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

Giselle Rodrigues dos Reis

Avaliação de técnicas para confecção e cimentação de retentores intrarradiculares reforçados por fibra

Tese apresentada ao Programa de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia, como parte dos requisitos para obtenção do título de Doutora em Odontologia.

Área de Concentração: Clínica Odontológica Integrada.

Giselle Rodrigues dos Reis

Avaliação de técnicas para confecção e cimentação de retentores intrarradiculares reforçados por fibra

Tese apresentada ao Programa de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia, para obtenção do Título de Doutora em Odontologia.

Área de concentração: Clínica Odontológica

Orientador: Prof. Dr. Murilo de Sousa Menezes

Banca Examinadora:
Prof. Dr. Murilo de Sousa Menezes
Prof. Dr. Paulo César de Freitas Santos Filhos
Prof. Dr. Vanderlei Luiz Gomes
Prof. Dr. Marcelo Bighetti Toniollo
Prof. Dr. Thiago Assunção Valentino

Uberlândia
2019

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da UFU, MG, Brasil.

R375a
2019

Reis, Giselle Rodrigues dos, 1989
Avaliação de técnicas para confecção e cimentação de retentores intrarradiculares reforçados por fibra [recurso eletrônico] / Giselle Rodrigues dos Reis. - 2019.

Orientador: Murilo de Sousa Menezes.
Tese (Doutorado) - Universidade Federal de Uberlândia, Programa de Pós-Graduação em Odontologia.
Modo de acesso: Internet.
Disponível em: http://dx.doi.org/10.14393/ufu.te.2019.1220
Inclui bibliografia.
Inclui ilustrações.

1. Odontologia. 2. Pinos dentários. 3. Materiais dentários. 4. Dentes. I. Menezes, Murilo de Sousa, 1979, (Orient.) II. Universidade Federal de Uberlândia. Programa de Pós-Graduação em Odontologia. III. Título.

CDU: 616.314

Angela Aparecida Vicentini Tzi Tziboy – CRB-6/947

UNIVERSIDADE FEDERAL DE UBERLÂNDIA
Coordenação do Programa de Pós-Graduação em Odontologia
Av. Pará, 1720, Bloco 4L, Anexo B, Sala 35 - Bairro Umuarama, Uberlândia-MG, CEP 38400-902
Telefone: (34) 3225-8115/8108 - www.ppgoufu.com - copod@umuarama.ufu.br

ATA

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

Defesa de: Tese de Doutorado nº - COPOD

Data: 21/02/2019

Discente: Giselle Rodrigues dos Reis **(11513ODO006)**

Título do Trabalho: Retentores intrarradiculares reforçados por fibra: avaliação de técnicas simplificadas

Área de concentração: Clínica Odontológica Integrada.

Linha de pesquisa: Propriedades físicas e biológicas dos materiais odontológicos e das estruturas dentais

Projeto de Pesquisa de vinculação: Propriedades físicas e biológicas dos materiais odontológicos e das estruturas dentais

As **quatorze horas** do **dia vinte e um de fevereiro de 2019** no Anfiteatro Bloco 4T, Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em janeiro de 2019, assim composta: Professores Doutores: Paulo César Freitas Santos-Filho (UFU); Vanderlei Luiz Gomes (UFU); Thiago Assunção Valentino (UNIUBE); Marcelo Bighetti Toniollo (UniRV); orientador(a) do(a) candidato(a) **Murilo de Sousa Menezes.**

Iniciando os trabalhos o(a) presidente da mesa Dr. Murilo de Sousa Menezes 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 (as), que passaram a argüir o(a) candidato(a). Finalizada a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Em face do resultado obtido, a Banca Examinadora considerou o(a) candidato(a) (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 19 horas e 00 minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada eletronicamente pela Banca Examinadora.

Documento assinado eletronicamente por **Murilo de Sousa Menezes**, **Professor(a) do Magistério Superior**, em 21/02/2019, às 19:06, conforme horário oficial de Brasília, com fundamento no art. 6º,

§ 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Paulo César de Freitas Santos Filho**, **Professor(a) do Magistério Superior**, em 21/02/2019, às 19:06, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Marcelo BighettiToniollo** , **Usuário Externo**, em 21/02/2019, às 19:09, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Thiago Assunção Valentino**, **Usuário Externo**, em 25/02/2019, às 07:46, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **VANDERLEI LUIZ GOMES**, **Usuário Externo**, em 26/02/2019, às 17:27, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

A autenticidade deste documento pode ser conferida no site https://www.sei.ufu.br/sei/controlador_externo.php?acao=documento_conferir&id_orgao_acesso_externo=0, informando o código verificador **0973385** e o código CRC **75BC9C4B**.

Referência: Processo nº 23117.004076/2019-11 SEI nº 0973385

DEDICATÓRIA

A Deus,

Por guiar meus passos desde o início dessa jornada e colocar no meu caminho oportunidades e pessoas maravilhosas. Obrigada Senhor!

Ao meu marido Lucas,

Que além de companheiro é um grande amigo e meu porto seguro! Obrigada por ouvir meus anseios, meus medos e minhas alegrias, por participar de todos os momentos, me ajudar em tudo que fosse possível e vibrar por todas as vitorias que consquitamos juntos! Sem você não teria sido possível, você dividiu esse sonho comigo! Amo você!

Aos meus pais Welson e Marta,

"Se enxerguei longe foi porque me apoiei nos ombros de gigantes". São vocês os principais responsáveis por esse momento, obrigada pelo trabalho incessante, pelas noites sem dormir, pelas escolhas e renúncias em prol do meu sonho, pelo exemplo de força e determinação, por me ensinarem a ir à luta, por uma vida de dedicação! Não há palavras que conseguiam mensurar ou descrever minha gratidão! Amo vocês!

Aos meus avós Abdias e Evani,

Obrigada por estarem sempre presente na minha vida e nos estenderem a mão sempre que precisamos. São os que mais se orgulham de mim e quem eu nunca quero decepcionar! Obrigada por cada carinho, oração e incentivo! Vocês são minha preciosidade!

Aos meus irmãos Natália e Junin,

Irmãos são as pessoas que tem amam e te aceitam mesmo conhecendo todos os seus defeitos. Obrigada pela amizade, cumplicidade, paciência e por compreenderem meu estresse e minha ausência.

Às minhas tias Mariza, Márcia, Marilda, Marina,

Como é bom ter tias "corujas". Vocês também estiveram presentes em todos os momentos e sempre contribuíram e vibraram a cada vitória. Obrigada pelo carinho, amizade e dedicação!

AGRADECIMENTOS

Ao Professor Murilo de Sousa Menezes,

Ao mestre e mentor meu profundo agradecimento por todo conhecimento transmitido muito além da Odontologia e pelas oportunidades que me deu ao longo de toda minha vida acadêmica. Seus conselhos e ensinamentos levarei por toda a vida.

Aos Professores Paulo César, Veridiana e Carlos José Soares,

Obrigada pelo exemplo de profissionais que são e por sempre estarem dispostos a ajudar e a dividir o conhecimento conosco. É um constante aprendizado estar próximo de vocês!

Aos demais professores da FOUFU,

Aos professores Paulo Vinicius, Paulo Simamoto, Denildo Magalhães, Flavio Domingues da Neves, Gisele Rodrigues, Alfredo Júlio, Luís Raposo, Paulo Quagliatto, Priscilla Soares, João Edson e Márcio Teixeira obrigada pela convivência agradável nesses anos. Vocês também contribuíram para o meu crescimento.

Aos funcionários da UFU,

Especialmente Graça, Brenda, John, Eliete, Bruno e demais funcionários. Obrigada por realizarem seus trabalhos com tanta dedicação e paciência, facilitando nossas tarefas diárias. Agradeço também ao laboratório de prótese dentária do Hospital Odontológico, especialmente ao técnico Simar pela confecção das coras metálicas utilizadas neste estudo.

À Escola Técnica em Sáude da UFU

Pela confecção de algumas coroas meticas utilizadas neste estudo.

Às amigas Fernanda, Marcela, Ana Laura, Thais e Fabiane,

Obrigada por todos os momentos de descontração e apoio que cada um teve da sua maneira, que nos momentos difíceis foram essenciais. Obrigada pela constante ajuda, por dividirmos o desespero, as tarefas e os sorrisos.

Aos alunos de Iniciação Científica Lucas e Gaby,

Obrigada pela paciência com meu aprendizado em orientar e pela amizade que podemos construir. Vocês me motivaram a ser sempre melhor!

Aos demais colegas da pós-graduação

Renata, Alexandre, Camilla, Belinha, Camilinha, Luana, Gabi, Fred e Ramon. A troca de experiências e conhecimento com vocês contribuíram para meu crescimento. Obrigada pelo convívio e auxílio nos momentos que necessitei.

À HD Ensinos Odontologicos,

Principalmente ao Professor Denildo Magalhães e Técnica Júlia por disponibilizar o equipamento de CAD/CAM e confecção das peças para que o trabalho fosse executado.

À Universidade Federal de Uberlândia,

Aos belos 11 anos de história que construí em minha trajetória na Universidade. Tenho muito orgulho em ter toda minha formação acadêmica por esta instituição.

Ao CPBio

Pela disponibilização dos equipamentos para que fossem realizados os ensaios laboratoriais.

À Universidade de Rio Verde,

Pela liberação de minhas atividades docentes para que realizasse o Doutorado.

Ao CNPq,

Pelo auxílio financeiro concedido por meio de dois anos de bolsa.

À Ângelus,

Pela doação de produtos para realização deste trabalho.

EPÍGRAFE

"Mas é preciso ter manha

É preciso ter graça

É preciso ter sonho sempre

Quem traz na pele essa marca

Possui a estranha mania

De ter fé na vida"

Milton Nascimento

SUMÁRIO

Resumo

RESUMO

Devido à grande perda de estrutura coronária, geralmente, dentes com tratamento endodôntico necessitam de retentores intrarradiculares para viabilizar e reter o material restaurador coronário. Nas últimas décadas os pinos de fibra têm sido amplamente indicados por serem estéticos, apresentarem a possibilidade de cimentação em sessão única e comportamento biomecânico semelhante à estrutura dentinária. A utilização dos pinos de fibras está consolidada na literatura, no entanto, a cimentação é um procedimento complexo e que agrega várias etapas com alta sensibilidade técnica. Assim, manejos simplificados, que eliminam passos clínicos e técnicas alternativas são estudadas. Neste contexto, uma nova opção de pinos de fibra obtidos pelo sistema CAD/CAM surgiu no mercado. Esse novo modelo de pinos pode ser viável, uma vez que prometem uma melhor adaptação às paredes do canal, aumentando a retenção por atrito, além da possibilidade de fresar pino e núcleo em corpo único eliminando a etapa de confecção de núcleo em resina composta. Assim, o objetivo geral deste estudo é avaliar, por meio de estudos laboratoriais, alternativas simplicadas para cimentação e confecção de retentores intrarradiculares de resina reforçados por fibra. O estudo foi dividido em três objetivos específicos. **Objetivo específico 1**: Avaliar qual o melhor momento para hibridização da dentina coronária, antes ou após a cimentação de pinos de fibra de vidro com cimento resinoso autoadesivo, bem como o uso deste cimento como agente de união ao núcleo de resina composta. **Objetivo específico 2:** Avaliar as propriedades mecânicas de resistência flexural e módulo de flexão do novo conceito de pino de fibra de vidro fresado por CAD/CAM e as características estruturais de proporção fibra e matriz, fibras por mm^2 e presença de vazios no interior dos pinos. **Objtivo espécifico 3:** Avaliar o comportamento biomecânico de dentes tratados endodonticamente reabilitados com pinos de fibra fresados por CAD/CAM e sua relação com o remanescente coronário. Os resultados encontrados mostraram que: 1) A utilização do cimento resinoso autoadesivo como agente de união demonstrou adequada resistência de união da dentina coronária ao núcleo de preenchimento em resina composta. O momento de hibridização da dentina coronária não afetou a resistência de união da resina composta. 2) Pinos de fibra fresados por CAD/CAM tem propriedades mecânicas e características estruturais semelhantes aos pinos pré-fabricados. Independente do método de fabricação (pré-fabricado ou fresado), vazios dentro da estrutura contribuem fortemente para a fragilidade dos pinos. 3) Reabilitações retidas por pinos obtidos pelo sistema CAD/CAM têm resistência à fratura semelhante as reabilitações retidas por pinos pré-fabricados. Entretanto, na ausência da remanescente coronário, há grande deformação na raiz em dentes restaurados com pinos de fibra fresados, levando a falhas irreparáveis. Portanto, conclui-se que materiais que visam a simplificação das etapas e o fluxo digital são promissores, mas são necessários mais estudos para que os pinos de fibra obtidos pelo sistema CAD/CAM sejam consolidados como primeira alternativa.

Palavras Chave: Pinos Dentários, Dente não Vital, Materiais Dentários

Abstract

Abastract

Due to the great loss of coronal structure, endodontically treated teeth usually require intraradicular retainers to enable and retain coronal restorative material. In the last decades the glassfber post have been widely indicated as being aesthetic, presenting the possibility of cementation in a single session and biomechanical behavior like the dentin structure. The use of glassfiber post is consolidated in the literature; however, luting is a complex procedure and adds several steps with high technical sensitivity. Thus, simplified and eliminating clinical steps are indicated. In this scenario, a novel concept of glassfiber post obtained by the CAD/CAM system appeared in the market. This new model of post can be feasible, since they promise a better adaptation to the walls of the root, increasing the retention by friction, besides the possibility of milling both the post/core in a single body eliminating the stage of preparation of core in composite resin. Thus, the general aim of this study is to evaluate, by means of laboratory studies, simpliced alternatives for luting and confection of fiber reinforced resin intraradicular retainers. The study was divided into three specific objectives. **Specific objective 1-** Evaluate the time when the coronal dentin hybridization is performed, before or after cementing glassfiber post with self adhesive resin cements (SARCs), as well the use of SARC as bonding agent to resin composite core filling. **Specific objective 2 –** Evaluate the mechanical properties of flexural proprieties and modulus of the novel concept of glassfiber post and to evaluate the structural characteristics of fiber and matrix ratio, fibers per mm2 and presence of voids inside the post. **Specific objective 3 –** To evaluate the biomechanical behavior of endodontically treated teeth rehabilitated with glassfiber post milled by CAD/CAM and its relationship with the coronaral remaning. The results showed that: 1) The use of sefl-adhesive only, as hybridization was shown to demonstrate adequate bond strength to composite resin. The time of coronal dentin hybridization did not affect the bond strength of composite resin. 2) CAD/CAM milled glassfiber post have mechanical properties and structural characteristics similar to prefabricated post. Regardless of the manufacturing method (prefabricated or milled), voids within the structure contribute strongly to the fragility of post. 3)

CAD/CAM-fabricated glassfiber post had the same fracture resistance of prefabricated glassfiber post. In absence of remaining coronal dentin, endodontically treated teeth restored with milled post presents higher strain and major potential of fractures irreparable. Therefore, it is concluded that materials that aim to simplify the steps and the digital flow are promising, however more studies are needed so that the glassfiber post CAD/CAM-fabricated are consolidated as a first alternative.

Keywords: Dental pins, Nonvital tooth, Dental materials

Introdução e Referencial Teórico

1. Introdução e Referencial Teórico:

A reabilitação funcional e estética de dentes com tratamento endodôntico tem sido alvo de diversos estudos que buscam compreender as diferentes propriedades entre dentes vitais e não vitais (Soares et al., 2007). Cáries extensas ou fraturas por trauma são os principais fatores que resultam em necessidade de tratamento endodôntico e geram fragilização da estrutura dentária. Somado a isto, os procedimentos clínicos necessários para realizar o tratamento, tais como a abertura para acesso endodôntico (remoção de teto da câmera pulpar), combinado com a perda das cristas marginais, representam os principais fatores da redução de resistência destes dentes (Dietschi et al., 2008; Magne et al., 2016). Além disso, soluções irrigantes utilizadas para desinfecção do canal radicular, como o hipoclorito de sódio (NaOCl) e ácido tetra-acético etilenodiamina (EDTA), interagem com os componentes orgânicos e minerais da dentina e produzem alterações na estrutura da matriz orgânica (Dietschi et al., 2007; Aranda-Garcia et al., 2013; Baldasso et al., 2017). Dessa forma, vários aspectos devem ser analisados durante a escolha do complexo reabilitador para que se possa garantir longevidade das reabilitações.

A resistência do dente tratado endodonticamente está diretamente relacionada à quantidade de estrutura dentária remanescente sendo este um fator determinante na longevidade do tratamento restaurador (Naumann et al., 2012; Verissimo et al., 2014; Naumann et al., 2018; Soares et al., 2018). O remanescente dentário foi inicialmente denominado por diversos autores como férula (Juloski et al., 2012; Naumann et al., 2018) e é referente ao recobrimento de metal fundido em torno da superfície coronária do dente destinada ao reforço da estrutura na região cervical. Um efeito protetor, ou “Efeito Férula”, ocorre devido ao remanescente dentário resistir às tensões resultantes das forças de alavancas exercidas pelo retentor, do efeito de cunha e das forças laterais exercidas durante a inserção e função dos pinos (Juloski et al., 2012). Assim, essa proteção atua minimizando os efeitos da fadiga mecânica nas interfaces, diminuindo a possibilidade de falha do complexo restaurador. Atualmente, um mínimo de 1,0 mm de férula é considerado sufuciente para o aumento da resistência à fratura e melhor padrão de distribuição das tensões em dentes tratados endodonticamente (Verissimo et al., 2014)

Devido à perda de grande quantidade de estrutura coronária, a maioria das reabilitações em dentes tratados endodonticamente requer utilização de retentores intrarradiculares como forma adicional de estabilizar e reter o material restaurador (Assif & Gorfil, 1994; Ferrari et al., 2012; Naumann et al., 2012). Vários sistemas de retentores são propostos para reabilitação destes dentes, destacando-se os núcleos metálicos moldados e fundidos e os pinos pré-fabricados (Schwartz & Robbins, 2004). Núcleos metálicos fundidos e retentores metálicos pré-fabricados possuem alto módulo de elasticidade, não se aderem aos tecidos dentários e podem comprometer a estética (Verissimo et al., 2014). Dessa forma, nas últimas décadas têm sido indicados como alternativa aos pinos metálicos, os pinos pré-fabricados de resina reforçados por fibra (Soares et al., 2012).

Os pinos de resina reforçados por fibra são pinos constituídos em sua maioria por fibras de vidro ou quarzto envolvidas por uma matriz polimérica (Zicari et al., 2013). A matriz resinosa é comumente composta por polímeros como a resina epóxi com alto grau de conversão em estrutura altamente reticulada (Lassila et al., 2004). As fibras são responsáveis pela resistência à flexão, enquanto a matriz polimérica fornece resistência à compressão (Zicari et al., 2013) assim, as propriedades mecânicas dos pinos de fibra podem ser determinadas por características estruturais e composição do pino (Lassila et al., 2004; Zicari et al., 2013; Novais et al., 2016). As características estruturais incluem integridade, tamanho, densidade e distribuição das fibras, bem como a natureza da ligação entre a matriz e as fibras (Lassila et al., 2004; Wandscher et al., 2015). Áreas de fragilidade no pino, tais como, vazios presentes na resina ou descontinuidades ao longo da interface entre as fibras e a matriz, podem reduzir suas propriedades mecânicas. A composição do pino confere ao material a vantagem de possuir módulo de elasticidade semelhante à estrutura dentinária e quando estão efetivamente aderidos à estrutura dental, as tensões provenientes dos esforços mastigatórios são distribuídas de forma homogênea ao longo do complexo restaurador (Santos-Filho et al., 2008). Portanto, o comportamento biomecânico dos pinos depende das propriedades mecânicas, como dureza e resistência flexural e também da efetiva união entre pino, material resinoso e estrutura dentária (Soares et al., 2008).

Outra grande vantagem dos pinos de fibra é a possibilidade de cimentação em sessão única e eliminação de etapas laboratoriais. No entanto, apesar de ser cimentado em sessão única, o procedimento restaurador é constituído por técnica altamente sensível e que agrega várias etapas (Sarkis-Onofre et al., 2014), assim, algumas falhas têm sido relatadas relacionadas a esta complexidade operatória. O deslocamento do pino no interior do canal radicular é a falha mais frequente (Sarkis-Onofre et al., 2014) e pode ser atribuída a alguns fatores como profundidade radicular (Pereira et al., 2015); alto fator cavitário (fator C) (Dietschi et al., 2008); procedimentos endodônticos prévios à fixação dos pinos (Menezes et al., 2008); incompatibilidade de cimentos resinosos com os sistemas adesivos simplificados (Cheong et al., 2003) e a variabilidade da dentina intrarradicular (Soares et al., 2007). Outra falha comumente relatada é a fratura do núcleo de preenchimento na porção coronária, representada pela falha na interface pino e resina do núcleo de preenchimento (Ferrari et al., 2012). Estudos mostram que tensões geradas durante as mastigações tendem a se acumular na interface entre o pino e materiais resinosos, contribuindo para a fragilidade dessa interface (Santos-Filho et al., 2008).

