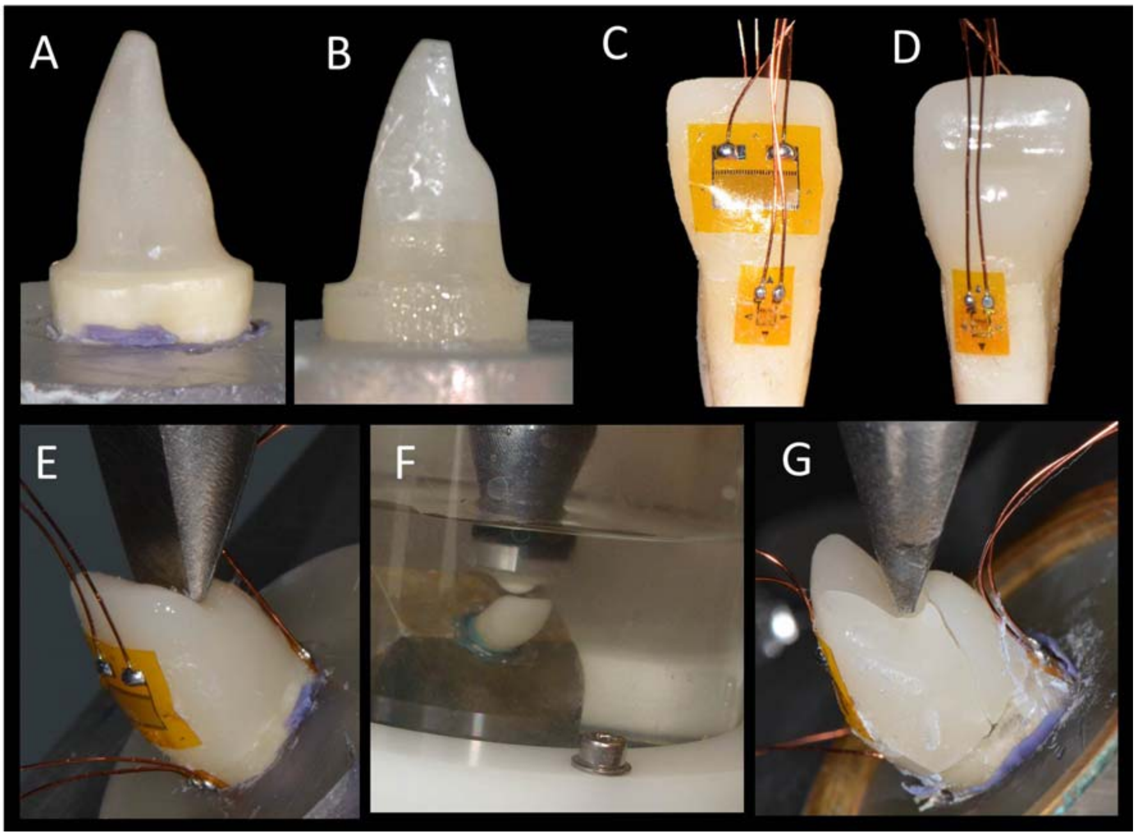
Fig. 3. SEM images of tested specimens: A, fracture mode type I showing several bubbles and voids presence; B, fracture mode type II showing the ceramic crown fracture and complete detaching between the ceramic crown and root dentin; C, fracture mode type III showing the ceramic and composite core fracture and detaching between composite core and dentin; D, fracture mode type Iv showing the root dentin fracture located on cervical third of root dentin adhered to ceramic crown.

Fig. 4. Von Mises stress distributions of buccal surface of ceramic crown of different Fe and NFe models.

Fig. 5. Von Mises stress distributions of external surface of different Fe and NFe models at buccal surface.

Fig. 6. Von Mises stress distributions of root dentin and post space of different Fe and NFe models.

Fig. 7. Stress distribution by Maximum Principal Stress for Fe and NFe models at buccal and lingual surface.


A
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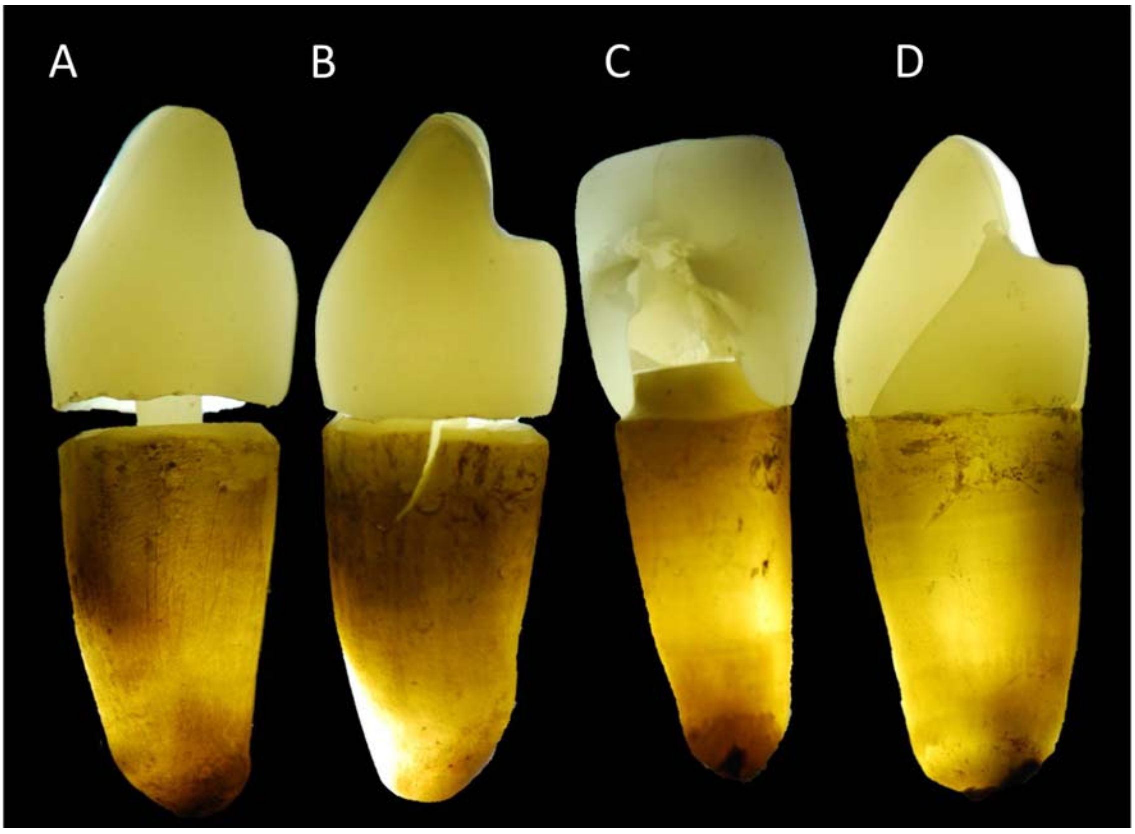
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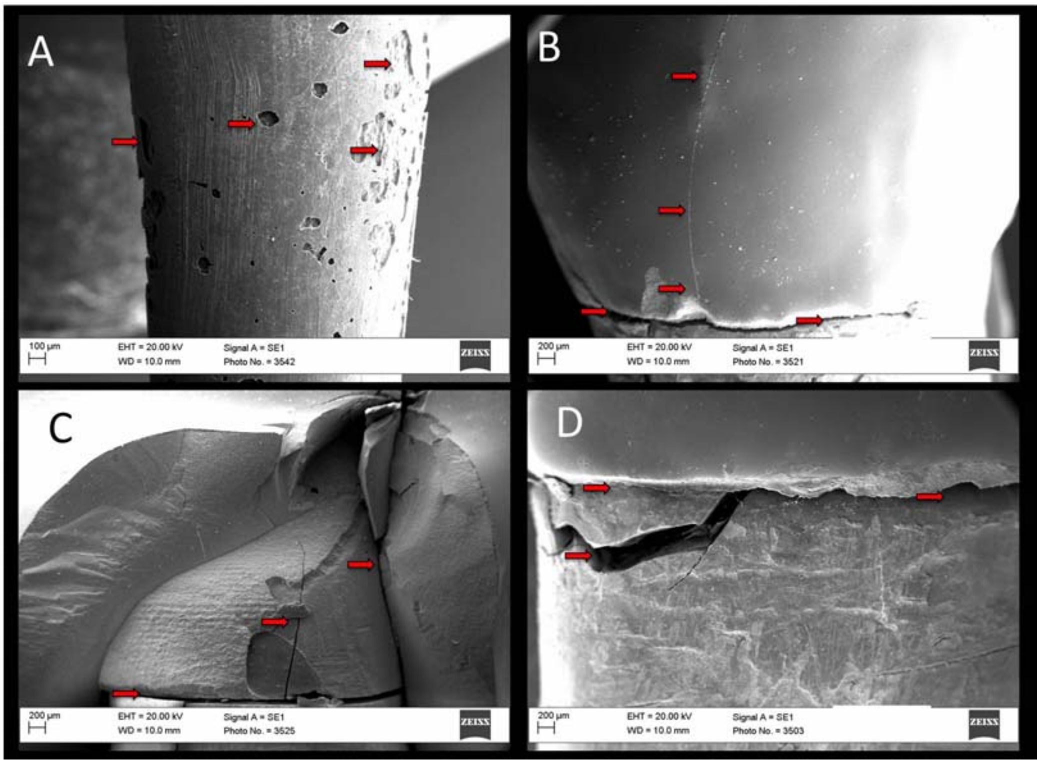
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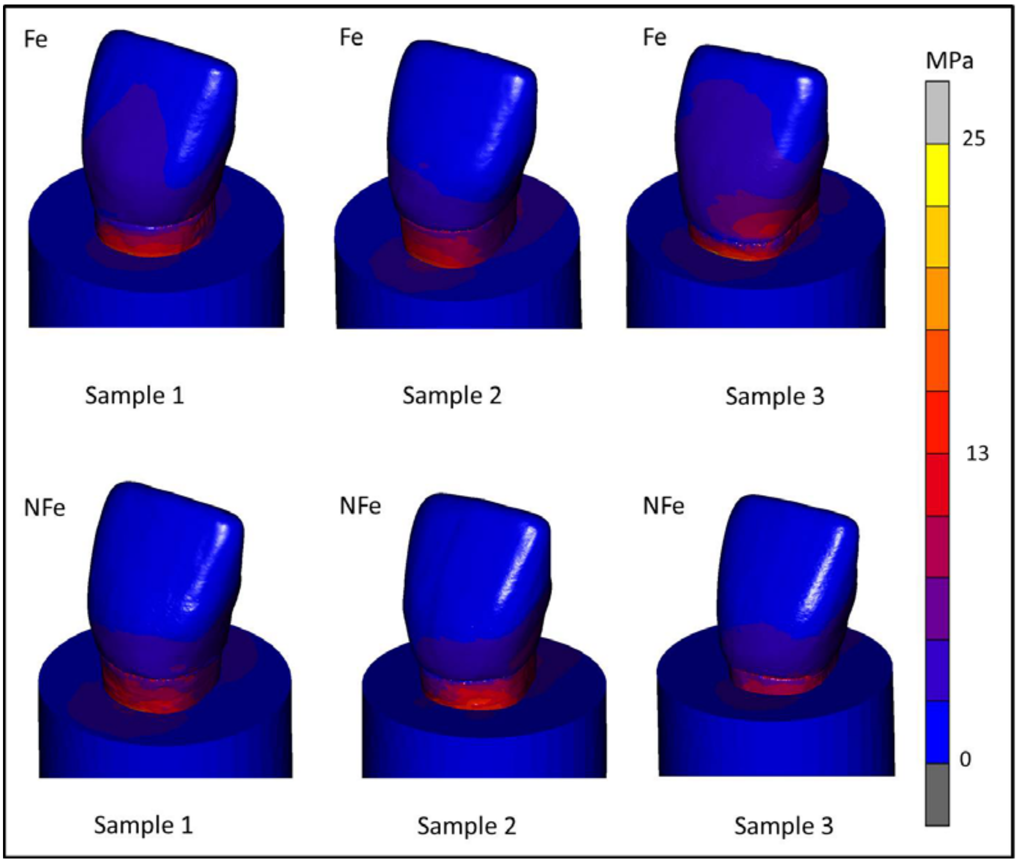
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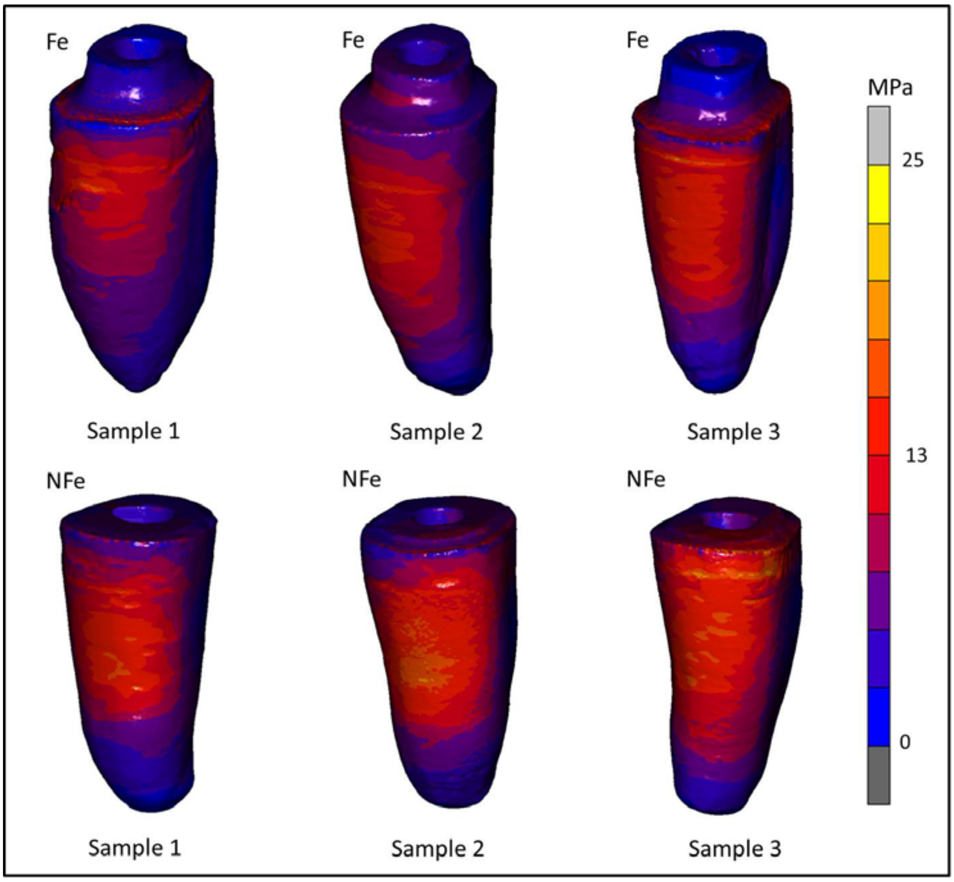
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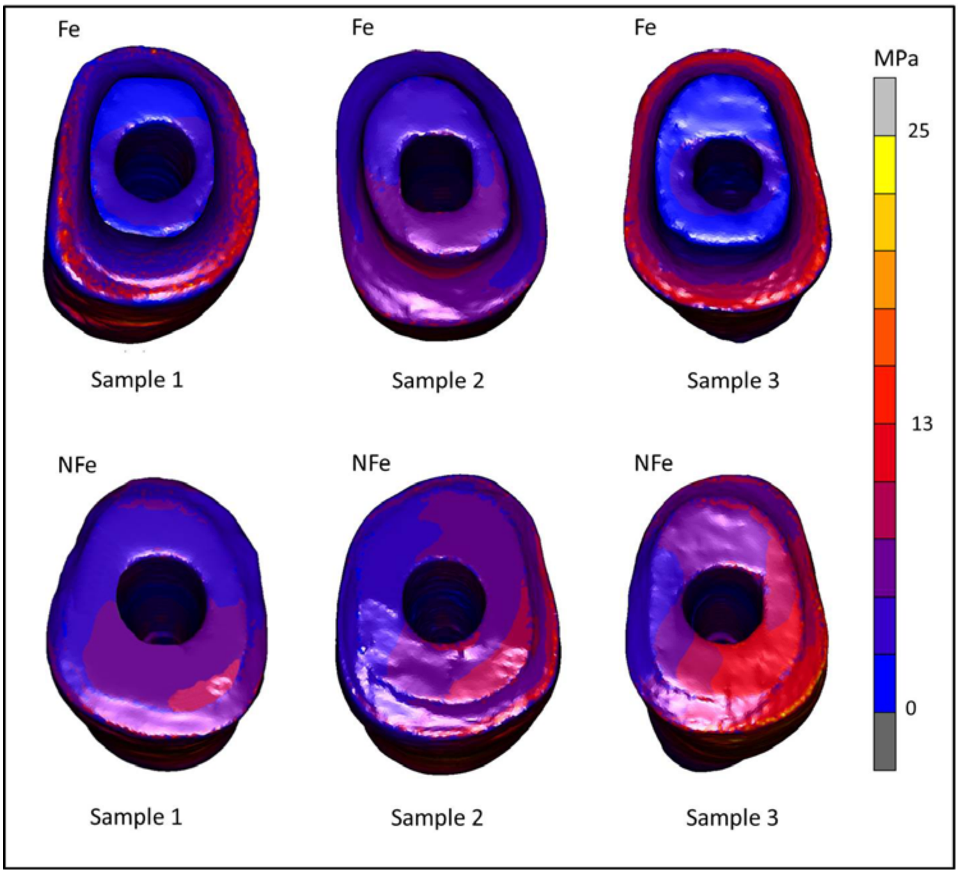
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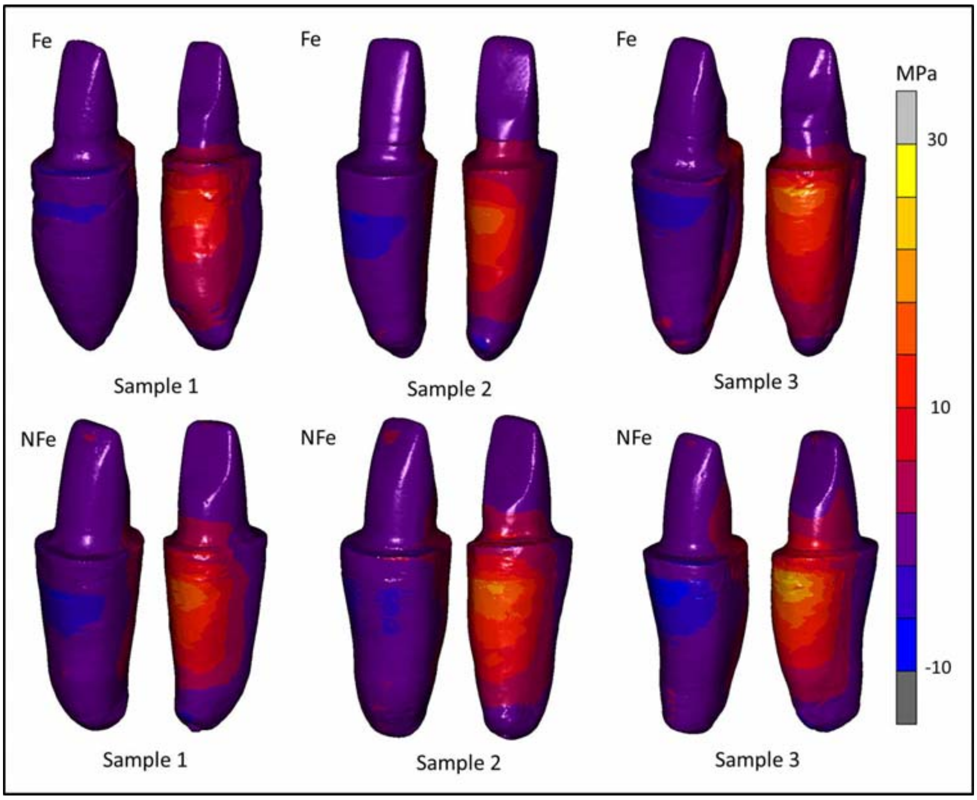
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CAPÍTULOS