Cimentos resinosos são indicados para cimentação dos pinos de fibra e podem ser classificados como cimento resinoso convencional e cimento resinoso autoadesivo. O cimento resinoso convencional requer múltiplas etapas (característica que já é inerente à cimentação dos pinos), determinando alta sensibilidade técnica (Faria-e-Silva et al., 2013). Neste contexto, cimentos simplificados, como o autoadesivo tem ganhado popularidade (Dos Santos et al., 2014; Sarkis-Onofre et al., 2014). Este cimento tem capacidade de adesão aos tecidos dentários sem a necessidade de condicionamento ácido e utilização de adesivos (Costa et al., 2014), assim, tem demonstrado melhores resultados de resistência de união (Sarkis-Onofre et al., 2014; Bitter et al., 2016). As propriedades dos cimentos autoadesivos são atribuídas à presença de monômeros metacrilatos modificados por grupos funcionais ácidos. Esses monômeros permitem a desmineralização e a infiltração no substrato dentário resultando em retenção micromecânica (Costa et al., 2014).

Embora não seja necessária a hibridização da dentina radicular quando os pinos de fibra são cimentados com cimentos autoadevisos, recomenda-se a hibridização do remanescente coronário para a reconstrução com resina composta (Bitter et al., 2014). No entanto, não existe clareza na literatura a respeito de qual o melhor momento para realizar a hibridização da dentina coronária; antes ou após a cimentação dos pinos. Além disso, é razoável especular que o excesso de cimento resinoso autoadesivo poderia executar a função de agente de união ao núcleo de preenchimento de resina. Esta ideia vai ao encontro das tendências atuais de simplificação dos procedimentos e redução do tempo clínico.

Com o desenvolvimento das tecnologias aplicadas à odontologia, o fluxo digital e a tecnologia CAD/CAM (computer-aided desing manufacturing) tem ganhado popularidade em procedimentos restauradores. Recentemente, um novo conceito de pino de fibra fabricado por CAD/CAM foi proposto. O canal radicular é moldado e um modelo computacional desse molde é obtido pelo sistema CAD. O pino intrarradicular é obtido através da fresagem do bloco pré-fabricado de resina reforçado por fibra (Liu et al., 2010; Tsintsadze et al., 2017). O uso da tecnologia CAD/CAM para produzir pinos de fibra anatômicos pode ser uma opção viável, considerando a possibilidade de fresar tanto o pino quanto o núcleo em um corpo único. Desta forma, poderia eliminar a necessidade de confecção do núcleo de preenchimento em resina composta (Tsintsadze et al., 2018). Além disso, o uso de CAD/CAM para produzir pinos personalizados poderia garantir uma melhor adaptação às paredes do canal, aumentando a retenção por atrito, redução da espessura da camada de cimento minimizando a contração de polimerização (Silva et al., 2011). No entanto, ainda há pouca literatura disponível sobre propriedades mecânicas e características estruturais desse novo tipo de pino, bem como informações sobre o comportamento biomecânico das reabilitações retidas por pinos fresados por CAD/CAM e sua relação como o remanescente dentário.

12

Objetivos

2- Objetivos:

2.1: Objetivo Geral:

Avaliar, por meio de estudos laboratoriais, alternativas simplicadas para cimentação e confecção de retentores intrarradiculares de resina reforçado por fibra.

2.2: Objetivos Específicos:

2.2.1: Objetivo específico 1:

Avaliar qual o melhor momento para hibridização da dentina coronária, antes ou após a cimentação de pinos de fibra de vidro com cimento resinoso autoadesivo, bem como o uso deste cimento como agente de união da dentina coronária ao núcleo da resina composta.

Este objetivo específico está contido no Capítulo 1 desta tese, intitulado:

Effect of coronal dentin treatment on bond strength of composite resin core-build in glass-fiber post luting

2.2.2: Objetivo específico 2:

Avaliar as propriedades mecânicas de resistência flexural e módulo de flexão do novo conceito de pino de fibra de vidro fresado por CAD/CAM e as características estruturais de proporção fibra/matriz, fibras por mm^2 e presença de bolhas e vazios no interior dos pinos.

Este objetivo específico está contido no Capítulo 2 desta tese, intitulado:

Mechanical properties and structural characteristics of a novel concept of CAD/CAM fabricated fiberglass posts

2.2.3: Objetivo específico 3:

Avaliar o comportamento biomecânico de dentes tratados endodonticamnte reabilitados com pinos de fibra fresados por CAD/CAM e sua relação com o remanescente coronário.

Este objetivo específico está contido no Capítulo 3 desta tese, intitulado:

Does CAD/CAM-fabricated glass fiber post improve the biomechanical behavior of endodontically treated teeth?

Capítulos

3. Capítulos:

Serão apresentados nesta sessão três artigos separadamente sendo que cada um corresponde a um capítulo.

Capítulo 1

3.1. Capítulo 1: Artigo enviado para publicação no periódico Dental Materials Jounal

Title: Effect of coronal dentin treatment on bond strength of composite resin core-build in glass-fiber post luting

Authors:

Giselle Rodrigues REIS[1],
Lucas Lemes QUEIROZ[2],
Ana Laura Resende VILELA[3], e
André Luis FARIA-E-SILVA[4],
Paulo César de Freitas SANTOS-FILHO[5],
Carlos José SOARES[5],
Murilo de Sousa MENEZES[5]

Adjunct Professor, Department of Dentistry, Dentistry School, University of Rio Verde, Rio Verde, Goiás, Brazil. Fazenda Fontes do Saber, Dentistry School, Rio Verde, GO, Brazil.

[2] Graduate in Dentistry School, Department of Restorative Dentistry and Dental Materials, Federal University of Uberlandia, Minas Gerais, Brazil. Avenida Pará, 1720, Bloco 4L, Campus Umuarama, Uberlândia, MG, Brazil,

[3] Master's Degree, Department of Restorative Dentistry and Dental Materials, Federal University of Uberlandia, Minas Gerais, Brazil. Avenida Pará, 1720, Bloco 4L, Campus Umuarama, Uberlândia, MG, Brazil,

[4] Adjunct Professor, Department of Dentistry, Dentistry School, Federal University of Sergipe, Sergipe, Brazil. R. Cláudio Batista s/n, Santório, Aracaju, SE, Brazil.

[5] Associated Professor, Department of Restorative Dentistry and Dental Materials, Dentistry School, Federal University of Uberlândia, Minas Gerais, Brazil. Avenida Pará, 1720, Bloco 4L, Campus Umuarama, Uberlândia, MG, Brazil,

Corresponding author:

Prof. Dr. Murilo de Sousa Menezes

Federal University of Uberlândia, School of Dentistry, Department of Restorative Dentistry and Dental Materials.

Avenida Pará, 1720, Bloco 4L, Anexo A, Sala 34, Campus Umuarama

Uberlândia - Minas Gerais – Brazil, Zip Code: 38400-902

Tel.: +55 34 3225-8106; Fax: +55 34 3225 8108

E-mail address: murilosmenezes@ufu.br

Abstract

This study evaluated the bond strength effect varying the time when coronal dentin is hybridized and the use of self-adhesive resin cement (SARC) for hybridization, during simulated glass-fiber posts restoration. The microshear bond strength (μSBS) specimens was made using dentin substrate obtained from bovine teeth (μSBS). Specimens were allocated to 7 groups: Sa- applying thin layer of SARC (RelyX U200); C- hybridization with a 3 step etch-and-rinse adhesive; Un- hybridization a universal adhesive with self-etch technique; CSa- C followed by SARC; UnSa- Un, followed by SARC; SaC- application of the SARC prior to hybridization as in C; SaUn- application of the SARC prior to hybridization as in Un. No statistically significant difference among groups was observed. The use of RelyX U200 only for hybridization demonstrated adequate bond strength to composite resin. The time when hybridization on coronal dentin was performed did not affect the bond strength of composite.

Introduction

Glass-fiber posts (GFPs) have been increasingly used in recent years compared with other types of posts due to advantages such as improved esthetics, reduced costs, and less time-consuming technique[1)]. In additional, the elastic modulus of GFP is closer to dentin, allowing a better stress distribution to the tooth structure [2)], thereby contributing to the formation of a homogeneous root/cement/post system/core complex[2)]. Failure related to any of these interfaces might negatively impair the formation of a homogeneous complex and compromise the success of GFPs restorations. The main reason for unsuccessful use of GFPs continues to be debonding from the root canal and fracture of the post/core, due to the complex cementation techniques and high level of technique sensitivity[3)].

Resin-based cements are recommended for cementing the GFPs in the root canal and might be classified as regular resin cement[4)] and self-adhesive cement (SARCs). Regular resin cement requires multiple-steps and has a high level of technique sensitivity procedures for post bonding that could lead to inappropriate bonding techniques[5)]. In this scenario, simplified luting agents, such as self-adhesive cements (SARCs) have gained increasing popularity[6, 7)]. SARCs were designed to bond to dental tissues without the need for any etching, priming and bonding steps[8)]. The use of this type of cement for luting fiber posts inside root canals has been shown to be more reliable, as demonstrated in a recently published review of *in vitro* studies[3, 9)]. Additionally, these resin cements resulted in significantly higher bond strength to root canal dentin after thermo-mechanical loading[10)]. The adhesive properties of SARCs are attributed to the presence of methacrylate monomers modified by acidic functionalities. These monomers allow demineralization of and infiltration into the dental substrate[11)] resulting in micro-mechanical retention[8)]. The acidic groups bond to the calcium in hydroxyapatite, and provide additional chemical bonding to the tooth structure [11, 12)].

Irrespective of the protocol used to lute GFPs, a composite core build-up is necessary to retain the coronal restoration. For this purpose, conventional hybridization with different adhesive techniques is recommended[13)]. However, coronal substrate hybridization can be performed before or after the post cementation. Nonetheless, there is lack information available regarding the best time to perform coronal dentin hybridization; before or after cementing GFPs. Moreover, it is reasonable to speculate that the extravasated SARCs themselves might serve to bond the resin composite core to dentin. Therefore, the purpose of this study was to evaluate the time when the coronal dentin hybridization is performed, before or after cementing GFPs with SARCs, as well the use of SARC as bonding agent to resin composite core filling. The null hypotheses were that bond strength of dentin to the core material would be not influenced by the time of conventional hybridization, and use of SARCs only as bond agent.

Materials and Methods

Specimen Preparation

Seventy-seven bovine tooth crowns were used as specimens for microshear bond strength *(μSBS)* testing. The teeth were embedded in PVC cylinders with polystyrene resin (Aerojet, Santo Amaro, SP, Brazil), and the buccal surfaces were wet-ground with silicon carbide papers (#60, 150, 240, 600-grit, Norton, Campinas, SP, Brazil) for 60 seconds to exposure the dentin surface and standardize the smear layer. Specimens were observed under a stereomicroscope at 40× magnification to verify the presence of remaining enamel, or pulp exposure. The specimens were rinsed with deionized water and ultrasonically cleaned to remove debris for 15 minutes. Afterwards, specimens were randomly allocated to 7 groups (n=11) according to the adhesive procedures, as described in Table 1. A sample calculation was performed based on the reported µSBS in the literature[14, 15)], considering a mean standard deviation of 20%, to 30% minimum significant difference among groups, as clinically significant, a desired power of 80%, and a type I error of 5%.

Table 1. Protocols used for treating the dentin surfaces for each group

Group code	Dentin treatment
C	1. Etching surface with 37% phosphoric acid for 15 s (Condac; FGM, Joinville, SC, Brazil), rinsed for 15 s and humidity control; 2. Application of primer (Scotchbond Multipurpose; 3M ESPE, St Paul, MN, USA), volatilization 20 s and application of single layer of adhesive resin (Scotchbond; 3M ESPE, St Paul, MN, USA) and light-cured for 40 s using a light-emitting diode curing unit (Radii-Cal; SDI, Bayswater, Victoria, Australia) at 1200 mW/cm^2
Un	1. Active application of the universal adhesive (Scotchbond Bond Universal; 3M ESPE, St Paul, MN, USA) for 20 s, volatilization with compressed air for 5 s and light-cured for 40 s.
Sa	1. Application of single layer of self-adhesive cement (RelyX U200; 3M ESPE, St Paul, MN, USA), waiting to allow chemical cure for 5 min and light-cured for 40 s.
CSa	1. Etching surface with 37% phosphoric acid for 15 s, rinsed for 15 s and humidity control; 2. Application of primer wait 20 s and application of single layer of adhesive resin and light-cured for 40 s. 3. Application of single layer of self-adhesive cement, waiting to

	allow chemical cure for 5 min and light-cured for 40 s.
UnSa	1. Active application of the universal adhesive for 20s, volatilization with compressed air for 5s and light-cured for 40s; 2. Application of single layer of self-adhesive cement, waiting to allow chemical cure for 5 min and light-cured for 40 s.
SaC	1. Application of single layer of self-adhesive cement, waiting to allow chemical cure for 5 min and light-cured for 40 s; 2. Etching surface with 37% phosphoric acid for 15 s, rinsed for 15 s, humidity control; 3. Application of primer waited 2O s and application of single layer of adhesive resin and light-cured for 40 s.
SaUn	1. Application of single layer of self-adhesive cement, waiting to allow chemical cure for 5 min and light-cured for 40 s; 2. Active application of the universal adhesive for 20 s, volatilization with compressed air for 5 s and light-cured for 40 s;

Two molds consisting of Tygon tubes (TYG-030, Small Parts Inc., Miami Lakes, FL, USA), with internal diameter and height of approximately 1.70 and 1.50 mm, respectively, were placed on the dentin surface and filled with the micro-hybrid resin composite (Brilliant; Coltène Whaledent AG, Altstätten, Switzerland). The composite was photoactivated for 40 seconds using a light-emitting diode curing unit (Radii-Cal; SDI, Bayswater, Victoria, Australia) with irradiance of 1200 mW/cm^2. All experimental procedures were carried out at room temperature by a single operator and the specimens were stored in distillated water at 37° for 24 hours.

Microshear bond strength testing (μSBS)

For the μSBS test, a metal jig was coupled to a mechanical testing machine (OM100, Odeme Dental Research, Luzerna, SC, Brazil), and the polystyrene cylinder containing the teeth was placed on the device. The Tygon tubing was carefully removed with a scalpel blade, and a loop made of orthodontic wire with a diameter of 0.3 mm (NiCr, Morelli, Sorocaba, SP, Brazil) was placed around the specimens that were positioned perpendicular to the testing machine. The µSBS test was performed by stressing specimens until to failure at speed of 0.7 mm/min. The bond strength of each specimen (MPa) was calculated according to the following formula:

$$S=F/A$$

where F was the force required to failure (N), and A was the bonded area of the specimens (mm^2). Statistical analysis was performed by one-way analysis of variance (ANOVA) followed by the Tukey post hoc test (α=0.05).

Failure mode analysis

After the test, the fractured specimens were observed under a stereomicroscope (40×). Failures were classified as adhesive, cohesive and mixed. Failures were adhesive when no residual resin material could be observed on the tooth surface; cohesive when dentin/resin was partially fractured, and mixed when the resin residue partially covered the bonded area.

Results

Results for the microshear bond strength tests are shown in Table 2. One-way ANOVA showed no significant difference among groups (*p*=0.749).

Table 2. Means (SD) shear bond strength values of the composite resin to the dentin (MPa) using different strategy adhesive (n=11).

Strategy adhesive	MPa (SD)
C	9.08 (5.45) ^{A}
Un	12.55 (4.63) ^{A}
Sa	11.71 (4.66) ^{A}
CSa	12.32 (6.57) ^{A}
UnSa	12.08 (5.50) ^{A}
SaC	11.84 (2.83) ^{A}
SaUn	12.62 (5.62) ^{A}

* Same Capital letters in each line indicate statistical similarity (*p*=0.749)

The failure mode distribution for all groups is presented in Figure 1. In general, adhesive failures were predominant irrespective of group. A significant number of cohesive and mixed failures was also observed for CSa, SaC and Un.

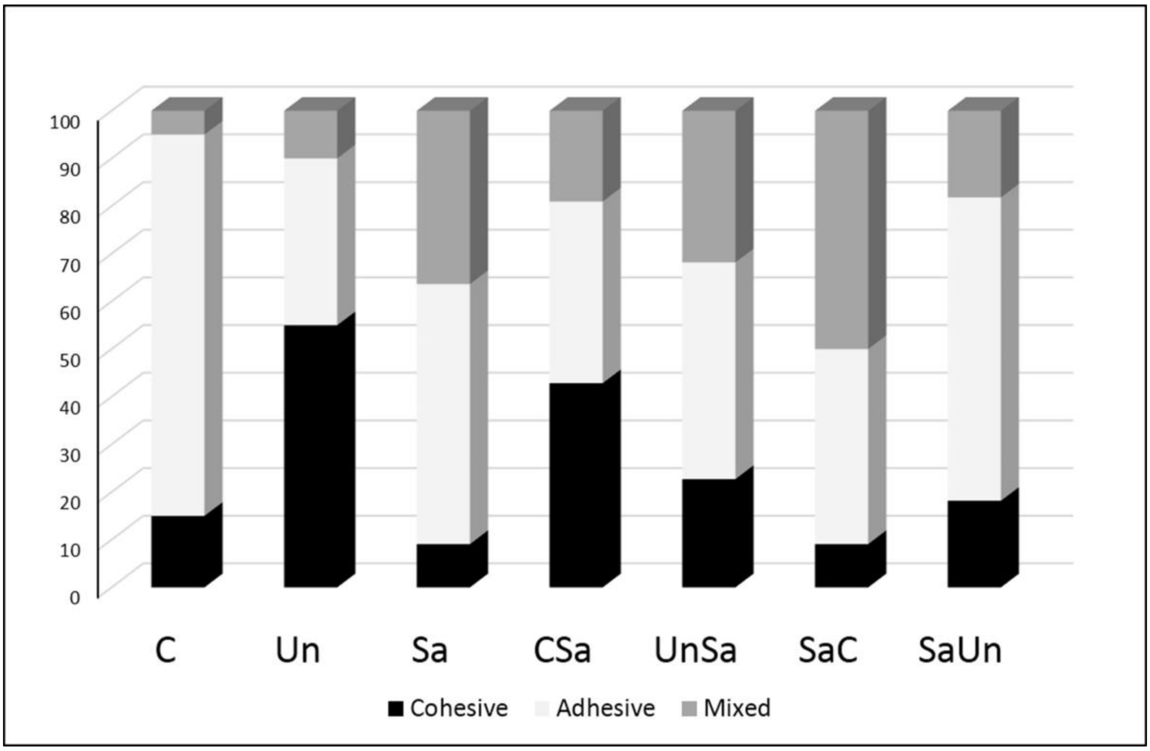

Figure 1 - Distribution of failure modes among groups (%).

Discussion

Glass Fiber Posts (GFPs) are frequently used nowadays, however bonding to root canal dentin is still a challenge due to the limited access, visibility and reduced number of dentinal tubules in the apical third of the root[16)]. In addition, the C-factor inside the root canal has been shown to be extremely high[17)] and previous endodontic treatment could affect the bond strength of GFPs[7, 18)]. Regular resin cements require multiple bonding steps and might affect post retention. The use of etch-and-rinse adhesives is technique-sensitive, because it requires control of dentin moisture and adhesive solution infiltration into the root canal[3]. In this scenario, SARCs appear to be a suitable and less technique-sensitive option than luting strategies that involve pretreating the canals with adhesive solutions, and their application is accomplished in a single clinical step[3, 4].

Although no hybridization of root dentin is necessary when SARCs are used for luting GFPs, prior coronal reconstruction by using resin composite is recommended to hybridization of the coronal dentin remaining[13]. The outcomes of the present study showed that the different times when the hybridization of coronal dentin was performed did not affect the bond strength to composite. Moreover, the use of SARC for hybridization did not influence bond strength either, thus we accepted the null hypothesis

The main bonding mechanism of SARCs is attributed to a chemical reaction between phosphate methacrylates and the calcium present in dentin and enamel tissues [3, 5, 11, 12, 19]. The phosphoric acidic methacrylates promote the intrinsic acidity of SARCs [8] and their low pH demineralizes the tooth hard tissue simultaneously allowing resin infiltration[19, 20]. Another property of SARCs is that they require water (as a constituent of the cement, or available in the bonding substrate) to ionize the acidic monomers and allow their interaction with the dental structures[11]. This includes ionizing the acid monomers coming into contact with the water present in the dental structure, and releasing H^+ ions that promote etching[21]. During the polymerization reaction of resin cement, when the resin components penetrate into the intertubular dentin and diffuse through dentinal tubules, the acid monomers are neutralized by the calcium in dental tissue, and the pH of the material becomes neutral[21]. Thus, even without the conventional hybridization with adhesive systems, the Sa group (use of SARCs only) presented *μSBS* values similar to values of other groups.