3.4 CAPÍTULO 4

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

Reabilitação estética do sorriso com uso de pino de fibra de vidro associado à coroa cerâmica CAD/CAM – Aspectos clínicos e biomecânicos.

Smile aesthetic rehabilitation with fiberglass post associated with CAD/CAM ceramic crown - Clinical and biomechanical aspects.

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Reabilitação estética do sorriso com uso de pino de fibra de vidro associado à coroa cerâmica CAD/CAM – Aspectos clínicos e biomecânicos.

RESUMO

A preservação da estrutura dental constitui fator importante para restauração de dentes tratados endodonticamente. Geralmente estes dentes se encontram enfraquecidos devido à perda de estrutura dentária, sendo necessário a utilização de retentores intrarradiculares para dar estabilidade e retenção à reconstrução coronária. Este trabalho tem por objetivo relatar o caso clínico de reabilitação estética do sorriso, associando, pino de fibra de vidro e coroa em cerâmica pura CAD/CAM, mostrando que para a finalização de casos estéticos deve se integrar tanto a estética dental quanto a estética gengival. São destacados os passos clínicos e breve revisão de aspectos biomecânicos e estéticos desta alternativa reabilitadora.

PALAVRAS CHAVES

Dente tratado endodonticamente. Pino de fibra de vidro. CAD/CAM. Coroa cerâmica. Estética.

ABSTRACT

The preservation of tooth structure is an important factor for restoration of endodontically treated teeth. Usually these teeth are weakened due to tooth structure loss, requiring the intraradicular posts to perform restorative procedures for stability and retention for the coronal reconstruction. This paper aimed to present clinical case of CAD/CAM ceramic crown rehabilitation associated with fiberglass post showing that for the completion of aesthetic cases should integrate both tooth restoration and gingival health. Highlights the

clinical steps and brief review of biomechanical and aesthetic rehabilitation of this alternative are described.
KEYWORDS
Endodontically treated teeth. Fiberglass post. CAD/CAM. Ceramic crown. Aesthetic.

SIGNIFICÂNCIA CLÍNICA

A manutenção da estrutura remanescente em dentes tratados endodonticamente, preservando a integridade dos procedimentos restauradores aumenta a longevidade da restauração. A interrelação entre as diversas áreas da odontologia é imperativa para o sucesso do restabelecimento estético e funcional de dentes com grandes perdas estruturais, assim como o uso de materiais que mimetizem as características biomecânicas dos tecidos dentários.

INTRODUÇÃO

Dentes tratados endodonticamente frequentemente requerem retentores intrarradiculares para realização de procedimentos restauradores, devido às grandes perdas de estrutura dental causada por cárie ou acessos endodônticos à cavidade.[1,2] A preservação da estrutura dental constitui fator importante para prevenir complicações biomecânicas dos retentores intra-radiculares.[3-6] Uma vez que estes podem interferir na resistência mecânica do dente, aumentando o risco de dano da estrutura dental remanescente.[7]

A introdução dos pinos de fibra de vidro surgiu como alternativa aos pinos metálicos para restauração de dentes tratados endodonticamente,[8,9] já que os pinos de fibra apresentam módulo de elasticidade similar ao da dentina,[10] favorecendo a distribuição de tensões e minimizando fraturas catastróficas.[11] Materiais com baixo módulo de elasticidade como a fibra e a resina epóxica, constituintes do pino de fibra de vidro, acompanham os movimentos de flexão natural do dente, reduzindo a concentração de tensão nas interfaces, capacitando o complexo restaurador a mimetizar o comportamento biomecânico de dentes hígidos.[10,11]

Outro fator importante na resistência do dente tratado endodonticamente é o abraçamento de estrutura dental em torno do retentor intrarradicular, denominado efeito férula, este é obtido quando se tem a preservação de 1,5 a 2,0 mm de estrutura dentária em torno da região cervical do núcleo.[12,13] Segundo Pegoraro (2000)[14], quando não existe estrutura coronária suficiente para propiciar base de sustentação, as forças que incidem sobre o núcleo são direcionadas obliquamente, tornando a raiz mais susceptível à fratura.

Hoje em dia, um sorriso estético não se baseia apenas em fatores dentários (forma, cor, alinhamento nas arcadas), mas implica também a presença de tecidos periodontais saudáveis, com um contorno gengival harmónico. Neste sentido, a execução de restaurações estéticas, funcionais e acima de tudo biológicas, pode implicar o recurso a técnicas cirúrgicas que visam aumentar a exposição de estrutura dentária supragengival, de modo a preservar a integridade do periodonto. A cirurgia periodontal engloba as diversas técnicas cirúrgicas que buscam a função gengival aliada às condições estéticas de normalidade.[15]

Determinadas situações clínicas geram dúvidas para os profissionais sobre qual o melhor planejamento reabilitador, principalmente em dentes tratados endodonticamente, onde já se verifica perda de estrutura dental. A escolha do material restaurador apropriado deve ser baseada na quantidade de estrutura dental remanescente assim como também pelas considerações estéticas e funcionais.[16] Diferentes técnicas e materiais restauradores têm sido utilizados para este propósito. O uso de resina composta tem se tornado rotineiro na prática clínica, mas estes materiais estão propensos a sofrer degradações na cavidade oral.[17] Além disso, em muitos casos, estes dentes ainda estão acometidos por alterações cromáticas que podem indicar a extensão do preparo para o recobrimento da face vestibular por meio de indicação de facetas ou de coroa total.

Embora nenhum sistema propicie solução restauradora ideal para diversas circunstâncias clínicas, profissionais têm procurado selecionar técnicas e materiais compatíveis com a estrutura dentária remanescente, objetivando resultados funcionais e estéticos, a fim de proteger a estrutura dentária remanescente.[18] O uso de coroas de cerâmica pura tem sido popularizado na reabilitação de dentes anteriores devido à melhora em suas propriedades.[19,20]

As cerâmicas possuem excelentes características, tais como: biocompatibilidade, estabilidade de cor, baixa condução térmica, baixo acúmulo de placa, resistência à abrasão, além de promover uma excelente estética.[21] Entretanto, as cerâmicas são frágeis quando submetidas às tensões de tração, o que pode comprometer seu desempenho clínico. As tradicionais coroas metalocerâmicas consistem em infraestrutura de metal recoberta por porcelana. A infraestrutura de metal é opaca e por consequência não consegue reproduz a translucidez do dente natural, o que muitas vezes é motivo de queixa, por parte dos pacientes, devido ao escurecimento marginal da gengiva proveniente da oxidação do metal e da translucidez gengival.[22] Quando utilizadas coroas livres de metal acentua-se a preocupação com a fratura.[23] Os sistemas totalmente cerâmicos surgiram com o intuito de eliminar as infraestruturas metálicas, na tentativa de promover melhor reflexão da luz, resultando assim, em melhor estética, com maior resistência à fratura, e menor propagação de trincas que os sistemas convencionais de cerâmicas feldspáticas. Atualmente existe uma grande variedade de classes cerâmicas disponíveis para distintas indicações, de acordo com seus fabricantes. Contudo, não existe um único sistema totalmente cerâmico passível de ser empregado em todas as situações clínicas. Atualmente os sistemas CAD/CAM (Computer Assisted Design/ Computer Assisted Machining) com scanners para captura de imagens sem contato e em três dimensões, transformam o sistema em um processo preciso e confiável. O sistema cerâmico a base de di-silicato de lítio, processado pelo sistema CAD/CAM é indicado como coroa monolítica ou como uma infraestrutura para revestimento com cerâmica feldspática. Para que estas cerâmicas desempenhem adequadamente os princípios biomecânicos de resistência é imperativo que as mesmas estejam adesivamente integrada ao remanescente dental.

O tratamento da superfície interna das restaurações cerâmicas indiretas é modulado, principalmente, pela sua composição. O desenvolvimento de protocolos de tratamento de superfície para cerâmicas predominantemente vítreas, favorece a consolidação do tratamento prévio com ácido hidrofluorídrico associado a silanização.[24] O condicionamento químico com ácido fluorídrico em concentração de 5 a 10% em cerâmicas de di-silicato de lítio, promove alteração morfológica da fase vítrea da cerâmica e cria topografia com aspecto de favo de mel, ideal para retenção micromecânica.[24]

Para fixação de restaurações indiretas cerâmicas é primordial a utilização de cimentos resinosos. Estes materiais possuem composição e característica similares às resinas compostas, sendo constituídos por partículas inorgânicas silanizadas embebidas em matriz resinosa, composta por monômeros como o Bis-GMA, TEGDMA e UDMA.[25] Entretanto, estes materiais apresentam menor quantidade de carga e alta fluidez quando comparados com as resinas compostas.[26] A união da restauração ao preparo, por meio do sistema adesivo e cimento resinoso, proporciona distribuição das tensões de forma homogênea entre o dente e a restauração indireta, o que reduz a probabilidade de geração e propagação de microtrincas nas cerâmicas.