When the GFP is cemented in the root canal, excess cement is generated in the coronal chamber, and this might bond to coronal dentin. In this study, this step was simulated when a thin layer of SARCs was applied on the dentin surface and the composite resin specimens were immediately built up. A reduced amount of unreacted monomers on the surface of cured cement probably reacted with the resin composite [(6)]. In a previous study, Bitter *et al.*

analyzed an experimental SARC as core build-up material in a one-stage post-and-core-procedure, however, no satisfactory results were found. Whereas, in the present study, the use of SARCs as bonding agents, was an attempt to eliminate steps to reduce the technique sensitivity and clinical time.

Otherwise, the conventional strategy for coronal dentin hybridization is to use an adhesive system. Dental adhesive systems can be classified into two main categories according to different bonding techniques to dental substrates: the etch-and-rinse and self-etch systems[22, 23]. Although etch-and-rinse adhesives continue to be adequate adhesive systems, the current trend is to use less sensitive techniques with simplified self-etching materials[22, 24]. Universal adhesives are the latest generation of adhesives available on the market[24], and are named multimode or universal since they can be used in either self-etch or etch-and-rinse approaches[24]. Universal adhesives in self-etch application are easy-to-use; have a faster application procedure; and are less susceptible to differences in the operator's technique, when compared with multi-step etch-and-rinse adhesives, leading to their increasing popularity. The mechanism for bonding to enamel and dentin, which involves the use of adhesive systems, promotes a micromechanical bond to the previously acid-etched enamel and the formation of a hybrid layer on dentin[21]. The general mechanisms for adhesive bonding to dentin are essentially based on superficial demineralization, followed by infiltration of resin monomers, which upon polymerization become micro-mechanically interlocked in the collagen fibrils[24]. Self-etch adhesives contain acid resin monomers that simultaneously "etch" and "prime" the dental substrates and do not require a prior phosphoric acid etching step[25]. In this study both strategies yielded similar bond strength values corroborating the findings of other studies[24]. The application of SARCs before or after adhesive systems did not affect the bond strength. Probably, the interaction between polymer matrices and adhesive systems occurred satisfactorily when the resin cement excess came into contact with coronal dentin resulting in bond strength similar to that produced by adhesive system application.

Various methods are used to evaluate bond strength, including tensile, shear, microtensile, and MSBS tests[23)]. Several studies have evaluated the bond strength of cements to dentin using the microtensile test. However, evaluating bond strength by means of microtensile testing might be problematic because the cutting procedure to obtain the beams produces defects on the corners of the sticks, resulting in high levels of defects that compromise testing[23, 26, 27)]. Thus, due to various interfaces tested and possibility of sample failure during cutting in this study, the shear test was chosen. On the other hand, the shear bond strength test presented many cohesive failures in the substrate due to non-uniform stress distribution concentrated in the substrate at time of the test[26)]. Therefore, cohesive or mixed failures were found in this study.

The common failures of restorations with GFPs are post and crown debonding or post fracture, which are usually combined with core failure, especially in teeth with few coronal walls[28)]. Thus, the bonding ability between the core and dentin is fundamental for longevity of restoration complex. Nonetheless, the core/dentin bonding surface area was small, the position was near the fulcrum, which was in a critical area[28)]. Furthermore, the number of steps in the bonding procedure is an important factor in obtaining more reliable and stronger bond between the resin and dentin[29)]. The clinical procedure of luting GFPs is complex, due to many bonding surfaces: root/cement, cement/post, post/resin and resin/coronal dentin. In this scenario, the use of excess SARC as bonding agent might be an alternative to simplify procedures and reduce the possibility of errors. In addition, application of an adhesive system allied to SARCs on coronal dentin create a new adhesive interface that could be prone to failure[30)]. Therefore, the idea of using the SARCs as bonding agent was consistent with the current trend to overcome the technique sensitivity of multiple-step systems by eliminating steps. Nevertheless, the results of this study are specific to the products used, other SARCs may behave differently. Thus, it is risky to generalize the results and make clinical recommendations. In addition, the study does not test long-term clinical performance, so further studies should thus be performed to accessed this.

Conclusion

Within the limitations of this study, the use of SARCs only, as hybridization was shown to demonstrate adequate bond strength to composite resin. The time of coronal dentin hybridization did not affect the bond strength of composite resin.

References

1) Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J 2011; 5677-5683.

2) Santos-Filho PC, Verissimo C, Raposo LH, Noritomi MecEng PY, Marcondes Martins LR. Influence of ferrule, post system, and length on stress distribution of weakened root-filled teeth. J Endod 2014; 40:1874-1878.

3) Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: a systematic review and meta-analysis of in vitro studies. Oper Dent 2014; 39:E31-44.

4) Simoes TC, Luque-Martinez I, Moraes RR, Sa A, Loguercio AD, Moura SK. Longevity of Bonding of Self-adhesive Resin Cement to Dentin. Oper Dent 2016; 41:E64-72.

5) Faria-e-Silva AL, Menezes Mde S, Silva FP, Reis GR, Moraes RR. Intra-radicular dentin treatments and retention of fiber posts with self-adhesive resin cements. Braz Oral Res 2013; 27:14-19.

6) Dos Santos VH, Griza S, de Moraes RR, Faria ESAL. Bond strength of self-adhesive resin cements to composite submitted to different surface pretreatments. Restor Dent Endod 2014; 39:12-16.

7) Skupien JA, Sarkis-Onofre R, Cenci MS, Moraes RR, Pereira-Cenci T. A systematic review of factors associated with the retention of glass fiber posts. Braz Oral Res 2015; 29.

8) Costa LA, Carneiro KK, Tanaka A, Lima DM, Bauer J. Evaluation of pH, ultimate tensile strength, and micro-shear bond strength of two self-adhesive resin cements. Braz Oral Res 2014; 28:1-7.

9) Bitter K, Schubert A, Neumann K, Blunck U, Sterzenbach G, Ruttermann S. Are self-adhesive resin cements suitable as core build-up materials? Analyses of maximum load capability, margin integrity, and physical properties. Clin Oral Investig 2016; 20:1337-1345.

10) Bitter K, Perdigao J, Exner M, Neumann K, Kielbassa A, Sterzenbach G. Reliability of fiber post bonding to root canal dentin after simulated clinical function in vitro. Oper Dent 2012; 37:397-405.

11) Madruga FC, Ogliari FA, Ramos TS, Bueno M, Moraes RR. Calcium hydroxide, pH-neutralization and formulation of model self-adhesive resin cements. Dent Mater 2013; 29:413-418.

12) Ferracane JL, Stansbury JW, Burke FJ. Self-adhesive resin cements - chemistry, properties and clinical considerations. J Oral Rehabil 2011; 38:295-314.

13) Bitter K, Glaser C, Neumann K, Blunck U, Frankenberger R. Analysis of resin-dentin interface morphology and bond strength evaluation of core materials for one stage post-endodontic restorations. PloS One 2014;9:e86294.

14) Lisboa DS, Santos SV, Griza S, Rodrigues JL, Faria-e-Silva AL. Dentin deproteinization effect on bond strength of self-adhesive resin cements. Braz Oral Res 2013; 27:73-75.

15) Faria ESAL, Fabiao MM, Sfalcin RA, de Souza Meneses M, Santos-Filho PC, Soares PV, et al. Bond Strength of One-Step Adhesives under Different Substrate Moisture Conditions. Eur J Dent 2009; 3:290-296.

16) Mjor IA, Smith MR, Ferrari M, Mannocci F. The structure of dentine in the apical region of human teeth. Int Endod J 2001; 34:346-353.

17) Fatemeh K, Mohammad Javad M, Samaneh K. The effect of silver nanoparticles on composite shear bond strength to dentin with different adhesion protocols. J Appl Oral Sci 2017; 25:367-373.

18) Menezes MS, Queiroz EC, Campos RE, Martins LR, Soares CJ. Influence of endodontic sealer cement on fibreglass post bond strength to root dentine. Int Endod J 2008; 41:476-484.

19) De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P, Van Meerbeek B. Bonding of an auto-adhesive luting material to enamel and dentin. Dent Mater 2004; 20:963-971.

20) Hikita K, Van Meerbeek B, De Munck J, Ikeda T, Van Landuyt K, Maida T, et al. Bonding effectiveness of adhesive luting agents to enamel and dentin. Dent Mater 2007; 23:71-80.

21) Barcellos DC, Batista GR, Silva MA, Rangel PM, Torres CR, Fava M. Evaluation of bond strength of self-adhesive cements to dentin with or without application of adhesive systems. J Adhes Dent 2011; 13:261-265.

22) Pashley DH, Tay FR, Breschi L, Tjaderhane L, Carvalho RM, Carrilho M, et al. State of the art etch-and-rinse adhesives. Dent Mater 2011; 27:1-16.

23) Thanaratikul B, Santiwong B, Harnirattisai C. Self-etch or etch-and-rinse mode did not affect the microshear bond strength of a universal adhesive to primary dentin. Dent Mater J 2016; 35:174-179.

24) Rosa WL, Piva E, Silva AF. Bond strength of universal adhesives: A systematic review and meta-analysis. J Dent 2015; 43:765-776.

25) Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL. State of the art of self-etch adhesives. Dent Mater 2011; 27:17-28.

26) Armstrong S, Geraldeli S, Maia R, Raposo LH, Soares CJ, Yamagawa J. Adhesion to tooth structure: a critical review of "micro" bond strength test methods. Dent Mater 2010; 26:e50-62.

27) Sano H, Shono T, Sonoda H, Takatsu T, Ciucchi B, Carvalho R, et al. Relationship between surface area for adhesion and tensile bond strength--evaluation of a micro-tensile bond test. Dent Mater 1994; 10:236-240.

28) Panitiwat P, Salimee P. Effect of different composite core materials on fracture resistance of endodontically treated teeth restored with FRC posts. J Appl Oral Sci 2017; 25:203-210.

29) Gomes GM, Gomes OM, Reis A, Gomes JC, Loguercio AD, Calixto AL. Effect of operator experience on the outcome of fiber post cementation with different resin cements. Oper Dent 2013; 38:555-564.

30) Leme AA, Pinho AL, de Goncalves L, Correr-Sobrinho L, Sinhoreti MA. Effects of silane application on luting fiber posts using self-adhesive resin cement. J Adhes Dent 2013; 15:269-274.

Capítulo 2

3.2. Capítulo 2: Artigo enviado para o periódico Brazilian Oral Reserach

Title: Mechanical properties and structural characteristics of a novel concept of CAD/CAM fabricated fiberglass posts

Authors:

Giselle Rodrigues REIS[1]
Gabriely Martins SILVA[2]
Veridiana Resende NOVAIS[2]
Priscilla Barbosa SOARES[2]
Paulo César de Freitas SANTOS-FILHO[2]
Murilo de Sousa MENEZES[2]

[1] Department of Dentistry, Dentistry School, University of Rio Verde, Rio Verde, Goiás, Brazil.
[2] Department of Restorative Dentistry and Dental Materials, Dentistry School, Federal University of Uberlândia, Minas Gerais, Brazil.

Corresponding author:

Prof. Dr. Murilo de Sousa Menezes

Federal University of Uberlândia, School of Dentistry, Department of Restorative Dentistry and Dental Materials.

Avenida Pará, 1720, Bloco 4L, Anexo A, Sala 34, Campus Umuarama

Uberlândia - Minas Gerais – Brazil, Zip Code: 38400-902

Tel.: +55 34 3225-8105; Fax: +55 34 3225 8108

E-mail address: murilomenezes@ufu.br

Abstract: This study assessed and compare the mechanical properties and structural characteristics of CAD/CAM fiberglass posts (FGPs) and prefabricated FGPs. Two prefabricated FGPs (n=10) – Exacto and WhitepostDC - were used in comparison with milled FGPs. A 3D virtual image was obtained from a prefabricated FGP, which guided the posterior milling of FGP from a fiber-reinforced composite disk (FiberCAD Post & Core). The FGPs were scanned using micro-CT after being loaded in a three-point bending test to calculate both flexural strength (*σf*) and flexural modulus (*Ef*). The cross-sections of the posts were examined by means of SEM. Data were submitted to one-way ANOVA and Tukey test ($p<0.05$) or Kruskal-Wallis test and post hoc Dunn's test ($p<0.05$). Correlation between the mechanical properties and structural variables was calculated by Pearson's correlation coefficients ($p<0.05$). The results show that WhitepostDC had a significantly higher percentage of pores compared to Exacto ($p=0.012$) and FiberCAD Post & Core presented an intermediate percentage. Exacto had significantly higher *σf* and *Ef* (p=<0.001) when compared to WhitepostDC. FiberCAD Post & Core presented intermediate values of *σf*, and similar *Ef* to WhitepostDC. Fiber/matrix ratio of FiberCAD Post & Core was significantly higher than Exacto ($p=0.004$) and WhitePostDC ($p<0.001$). Exacto and WhitePostDC presented a similar amount of fibers per mm^2 and a higher amount than FiberCAD Post & Core. In conclusion, CAD/CAM FGPs have mechanical properties and structural characteristics similar to prefabricated FGP. Regardless of the manufacturing method, voids inside the structure contribute strongly to the fragility of FGP.

Key word: Dental Materials**,** CAD/CAM, Dental Pins.

Introduction

Over the past few decades, fiberglass post (FGP) has been widely used to endodontically restore treated teeth with a severe loss of dental structure to improve the retention of the build-up material, as an alternative to metallic post-and-cores.[1] The advantages of FGP include an elastic modulus akin to dentin which reduces stress arising at the interfaces, mimicking the mechanical behavior of a natural tooth.[2, 3] Failure related to any post/resin/dentin interfaces might impair the formation of a homogeneous complex and increase the risk of a post/core fracture.[2] Studies have reported that fracture of the post/ core and debonding of the post commonly occur in FGP–retained restorations.[4-6]

Current FGPs are composed of unidirectional fibers (quartz or glass) embedded in a resin matrix.[1, 7] Matrix polymers are commonly epoxy polymers with a high degree of conversion and a highly cross-linked structure.[8] Fibers are responsible for resistance against flexure, while the resin matrix provides resistance against compression stress.[1] The mechanical properties of FGPs may be determined by structural characteristics and the post composition.[1, 7-9] These characteristics include integrity, size, density and distribution of the fibers as well as the nature of the bond between the matrix and the fibers, which may be the determining factors for different flexural strength values.[8, 10] Areas of weakness in a FGP, such as voids, present within the resin or in the discontinuities along the interface between the fibers and matrix, may reduce their mechanical properties.[7]

Due to the development of dental material and technology, computer-aided design and computer-aided manufacturing (CAD/CAM) technology has become popular in restorative procedures[11] and a novel concept of CAD/CAM fabricated FGP has been proposed.[12, 13] The use of CAD/CAM technology to produce anatomic custom intraradicular retainers seems a viable option, especially considering the possibility of milling both the post and core, which would eliminate the need for a composite resin to build-up a resin core[14] and reduce failures in post/resin interface. Moreover, the use of CAD/CAM to produce customized post and cores could ensure a better adaptation of the post to the canal walls, increasing frictional retention, reducing cement layer thickness and minimizing polymerization shrinkage.[15] However, there is a gap in the available literature regarding mechanical properties – flexural strength and flexural modulus - and structural characteristics, such as fiber/matrix ratio, fibers per mm^2 and presence of voids inside the CAD/CAM FGP. Therefore, the present study was conducted to assess the mechanical properties of the novel concept of FGP and to evaluate the structural characteristics by means of scanning electron microscopy (SEM) and Micro-CT Analysis. Besides, we attempted to evaluate a possible correlation between the analyzed variables. The null hypothesis was that there is no difference between mechanical and structural characteristics of FGPs milled by CAD/CAM and prefabricated FGPs.

Methodology

Sample Preparation

Different types of fiber posts were evaluated (n=10): two prefabricated FGPs – Whitepost DC #3 (FGM; Joinville, Brazil, n. lot: 43776) and Exacto #3 (Angelus; Londrina, Brazil, n. lot 8219); and a CAD/CAM FGP. The pre-fabricated FGPs were conical but tapered at the apex, translucent, 20 mm in length and about 2 mm in diameter in the cylindrical part. For production of CAD/CAM FGP, Exacto post was digitized with a bench-top scanner (Ceramill Map 400, Amann Girrbach AG, Koblach, Austria) and modeled with design software (Ceramill Mind, Amann Girrbach AG). The posts were milled on the Ceramill Motion 2 (Amann Girrbach AG) with water-cooling using a fiberglass-reinforced epoxy-resin block (FiberCAD Post & Core, Angelus, lot number: 200218).

Micro-CT Analysis

For evaluation of presence of bubbles and voids the posts were mounted on a custom attachment, and scanned in a micro-CT scanner (SkyScan 1272; Bruker-microCT, Kontich, Belgium). The scanner was operated at 100 kV and 111 mA (0.5-mm Al/0.038- mm Cu filter). The resolution used was 1632/1092 pixels- 15 µm. The scanning was performed by 360° rotation around the vertical axis with a rotation step of 0.7. Images of each specimen were reconstructed (NRecon v., Bruker-microCT) providing axial cross-sections of their inner structure. CTAn v. software (Bruker-microCT) was used for the 3-dimensional (3D) (volume, surface area and structure model index) evaluation of the root canal (Fig. 1). CTVol v. software (Bruker-microCT) was used for visualization and quantitative evaluation of the specimens.[17]

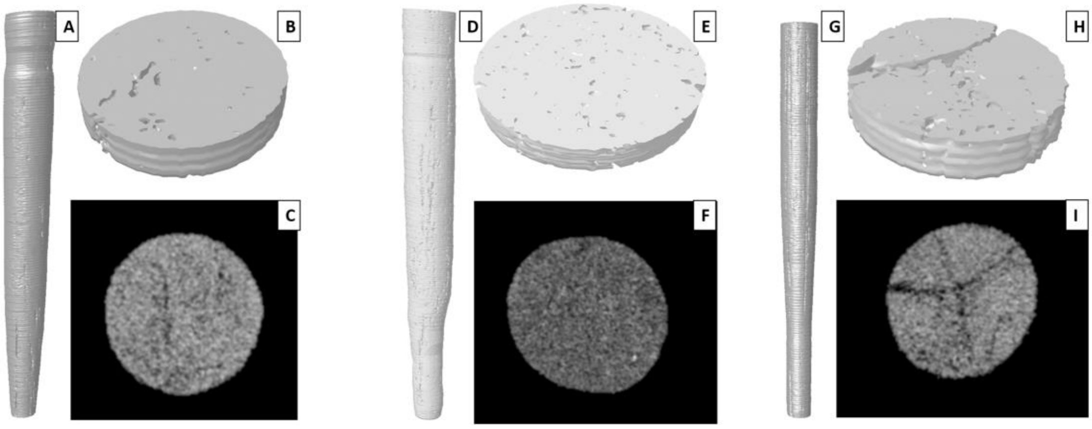

Figure 2 - Micro-CT evaluation. 3D reconstruction of FGP (A – Exacto, D – FiberCAD Post & Core and G – WhitepostDC); 3D reconstruction of slices showing the presence of bubbles in FGP (B – Exacto, E – FiberCAD Post & Core and H – WhitepostDC); slices showing the

Three-Point Bending Test

A three-point bending test was used to measure the mechanical properties of all specimens in a mechanical testing machine (EMIC DL2000; EMIC, São José dos Pinhais, Brazil) using a 500 N load cell and 0.5 mm/min crosshead speed. The mechanical test consisted of positioning the sample on two supports, which define the length of the span distance of the test and applying the vertical load at the mid-point of the specimen.[16] The two supports and the central loading rod had a 2.0 mm cross-sectional diameter. To reduce the influence of the conical end of the posts, the length of the span between the supports was 6.0 mm to assure testing only on the parallel portion of the post.[17] The diameter of each sample was measured at the point where the load was applied using a digital micrometer (Mitutoyo, Japan). The flexural strength (σ_f) and flexural modulus (E_f) were calculated using the following equations:

$$\sigma_f = 8F_{Max}\,L/\pi d^3$$

$$E_f = 4FMaxL^3/(D3\pi d^4)$$

where FMax is the applied load (in Newtons) at the highest point of the load–deflection curve, L is the span length (6.0 mm), d is the diameter of the posts (in mm), and D is the deflection (in mm) corresponding to load F at a point in the straight-line portion of the curve.[16]

Scanning Electron Microscopy (SEM) Evaluation

All tested FGP were cross-sectioned using a diamond saw (Isomet, Buehler, Lake Bluff, USA) for evaluation of fiber/matrix ratio and fibers per mm^2 .The sectioned surface was embedded in polymethyl methacrylate resin (Instrumental, Instrumentos de Medição Ltda, São Paulo, Brazil) and polished. The finishing was first carried out with silicon carbide paper following the 600, 800, 1200, and 1500 sequence (Norton S/A, Campinas, Brazil) grit size under running water; the surface was then polished by felt discs (Polishing Cloth, METADI, Buehler, USA) with diamond paste (6, 3, 1, M ¼; Arotec, São Paulo, Brazil). The specimens were ultrasonically cleaned in deionized water for 10 min and then were mounted on metallic stubs before being sputtered with gold in an ion-sputtering device (Bal-Tec SCD 050, Balzers, Germany). Finally, the specimens were analyzed under a SEM (VO MA 10, Carl Zeiss, Germany) at the same magnification (x80, x500 and x1000) and operated at 15 kV. The SEM micrographs of the FGPs were analyzed using an image processing and analysis program (ImageJ, NIH, Bethesda, USA). The number of fibers and the area occupied by the fibers per square millimeter of the post area were measured.