Atualmente, surgem cimentos resinosos com propriedades autoadesivas que eliminam a etapa de pré-tratamento, sem a necessidade das etapas de condicionamento e aplicação de sistema adesivo no substrato dentário. A adesão à estrutura dental é baseada no princípio de que monômeros reagem com sais básicos e apatita do dente por meio de grupos funcionais de ácido fosfórico modificado.[27] Além disso, o cimento autoadesivo demonstra boa estabilidade de união com as cerâmicas.[28]

Este trabalho tem por objetivo apresentar relato de caso clínico de reabilitação estética do sorriso em paciente com incisivo central superior tratado endodonticamente com extensa restauração em resina composta e alteração cromática, associado ao uso de pino de fibra de vidro e coroa em cerâmica de di-silicato de lítio CAD/CAM. Objetiva ainda demonstrar que a estética gengival é fundamental para o restabelecimento do sorriso.

RELATO DE CASO

O objetivo deste trabalho é descrever relato de caso clínico de reabilitação estética do sorriso, associando, cirurgia periodontal, pino de fibra de vidro e coroa em cerâmica pura CAD/CAM em incisivo central superior tratado endodonticamente (Figura 1). Paciente R.C.R.S, de 42 anos, sexo feminino, apresentou-se na Clínica de Pesquisa da Faculdade de Odontologia da Universidade Federal de Uberlândia (FOUFU) queixando-se de insatisfação estética de seu sorriso. Ao exame clínico e radiográfico, verificou-se presença de faceta em resina composta com alteração de cor no incisivo central superior (11) e tratamento endodôntico satisfatório. Mediante diagnóstico e plano de tratamento foi indicado cirurgia para aumento de coroa clínica na região ântero-superior com retalho vestibular dividido e retalho palatino total, com osteotomia. Para tanto, após os procedimentos de anestesia e aferição das profundidades da bolsa gengival, foi demarcada com sonda periodontal o local das incisões em toda extensão da margem gengival compreendida entre os dentes 13 a 23. As incisões para remoção do excesso gengival foram realizadas com lâmina de bisturi 15C em bisel interno de 45° em relação à gengiva, iniciando do elemento 13 e indo até o elemento 23 (Figura 2). Foi removido excesso gengival com cureta periodontal tipo Gracey. Verificada a profundidade de sondagem após remoção do excesso gengival, esta apresentava apenas 2 mm nos incisivos centrais e laterais, sendo necessário a realização de osteotomia por meio de cinzéis de Ochsenbein nº3 e nº4, acompanhando o contorno da anatomia dental para a devolução do espaço biológico periodontal. Com nova aferição a profundidade de sondagem foi estabelecida com 3mm (Figura 3), o que é de extrema importância para manter a saúde e estética do periodonto e a integração com a reabilitação protética. Realizada irrigação com soro fisiológico e compressão com gaze umedecida após o fim da cirurgia periodontal de aumento de coroa clínica, foi realizada a sutura de modo a posicionar a margem gengival ao nível da junção amelocementária proporcionando assim o novo contorno gengival (Figura 4).

Após o período de 45 dias indicado para o procedimento restaurador, foi verificada a extensão da restauração insatisfatória em resina do dente 11 (Figura 5). A restauração foi removida com ponta diamantada em alta rotação sob constante e abundante irrigação. Foi então realizado o isolamento absoluto para cimentação de pino de fibra de vidro (PFV) cônico liso (Exacto nº3, Ângelus, Londrina, PR, Brasil). A seleção do pino foi realizada usando radiografia periapical do dente 11, tendo como padrão a largura do canal, evitando assim remoção desnecessária e prejudicial de dentina radicular. O alívio do canal radicular foi realizado com brocas Gates n°2 (Dentsply Maillefer, Petrópolis, Rio de Janeiro, Brasil) e para finalização a broca específica do sistema do pino; conservando remanescente de guta percha de 4 mm na região apical do canal radicular, objetivando bom selamento apical.[29]

Em seguida, o PFV foi introduzido no canal para a avaliação radiográfica e verificação da adaptação (Figura 6). Foi realizada limpeza do canal radicular por meio de irrigação com soro e secagem com pontas de papel absorvente. Para cimentação do PFV (Exacto Nº 3, Angelus) foi utilizado cimento resinoso autoadesivo (RelyX U200, 3M-Espe), a limpeza do PFV foi realizada com microbrush (KG Sorensen, Barueri, SP, Brasil) embebido em álcool 70% (Wirath Ind. e Com., São Paulo, Brasil). Em seguida o pino foi imerso em solução de peróxido de hidrogênio a 24% (H2O2, Dinâmica, SP, Brasil) seguido de aplicação por 1 minuto de silano pré-hidrolisado (Silano, Angelus), seguindo o protocolo utilizado por Menezes *et al.,* (2011)[30-32]. O cimento foi preparado seguindo as instruções do fabricante. Foi aguardado o período de 5 minutos para a ativação do cimento, este passo visa minimizar as tensões de contração de polimerização do cimento resinoso.[33] Após a cimentação do PFV, as paredes circundantes das câmaras pulpares foram condicionadas com ácido fosfórico 37% (Condac 37, FGM, Joinville, SC, Brasil) durante 15s, lavadas com jatos de ar/água por 15s e secas com papel absorvente. Foi utilizado sistema adesivo convencional de 3 passos (Scotchbond Multi-Purpose, 3M-Espe) de acordo com as instruções do fabricante. Em seguida, o núcleo de preenchimento foi confeccionado com resina composta (Tetric Ceram, cor A3, Ivoclar Vivadent, Ellwangen, Germany) por meio de técnica incremental, sendo fotopolimerizada por 40s cada incremento com unidade de fotoativação de luz halógena (Demetron LC, Kerr, Orange, CA, EUA).

O preparo para coroa total em cerâmica pura foi realizado utilizando brocas Nº1014, Nº4138 e Nº3168 (KG Sorensen) em alta rotação (Kavo do Brasil, Joinville, SC, Brasil) sob irrigação constante, realizando redução axial de 1,5mm, confecção de término cervical em ombro arredondado e convergência axial das paredes de 6º (Figura 7). Foi realizado então modificação dental com resina composta (Filtek Z350 3M-Espe) na face mesial do dente 21 para harmonizar a estética do sorriso e no intuito de fechamento do diastema que apresentava entre os dentes 11 e 21. Em seguida, foi obtida moldagem do arco superior com silicone por adição (Express, 3M-Espe) que foi encaminhado para o laboratório de Prótese Dental onde foi realizada confecção da restauração final em cerâmica reforçada de di-silicato de lítio (IPS E-max CAD/CAM). Para cimentação da restauração indireta foi seguido o protocolo proposto por Soares *et al.,* (2005)[24] de condicionamento de cerâmica de di-silicato de lítio, realizando o tratamento de superfície primeiramente com ácido hidrofluorídrico a 10% (Condac Porcelana, FGM, Joinville, SC, Brasil) por 20 segundos, depois lavagem e secagem da peça, aplicado silano (Silano, Ângelus, Londrina, PR, Brasil) por 1 minuto e cimentado com cimento auto adesivo RelyX U200 (3M-Espe) como descrito para cimentação do PFV (Figura 8). As imagens finais demonstram o resultado satisfatório do procedimento restaurador (Figuras 9 e 10).

DISCUSSÃO

O sorriso desarmônico decorrente de excesso gengival compromete a estética facial e gera desconforto estético em pacientes. Para harmonização do sorriso deve-se englobar simetria entre dentes, gengiva e lábio, onde o aumento de coroa clínica muitas vezes é uma grande opção de tratamento para correção dessas discrepâncias. A queixa em relação à estética dental tem se acentuado bastante na população, porém devemos nos questionar se as queixas das pessoas condizem com as percepções dos profissionais em relação à alteração estética e avaliar o que é realmente necessário para a correção de cada sorriso considerado desarmônico para o paciente.