Statistical analysis

Data analysis was carried out using SigmaPlot 12.0 software (Systat Software Inc., San Jose, USA) and subjected to one-way analysis of variance (ANOVA) and multiple comparisons were applied using the post hoc Tukey test to identify the influence of particularities of FGP on the mechanical properties and structural characteristics at a 0.05 significance level. Variables that did not present normal data distribution (flexural strength and quantity fibers per square millimeter) were analyzed by the Kruskal-Wallis test and post hoc Dunn's test at a 0.05 significance level. To verify the correlation between the mechanical properties (flexural strength and flexural modulus), and the structural characteristics (number of fibers per mm^2, fiber/matrix ratio [%] and porosity [%]) for all FGP, we used Pearson's correlation coefficients test at a significance level of $\alpha=0.05$.

Results

The percentage of voids found in each FGP was significantly different (p=0.016) and are shown in Figure 2. Whitepost DC had a significantly higher percentage of pores compared to Exacto (p=0.012) and Fiber CAD Post & Core presented intermediate percentage.

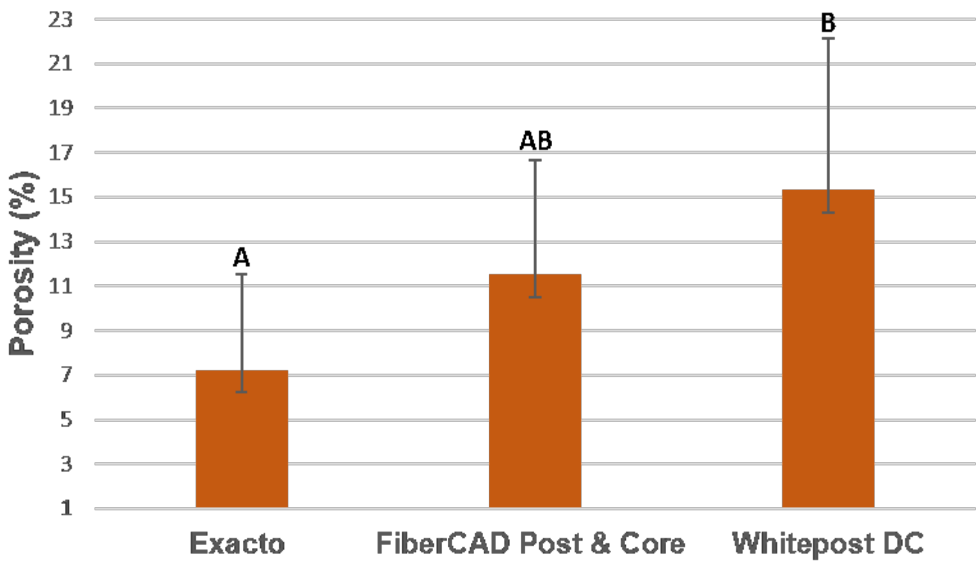

Figure 3 - Micro-CT analysis results - Mean values and standard deviation of volume of pores in FGP structure.

The results for the mechanical properties tested are shown in Table 1. The FGP type had significant effect on *σf* and *Ef* (p=<0.001). Exacto FGPs had significantly higher *σf* and *Ef* when compared to the Whitepost DC FGPs. Fiber CAD Post & Core presented intermediate values of *σf,* and similar *Ef* of Whitepost DC GFPs.

Data expressing structural characteristics are in Table 2. The post SEM images revealed differences between the tested FGP (Fig. 3). Fiber/matrix ratio of FiberCAD Post & Core was significantly higher than Exacto (p=0.004) and White PostDC (p<0.001), yielded the lowest ratio. Exacto and Whitepost DC presented similar amount of fibers per mm^2, which, in turn, was higher that FiberCAD Post & Core. A negative correlation was only observed between flexural strength and porosity (%) (r = -0.799; p<0.011). The fiber matrix/ratio and amount of fiber per mm^2 presented no correlation with flexural strength or modulus (Speraman, $p > 0.05$).

Table 1. Mean (SD) flexural strength (σ_f) and flexural modulus (E_f) for the different FGPs tested (n=10).

Fiberglass post *	σ_f (MPa)	E_f (GPa)
Exacto	491.12 (20.11) A	21.0 (1.5) A
FiberCAD Post & Core	449.18 (41.02) AB	17.66 (2.3) B
WhitepostDC	399.47 (23.49) B	17.90 (2.4) B

*For each mechanical property, a distinct uppercase in each line indicates significant differences (p<0.05).

Table 2. Mean (SD) fiber/matrix ratio, number of fibers per mm^2 and post-diameter (mm) of post tested (n=10).

Fiberglass post *	Fiber/matrix ratio (%)	Number of fibers per mm^2	Post Diameter (mm)
Exacto	61 (4.2) B	1139 (213.21) A	1,96
FiberCAD Post & Core	69 (4.8) A	900 (85.16) B	2,15
Whitepost DC	54 (5.9) C	1375 (434.91) A	1,94

*For each mechanical property, a distinct uppercase in each line indicates significant differences (p<0.05).

A similar pattern of distribution and size of the fibers was observed in each FGPs for Exacto (Figure 3 A, B and C) and FiberCAD Post & Core (Figure 3 D, E and F). While Whitepost DC presented large spaces filled only with matrix and different fiber diameters (Figure 3 G, H and I). Pores were observed in all posts; however, they were seen more frequently in Whitepost DC and FiberCAD Post & Core. Defects in interface between fiber and resin matrix were observed in some images of FiberCAD Post & Core (Figure 3 F).

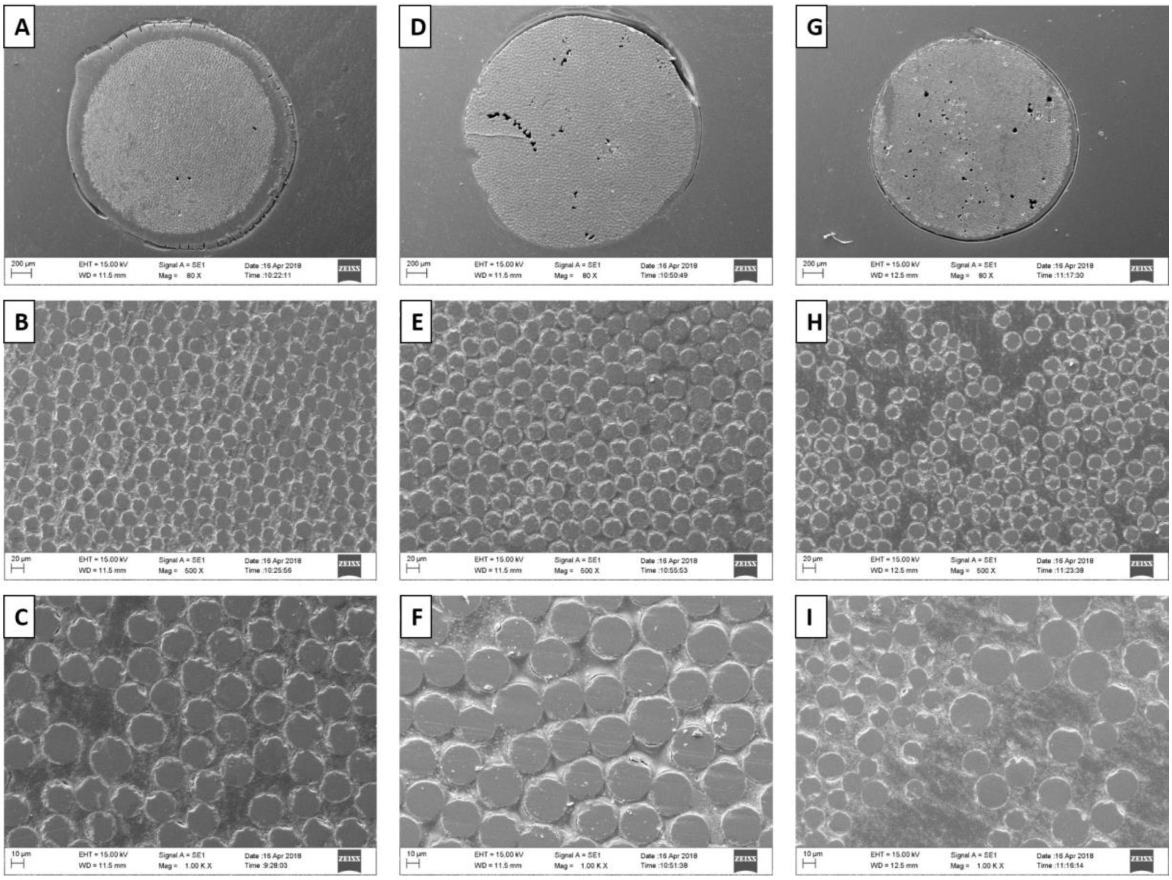

Figure 3 - SEM images of the FGP systems evaluated at x 80, x 500 and ×1000 magnification: Exacto (A, B e C), FiberCAD Post & Core (D, E e F) and Whitepost DC (G, H e I).

Discussion

In this study, flexural properties and structural characteristics of different concepts of FGP were evaluated. CAD/CAM FGPs have demonstrated superior flexural strength than that WhitepostDC and similar to that of Exacto. Overall, the structural characteristics were similar to both prefabricated FGPs, thus, the null hypothesis was accepted. Glass, quartz, carbon and ceramic fibers have been used for fabrication of endodontic posts.[7] FGPs tested in this study contain e-glass fibers (electric glass) that consist of SiO_2, CaO, B_2O, Al_2O, and a few other oxides of alkali metals in the amorphous phase.[8] FGP resin matrix generally consists of epoxy or methacrylate resin with a high degree of conversion and a highly cross-linked structure, to which fillers and radiopaque agents are added as well. Few systems also contain PMMA chains of high molecular weight.[1] The manufacturers of the tested FGP report the same composition, therefore it is reasonable to speculate that the differences in the mechanical properties are related to the differences in the structural characteristics, such as presence of voids, fiber/matrix ratio and fiber per mm^2.

The addition of fibers to a polymer matrix leads to a significant increase in the physical properties of polymer-based materials. The increase of fiber density in FGP may occur with an increase in the number of fibers or in the diameter of the fibers. Thus, the posts that exhibit a higher fiber/matrix ratio or high fiber/mm^2 are expected to yield a greater fracture resistance;[8, 17] however, no correlation was found between these variables in this study. Although FiberCAD Post & Core have the highest fiber/matrix ratio, they yielded intermediate values of flexural strength. Whitepost DC and Exacto had the same quantity of fiber/mm^2; however, Exacto had highest flexural strength. These results show that the fiber density contributes only partially to the mechanical performance of the FGP and the individual properties of the fiber and matrix may be substantial.[7] This outcome corroborates earlier studies that revealed that higher fiber content does not yield better mechanical properties.[1, 18, 19] Fiber and matrix differences in the FGP posts (volume fraction of fibers, orientation and thickness, bonding to resin matrix, polymerization-induced stress, manufacturing process, global integrity of the posts, and intrinsic properties of fibers and matrix) are especially important to understand the flexural strength and flexural modulus of FGP posts.[10, 18, 20]

The first concern is that failure results from a small structural defect such as a void or microcrack within the material. Therefore, potential areas of weakness in a FGP should be observed in the voids within the resin or in the discontinuities along the interfaces between the fibers and matrix.[1, 7, 18] The porosity analysis using MicroCT (Figure 1) demonstrate a high pores percentage in Whitepost DC, which yielded low values of flexural strength and modulus, confirming the linear correlation of the two variables. Some previous studies highlighted the effect of the fiber/matrix ratio, fibers per square millimeter and other structural characteristics on the flexural properties of fiber posts.[1, 7, 8, 18, 19] Regrettably, they revealed contradictory results. All of these studies mention that voids and bubbles within the FGP may weaken the structure, but few have quantitatively assessed this. The bubbles and voids can be evaluated by means of micro-CT technology, which was able to nondestructively measure the volume and percentage of bubbles and voids within the materials and structures.[21, 22] Micro-CT system using microfocal spot X-ray sources and high-resolution detectors allow projections rotated through multiple viewing directions to produce 3D reconstructed images of samples. Since the imaging process is nondestructive, the internal features of the same entire sample may be examined.[21] These findings confirm that empty areas within the post may act as voids and initiate cracks propagation weakening the entire structure. Thus, even with a high percentage of fibers in its structure FIberCAD Post & Core did not yield the best values of flexural strength. This leads us to believe that the presence of voids is probably related to the manufacturing process during fiber agglutination[7], mainly in the FIberCAD Post & Core which need to be agglutinated in a larger amount.

Exacto and WhitepostDC FGP consist of fibers with diameters much smaller than the FiberCAD Post & Core. The fiber diameters in the WhitepostDC (Fig. 2I) were non-homogeneous compared to the other systems. The variation in the diameter of fibers was remarkable; in some cases, there were small diameter fibers located next to areas of large diameter fibers. However, the flexural strength and flexural modulus were not affected by differences in the fiber diameters of the FGP posts. The type and stiffness of the fiber reinforcement are dominant over the properties of the organic matrix.[23] Although this characteristic does not affect the mechanical properties of FGP, it is important to note that there is a lack of standardization during the manufacturing process of FGP. This can also be attested by the high variation in sample data within the WhitepostDC group. Thus, we assume that there may be differences in the characteristics and property of the FGP from one lot to another.

If the bond interface between the fibers and the matrix is inadequate, poor mechanical properties may be expected.[24] A better total interface area (fiber and matrix) will result in better mechanical interlocking and increase stiffness and flexural modulus.[25] This relationship between the interface and stiffness could explain the low flexural modulus for WhitepostDC. Another aspect that affects FGP flexural modulus is diameter: the higher the diameter, the lower the flexural modulus tends to be. CAD/CAM technologies involve scanning, software, and machine procedures, each single step could lead to inaccuracy.[26.] For other materials (e.g. ceramics and metals), there are parameters to minimize these ditches and there is still a lack of these parameters for the material used in this study. Probably because of this, the milled post presented higher diameters. Because the three-point bending test is determined by the span distance, the post design and diameter of the post, differences in the diameter may affect the flexural response.[24] The higher order diameter term in the expression used to calculate the flexural modulus - d^4 ($4F_{Max}L^3/D3\pi d^4$) compared to the expression used to calculate the flexural strength - d^3 ($8F_{Max}\ L/\pi d^3$) indicates that the flexural modulus has a higher sensitivity to changes in the diameter.[7] FiberCAD Post & Core presented better value of flexural strength e lower flexural modulus likely owing to this. While a high flexural strength is essential to enhance the durability of restoration and fracture resistance during function, a low flexural modulus may avoid stress concentration and effectively prevent root fractures.[1] All FGP systems evaluated in this study exhibit a flexural modulus which is in the same range of that of dentin.

Surface treatment of fibers and their impregnation in resin and position and water absorption by the matrix are important factors that need to be considered for mechanical properties of FGP.[27] FiberCAD Post & Core require water cooling for milling and it may cause water absorption by the matrix and jeopardize the mechanical properties. The fiber-reinforced composites (FRC) exposed to water can destroy the fiber–polymer matrix bond, which results in an irreversible reduction of strength of the FRC.[27] Moreover, plasticization of the polymer matrix by water molecules may occur.[27] This probably explains why the FiberCAD Post & Core SEM images demonstrated some defects in interface between fiber and resin matrix. An important factor that needs to be taken into account is the curing process, which has been proven to influence the hardness and flexural properties of a composite resin surface treatment of the fibers;[1] however, much of this information is manufacturing secret.

Prefabricated FGPs are widely used in the restoration of endodontically treated teeth and their use is consolidated in the literature.[6, 28, 29] The relevance of using CAD/CAM-fabricated fiber posts in clinical practice lies in the possibility to combine the advantages of traditionally custom-made posts and the prefabricated FGP. Such posts may have better fit to the post space as well as the modulus of elasticity close to that of dentin, which is considered one of the main advantages of fiber-reinforced composite material.[30] Moreover, this process can allow for a cement layer of minimum thickness, simplifies the technique by reducing clinical steps, and eliminates the necessity to adhesively bond a composite resin to build-up an adequate core for assisting restoration retaining, creating a monolayer intraradicular retainer system.[13, 14, 31] Nevertheless, CAD/CAM FGPs would require a longer appointment for scanning of the post space, an additional clinical step for the impression of the post, and a main prerequisite is a chair-side CAD/CAM device in the dental office. Therefore, fabrication of FGP may represent an additional option for the practitioners already working with a CAD/CAM chair-side system and also for the dental laboratories using the digital workflow.[30] This study was not an assessment of the FGP' behavior inside the oral cavity, but, instead, it reflected the properties of the materials themselves. Further studies should thus be performed to evaluate the fatigue factors to better understand the effectiveness and durability of the CAD/CAM FGPs and to evaluate the behavior of the posts cemented in roots for their clinical use to be consolidated. That type of analysis may help verifying whether the structural defects of the posts affect their long-term use in the clinical setting as well as the stress distribution.[7, 32]

Conclusion

CAD/CAM milled FGP have mechanical properties and structural characteristics similar to prefabricated FGP. Regardless of the manufacturing method (prefabricated or milled), bubbles and voids within the structure contribute strongly to the fragility of FGP.

References

1. Zicari F, Coutinho E, Scotti R, Van Meerbeek B, Naert I. Mechanical properties and micro-morphology of fiber posts. Dent Mater. 2013 Apr;29(4):e45-52.
https://doi.org/10.1016/j.dental.2012.11.001.

2. Santos-Filho PC, Verissimo C, Raposo LH, Noritomi MecEng PY, Marcondes Martins LR. Influence of ferrule, post system, and length on stress distribution of weakened root-filled teeth. J Endod. 2014 Nov;40(11):1874-8.
https://doi.org/10.1016/j.joen.2014.07.015.

3. Santos-Filho PC, Castro CG, Silva GR, Campos RE, Soares CJ. Effects of post system and length on the strain and fracture resistance of root filled bovine teeth. Int Endod J. 2008 Jun;41(6):493-501.
https://doi.org/10.1111/j.1365-2591.2008.01383.x.

4. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. J Dent Res. 2012 Jul;91(7 Suppl):72S-78S.
https://doi.org/10.1177/0022034512447949

5. Monticelli F, Osorio R, Sadek FT, Radovic I, Toledano M, Ferrari M. Surface treatments for improving bond strength to prefabricated fiber posts: a literature review. Oper Dent. 2008 May-Jun;33(3):346-55.
https://doi.org/10.2341/07-86

6. Naumann M, Koelpin M, Beuer F, Meyer-Lueckel H. 10-year survival evaluation for glass-fiber-supported postendodontic restoration: a prospective observational clinical study. J Endod. 2012 Apr;38(4):432-5.
https://doi.org/10.1016/j.joen.2012.01.003.

7. Novais VR, Rodrigues RB, Simamoto Junior PC, Lourenco CS, Soares CJ. Correlation between the Mechanical Properties and Structural Characteristics of Different Fiber Posts Systems. Braz Dent J. 2016 Jan-Feb;27(1):46-51.
https://doi.org/10.1590/0103-6440201600377.

8. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts Dent Mater. 2004 Jan;20(1):29-36.
https://doi.org/10.1016/S0109-5641(03)00065-4

9. Chieruzzi M, Pagano S, Pennacchi M, Lombardo G, D'Errico P, Kenny JM. Compressive and flexural behaviour of fibre reinforced endodontic posts. J Dent. 2012 Nov;40(11):968-78.
https://doi.org/10.1016/j.jdent.2012.08.003

10. Wandscher VF, Bergoli CD, de Oliveira AF, Kaizer OB, Souto Borges AL, Limberguer Ida F, et al. Fatigue surviving, fracture resistance, shear stress and finite element analysis of glass fiber posts with different diameters. J Mech Behav Biomed Mater. 2015 Mar;43:69-77.
https://doi.org/10.1016/j.jmbbm.2014.11.016.

11. Hwang HJ, Lee SJ, Park EJ, Yoon HI. Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture bases manufactured using digital light processing. J Prosthet Dent. 2018 Jul 10. pii: S0022-3913(18)30227-0.
https://doi.org/10.1016/j.prosdent.2018.02.018.

12. Marghalani TY, Hamed MT, Awad MA, Naguib GH, Elragi AF. Three-dimensional finite element analysis of custom-made ceramic dowel made using CAD/CAM technology. J Prosthet Dent. 2018 Jul 10. pii: S0022-3913(18)30227-0.
https://doi.org/10.1016/j.prosdent.2018.02.018.

13. Tsintsadze N, Juloski J, Carrabba M, Tricarico M, Goracci C, Vichi A, et al. Performance of CAD/CAM fabricated fiber posts in oval-shaped root canals: An in vitro study. Am J Dent. 2017 Oct;30(5):248-254.

14. Liu P, Deng XL, Wang XZ. Use of a CAD/CAM-fabricated glass fiber post and core to restore fractured anterior teeth: A clinical report. J Prosthet Dent. 2010 Jun;103(6):330-3.
https://doi.org/10.1016/S0022-3913(10)60071-6.

15. da Costa RG, Freire A, Caregnatto de Morais EC, Machado de Souza E, Correr GM, Rached RN. Effect of CAD/CAM glass fiber post-core on

cement micromorphology and fracture resistance of endodontically treated roots. Am J Dent. 2017 Feb;30(1):3-8
16. (I) ADP. Standard test methods for flexural properties of unreinforced and reinforced plastics and electrical insulating materials. Annual book of ASTM standards: American Society for Testing and Materials; 1999.
17. Novais VR, Versluis A, Correr-Sobrinho L, Soares CJ. Three-point bending testing of fibre posts: critical analysis by finite element analysis. Int Endod J. 2011 Jun;44(6):519-24.
https://doi.org/10.1111/j.1365-2591.2011.01856.x
18. Grandini S, Chieffi N, Cagidiaco MC, Goracci C, Ferrari M. Fatigue resistance and structural integrity of different types of fiber posts. Dent Mater J. 2008 Sep;27(5):687-94.
https://doi.org/10.4012/dmj.27.687
19. Grandini S, Goracci C, Monticelli F, Tay FR, Ferrari M. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. Dent Mater. 2005 Feb;21(2):75-82.
https://doi.org/10.1016/j.dental.2004.02.012
20. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent. 1999 May;27(4):275-8.
https://doi.org/10.1016/S0300-5712(98)00066-9
21. Da Silva NR, Aguiar GC, Rodrigues Mde P, Bicalho AA, Soares PB, Verissimo C, et al. Effect of Resin Cement Porosity on Retention of Glass-Fiber Posts to Root Dentin: An Experimental and Finite Element Analysis. Braz Dent J. 2015 Nov-Dec;26(6):630-6.
https://doi.org/10.1590/0103-6440201300589.
22. Rengo C, Spagnuolo G, Ametrano G, Juloski J, Rengo S, Ferrari M. Micro-computerized tomographic analysis of premolars restored with oval and circular posts. Clin Oral Investig. 2014;18(2):571-8
https://doi.org/10.1007/s00784-013-0982-7
23. Narva KK, Lassila LV, Vallittu PK. The static strength and modulus of fiber reinforced denture base polymer. Dent Mater. 2005 May;21(5):421-8.
https://doi.org/10.1016/j.dental.2004.07.007

24. Soares CJ, Castro CG, Santos Filho PC, Soares PV, Magalhaes D, Martins LR. Two-dimensional FEA of dowels of different compositions and external surface configurations. J Prosthodont. 2009 Jan;18(1):36-42. https://doi.org/10.1111/j.1532-849X.2008.00367.x.

25. Seefeld F, Wenz HJ, Ludwig K, Kern M. Resistance to fracture and structural characteristics of different fiber reinforced post systems. Dent Mater. 2007 Mar;23(3):265-71. https://doi.org/10.1016/j.dental.2006.01.018

26. Schonberger J, Erdelt KJ, Baumer D, Beuer F. Marginal and internal fit of posterior three-unit fixed zirconia dental prostheses fabricated with two different CAD/CAM systems and materials. Clin Oral Investig. 2017 Nov;21(8):2629-2635. https://doi.org/10.1007/s00784-017-2064-8.

27. Lassila LV, Nohrstrom T, Vallittu PK. The influence of short-term water storage on the flexural properties of unidirectional glass fiber-reinforced composites. Biomaterials. 2002 May;23(10):2221-9. https://doi.org/10.1016/S0142-9612(01)00355-6

28. Skupien JA, Cenci MS, Opdam NJ, Kreulen CM, Huysmans MC, Pereira-Cenci T. Crown vs. composite for post-retained restorations: A randomized clinical trial. J Dent. 2016 May;48:34-9. https://doi.org/10.1016/j.jdent.2016.03.007.

29. von Stein-Lausnitz M, von Stein-Lausnitz A, Reissmann DR, Roggendorf MJ, Beuer F, Naumann M, et al. Impact of endodontic post material on longitudinal changes in interproximal bone level: a randomized controlled pilot trial. Clin Oral Investig. 2018 Oct 6. https://doi.org/10.1007/s00784-018-2698-1.

30. Tsintsadze N, Juloski J, Carrabba M, Goracci C, Vichi A, Grandini S, et al. Effects of scanning technique on in vitro performance of CAD/CAM-fabricated fiber posts. J Oral Sci. 2018;60(2):262-268. https://doi.org/10.2334/josnusd.17-0254.

31. Ruschel GH, Gomes EA, Silva-Sousa YT, Pinelli RGP, Sousa-Neto MD, Pereira GKR, et al. Mechanical properties and superficial

characterization of a milled CAD-CAM glass fiber post. J Mech Behav Biomed Mater. 2018 Jun;82:187-192.
https://doi.org/10.1016/j.jmbbm.2018.03.035
32. Lazari PC, Oliveira RC, Anchieta RB, Almeida EO, Freitas Junior AC, Kina S, et al. Stress distribution on dentin-cement-post interface varying root canal and glass fiber post diameters. A three-dimensional finite element analysis based on micro-CT data. J Appl Oral Sci. 2013 Nov-Dec;21(6):511-7.
https://doi.org/10.1590/1679-775720130203.

Capítulo 3

3.3. Capítulo 3: Artigo será enviado para o periódico Jounal of Endodontics

Title: Does CAD/CAM-fabricated glass fiber post improve the biomechanical behavior of endodontically treated teeth?

Authors:

Giselle Rodrigues REIS[1]
Gabriely Martins SILVA[2]
Paulo César de Freitas SANTOS-FILHO[2]
Murilo de Sousa MENEZES[2]

[1] Department of Dentistry, Dentistry School, University of Rio Verde, Rio Verde, Goiás, Brazil.
[2] Department of Restorative Dentistry and Dental Materials, Dentistry School, Federal University of Uberlândia, Minas Gerais, Brazil.

Corresponding author:

Prof. Dr. Murilo de Sousa Menezes

Federal University of Uberlândia, School of Dentistry, Department of Restorative Dentistry and Dental Materials.

Avenida Pará, 1720, Bloco 4L, Anexo A, Sala 34, Campus Umuarama

Uberlândia - Minas Gerais – Brazil, Zip Code: 38400-902

Tel.: +55 34 3225-8105; Fax: +55 34 3225 8108

E-mail address: murilomenezes@ufu.br

Abstract

Introduction: The aim of this study was to evaluate the effect of CAD/CAM-fabricated glass fiber post (GFP) rehabilitation and the amount of remaining coronal dentin on biomechanical behavior of endodontically treated teeth (ETT). **Methods:** Forty bovine incisors were selected and divided into 2 groups – with 1 mm of remaining coronal dentin and without remaining coronal dentin. Then, subdivide in more 2 groups (n=10): post-retained whit prefabricated GFP and CAD/CAM-fabricated GFP. A 3D virtual image was obtained from an impression of root canal, which guided the posterior milling of GFP from a fiber-reinforced composite disk. After GFP luting, the teeth were load cycled at a 135-degree angle, load to perform strain measurements, and were then loaded until fracture. The strain and fracture resistance results were analyzed with 2-way analysis of variance and the Tukey honestly significant difference test (α>05). **Results:** For strain, the teeth without remaining and milled GFP had higher strain, while teeth restored whit prefabricated GFP had lower strain (p<0.001). Regardless of the type of GFPs, teeth with remaining coronal dentin presented higher values of resistance (p=0.017). The teeth whit prefabricated GPF presented greater amount of favorable fracture and teeth with milled GFP and whithout remaining presented greater number of irreparable fractures. **Conclusion:** CAD/CAM-fabricated GPF had the same fracture resistance of prefabricated GFP. In absence of remaining coronal dentin, ETT restored with milled GPF presents higher strain and major potential of fractures irreparable.

Key Words: Endodontically treated teeth, post and core technique, CAD/CAM

Introduction

Endodontically treated teeth (ETT) are generally considered weaker and more susceptible to fracture than vital teeth (1). The main change in the biomechanical behavior is attributed the considerable loss of tooth structure (1) that often requires a post-retained fixed prosthetic restoration (2, 3). Preservation of sound radicular and coronal tooth tissue and especially presence of ferrule are important factors for enhancing the biomechanical behavior compromised ETT (4).

Glass fiber post (GFP) have widely been used to improve the restoration retention of ETT (5). The major advantage of the GFP is they have an elastic modulus that is similar to dentin, which results in a more even distribution of occlusal loads through the root (6-8). However, the clinical procedure of luting GFPs is complex, due to the various steps involved in the process. The application of computer-aided design/computer-aided manufacturing (CAD/CAM) restorations provides innovative, state-of-the-art dental service, and its application has increased significantly in the last years (9), thus a novel concept of GFP CAD/CAM-fabricated has been proposed (10, 11). The use of CAD-CAM technology to produce anatomic custom GFP seems a viable option, especially considering the possibility of milling both the post/core, which would eliminate the need for a composite resin to build-up a resin core (12) and reduce failures in post/resin interface (3).

However, there is lack information available regarding the biomechanical behavior of ETT restored with CAD/CAM milled GFP and the role of the ferrule effect in this rehabilitation. Thus, the aim of this in vitro study was to evaluate the effect of the type of post and the amount of remaining coronal dentin on the biomechanical behavior of ETT. Two hypothesis tested was that strain, fracture resistance and failure mode would not be affected by the different (1) GFP - milled or prefabricated - or (2) amount of remaining coronal dentin.

Materials and Methods

Sample preparation

Forty bovine roots of similar size and shape were selected by measuring the buccolingual and mesiodistal widths, allowing a maximum deviation of 10% from the average. The crowns were sectioned perpendicularly to the long axis up to 14.0 mm for the specimens with 1.0 mm of remaining, and 13.0 mm from the apical limit for the specimens without remaining. Root canals were instrumented and endodontically treated with gutta percha points (Dentsply Maillefer, Ballaigues, Switzerland) and calcium hydroxide-based cement (Sealer 26; Dentsply). The roots were then embedded in an autopolymerizing polystyrene resin (AM 190 resin; Aerojet, São Paulo, Brazil) 2 mm below the cervical limit, and the periodontal ligament was simulated with polyether impression material (Impregum Soft; 3M ESPE, St. Paul USA) (13). After, the specimens with 1.0 mm of remaining and the specimens without remaining were subdivided into 2 subgroups (n=10) according to the type of post/core: prefabricated (Exacto, Angelus, Londrina, Brazil) and milled (FiberCAD Post & Core, Angelus).

CAD/CAM milled GFP preparation

The post space was prepared by removing the gutta percha to a length of 10 mm for specimens without remaining and 11 mm for specimens with 1.0 mm of remaining. For CAD/CAM milled GFP fabrication, prefabricated polycarbonate patterns (Nucleojet; Angelus) were used to standardize the coronal portion. The patterns were aligned by using autopolymerizing acrylic resin (Duralay; Reliance Dental Mfg Co). The patterns were digitized with a bench-top scanner (Ceramill Map 400+, Amann Girrbach AG, Koblach, Austria) and modeled with design software (Ceramill Mind, Amann Girrbach). The one-piece post/cores were milled on the Motion 2 (Amann Girrbach) with water cooling using a glass-fiber reinforced epoxy-resin block (FiberCAD Post & Core, Angelus). After milling, the customized post and cores were checked for correct fit and adjusted as necessary with an multilaminated burs (#218, Angelus Prima Dental, Angelus).

Post and Crowns Cementation

Prefabricated (Exacto #3, Angelus) and milled GFPs were treated with a 35 % hydrogen peroxide (Whitness HP 35%, FGM, Joinville, Brazil) for 1 minute, after drying, a silane coupling agent (Prosil; FGM) was applied for 1 minute and one layer of bond (Clearfil SE Bond, Kuraray, Tokyo, Japan) was applied. Both post systems were cemented by the same protocol. The post space was cleaned with EDTA for 1 minute (Edta Trissódico Líquido, Biodinamica, Ibiporã, Brazil), and the self-adhesive resin cement (RelyX U200; 3M ESPE) was manipulated and inserted in the canal with syringe (Sistema Centrix, Nova DFL, Rio de Janeiro, Brazil). After 5 minutes, light activation was performed for 60 seconds in each face (BluePhase G2, Ivoclar Vivadent, Schaan, Liechtenstein). Composite resin cores (Filtek Z350; 3M ESPE) were fabricated in 2-mm increments and light polymerized for 30 seconds.

All the specimens were prepared with a tapered, rounded-end diamond rotary cutting instrument (no. 4138; KG Sorensen) in a high speed handpiece with water spray. The crowns was make with Ni-Cr alloy (FIT CASTSB Plus, Curitiba, Brazil) directly on the specimens and cemented with self-adhesive resin cement (RelyX U200; 3M ESPE).

Mechanical Fatigue Cycling

Mechanical fatigue cycling was used to simulate chewing (Biocycle, Biopdi, São Paulo, SP, Brazil). The samples were immersed in water at approximately 37° C and were cycled 1.2 X 10^6 times at a 0 to 50–N l be positioned at a 135-degree angle to the long axis of the specimen load with a 2-Hz frequency and an 8-mm-diameter stainless-steel sphere on the occlusal, simulating five years of aging (14).

Strain measurement tests and fracture resistance

Five specimens of each subgroup were selected for the strain gauge measurements. The strain gauge (01.06.120.LEN; Excel Sensores, São Paulo, Brazil) grid had an area of 1 mm^2 and an electrical resistance of 120 U and was placed at the proximal surface in a transverse direction; were placed 1.0 mm below the cervical limit of the root. The strain gauges were bonded to the tooth with cyanoacrylate resin adhesive (Super Bonder; Loctite, Brazil) and connected to a data acquisition device (ADS0500IP; Lynx, São Paulo, Brazil). Each specimen was positioned at a 135° to the long axis of the teeth and subjected to a nondestructive ramp load from 0 to 100 N a crosshead speed of 0.5 mm/min (DL2000; EMIC, São Jose dos Pinhais, Brazil). The data were transferred to a computer by using specific acquisition signal transformation and data analysis software (AQDADOS 7.02 and AQANALISYS; Lynx). After the strain measurements, all the specimens were loaded until fracture. The load required (N) to fracture the specimens was recorded by a 5 kN load cell hardwired to software (TESC; EMIC). The fractured specimens were evaluated to determine the failure modes: (I) post or core fracture, (II) root fracture in the cervical third, (III) root fracture in the middlethird, (IV) root fracture in the apical third, and (V) vertical root fracture (6).

Statistical analysis

Data were analyzed with the two-way analysis of variance test using SigmaPlot 12.0 software (Systat Software Inc., San Jose, USA). Also, in significant cases, the least significant difference post hoc test was used for pair-wise comparison of the groups. The significance level was set at $p < .05$.

Results

Strain measurement

The results for the strain measurement of tested groups are shown in Table 1. Data indicated that the remaining coronal dentin factor ($p<0.001$) was statistically significant, whereas the GPF factor ($p = 0.107$) and the interaction of the factors ($p = 0.161$) did not present statistical difference. The teeth restored with milled GFP and whiteout remaining had higher strain. In the case of teeth restored with prefabricated GFP and 1 mm remaining had higher strain.

Table 1. Mean proximal strain values (standard deviation) and results of Tukey honestly significant difference test (mS)*

Remaining Coronal Dentin	CAD/CAM milled GFPs	Prefabricated GFPs
Without remaining	225 (69,14) Aa	70,06 (26,45) Ab
1 mm of remaining	54,01 (24,76) Ab	142,36 (38,96) Aa

Different uppercase letters indicate significant differences in rows; different lowercase letters in vertical columns indicate significant differences; Tukey honestly significant difference test (P<.05).

Fracture resistance and mode

The results for the fracture resistance of tested groups are shown in Table 2. Data indicated that the remaining coronal dentin factor (p = 0.017) was statistically significant, whereas the GPF factor (p = 0.840) and the interaction of the factors (p = 0.086) did not present statistical difference. The teeth with a 1 mm remaining coronal dentin presented higher resistance values independently of the type of GFPs.

Table 2. Mean fracture resistance values (standard deviation) and results of Tukey honestly significant difference test (mS)*

Remaining Coronal Dentin	CAD/CAM milled GFPs	Prefabricated GFPs
Without remaining	587,91 (164,09) Ab	767,95 (167,6) Ab
1 mm of remaining	1014,68 (325,19) Aa	842,56 (307,67) Aa

*Different uppercase letters indicate significant differences in rows; different lowercase letters indicated significant differences in vertical columns; Tukey honestly significant difference test (p<.05).

The failure mode distribution for the different groups is presented in Figure 1. The teeth restored whit prefabricated GPF presented greater amount of reparable fractures (type I and II). Only the teeth restored with milled GFP and whiteout remaining presented greater number of irreparable fractures (type III). There were no type IV fractures in any of the groups studied. Fractures type V were found in small amounts in roots with a 1 mm remaining and restored with milled GFP.

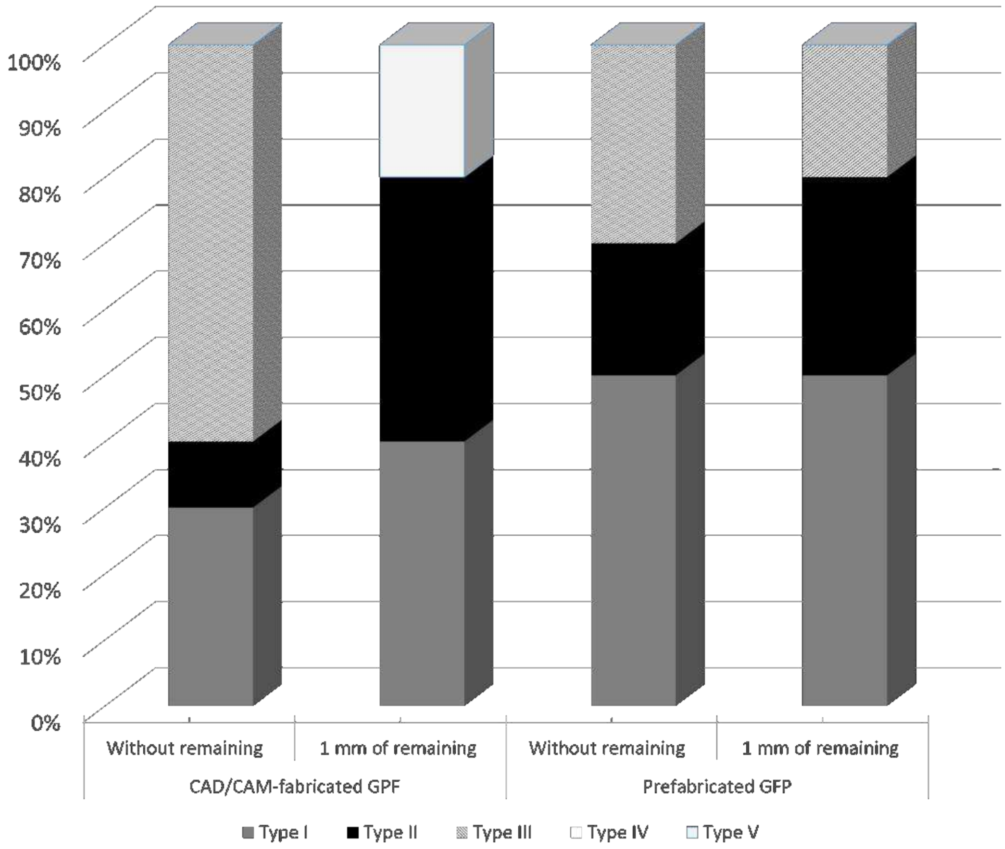

Figure 1 - Distribution of failure modes among groups (%).

Discussion

The type of GFP did not affected biomechanical behavior and the amount of remaining coronal dentin influenced the strain, fracture resistance and failure mode in ETT. Thus, the first hypothesis was accept and the second was rejected.

Fracture resistance of restored teeth and the mode of failure are the result of the interaction between multiple mechanical properties. Fracture tests have limitations with regard to obtaining information on the internal behavior of the tooth-restoration complex before the failure (15). This test use increasing compressive loading generated by a universal testing machine, the load required to fracture specimens tends to be non-physiological (16). Loads generated intraorally vary in magnitude, speed and direction, while loads applied to teeth in laboratory fracture resistance testing are generally constant in their speed of application and direction, and increase continuously until fracture occurs. Thus, both non-destructive and destructive testing methods the tests were used in a complementary way so that the mechanisms of strain deformation were better understood (6, 17, 18). Mechanical fatigue was induced as the oral environment experiences functional load that can lead to the degradation and subsequent fatigue failure of weakened regions. Supposing 240,000 to 250,000 occlusal contacts occur per year, 1.2 million cycles is equivalent to five years of masticatory simulation (19). In this investigation, a force of 100 N was chosen to simulate the effect of chewing on stain and for the stress analysis because physiological biting forces during eating were found to be between 20 and 160N (20).