O aumento de coroa clínica com finalidade estética está indicado quando os dentes anteriores são curtos ou tem exposição excessiva de tecido gengival e quando o contorno gengival é irregular.[34] No entanto, quando este procedimento é realizado em um dente isolado, pode causar desarmonia no arco gengival e trazer prejuízos estéticos para aqueles pacientes que possuem linha do sorriso alta. Seu principal objetivo cirúrgico é estabelecer relação adequada na posição da margem gengival com o lábio e aumentar a coroa dos dentes, proporcionando harmonia estética entre altura e largura das coroas clínicas dos dentes anteriores e em alguns casos possibilitando o fechamento de diastemas por meio de restaurações diretas com resina composta mantendo o equilíbrio e simetria.[34]

Diversos autores relatam que a preservação de estrutura dentária e a manutenção de 1,5 a 2mm de remanescente coronário garantem um aumento de resistência à fratura e um melhor padrão de distribuição de tensões em dentes tratados endodonticamente.[13] A conservação da estrutura dental é crucial para oferecer resistência em dentes tratados endodonticamente, uma vez que a remoção da dentina no preparo do canal radicular promove alteração na distribuição de tensões. Na pesquisa, a associação de metodologias computacionais como o método de elementos finitos (MEF) constitui um importante aliado na compreensão dos processos no comportamento das estruturas dentais, favorecendo análise biomecânica sequencial e detalhada do comportamento dentro do dente, na figura 11 é possível avaliar a distribuição de tensões dentro de incisivos centrais superiores tratados endodonticamente com férula e sem férula onde a concentração de tensões é influenciada pela perda de estrutura do dente.

Determinadas situações clínicas geram dúvidas para os profissionais sobre qual o melhor planejamento reabilitador, principalmente em dentes tratados endodonticamente, onde já se verifica perda de estrutura dental. O emprego de materiais com propriedades físicas e mecânicas semelhantes à da dentina consegue mimetizar a estrutura dentária remanescente e possibilita menor incidência de fraturas catastróficas.[1,10] Vários estudos têm demonstrado que quando um dente unirradicular é submetido a forças aplicadas no seu longo eixo, tensões de compressão e tração são geradas nas superfícies vestibular e lingual do terço cervical da raiz.[10,11,17] Os pinos de fibra de vidro possuem propriedades mecânicas, como o módulo de elasticidade, muito similares as da dentina humana[35] e por isso distribuem as tensões ao remanescente radicular de modo mais homogêneo, evitando fraturas radiculares que podem levar a perda do elemento dentário.

Com a evolução dos materiais cerâmicos, técnicas laboratoriais e adesão das cerâmicas às estruturas do dente, técnicas de preservação durante o planejamento e preparação das restaurações vêm sendo cada vez mais procuradas. A tecnologia CAD/CAM corresponde à integração das técnicas CAD (desenho pelo computador) e CAM (unidade de fresagem) num sistema único e completo. Isto significa, por exemplo, que se pode scannear o preparo transferindo a imagem para o computador e transmitir a informação por meio de interfaces de comunicação entre o computador e um sistema de fresagem, onde a peça protética será produzida automaticamente. Na Odontologia o sistema CAD/CAM é a mais alta tecnologia para a confecção de diversos tipos de próteses, convencional e sobre implante. A adaptação marginal das restaurações cerâmicas é muito importante para o sucesso clínico. Uma adaptação marginal entre 25 e 40 micrômetros (μm) para restaurações cimentadas tem sido sugerido como sucesso clinico, porem esses níveis são raramente conseguidos.[36] Discrepâncias são encontradas na adaptação marginal de coroas cerâmicas comparando o método laboratorial para sua obtenção; cerâmicas prensadas ou obtidas pelo sistema CAD/CAM; que podem ser resultado dos múltiplos passos laboratoriais na execução da cerâmica prensada, [37] porem erros cometidos pelo profissional no momento do preparo dos dentes para coroas cerâmicas também podem vir a aumentar a desadaptação da peça no momento da cimentação definitiva.

No presente relato de caso foi utilizado sistema cerâmico de di-silicato de lítio que são embebidos e unidos à matriz de vidro (cerâmica vítrea), numa proporção variando de 60 a 70% em volume de cristais para matriz de vidro. Além da versatilidade do sistema, apresenta-se também com excelente resultado estético, garantindo à restauração de cerâmica propriedades ópticas semelhantes às da estrutura dentária. Para garantir o sucesso das restaurações cerâmicas, a união entre o cimento resinoso e o substrato dentário deve ser adequada e duradoura e isto está diretamente relacionado ao grau de conversão dos cimentos em questão. A ativação adequada também é fator crucial para se alcançar ótimas propriedades físicas e desempenho clínico satisfatório dos materiais resinosos.[24] Adicionalmente, os materiais de fixação resinosos apresentam forte união química aos substratos, que aumenta a resistência das restaurações às condições impostas pela cavidade bucal como fadiga termomecânica e carregamento oclusal que podem levar ao desenvolvimento de fraturas.[24]

Desta forma, as ações multidisciplinares empregadas permitiram proporcionar com sucesso a reabilitação funcional e estética deste caso clinico; juntamente com a escolha dos materiais adequados e a habilidade necessária, sempre aliada a decisões e práticas baseadas em evidências científicas.

CONCLUSÕES E ORIENTAÇÕES AO CLÍNICO

A intervenção periodontal voltada aos tecidos de revestimento demonstrou-se adequada ao recontorno gengival enquanto que os procedimentos restauradores possibilitaram de forma eficaz a reconstrução estética e funcional da região anterior. O uso de pino de fibra de vidro associado à coroa em cerâmica pura permitiu o restabelecimento da estética e funcionalidade biomecânica do dente tratado endodonticamente.

Fatores devem ser considerados para redução de falhas no uso de pinos de fibra de vidro como:

1. adequada indicação do caso e seleção correta do sistema de pinos só devem ser indicados na ausência de retenção para reconstrução coronária;
2. deve ser priorizado o desgaste mínimo da estrutura dentária existente – o diâmetro do pino deve ser adequado à dimensão da luz do canal recém tratado;
3. a presença de férula melhora a previsibilidade e longevidade das restaurações com retentores intrarradiculares
4. atenção especial deve ser dada no planejamento reabilitador as distâncias biológicas e ao contorno gengival para harmonizar procedimentos reabilitadores com saúde periodontal;
5. viabilizar isolamento absoluto para realizar a cimentação do pino de fibra de vidro para diminuição de ocorrências que causem contaminação do canal radicular;
6. utilização de cimento resinoso autoadesivo reduz os passos clínicos e possíveis erros de técnica na cimentação de retentores intrarradiculares;
7. reconstrução coronária com resina de alta resistência representada pela presença de alta quantidade de carga está indicada para ser reconstrução do preparo coronário;
8. emprego de coroas cerâmicas com adequada resistência e qualidade estética como o di-silicato de lítio mimetiza adequadamente a estrutura dental;
9. procedimentos reabilitadores empregando sistema CAD-CAM viabiliza procedimentos com maior agilidade e com excelente previsibilidade clínica.

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FIGURAS

Figura 1: Aspecto inicial do dente 11 com alteração de cor e com estética gengival comprometida.

Figura 2: Cirurgia periodontal para aumento de coroas clinicas em região antero-superior.

Figura 3: Região de incisivos após a osteotomia.

Figura 4: Sutura com reposicionamento do contorno gengival.

Figura 5: Característica clínica gengival após período pós operatório de 45 dias.