Both GFP used in this study contain e-glass fibers (electric glass) in a unidirectional array, a few other oxides of alkali metals in the amorphous phase and resin matrix that consists of epoxy or methacrylate resin (5). Thus, the mechanical proprieties, such as, flexural strength and modulus, rigidity and structural characteristic are similar and, consequently, the resistance was similar. In contrast, the maintaining 1 mm of coronal dentin increases the fracture resistance of ETT, regardless of the type GFP. The change in biomechanical behavior was expected when comparing presence and absence of remaining coronal. Many authors have reported biomechanical damages when ETT do not have any remaining (4, 8, 21). The height of the remaining coronal is well known as ferrule, and offers support to the remaining tooth structure against occlusal loadings and lateral forces exerted during the post insertion. Studies have shown that the maintenance 1 mm of coronal dentin improve the stress distributions in the root dentin and along the post-dentin interface (17, 18, 22). The analysis of the remaining factor in the present study was important due to the innovative character of the tested product. The milled CAD/CAM GFP could have a better behavior than the prefabricated GFP in teeth without remaining. However, this result was not found, the presence of the ferrule also contributes to increase the fracture resistance and better failure or fracture modes for both GPF.

These findings can be explained by the analysis of the strain generated in the roots. The proximal strain gauges were oriented perpendicular to the longitudinal root axis because this strain component can initiate cracks that lead to catastrophic fractures (23). Vertical root fractures seem to be the result of stresses generated inside the post space, typically occurring in the buccolingual direction (15). When a body or structure is subjected to load, the stresses will concentrate on the structure with a higher elastic modulus, transferring the load with more intensity to the adjacent structures (18). In the case of teeth restored whit milled GPF, the one-piece post/core have the core with higher elastic modulus that roots restores whit prefabricate GPF and composite resin core. While the elastic modulus of composite resin is about 15 GPa (18, 20), the elastic modulus of milled GFP is about 25 GPa (manufacture's information). Thus, in root restored whit milled GFP and without remaining the strain was higher, probably because the lower strain and deflection in one-piece post/core. In another hand, in roots restored whit prefabricated GPF and resin core, in absence of remaining had lower strain in the root. Probably, due to lower elastics modulus of core and major strain at resin core.

In the failure mode analysis, the teeth restored whit milled GPF and without remaining had a great percentage of irreparable failures (Type III). Teeth with no remaining post-retained with milled GPF had greater deformation and the high stress concentrations within the root canal could be transferred to the origin of the crack (18). During normal occlusal function, dentin exhibits considerable plastic deformation, resisting varying degrees and angles of load (24). However, loads exceeding the tensile strength or proportional limit of dentin can decrease the ability of dentin for plastic deformation, which leads to fractures (15, 25). The elastic modulus of milled GFP is higher than dentin (about 18GMPa) (18, 20), thus the strains of dentin was higher and the fracture occur at root. Roots whit 1 mm of remaining coronal dentin and milled GFP had prevalence of favorable failures probably because the stresses were concentrated at the remaining coronal dentin (18, 25) due to ferrule effect. In contrast, roots restored whit prefabricated GPF had a great percentage of favorable failures (type I and II) regardless of coronal structure. In this case that the composite resin had the elastic modulus lower that dentin, the strain tend to occur in the composite resin core and the stress concentered in the post/resin interface leads to more fracture in the core (Type I) or in cervical third of root (Type II) (15).

Prefabricated GFPs are widely used in the restoration of ETT and their use is consolidated in the literature due advantages as shorter clinical time for luting (single session) and biomechanics similar to dentin (3, 26, 27). The idea of using CAD/CAM-fabricated fiber posts in clinical practice lies in the possibility to combine the advantages of traditionally custom-made posts and the prefabricated GFP. Such posts may have better fit to the post space as well as the modulus of elasticity close to that of dentin, which is considered one of the main advantages of fiber-reinforced composite material (28). However, the results of this study showed that for roots without remaining dentin the CAD/CAM-fabricated fiber posts may not have favorable biomechanical behavior. Moreover, CAD/CAM FGPs would require a longer appointment for scanning of the post space or additional clinical step for the impression of the post, and a main prerequisite is a chair-side CAD/CAM device in the dental office. Thus, the use of this new technology should be indicated with caution, especially on severely weakened teeth. The digital workflow is an increasingly present reality in dentistry, however, for fabrication of GFP, further studies are still needed to be the first restorative option.

Significance

CAD/CAM-fabricated GFP has similar fracture resistance of prefabricated GPF. However, in absence of remaining coronal dentin there are major strain in the root if restored whit milled GPF, leading to irreparable failures.

References

1. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature--Part 1. Composition and micro- and macrostructure alterations. Quintessence international. 2007;38(9):733-43.

2. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. Journal of dental research. 2012;91(7 Suppl):72S-8S.

3. Naumann M, Koelpin M, Beuer F, Meyer-Lueckel H. 10-year survival evaluation for glass-fiber-supported postendodontic restoration: a prospective observational clinical study. Journal of endodontics. 2012;38(4):432-5.

4. Juloski J, Radovic I, Goracci C, Vulicevic ZR, Ferrari M. Ferrule effect: a literature review. Journal of endodontics. 2012;38(1):11-9.

5. Zicari F, Coutinho E, Scotti R, Van Meerbeek B, Naert I. Mechanical properties and micro-morphology of fiber posts. Dental materials : official publication of the Academy of Dental Materials. 2013;29(4):e45-52.

6. Santos-Filho PC, Castro CG, Silva GR, Campos RE, Soares CJ. Effects of post system and length on the strain and fracture resistance of root filled bovine teeth. International endodontic journal. 2008;41(6):493-501.

7. Santos-Filho PC, Verissimo C, Raposo LH, Noritomi MecEng PY, Marcondes Martins LR. Influence of ferrule, post system, and length on stress distribution of weakened root-filled teeth. Journal of endodontics. 2014;40(11):1874-8.

8. Soares CJ, Rodrigues MP, Faria ESAL, Santos-Filho PCF, Verissimo C, Kim HC, et al. How biomechanics can affect the endodontic treated teeth and their restorative procedures? Brazilian oral research. 2018;32(suppl 1):e76.

9. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dental materials journal. 2009;28(1):44-56.

10. Marghalani TY, Hamed MT, Awad MA, Naguib GH, Elragi AF. Three-dimensional finite element analysis of custom-made ceramic dowel made using CAD/CAM technology. Journal of prosthodontics : official journal of the American College of Prosthodontists. 2012;21(6):440-50.

11. Tsintsadze N, Juloski J, Carrabba M, Tricarico M, Goracci C, Vichi A, et al. Performance of CAD/CAM fabricated fiber posts in oval-shaped root canals: An in vitro study. American journal of dentistry. 2017;30(5):248-54.

12. Liu P, Deng XL, Wang XZ. Use of a CAD/CAM-fabricated glass fiber post and core to restore fractured anterior teeth: A clinical report. The Journal of prosthetic dentistry. 2010;103(6):330-3.

13. Soares CJ, Pizi EC, Fonseca RB, Martins LR. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. Brazilian oral research. 2005;19(1):11-6.

14. Ornaghi BP, Meier MM, Rosa V, Cesar PF, Lohbauer U, Braga RR. Subcritical crack growth and in vitro lifetime prediction of resin composites with different filler distributions. Dental materials : official publication of the Academy of Dental Materials. 2012;28(9):985-95.

15. Silva GR, Santos-Filho PC, Simamoto-Junior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. Brazilian dental journal. 2011;22(3):230-7.

16. Seow LL, Toh CG, Wilson NH. Strain measurements and fracture resistance of endodontically treated premolars restored with all-ceramic restorations. Journal of dentistry. 2015;43(1):126-32.

17. da Silva NR, Raposo LH, Versluis A, Fernandes-Neto AJ, Soares CJ. The effect of post, core, crown type, and ferrule presence on the biomechanical

behavior of endodontically treated bovine anterior teeth. The Journal of prosthetic dentistry. 2010;104(5):306-17.

18. Verissimo C, Simamoto Junior PC, Soares CJ, Noritomi PY, Santos-Filho PC. Effect of the crown, post, and remaining coronal dentin on the biomechanical behavior of endodontically treated maxillary central incisors. The Journal of prosthetic dentistry. 2014;111(3):234-46.

19. Schwindling FS, Hartmann T, Panagidis D, Krisam J, Rues S, Schmitter M. In vitro investigation on extensively destroyed vital teeth: is fracture force a limiting factor for direct restoration? Journal of oral rehabilitation. 2014;41(12):920-7.

20. Barcelos LM, Bicalho AA, Verissimo C, Rodrigues MP, Soares CJ. Stress Distribution, Tooth Remaining Strain, and Fracture Resistance of Endodontically Treated Molars Restored Without or With One or Two Fiberglass Posts And Direct Composite Resin. Operative dentistry. 2017;42(6):646-57.

21. Naumann M, Schmitter M, Frankenberger R, Krastl G. "Ferrule Comes First. Post Is Second!" Fake News and Alternative Facts? A Systematic Review. Journal of endodontics. 2018;44(2):212-9.

22. Zhi-Yue L, Yu-Xing Z. Effects of post-core design and ferrule on fracture resistance of endodontically treated maxillary central incisors. The Journal of prosthetic dentistry. 2003;89(4):368-73.

23. Soares PV, Santos-Filho PC, Martins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part I: fracture resistance and fracture mode. The Journal of prosthetic dentistry. 2008;99(1):30-7.

24. Soares PV, Santos-Filho PC, Gomide HA, Araujo CA, Martins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part II: strain measurement and stress distribution. The Journal of prosthetic dentistry. 2008;99(2):114-22.

25. Santos AF, Meira JB, Tanaka CB, Xavier TA, Ballester RY, Lima RG, et al. Can fiber posts increase root stresses and reduce fracture? Journal of dental research. 2010;89(6):587-91.

26. Skupien JA, Cenci MS, Opdam NJ, Kreulen CM, Huysmans MC, Pereira-Cenci T. Crown vs. composite for post-retained restorations: A randomized clinical trial. Journal of dentistry. 2016;48:34-9.

27. von Stein-Lausnitz M, von Stein-Lausnitz A, Reissmann DR, Roggendorf MJ, Beuer F, Naumann M, et al. Impact of endodontic post material on longitudinal changes in interproximal bone level: a randomized controlled pilot trial. Clinical oral investigations. 2018.

28. Tsintsadze N, Juloski J, Carrabba M, Goracci C, Vichi A, Grandini S, et al. Effects of scanning technique on in vitro performance of CAD/CAM-fabricated fiber posts. Journal of oral science. 2018;60(2):262-8.

Considerações Finais

4 - Considerações Finais

Dentro das restrições do delineamento experimental e frente a análise dos dados, pode-se obesevar que a utilização do cimento resinoso autoadesivo como agente de união demonstrou adequada resistência adesiva da dentina coronária ao núcleo de preenchimento em resina composta. O momento de hibridização da dentina coronária não afetou a resistência de união da resina composta. No entanto, os resultados deste trabalho devem ser analisados com cautela, uma vez que produtos de marca comercial diferente dos usados no trabalho podem ter comportamentos diferentes. Além disso, a análise da interface adesiva a longo prazo também é importante para que se possa fazer recomendações clínicas.

Pinos de fibra fresados por CAD/CAM têm propriedades mecânicas de resistência flexural e módulo de flexão e características estruturais semelhantes aos pinos pré-fabricados. Independentemente do método de fabricação (pré-fabricado ou fresado), bolhas e vazios dentro da estrutura contribuem fortemente para a fragilidade dos pinos. Quando analisado esse tipo de pino integrado às reabilitações, pode-se perceber que dentes reabilitados com pinos obtidos pelo sistema CAD/CAM têm resistência à fratura semelhante às reabilitações retidas por pinos pré-fabricados. Entretanto, na ausência do remanescente coronário, há grande deformação na raiz em dentes reabilitados com pinos de fibra fresados, levando a falhas irreparáveis. Os resultados de propriedades mecânicas e análise das características estruturais revelaram que os blocos possuem pequenas falhas que podem ter implicações diretas nos resultados de comportamento biomecânico. Assim, ajustes destas falhas podem melhorar as propriedades dos pinos e, também, a resistência à fratura em relação aos sistemas pré-fabricados.

Materiais que visam a simplificação das etapas e o fluxo digital são a tendência atual da odontologia, por isso, técnicas e produtos com esses conceitos são facilmente incoporados ao mercado. No entanto, os pinos obtidos por CAD/CAM ainda possuem fatores que limitam o seu uso. Um destes fatores é a necessidade de moldagem do canal radicular para posterior fresagem do pino. O escaneamento do canal radicular seria uma alternativa mais viável, assim estudos futuros devem ser realizados para o desenvolviemento de *scanners* intraraduculares.

Outro aspecto a ser analisado é o aumento do custo dos pinos quando utilizado o sistema CAD/CAM, o que pode limitar sua utilização. Existe um elevado custo de produção dos pinos devido ao alto desgaste das brocas que são utilizadas para fresagem do bloco de resina reforçada por fibra. Esta limitação é inerente a todo sistema resinoso utilizado pelas fresadoras, mas como o bloco reforçado por fibra é mais reistente, o desgaste é ainda maior. Por fim, podemos concluir que o sistema é promissor, principalmente para os profissionais que possuem fácil acesso aos equipamentos e representa mais uma opção de retentores intrarradiculares. No entanto, mais estudos são necessários para que o sistema seja consolidado como primeira alternativa.

Referências Bibliográficas

5- Referências:

1. Aranda-Garcia AJ, Kuga MC, Chavez-Andrade GM, Kalatzis-Sousa NG, Hungaro Duarte MA, Faria G, et al. Effect of final irrigation protocols on microhardness and erosion of root canal dentin. **Microscopy research and technique.** 2013;76(10):1079-83.
https://doi.org/10.1002/jemt.22268

2. Assif D, Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. **The Journal of prosthetic dentistry.** 1994;71(6):565-7.
https://doi.org/10.1016/0022-3913(94)90438-3

3. Baldasso FER, Roleto L, Silva VDD, Morgental RD, Kopper PMP. Effect of final irrigation protocols on microhardness reduction and erosion of root canal dentin. **Brazilian oral research.** 2017;31(e40.
https://doi.org/10.1590/1807-3107bor-2017.vol31.0040

4. Bitter K, Glaser C, Neumann K, Blunck U, Frankenberger R. Analysis of resin-dentin interface morphology and bond strength evaluation of core materials for one stage post-endodontic restorations. **PloS one.** 2014;9(2):e86294.
https://doi.org/10.1371/journal.pone.0086294

5. Bitter K, Schubert A, Neumann K, Blunck U, Sterzenbach G, Ruttermann S. Are self-adhesive resin cements suitable as core build-up materials? Analyses of maximum load capability, margin integrity, and physical properties. **Clinical oral investigations.** 2016;20(6):1337-45.
https://doi.org/10.1007/s00784-015-1623-0

6. Cheong C, King NM, Pashley DH, Ferrari M, Toledano M, Tay FR. Incompatibility of self-etch adhesives with chemical/dual-cured composites: two-step vs one-step systems. **Operative dentistry.** 2003;28(6):747-55.

7. Costa LA, Carneiro KK, Tanaka A, Lima DM, Bauer J. Evaluation of pH, ultimate tensile strength, and micro-shear bond strength of two self-adhesive resin cements. **Brazilian oral research.** 2014;28(1-7.
https://doi.org/10.1590/1807-3107BOR-2014.vol28.0055

8. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature--

Part 1. Composition and micro- and macrostructure alterations. **Quintessence international.** 2007;38(9):733-43.

9. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). **Quintessence international.** 2008;39(2):117-29.

10. Dos Santos VH, Griza S, de Moraes RR, Faria ESAL. Bond strength of self-adhesive resin cements to composite submitted to different surface pretreatments. **Restorative dentistry & endodontics.** 2014;39(1):12-6. https://doi.org/10.5395/rde.2014.39.1.12

11. Faria-e-Silva AL, Menezes Mde S, Silva FP, Reis GR, Moraes RR. Intra-radicular dentin treatments and retention of fiber posts with self-adhesive resin cements. **Brazilian oral research.** 2013;27(1):14-9. https://doi.org/10.1590/S1806-83242013000100003

12. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. **Journal of dental research.** 2012;91(7 Suppl):72S-8S. https://doi.org/10.1177/0022034512447949

13. Juloski J, Radovic I, Goracci C, Vulicevic ZR, Ferrari M. Ferrule effect: a literature review. **Journal of endodontics.** 2012;38(1):11-9. https://doi.org/10.1016/j.joen.2011.09.024

14. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts. **Dental materials : official publication of the Academy of Dental Materials.** 2004;20(1):29-36. https://doi.org/10.1016/S0109-5641(03)00065-4

15. Liu P, Deng XL, Wang XZ. Use of a CAD/CAM-fabricated glass fiber post and core to restore fractured anterior teeth: A clinical report. **The Journal of prosthetic dentistry.** 2010;103(6):330-3. https://doi.org/10.1016/S0022-3913(10)60071-6

16. Magne P, Goldberg J, Edelhoff D, Guth JF. Composite Resin Core Buildups With and Without Post for the Restoration of Endodontically Treated Molars Without Ferrule. **Operative dentistry.** 2016;41(1):64-75. https://doi.org/10.2341/14-258-L

17. Menezes MS, Queiroz EC, Campos RE, Martins LR, Soares CJ. Influence of endodontic sealer cement on fibreglass post bond strength to root dentine. **International endodontic journal.** 2008;41(6):476-84.
https://doi.org/10.1111/j.1365-2591.2008.01378.x
18. Naumann M, Koelpin M, Beuer F, Meyer-Lueckel H. 10-year survival evaluation for glass-fiber-supported postendodontic restoration: a prospective observational clinical study. **Journal of endodontics.** 2012;38(4):432-5.
https://doi.org/10.1016/j.joen.2012.01.003
19. Naumann M, Schmitter M, Frankenberger R, Krastl G. "Ferrule Comes First. Post Is Second!" Fake News and Alternative Facts? A Systematic Review. **Journal of endodontics.** 2018;44(2):212-9.
https://doi.org/10.1016/j.joen.2017.09.020
20. Novais VR, Rodrigues RB, Simamoto Junior PC, Lourenco CS, Soares CJ. Correlation between the Mechanical Properties and Structural Characteristics of Different Fiber Posts Systems. **Brazilian dental journal.** 2016;27(1):46-51.
https://doi.org/10.1590/0103-6440201600377
21. Pereira RD, Valdivia AD, Bicalho AA, Franco SD, Tantbirojn D, Versluis A, et al. Effect of Photoactivation Timing on the Mechanical Properties of Resin Cements and Bond Strength of Fiberglass Post to Root Dentin. **Operative dentistry.** 2015;40(5):E206-21.
https://doi.org/10.2341/14-115-L
22. Santos-Filho PC, Castro CG, Silva GR, Campos RE, Soares CJ. Effects of post system and length on the strain and fracture resistance of root filled bovine teeth. **International endodontic journal.** 2008;41(6):493-501.
https://doi.org/10.1111/j.1365-2591.2008.01383.x
23. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: a systematic review and meta-analysis of in vitro studies. **Operative dentistry.** 2014;39(1):E31-44.
https://doi.org/10.2341/13-070-LIT
24. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. **Journal of endodontics.** 2004;30(5):289-301.
https://doi.org/10.1097/00004770-200405000-00001

25. Silva GR, Santos-Filho PC, Simamoto-Junior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. **Brazilian dental journal.** 2011;22(3):230-7.
https://doi.org/10.1590/S0103-64402011000300009

26. Soares CJ, Rodrigues MP, Faria ESAL, Santos-Filho PCF, Verissimo C, Kim HC, et al. How biomechanics can affect the endodontic treated teeth and their restorative procedures? **Brazilian oral research.** 2018;32(suppl 1):e76.
https://doi.org/10.1590/1807-3107bor-2018.vol32.0076

27. Soares CJ, Santana FR, Silva NR, Preira JC, Pereira CA. Influence of the endodontic treatment on mechanical properties of root dentin. **Journal of endodontics.** 2007;33(5):603-6.
https://doi.org/10.1016/j.joen.2007.01.016

28. Soares CJ, Soares PV, de Freitas Santos-Filho PC, Castro CG, Magalhaes D, Versluis A. The influence of cavity design and glass fiber posts on biomechanical behavior of endodontically treated premolars. **Journal of endodontics.** 2008;34(8):1015-9.
https://doi.org/10.1016/j.joen.2008.05.017

29. Soares CJ, Valdivia AD, da Silva GR, Santana FR, Menezes Mde S. Longitudinal clinical evaluation of post systems: a literature review. **Brazilian dental journal.** 2012;23(2):135-740.
https://doi.org/10.1590/S0103-64402012000200008

30. Tsintsadze N, Juloski J, Carrabba M, Goracci C, Vichi A, Grandini S, et al. Effects of scanning technique on in vitro performance of CAD/CAM-fabricated fiber posts. **Journal of oral science.** 2018;60(2):262-8.
https://doi.org/10.2334/josnusd.17-0254

31. Tsintsadze N, Juloski J, Carrabba M, Tricarico M, Goracci C, Vichi A, et al. Performance of CAD/CAM fabricated fiber posts in oval-shaped root canals: An in vitro study. **American journal of dentistry.** 2017;30(5):248-54.