Figura 6: Cimentação do pino de fibra de vidro note-se a alteração cromática do dente 11.

Figura 7: Preparo para coroa total finalizado com núcleo de preenchimento confeccionado em resina composta.

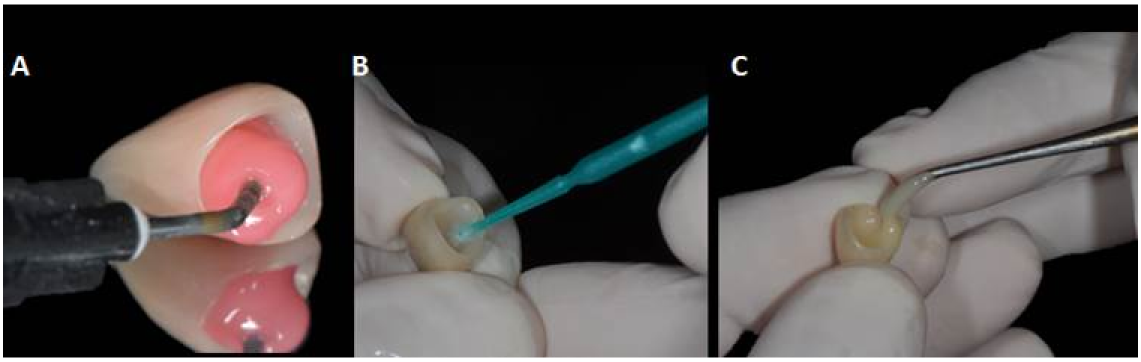

Figura 8: Tratamento da superfície interna da restauração final: A, Ácido hidrofluorídrico 10% 20 segundos; B, Silano 1 minuto; D, Inserção de cimento resinoso.

Figura 9: Caso clínico finalizado

Figura 10: Aspecto final da restauração.

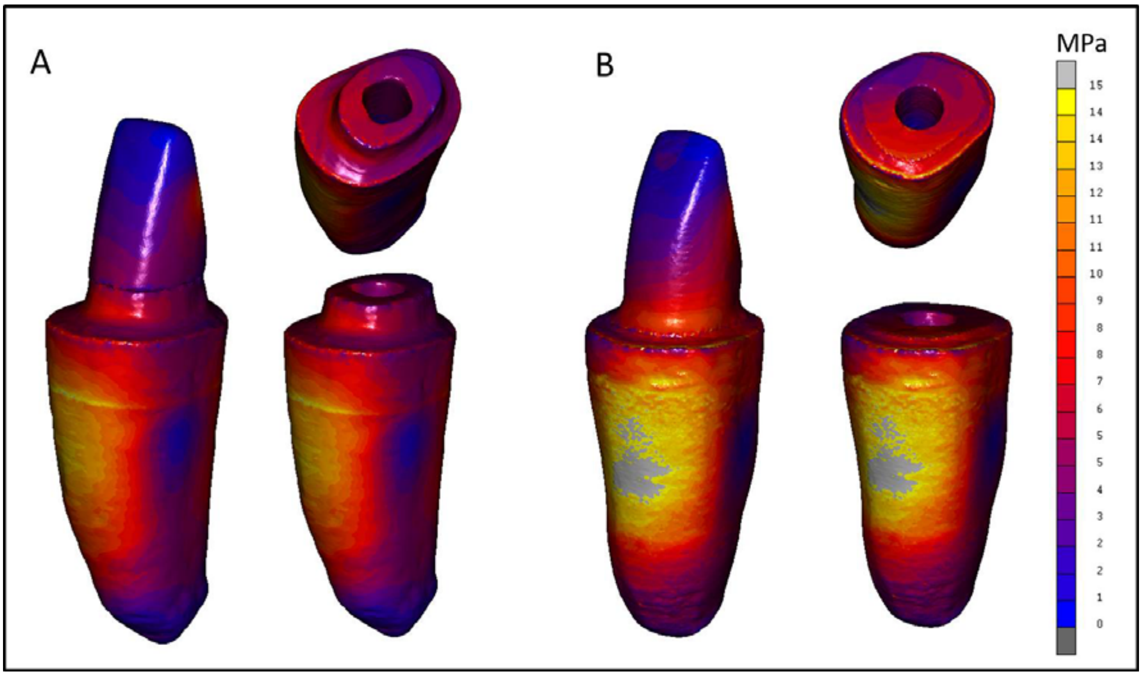

Figura 11: Imagem de modelo de elementos finitos mostrando incisivo central com férula (A) e sem férula (B) onde a férula promove melhor distribuição de tensões à estrutura dental remanescente.

CONCLUSÕES

4- CONCLUSÕES

Dentro das limitações metodológicas impostas pelo delineamento experimental destes estudos que envolveram 2 estudos laboratoriais e computacionais, 1 estudo *in vivo* e 1 relato de caso clínico pode-se concluir-se que:

- O tratamento de superfície com peróxido de hidrogênio a 24% por 1 minuto rendeu significativamente maior resistência de união na cimentação de pinos de fibra de vidro;
- A definição do protocolo de modelagem individualizada forneceu as etapas necessárias para a aplicação da metodologia em paciente;
- A distribuição de tensões dos dentes avaliados no capítulo 2 mostrou que as tensões geradas no dente 21, que não tinha férula uniforme, foram maiores em comparação com o dente 11, independentemente do método de carregamento;
- A manutenção de uma férula uniforme foi mais relevante do que uma férula maior nas regiões proximais;
- A presença de férula evitou o descolamento do pino de fibra da dentina radicular após fadiga térmica e mecânica;
- O grupo sem férula apresentou maior deformação radicular após processo de envelhecimento;
- O grupo com férula apresentou maiores valores de resistência à fratura, baixa concentração de tensões na dentina radicular e menos fraturas catastróficas;
- O uso de pino de fibra de vidro associado à coroa em cerâmica pura permitiu o restabelecimento da estética e funcionalidade biomecânica do dente tratado endodonticamente com intervenção periodontal voltada aos tecidos de revestimento que possibilitou um recontorno gengival adequado para realização dos procedimentos restauradores.

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5- REFERÊNCIAS

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ANEXOS

6- ANEXOS

Parecer do Comitê de ética

UNIVERSIDADE FEDERAL DE UBERLÂNDIA/MG

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Análise comparativa de comportamento in vivo e in vitro de protocolos de reabilitação de dentes tratados endodonticamente

Pesquisador: Carlos José Soares

Área Temática:

Versão: 3

CAAE: 05624712.5.0000.5152

Instituição Proponente: Universidade Federal de Uberlândia/ UFU/ MG

DADOS DO PARECER

Número do Parecer: 144.423

Data da Relatoria: 26/10/2012

Apresentação do Projeto:

Este projeto visa de forma sequencial e progressiva analisar o efeito do protocolo restaurador de dente tratado endodonticamente por meio de avaliação comparativa in vivo e simultânea in vitro, empregando ensaios mecânicos e computacionais pelo método de elementos finitos. Visa ainda validar os ensaios computacionais e ensaios experimentais laboratoriais por meio de análise comparativa com parâmetros clínicos.

Objetivo da Pesquisa:

Objetivo Primário:

Este projeto visa de forma sequencial e progressiva analisar o efeito do protocolo restaurador de dente tratado endodonticamente por meio de avaliação comparativa in vivo e simultânea in vitro, empregando ensaios mecânicos e computacionais pelo método de elementos finitos. Visa ainda validar os ensaios computacionais e ensaios experimentais laboratoriais por meio de análise comparativa com parâmetros clínicos.