32. Verissimo C, Simamoto Junior PC, Soares CJ, Noritomi PY, Santos-Filho PC. Effect of the crown, post, and remaining coronal dentin on the biomechanical behavior of endodontically treated maxillary central incisors. **The Journal of prosthetic dentistry.** 2014;111(3):234-46.
https://doi.org/10.1016/j.prosdent.2013.07.006

33. Wandscher VF, Bergoli CD, de Oliveira AF, Kaizer OB, Souto Borges AL, Limberguer Ida F, et al. Fatigue surviving, fracture resistance, shear stress and finite element analysis of glass fiber posts with different diameters. **Journal of the mechanical behavior of biomedical materials.** 2015;43(69-77.
https://doi.org/10.1016/j.jmbbm.2014.11.016
34. Zicari F, Coutinho E, Scotti R, Van Meerbeek B, Naert I. Mechanical properties and micro-morphology of fiber posts. **Dental materials : official publication of the Academy of Dental Materials.** 2013;29(4):e45-52.

https://doi.org/10.1016/j.dental.2012.11.001

Anexos

6.1. Normas e submissão ao periódico Dental Materials Journal (Quallis B1)

Instruction for Authors

(Edited 2015-3-1)

1. Papers submitted to Dental Materials Journal should be directed to the research and development of dental materials, devices and new techniques in dentistry or related fields. Manuscripts in the following categories are acceptable; original and review papers.
    - Original papers: Full length papers consisting of complete and detailed descriptions of a research problem, the experimental approach, the findings and appropriate discussion.
    - Review papers: Intending authors should communicate with the editorial board beforehand by e-mail.
2. Manuscripts should be written in English. They should not be under consideration for publication in any other Journal and must not have been previously published.
3. Manuscripts should be conforming to Dental materials Journal style and have English language errors corrected before submission. The editorial board may return the manuscript without refereeing due to the poor style and language usage. In the case of authors who are not native speaker of English, before submission, English grammar and syntax in the manuscripts should be checked and corrected by a native English-speaking person.
4. Experimentation involving human subjects should be carried out in full accordance with ethical principle, including the World Medical Association Declaration of Helsinki. All studies using human subjects should include an explicit statement in the Material and Methods section identifying the ethics committee approval for each study. When experimental animals are used, the manuscript must state that the care to minimize pain and discomfort was in accordance with institution guidelines.
5. All manuscripts will be sent to reviewers. Authors will be asked to revise the manuscripts according to the reviewer's comments. Acceptance or rejection of the manuscripts will be decided by the editorial board of Dental Materials Journal.
6. Copyright of papers accepted for publication will be property of the Japanese Society for Dental Materials and Devices. Direct quotations, tables and illustrations in the published paper should be accompanied by written permission for their use from the copyright owners.
7. The manuscripts should be typed, double-spaced, on white paper of A4 size (297 mm×210 mm) with a word processor. Top, bottom and side margins should be about 25 mm. Number all pages consecutively at the middle of the bottom margin.
8. Title page should include the following items:
    - Category of the manuscript
    - Title (the head of title sentence in capital letters and the others in lower

case)

- Full names of the authors (Daisuke YAMASHITA[1] and Seiji BAN[2])
- Institutions and addresses (including the all institutions' addresses; [1]Department of Periodontology, Graduate school of Medical and Dental Sciences, Kagoshima University, 8-35-1 Sakuragaoka, Kagoshima 890-8544, Japan [2]Department of Biomaterials Science, Graduate school of Medical and Dental Sciences, Kagoshima University, 8-35-1 Sakuragaoka, Kagoshima 890-8544, Japan)
- Key words (3-5 words and the head of each keyword in capital letters)
- Numbers of reprints (number of reprints should be 50 multiples)
- Corresponding author (full name; e-mail address: phone number, fax number)

9. Manuscripts should include the following items:
    - ABSTRACT (100-150 words)
    - INTRODUCTION
    - MATERIALS AND METHODS
    - RESULTS
    - DISCUSSION
    - CONCLUSION (if included)
    - ACKNOWLEDGMENTS (if applicable)
    - REFERENCES
10. Proprietary names of commercial products should be expressed in parentheses by their brand names, model, company, city, states and country.
    - a cutting instrument (Komet-Brasseler, GmbH, Lemgo, Germany)
    - a luting cement (Maxcem, Kerr Corporation, Orange, CA, USA)
11. Do not use the space key before ºC, º, or % in the text (2ºC, 25%).
12. Do not use the space key before and after >, =, /, ±, or × in the text (t=18, 25×70).
13. The dash markers should be used referring to three examples.
    - Au-Ag alloy, all-ceramic inlay, 1-mm-deep, or p18-21 (Hyphen; Unicode: 002D)
    - ranged in 2.5–3.6 mg weight or for 20–25 days (n-dash; Unicode: 2013)
    - observed adjacent to the hybrid layer —but with differing appearances. main text□—text—□main text (□ means space) (m-dash; Unicode: 2014)
14. Cite references in text should be in numerical order and used in superscript in line without any space (reference[1)], reference[1,2)] or reference[2-6)].).
15. The reference applies to the Vancouver style; follow the sample references of NLM (http://www.nlm.nih.gov/bsd/uniform_requirements.html). The references should be grouped in a section at the end of the text in numerical order as they appear in the text and should take the following form:
    - *For journals*

Authors' surname together with their initials, full title of the article, the abbreviated name of the journal (as shown in Index Medicus), year, volume, inclusive page numbers.

1) Kono H, Miyamoto M, Ban S. Bioactive apatite coating on titanium using an alternative soaking process. Dent Mater J

2007; 26: 186-193.

2) Ban S, Tsuruta S. Effect of surface modification using super critical water for metal substrate on the bonding strength of veneering resins. J J Dent Mater 2002; 21: 82-89.

- *For books*

Authors' surname together with their initials: title of the book, city of publication, publisher, year of publication, inclusive page numbers.

1) Anusavice KJ. In: Anusavice KJ, editor. Phillips' science of dental materials. 11th ed. St. Louis: Saunders Co; 2003. p. 655-719.

- *For Proceedings*

1) Sato H, Ban S, Yamasaki Y. Effect of surface treatments on bonding strength of dental zirconia ceramics to resin cements. Proceedings of the 9th Asian BioCeramics Symposium; 2009 Dec 8-11; Nagoya, Japan. Sendai: Meirin-sha; 2009. p. 8-11.

16. Figures should be numbered according to their order in the text. Each figure should be drawn separately. Figure captions are to appear on a separate page at the end of the manuscript.
17. Tables should be numbered according to their order in the text. Each table should be typed on a separate sheet and should be understandable without referring to the text. Standard deviations of values should be indicated in parentheses.
18. As a unit system, the international system of units (SI), MKS-system and CGS system are acceptable, whereas the yard-pound system is not permitted.
19. The variable and abbreviation of lingua Ratina should be written in italic alphabet (p<0.05, *et al.*, *i.e.*).
20. When proof-reading, the author must not insert or eliminate sentences for revision purposes; only the correction of errors is allowed.
21. The publishing charge is 30,000 yen for a paper that does not exceed four Journal pages including tables and figures. As for charges over four pages, 9,000 yen per page will be paid by the authors. Extra charges for such as figures and tables preparation, color printing of photographs will also be paid by the authors. If authors do not pay publishing charge, the article may be retracted.

22. <u>Instructions for online submission</u>

(1) Dental Materials Journal now only accepts online submissions. All manuscripts should be submitted on the DMJ-Web site (J-STAGE).

http://mc.manuscriptcentral.com/dmj

(2) The authors should fill up all required information on the DMJ-Web site and upload the following files; a text, figures and tables as specified forms.

- Text: DOC
- Table: DOC or XLS
- Figure: PDF, JPG, BMP, TIF, PPT (not PPTX)
- Color information: DOC or PDF

(3) All files should be within 20MB.

(4) The resolution of the photos and figures is desirable in 1200 dpi. The extra white space around the actual figure should be erased.

(5)Use the surname and type of document as the file name such as riko-text, riko-fig3, riko-fig10, etc.

(6)All text and file names should be free from non-English fonts. Times or Times New Roman is adequate.

(7) Figure numbers and captions should be appeared on a separate page at the end of the text, not be indicated inside of the figure.

(8) The mode of the images can be selected from three cases in (a)-(c).

(a) If figures appear in gray-scale both in the printed version and in the electronic version of the journal, the illustrations should be produced in gray-scale.

(b) If figures appear in gray-scale in the printed version and in color in the electronic version of the journal, the illustrations should be produced in color. There will be no charges of color in the electronic version to the authors. The illustrations in gray-scale may be required together with your accepted article based on the decision by the Editor-in-Chief.

(c) If figures appear in color both in the printed version and in the electronic version of the journal, the illustrations should be produced in color. There will be the additional charges of color printing to the authors.

If you use the color images, please indicate your preference for (b) color in the electronic version only or (c) color both in the printed version and in the electronic version and your information of gray-scale printing or color printing for each image on a separate file for the color information.

23. All questions and contact sent by e-mail to the editorial office should be titled as "DMJ-Inquiry". E-mail: edit-dmj@kokuhoken.or.jp

Dental Materials Journal

Home

Author

Submission Confirmation

Print

Thank you for your submission

Submitted to	Dental Materials Journal
Manuscript ID	DMJ2018-422
Title	Effect of coronal dentin treatment on bond strength of composite resin core-build in glass-fiber post luting
Authors	Reis, Giselle Queiroz , Lucas Vilela, Ana Laura Faria-e-Silva , André Santos-Filho, Paulo César Soares, Carlos Menezes, Murilo
Date Submitted	19-Dec-2018

Author Dashboard

6.2. Normas e submissão ao periódico Brazilian Oral Reserch (Quallis A2)

Brazilian Oral Research

ISSN 1807-3107 *online version*

INSTRUCTIONS TO AUTHORS

Mission, scope, and submission policy

Brazilian Oral Research - BOR (online version ISSN 1807-3107) is the official publication of the *Sociedade Brasileira de Pesquisa Odontológica* - SBPqO (the Brazilian division of the International Association for Dental Research - IADR). The journal has an Impact Factor™ of 0.937 (Institute for Scientific Information - ISI), is peer-reviewed (double-blind system), and its mission is to disseminate and promote an information interchange concerning the several fields in dentistry research and/or related areas with gold open access.

BOR invites the submission of original and review manuscripts and papers in the following typology: Original Research (complete manuscript or Short Communication), Critical Review of Literature, Systematic Review (and Meta-Analysis) and Letters to the Editor. All submissions must be exclusive to.

Manuscripts and all corresponding documentation should be exclusively submitted through ScholarOne Manuscripts™ via the online submission link (http://mc04.manuscriptcentral.com/bor-scielo).

The evaluation process of manuscript's scientific content will only be initiated after meeting of all the requirements described in the present Instructions for Authors. Any manuscript that does not meet these requirements will be returned to the corresponding author for adaptations.

Important: Once having been accepted on their scientific merit, all manuscripts will be submitted for grammar and style revision as per the English language. Contact BOR by bor@sbpqo.org.br to get information about the recommended translation companies.The authors should forward the revised text with the enclosed revision certificate provided by the chosen editing company. **Linguistic revisions performed by companies that do not provide the mentioned certificate will not be accepted.** As an exception, this rule does not apply when one of the authors is a native English speaker.

Presentation of the manuscript

The manuscript text should be written in English and provided in a digital file compatible with "Microsoft Word" (in DOC, DOCX, or RTF format).

All figures (including those in layouts/combinations) must be provided in individual and separate files, according to recommendations described under the specific topic. Photographs, micrographs, and radiographs should be provided in TIFF format, according to the recommendations described under the specific topic.

Charts, drawings, layouts, and other vector illustrations must be provided in a PDF format individually in separate files, according to the recommendations described under the specific topic.

Video files may be submitted as per the specifications, including the author's anonymity (for purposes of evaluation) and respect for the patient's rights.

Important: ScholarOne™ allows upload of a set of files up to 10 MB. In case the video file exceeds this size, it is possible to leave information about the link to access the video. The use of patients' initials, names, and/or registry numbers is prohibited in the reproduction of clinical documentation. The identification of patients is prohibited. An informed consent statement, signed by the patient, concerning the use of his/her image should be provided by the author(s) when requested by **BOR**. The Copyright legislation in force must be respected and the source cited when the manuscript reproduces any previously published material (including texts, charts, tables, figures, or any other materials).

Title page (compulsory data)

- This must indicate the specialty* or research field focused on in the manuscript.

*Anatomy; Basic Implantodontology and Biomaterials; Behavioral Sciences; Biochemistry; Cariology; Community Dental Health; Craniofacial Biology; Dental Materials; Dentistry; Endodontic Therapy; Forensic Dentistry; Geriatric Dentistry; Imaginology; Immunology; Implantodontology – Prosthetics; Implantodontology – Surgical; Infection Control; Microbiology; Mouth and Jaw Surgery; Occlusion; Oral Pathology; Orthodontics; Orthopedics; Pediatric Dentistry; Periodontics; Pharmacology; Physiology; Prosthesis; Pulp Biology; Social/Community Dentistry; Stomatology; Temporomandibular Joint Dysfunction.

- Informative and concise title, limited to a maximum of 110 characters, including spaces.
- Names of all authors written out in full, including respective telephone numbers and email addresses for correspondence. We recommend that authors collate the names present in the Cover Letter with the profile created in ScholarOne™, to avoid discrepancies.
- The participation of each author must be justified on a separate page, which should meet the authorship and co-authorship criteria adopted by the International Committee of Medical Journal Editors, available at http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html
- Data of institutional/professional affiliation of all authors, including university (or other institution), college/program, department, city, state, and country, presented according to internal citation norms established by each author's institution. Verify that such affiliations are correctly entered in ScholarOne™.

Abstract: This should be presented as a single structured paragraph (but with no subdivisions into sections) containing the objective of the work, methodology, results, and conclusions. In the System if applicable, use the Special characters tool for special characters.

Keywords: Ranging from 3 (three) to 5 (five) main descriptors should be provided, chosen from the keywords registered at http://decs.bvs.br/ or http://www.nlm.nih.gov/mesh/MBrowser.html (no synonyms will be accepted).

Main Text

Introduction: This should present the relevance of the study, and its connection with other published works in the same line of research or field, identifying its limitations and possible biases. The objective of the study should be concisely presented at the end of this section.

Methodology: All the features of the material pertinent to the research subject should be provided (*e.g.*, tissue samples or research subjects). The experimental, analytical, and statistical methods should be described in a concise manner, although in detail, sufficient to allow others to recreate the work. Data from manufacturers or suppliers of products, equipment, or software must be explicit when first mentioned in this section, as follows: manufacturer's name, city, and country. The computer programs and statistical methods must also be specified. Unless the objective of the work is to compare products or specific systems, the trade names of techniques, as well as products, or scientific and clinical equipment should only be cited in the "Methodology" and "Acknowledgments" sections, according to each case. Generic names should be used in the remainder of the manuscript, including the title. Manuscripts containing radiographs, microradiographs, or SEM images, the following information must be included: radiation source, filters, and kV levels used. Manuscripts reporting studies on humans should include proof that the research was ethically conducted according to the Helsinki Declaration (*World Medical Association,* http://www.wma.net/en/30publications/10policies/b3/). The approval protocol number issued by an Institutional Ethics Committee must be cited. Observational studies should follow the STROBE guidelines (http://strobe-statement.org/), and the check list must be submitted. Clinical Trials must be reported according to the CONSORT Statement standard protocol (http://www.consort-statement.org/); systematic reviews and meta-analysis must follow the PRISMA (http://www.prisma-statement.org/), or Cochrane protocol (http://www.cochrane.org/).

Clinical Trials

Clinical Trials according to the CONSORT guidelines, available at www.consort-statement.org. The clinical trial registration number and the research registration name will be published along with the article.

Manuscripts reporting studies performed on animals must also include proof that the research was conducted in an ethical manner, and the approval protocol number issued by an Institutional Ethics Committee should be cited. In case the research contains a gene registration, before submission, the new gene sequences must be included in a public database, and the access number should be provided to BOR. The authors may use the following databases:

- GenBank: http://www.ncbi.nlm.nih.gov/Genbank/submit
- EMBL: http://www.ebi.ac.uk/embl/Submission/index.html
- DDBJ: http://www.ddbj.nig.ac.jp

Manuscript submissions including microarray data must include the information recommended by the MIAME guidelines (Minimum Information About a Microarray Experiment: http://www.mged.org/index.html) and/or itemize how the experimental details were submitted to a publicly available database, such as:

- ArrayExpress: http://www.ebi.ac.uk/arrayexpress/
- GEO: http://www.ncbi.nlm.nih.gov/geo/

Results: These should be presented in the same order as the experiment was performed, as described under the "Methodology" section. The most significant results should be described. Text, tables, and figures should not be repetitive. Statistically relevant results should be presented with enclosed corresponding p values.

Tables: These must be numbered and cited consecutively in the main text, in Arabic numerals. Tables must be submitted separately from the text in DOC, DOCX, or RTF format.

Discussion: This must discuss the study results in relation to the work hypothesis and relevant literature. It should describe the similarities and differences of the study in relation to similar studies found in literature, and provide explanations for the possible differences found. It must also identify the study's limitations and make suggestions for future research.

Conclusions: These must be presented in a concise manner and be strictly based on the results obtained in the research. Detailing of results, including numerical values, etc., must not be repeated.

Acknowledgments: Contributions by colleagues (technical assistance, critical comments, etc.) must be given, and any bond between authors and companies must be revealed. This section must describe the research funding source(s), including the corresponding process numbers.

Plagiarism

BOR employs a plagiarism detection system. When you send your manuscript to the journal it may be analyzed-not merely for the repetition of names/affiliations, but rather the sentences or texts used.

References: Only publications from peer-reviewed journals will be accepted as references. Unfinished manuscripts, dissertations, theses, or abstracts presented in congresses will not be accepted as references. References to books should be avoided.

Reference citations must be identified in the text with superscript Arabic numerals. The complete reference list must be presented after the "Acknowledgments" section, and the references must be numbered and presented in Vancouver Style in compliance with the guidelines provided by the International Committee of Medical Journal Editors, as presented in Uniform Requirements for Manuscripts Submitted to Biomedical Journals (http://www.ncbi.nlm.nih.gov/books/NBK7256/). The journal titles should be abbreviated according to the List of Journals Indexed in Index Medicus (http://www.ncbi.nlm.nih.gov/nlmcatalog/journals). The authors shall bear full responsibility for the accuracy of their references.

Spelling of scientific terms: When first mentioned in the main text, scientific names (binomials of microbiological, zoological, and botanical nomenclature) must be written out in full, as well as the names of chemical compounds and elements.

Units of measurement: These must be presented according to the International System of Units (http://www.bipm.org or http://www.inmetro.gov.br/consumidor/unidLegaisMed.asp).

Footnotes on the main text: These must be indicated by asterisks and restricted to the bare minimum.

Figures: Photographs, microradiographs, and radiographs must be at least 10 cm wide, have at least 500 dpi of resolution, and be provided in TIFF format. Charts, drawings, layouts, and other vector illustrations must be provided in a PDF format. All the figures must be submitted individually in separate files (not inserted into the text file). Figures must be numbered and consecutively cited in the main text in Arabic numerals. Figure legends should be inserted together at the end of the text, after the references.

Characteristics and layouts of types of manuscripts

Original Research

Limited to 30,000 characters including spaces (considering the introduction, methodology, results, discussion, conclusion, acknowledgments, tables, references, and figure legends). A maximum of 8 (eight) figures and 40 (forty) references will be accepted. The abstract can contain a maximum of 250 words.

Layout - Text Files

- Title Page
- Main text (30,000 characters including spaces)
- Abstract: a maximum of 250 words
- Keywords: 3 (three)-5 (five) main descriptors
- Introduction
- Methodology
- Results
- Discussion
- Conclusion
- Acknowledgments
- Tables
- References: maximum of 40 references
- Figure legends

Layout - Graphic Files

- Figures: a maximum of 8 (eight) figures, as described above.

Short Communication

Limited to 10,000 characters including spaces (considering the introduction, methodology, results, discussion, conclusion, acknowledgments, tables, references, and figure legends). A maximum of 2 (two) figures and 12 (twelve) references will be allowed. The abstract can contain a maximum of 100 words.

Layout - Text Files

- Title page
- Main text (10,000 characters including spaces)
- Abstract: a maximum of 100 words
- Descriptors: 3 (three)-5 (five) main descriptors
- Introduction
- Methodology
- Results
- Discussion
- Conclusion
- Acknowledgments
- Tables
- References: a maximum of 12 references
- Figure legends

Layout- Graphic Files

- Figures: a maximum of 2 (two) figures, as described above.

Critical Review of Literature
The submission of this type of manuscript will be performed only by invitation of the BOR Publishing Commission. All manuscripts will be submitted to peer-review. This type of manuscript must have a descriptive and discursive content, focusing on a comprehensive presentation and discussion of important and innovative scientific issues, with a limit of 30,000 characters including spaces (considering the introduction, methodology, results, discussion, conclusion, acknowledgments, tables, references, and figure legends). It must include a clear presentation of the scientific object, logical argumentation, a methodological and theoretical critical analysis of the studies, and a summarized conclusion. A maximum of 6 (six) figures and 50 (fifty) references is permitted. The abstract must contain a maximum of 250 words.

Layout- Text Files

- Title page
- Main text (30,000 characters including spaces)
- Abstract: a maximum of 250 words
- Keywords: 3 (three)-5 (five) main descriptors
- Introduction
- Methodology
- Results
- Discussion

- Conclusion
- Acknowledgments
- Tables
- References: maximum of 50 references
- Figure legends

Layout - Graphic Files

- Figures: a maximum of 6 (six) figures, as described above.

Systematic Review and Meta-Analysis

While summarizing the results of original studies, quantitative or qualitative, this type of manuscript should answer a specific question, with a limit of 30,000 characters, including spaces, and follow the Cochrane format and style (www.cochrane.org). The manuscript must report, in detail, the process of the search and retrieval of the original works, the selection criteria of the studies included in the review, and provide an abstract of the results obtained in the reviewed studies (with or without a meta-analysis approach). There is no limit to the number of references or figures. Tables and figures, if included, must present the features of the reviewed studies, the compared interventions, and the corresponding results, as well as those studies excluded from the review. Other tables and figures relevant to the review must be presented as previously described. The abstract can contain a maximum of 250 words.

Layout - Text Files

- Title page
- Main text (30,000 characters including spaces)
- Abstract: a maximum of 250 words
- Question formulation
- Location of the studies
- Critical Evaluation and Data Collection
- Data analysis and presentation
- Improvement
- Review update
- References: no limit on the number of references
- Tables

Layout - Graphic Files

- Figures: no limit on the number of figures

Letter to the Editor

Letters must include evidence to support an opinion of the author(s) about the scientific or editorial content of the BOR, and must be limited to 500 words. No figures or tables are permitted.

Copyright transfer agreement and responsibility statements

The manuscript submitted for publication must include the Copyright Transfer Agreement and the Responsibility Statements, available in the online system and mandatory.

CHECKLIST FOR INITIAL SUBMISSION

- Title Page file (in DOC, DOCX, or RTF format).
- Main text file (Main Document, manuscript), in DOC, DOCX, or RTF format.
- Tables, in DOC, DOCX, or RTF format.
- Declaration of interests and funding, submitted in a separate document and in a PDF format. (if applicable)
- Justification for participation of each author, provided in a separate document and in a PDF format.
- Photographs, microradiographs, and radiographs (10 cm minimum width, 500 dpi minimum resolution) in TIFF format. (http://www.ncbi.nlm.nih.gov/pmc/pub/filespec-images/)
- Charts, drawings, layouts, and other vector illustrations in a PDF format.
- Each figure should be submitted individually in separate files (not inserted in the text file).

Publication fees

Authors are not required to pay for the submission or review of articles.

EXAMPLES OF REFERENCES

Journals

Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci. 2004 Aug;112(4):353-61.

Bhutta ZA, Darmstadt GL, Hasan BS, Haws RA. Community-based interventions for improving perinatal and neonatal health outcomes in developing countries: a review of the evidence. Pediatrics. 2005;115(2 Suppl):519-617. doi:10.1542/peds.2004-1441.

Usunoff KG, Itzev DE, Rolfs A, Schmitt O, Wree A. Nitric oxide synthase-containing neurons in the amygdaloid nuclear complex of the rat. Anat Embryol (Berl). 2006 Oct 27. Epub ahead of print. doi: 10.1007/s00429-006-0134-9

Walsh B, Steiner A, Pickering RM, Ward-Basu J. Economic evaluation of nurse led intermediate care versus standard care for post-acute medical patients: cost minimisation analysis of data from a randomised controlled trial. BMJ. 2005 Mar 26;330(7493):699. Epub 2005 Mar 9.

Papers with Title and Text in Languages Other Than English

Li YJ, He X, Liu LN, Lan YY, Wang AM, Wang YL. [Studies on chemical constituents in herb of Polygonum orientale]. Zhongguo Ahong Yao Za Zhi. 2005 Mar;30(6):444-6. Chinese.

Supplements or Special Editions

Pucca Junior GA, Lucena EHG, Cawahisa PT. Financing national policy on oral health in Brazil in the context of the Unified Health System. Braz Oral Res. 2010 Aug;24 Spec Iss 1:26-32.

Online Journals

Barata RB, Ribeiro MCSA, De Sordi M. Desigualdades sociais e homicídios na cidade de São Paulo, 1998. Rev Bras Epidemiol. 2008;11(1):3-13 [cited 2008 Feb 23]. Available from: http://www.scielosp.org/pdf/rbepid/v11n1/01.pdf.

Books

Stedman TL. Stedman's medical dictionary: a vocabulary of medicine and its allied sciences, with pronunciations and derivations. 20th ed. Baltimore: Williams & Wilkins; 1961. 259 p.

Books Online

Foley KM, Gelband H, editors. Improving palliative care for cancer [monograph on the Internet]. Washington: National Academy Press; 2001 [cited 2002 Jul 9]. Available from: http://www.nap.edu/books/0309074029/html/.

Websites

Cancer-Pain.org [homepage on the Internet]. New York: Association of Cancer Online Resources, Inc.; c2000 [cited 2002 Jul 9]. Available from: http://www.cancer-pain.org/.

Instituto Brasileiro de Geografia e Estatística [homepage]. Brasília (DF): Instituto Brasileiro de Geografia e Estatística; 2010 [cited 2010

Nov 27]. Available from: http://www.ibge.gov.br/home/default.php.

World Health Organization [homepage]. Geneva: World Health Organization; 2011 [cited 2011 Jan 17]. Available from: http://www.who.int/en/

Brazilian Oral Research

Home

Author

Submission Confirmation

Print

Thank you for your submission

Submitted to	Brazilian Oral Research
Manuscript ID	BOR-2018-0878
Title	Mechanical properties and structural characteristics of a novel concept of CAD/CAM fabricated fiberglass posts
Authors	Reis, Giselle Silva, Gabriely Novais, Veridiana Soares, Priscilla Santos-Filho, Paulo Cesar Menezes, Murilo
Date Submitted	08-Nov-2018

Author Dashboard

6.3. Normas do periódico Journal of Endodontics (Quallis A1)

Guidelines for Publishing Papers in the JOE

Writing an effective article is a challenging assignment. The following guidelines are provided to assist authors in submitting manuscripts.

The *JOE* publishes original and reviews articles related to the scientific and applied aspects of endodontics. Moreover, the *JOE* has a diverse readership that includes full-time clinicians, full-time academicians, residents, students, and scientists. Effective communication with this diverse readership requires careful attention to writing style.

General Points on Composition

1. Authors are strongly encouraged to analyze their final draft with both software (e.g., spelling and grammar programs) and colleagues who have expertise in English grammar. References listed at the end of this section provide a more extensive review of rules of English grammar and guidelines for writing a scientific article. Always remember that clarity is the most important feature of scientific writing. Scientific articles must be clear and precise in their content and concise in their delivery since their purpose is to inform the reader. The Editor reserves the right to edit all manuscripts or to reject those manuscripts that lack clarity or precision, or have unacceptable grammar or syntax. The following list represents common errors in manuscripts submitted to the *JOE*:
2. The paragraph is the ideal unit of organization. Paragraphs typically start with an introductory sentence that is followed by sentences that describe additional detail or examples. The last sentence of the paragraph provides conclusions and forms a transition to the next paragraph. Common problems include one-sentence paragraphs, sentences that do not develop the theme of the paragraph (see also section "c" below), or sentences with little to no transition within a paragraph.
3. Keep to the point. The subject of the sentence should support the subject of the paragraph. For example, the introduction of authors' names in a sentence changes the subject and lengthens the text. In a paragraph on sodium hypochlorite, the sentence, "In 1983, Langeland et al., reported that sodium hypochlorite acts as a lubricating factor during instrumentation and helps to flush debris from the root canals" can be edited to: "Sodium hypochlorite acts as a lubricant during instrumentation and as a vehicle for flushing the generated debris (Langeland et al., 1983)." In this example, the paragraph's subject is sodium hypochlorite and sentences should focus on this subject.
4. Sentences are stronger when written in the active voice, *i.e.*, the subject performs the action. Passive sentences are identified by the use of passive verbs such as "was,"

"were," "could," etc. For example: "Dexamethasone was found in this study to be a factor that was associated with reduced inflammation," can be edited to: "Our results demonstrated that dexamethasone reduced inflammation." Sentences written in a direct and active voice are generally more powerful and shorter than sentences written in the passive voice.

5. Reduce verbiage. Short sentences are easier to understand. The inclusion of unnecessary words is often associated with the use of a passive voice, a lack of focus or run-on sentences. This is not to imply that all sentences need be short or even the same length. Indeed, variation in sentence structure and length often helps to maintain reader interest. However, make all words count. A more formal way of stating this point is that the use of subordinate clauses adds variety and information when constructing a paragraph. (This section was written deliberately with sentences of varying length to illustrate this point.)
6. Use parallel construction to express related ideas. For example, the sentence, "Formerly, endodontics was taught by hand instrumentation, while now rotary instrumentation is the common method," can be edited to "Formerly, endodontics was taught using hand instrumentation; now it is commonly taught using rotary instrumentation." The use of parallel construction in sentences simply means that similar ideas are expressed in similar ways, and this helps the reader recognize that the ideas are related.
7. Keep modifying phrases close to the word that they modify. This is a common problem in complex sentences that may confuse the reader. For example, the statement, "Accordingly, when conclusions are drawn from the results of this study, caution must be used," can be edited to "Caution must be used when conclusions are drawn from the results of this study."
8. To summarize these points, effective sentences are clear and precise, and often are short, simple and focused on one key point that supports the paragraph's theme.
9. Authors should be aware that the *JOE* uses iThenticate, plagiarism detection software, to assure originality and integrity of material published in the *Journal*. The use of copied sentences, even when present within quotation marks, is highly discouraged. Instead, the information of the original research should be expressed by new manuscript author's own words, and a proper citation given at the end of the sentence. Plagiarism will not be tolerated and manuscripts will be rejected, or papers withdrawn after publication based on unethical actions by the authors. In addition, authors may be sanctioned for future publication.
10.

Top ^

Organization of Original Research Manuscripts

Please Note: *All abstracts should be organized into sections that start with a one-word title (in bold),* i.e., *Introduction, Methods, Results, Conclusions, etc., and should not exceed more than 250 words in length.*

1. **Title Page:** The title should describe the major emphasis of the paper. It should be as short as possible without loss of clarity. Remember that the title is your advertising billboard—it represents your major opportunity to solicit readers to spend the time to

read your paper. It is best not to use abbreviations in the title since this may lead to imprecise coding by electronic citation programs such as PubMed (*e.g.*, use "sodium hypochlorite" rather than NaOCl). The author list must conform to published standards on authorship (see authorship criteria in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals at icmje.org). The manuscript title, name and address (including email) of one author designated as the corresponding author. This author will be responsible for editing proofs and order reprints when applicable. The contribution of each author should also be highlighted in the cover letter.

2. **Abstract:** The abstract should concisely describe the purpose of the study, the hypothesis, methods, major findings, and conclusions. The abstract should describe the new contributions made by this study. The word limitations (250 words) and the wide distribution of the abstract (*e.g*., PubMed) make this section challenging to write clearly. This section often is written last by many authors since they can draw on the rest of the manuscript. Write the abstract in past tense since the study has been completed. Three to ten keywords should be listed below the abstract.
3. **Introduction:** The introduction should briefly review the pertinent literature in order to identify the gap in knowledge that the study is intended to address and the limitations of previous studies in the area. The purpose of the study, the tested hypothesis and its scope should be clearly described. Authors should realize that this section of the paper is their primary opportunity to establish communication with the diverse readership of the *JOE*. Readers who are not expert in the topic of the manuscript are likely to skip the paper if the introduction fails to succinctly summarize the gap in knowledge that the study addresses. It is important to note that many successful manuscripts require no more than a few paragraphs to accomplish these goals. Therefore, authors should refrain from performing the extensive review or the literature, and discuss the results of the study in this section.
4. **Materials and Methods:** The objective of the materials and methods section is to permit other investigators to repeat your experiments. The four components of this section are the detailed description of the materials used and their components, the experimental design, the procedures employed, and the statistical tests used to analyze the results. The vast majority of manuscripts should cite prior studies using similar methods and succinctly describe the essential aspects used in the present study. Thus, the reader should still be able to understand the method used in the experimental approach and concentration of the main reagents (*e.g.*, antibodies, drugs, etc.) even when citing a previously published method. The inclusion of a "methods figure" will be rejected unless the procedure is novel and requires an illustration for comprehension. If the method is novel, then the authors should carefully describe the method and include validation experiments. If the study utilized a **commercial product**, the manuscript must state that they either followed manufacturer's protocol or specify any changes made to the protocol. If the study used an ***in vitro*** model to simulate a clinical outcome, the authors must describe experiments made to validate the **model**, or previous literature that proved the clinical relevance of the model. Studies on **humans** must conform to the Helsinki Declaration of 1975 and state that the institutional IRB/equivalent committee(s) approved the protocol and that informed consent was obtained after the risks and benefits of participation were described to the subjects or patients recruited. Studies involving **animals** must state that the institutional animal care and use committee approved the protocol. The statistical analysis section should describe which tests were used to analyze which dependent measures; p-values should be specified. Additional details may include randomization scheme, stratification (if any), power analysis as a basis for

sample size computation, drop-outs from clinical trials, the effects of important confounding variables, and bivariate versus multivariate analysis.

5. **Results:** Only experimental results are appropriate in this section (*i.e.*, neither methods, discussion, nor conclusions should be in this section). Include only those data that are critical for the study, as defined by the aim(s). Do not include all available data without justification; any repetitive findings will be rejected from publication. All Figures, Charts, and Tables should be described in their order of numbering with a brief description of the major findings. The author may consider the use of supplemental figures, tables or video clips that will be published online. Supplemental material is often used to provide additional information or control experiments that support the results section (*e.g.*, microarray data).
6. **Figures:** There are two general types of figures. The first type of figures includes photographs, radiographs or micrographs. Include only essential figures, and even if essential, the use of composite figures containing several panels of photographs is encouraged. For example, most photos, radio- or micrographs take up one column-width, or about 185 mm wide X 185 mm tall. If instead, you construct a two columns-width figure (*i.e.*, about 175 mm wide X 125 mm high when published in the *JOE*), you would be able to place about 12 panels of photomicrographs (or radiographs, etc.) as an array of four columns across and three rows down (with each panel about 40 X 40 mm). This will require some editing to emphasize the most important feature of each photomicrograph, but it greatly increases the total number of illustrations that you can present in your paper. Remember that each panel must be clearly identified with a letter (*e.g.*, "A," "B," etc.), in order for the reader to understand each individual panel. Several nice examples of composite figures are seen in recent articles by Jeger et al (J Endod 2012;38:884–888); Olivieri et al., (J Endod 2012;38:1007 1011); Tsai et al (J Endod 2012;38:965–970). Please note that color figures may be published at no cost to the authors and authors are encouraged to use color to enhance the value of the illustration. Please note that a multi-panel, composite figure only counts as one figure when considering the total number of figures in a manuscript (see section 3, below, for the maximum number of allowable figures).The second type of figures is graphs (*i.e.*, line drawings including bar graphs) that plot a dependent measure (on the Y-axis) as a function of an independent measure (usually plotted on the X axis). Examples include a graph depicting pain scores over time, etc. Graphs should be used when the overall trend of the results are more important than the exact numerical values of the results. For example, a graph is a convenient way of reporting that an ibuprofen-treated group reported less pain than a placebo group over the first 24 hours, but was the same as the placebo group for the next 96 hours. In this case, the trend of the results is the primary finding; the actual pain scores are not as critical as the relative differences between the NSAID and placebo groups.
7. **Tables:** Tables are appropriate when it is critical to present exact numerical values. However, not all results need be placed in either a table or figure. For example, the following table may not be necessary:Instead, the results could simply state that there was no inhibition of growth from 0.001-0.03% NaOCl, and a 100% inhibition of growth from 0.03-3% NaOCl (N=5/group). Similarly, if the results are not significant, then it is probably not necessary to include the results in either a table or as a figure. These and many other suggestions on figure and table construction are described in additional detail in Day (1998).

% NaOCl	N/Group	% Inhibition of Growth

% NaOCl	N/Group	% Inhibition of Growth
0.001	5	0
0.003	5	0
0.01	5	0
0.03	5	0
0.1	5	100
0.3	5	100
1	5	100
3	5	100

8. **Discussion:** This section should be used to interpret and explain the results. Both the strengths and weaknesses of the observations should be discussed. How do these findings compare to the published literature? What are the clinical implications? Although this last section might be tentative given the nature of a particular study, the authors should realize that even preliminary clinical implications might have value for the clinical leadership. Ideally, a review of the potential clinical significance is the last section of the discussion. What are the major conclusions of the study? How does the data support these conclusions
9. **Acknowledgments:** All authors must affirm that they have no financial affiliation (e.g., employment, direct payment, stock holdings, retainers, consultantships, patent licensing arrangements or honoraria), or involvement with any commercial organization with direct financial interest in the subject or materials discussed in this manuscript, nor have any such arrangements existed in the past three years. Any other potential conflict of interest should be disclosed. Any author for whom this statement is not true must append a paragraph to the manuscript that fully discloses any financial or other interest that poses a conflict. Likewise, the sources and correct attributions of all other grants, contracts or donations that funded the study must be disclosed
10. **References:** The reference style follows Index Medicus and can be easily learned from reading past issues of the JOE. The JOE uses the Vancouver reference style, which can be found in most citation management software products. Citations are placed in parentheses at the end of a sentence or at the end of a clause that requires a literature citation. Do not use superscript for references. Original reports are limited to 35 references. There are no limits to the number of references for review articles.
11.

Top ^

Manuscripts Category Classifications and Requirements

Manuscripts submitted to the *JOE* must fall into one of the following categories. The abstracts for all these categories would have a maximum word count of 250 words:

1. CONSORT Randomized Clinical Trial-Manuscripts in this category must strictly adhere to the Consolidated Standards of Reporting Trials-CONSORT- minimum guidelines for the publication of randomized clinical trials. These guidelines can be found at consort-statement.org. These manuscripts have a limit of 3,500 words, [including abstract, introduction, materials and methods, results, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 4 figures and 4 tables*.
2. Review Article-Manuscripts in this category is either narrative articles, or systematic reviews/meta-analyses. Case report/Clinical Technique articles even when followed by the extensive review of the literature will be categorized as "Case Report/Clinical Technique". These manuscripts have a limit of 3,500 words, [including abstract, introduction, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 4 figures and 4 tables*.
3. Clinical Research (*e.g.*, prospective or retrospective studies on patients or patient records, or research on biopsies, excluding the use of human teeth for technique studies). These manuscripts have a limit of 3,500 words [including abstract, introduction, materials and methods, results, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 4 figures and 4 tables*.
4. Basic Research Biology (animal or culture studies on biological research on physiology, development, stem cell differentiation, inflammation or pathology). Manuscripts that have a primary focus on biology should be submitted in this category while manuscripts that have a primary focus on materials should be submitted in the Basic Research Technology category. For example, a study on cytotoxicity of a material should be submitted in the Basic Research Technology category, even if it was performed in animals with histological analyses. These manuscripts have a limit of 2,500 words [including abstract, introduction, materials and methods, results, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 4 figures or 4 tables*.
5. Basic Research Technology (Manuscripts submitted in this category focus primarily on research related to techniques and materials used, or with potential clinical use, in endodontics). These manuscripts have a limit of 2,500 words [including abstract, introduction, materials and methods, results, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 3 figures and tables *.
6. Case Report/Clinical Technique (*e.g.*, report of an unusual clinical case or the use of cutting-edge technology in a clinical case). These manuscripts have a limit of 2,500 words [including abstract, introduction, materials and methods, results, discussion, and acknowledgments; excluding figure legends and references]. In addition, there is a limit of a total of 4 figures or tables*.* Figures, if submitted as multi-panel figures must not exceed 1-page length. Manuscripts submitted with more than the allowed number of figures or tables will require the approval of the JOE Editor or associate editors. If you are not sure whether your manuscript falls within one of the categories above, or would like to request preapproval for submission of additional figures please contact the Editor by email at jendodontics@uthscsa.edu.Importantly, adhering to the general

writing methods described in these guidelines (and in the resources listed below) will help to reduce the size of the manuscript while maintaining its focus and significance. Authors are encouraged to focus on only the essential aspects of the study and to avoid inclusion of extraneous text and figures. The Editor may reject manuscripts that exceed these limitations.