Objetivo Secundário:

Objetivo específico 1- Avaliação clínica - estudo clínico prospectivo de até 24 meses a ser realizado em pacientes que apresentem incisivos centrais superiores com necessidade de reabilitação com pino de fibra de vidro e coroa metalo-cerâmica, variando a quantidade de remanescente dental (Fe, com férula de 2mm e fe, com férula menor do que 2mm, com mínimo N= 15). Objetivo específico 2- Avaliação computacional - estudo por meio do método de

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elementos finitos (MEF) de cada um dos dentes envolvidos na avaliação clinica. Objetivo específico 3- Avaliação de previsibilidade in vitro, utilizando 20 incisivos centrais superiores que serão reabilitados conforme o estudo clínico. Estes dentes serão submetidos à escaneamento em Micro-CT e estes arquivos utilizados para geração de modelos computacionais.

Avaliação dos Riscos e Benefícios:

Riscos:

Não há riscos evidentes que estejam relacionados com este projeto, que comprometa a saúde dos pacientes participantes das avaliações clínicas referente ao objetivo específico 1, dos exames radiológicos (para o objetivo especifico 2), e da obtenção dos dentes extraídos (objetivo específico 3). Os riscos à exposição para os exames radiológicos serão pequenos, dentro das doses e proteções estabelecidas seguras, o paciente será orientado sobre o mesmo no termo de consentimento. Todas as medidas de biosegurança serão tomadas como protocolo de rotina durante as avaliações clínicas e exodontias necessárias. A análise clínica das restaurações (objetivo especifico 1), e as exodontias dos incisivos centrais superiores dos pacientes doadores dos mesmos (objetivo especifico 3) será feita após a autorização do paciente, entretanto, são procedimentos realizados a partir de indicação prévia pelo dentista que atenderá o paciente no Hospital Odontológico, sem qualquer relação com este projeto de pesquisa. O único risco é a identificação do sujeito de pesquisa no momento da coleta e análise, o que contraria a Resolução 196/96. Porém, a equipe executora se compromete a tratar os sujeitos participantes de forma sigilosa, não fazendo a identificação dos mesmos. Além disso, após a avaliação, os participantes receberão orientações acerca da higienização bucal assim como hábitos alimentares saudáveis.

Benefícios:

Há benefícios diretos aos participantes, pois a pesquisa objetiva a avaliação da longevidade e eficácia das restaurações de dentes tratados endodonticamente com pino de fibra de vidro e coroa total, isso beneficia não só o paciente participante como também toda a sociedade, uma vez que essas avaliações julgarão a qualidade das técnicas restauradoras e o emprego de retentores intra-radiculares, no comportamento biomecânico de incisivos tratados endodonticamente, buscando minimizar as falhas e, conseqüentes insucessos clínicos. Por meio deste projeto resultará a definição de um protocolo de geração de modelos numéricos tridimensionais de pacientes, sendo fator de facilitação de estudos sequenciais, resultando em maior confiabilidade dos resultados pela comparação com método estatístico da grande variabilidade de modelos gerados e facilitando a correlação com dados experimentais.

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Comentários e Considerações sobre a Pesquisa:

O referido projeto mostra ser de suma importância, pois busca a avaliação da durabilidade e eficácia das restaurações de dentes com canal usando pino de fibra de vidro e coroa total estética. I isso beneficia não só o paciente participante como também toda a sociedade, uma vez que essas avaliações julgarão a qualidade das técnicas restauradoras e o emprego destes pinos, no comportamento de incisivos com canal, buscando minimizar as falhas e, consequentes insucessos clínicos.

Considerações sobre os Termos de apresentação obrigatória:

Os seguintes termos foram devidamente apresentados: TCLE, Declaração da Instituição Co-participante, folha de rosto, Solicitação do pesquisador para a Instituição, links para os currículos dos pesquisadores e Termo de compromisso da equipe executora.

Recomendações:

Não há nenhuma recomendação a ser considerada.

Conclusões ou Pendências e Lista de Inadequações:

A pendência apontada no parecer 128.739, de 05/10/2012, foi atendida.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

Data para entrega de Relatórios Parciais: agosto de 2013 e 2014.
Data para entrega de Relatório Final: agosto de 2015.

OBS.: O CEP/UFU LEMBRA QUE QUALQUER MUDANÇA NO PROTOCOLO DEVE SER INFORMADA IMEDIATAMENTE AO CEP PARA FINS DE ANÁLISE E APROVAÇÃO DA MESMA.

Orientações ao pesquisador :

¿ O sujeito da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado (Res. CNS 196/96 - Item IV.1.f) e deve receber uma cópia do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado (Item IV.2.d).

¿ O pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado e descontinuar o estudo somente após análise das razões da descontinuidade pelo CEP que o aprovou (Res. CNS Item III.3.z), aguardando seu parecer, exceto quando perceber risco ou dano

não previsto ao sujeito participante ou quando constatar a superioridade de regime oferecido a um dos grupos da pesquisa (Item V.3) que requeiram ação imediata.
¿ O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo (Res. CNS Item V.4). É papel de o pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária ¿ ANVISA ¿ junto com seu posicionamento.
¿ Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas. Em caso de projetos do Grupo I ou II apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma, junto com o parecer aprobatório do CEP, para serem juntadas ao protocolo inicial (Res.251/97, item III.2.e). O prazo para entrega de relatório é de 120 dias após o término da execução prevista no cronograma do projeto, conforme norma.

UBERLANDIA, 12 de Novembro de 2012

Assinador por:
Sandra Terezinha de Farias Furtado
(Coordenador)

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Release para Imprensa

Modalidade: Pesquisa Científica.

Assunto: Tese defendida no Programa de Pós-Graduação em Odontologia – Faculdade de Odontologia, UFU.

Autores: Andréa D. C. M. Valdivia; Orientador: Prof. Dr. Carlos José Soares.

Restauração de dentes que receberam tratamento de canal têm sido grande desafio para a odontologia restauradora, pois, geralmente, estes dentes apresentam perda de estrutura que compromete a retenção da restauração, sendo necessária a utilização de pinos intracanais. A preservação da estrutura dental constitui fator importante para prevenir complicações destes pinos. Uma vez que estes podem interferir na resistência mecânica do dente, aumentando o risco de fratura do remanescente dental. A escolha do material restaurador apropriado deve ser baseada na quantidade de estrutura dental remanescente assim como também pelas considerações estéticas e funcionais. Após análise dos resultados das pesquisas desenvolvidas nesta tese, podemos concluir que o tratamento de superfície com 24% de peróxido de hidrogênio por 1 minuto melhorou a retenção e estabilização de pinos de fibra de vidro no interior do canal. A manutenção de férula uniforme, caracterizada pelo dentina preparada na raiz do dente foi relevante para a precisão de sucesso de procedimentos reabilitadores. A presença de férula evitou o descolamento do pino de fibra da dentina radicular após fadiga térmica e mecânica. O uso de pino de fibra de vidro associado à coroa em cerâmica pura permite o restabelecimento da estética e funcionalidade biomecânica do dente tratado endodonticamente. Desta forma, a escolha do material adequado, juntamente com a habilidade necessária para a confecção dos procedimentos restauradores, sempre aliada à decisões e práticas baseadas em evidências científicas, promovem a realização de procedimentos de sucesso.

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Contato: Secretaria PPG Odontologia, Sra. Maria das Graças, Fone: (34) 3225-8115