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Evidências científicas na utilização de pinos de fibra de vidro e núcleos metálicos fundidos

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Aos meus pais,

À minha irmã,

Ao meu marido

pelo amor incondicional e

apoio em todos os momentos da minha vida,

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“Todos os seus sonhos vão se realizar se você tiver a coragem de conquistá-los!!!”

Walt Disney

Resumo

MORAES, Aline Pinheiro de. **Evidências científicas na utilização de pinos de fibra de vidro e núcleos metálicos fundidos.** 2014. 133f. Tese (Doutorado em Odontologia). Programa de Pós Graduação em Odontologia. Universidade Federal de Pelotas, Pelotas, Pelotas, 2014.

Tradicionalmente, os metais têm sido utilizados como retentores intrarradiculares como meio para fornecer ancoragem às restaurações devido às suas propriedades físicas adequadas e possibilidade de serem fundidos ou usinados em formas precisas. No entanto, a crescente demanda por estética tem levado ao desenvolvimento de retentores mais estéticos sendo especialmente os de fibra de vidro considerados uma alternativa aos núcleos metálicos fundidos (NMFs) na restauração de dentes tratados endodonticamente. Considerando ambos os tipos de retentores intrarradiculares, este estudo foi dividido em quatro partes. Na primeira, foi realizada uma revisão narrativa de literatura sobre os conceitos atuais na utilização de pinos de fibra de vidro. De maneira geral, concluiu-se com que o uso de pinos de fibra de vidro é uma importante opção clínica, mas deve-se tomar especial atenção às dificuldades de se obter uma boa adesão ao longo do canal radicular. Na segunda parte, foi realizada uma revisão sistemática na qual se avaliou se a utilização de silano seria benéfica para a resistência de união de pinos de fibra de vidro. Esta revisão mostrou que embora haja pouca evidência na literatura, a silanização pode melhorar a retenção de pinos de fibra de vidro quando tratamentos físicos/químicos seletivos são aplicados ao pino antes da silanização. Na terceira parte, foi realizado um estudo *in vitro* com o objetivo de comparar como os operadores com diferentes níveis de *expertise* e as técnicas de moldagem intracanal (direta ou indireta) influenciariam nas características de superfície das moldagens e qualidade dos núcleos metálicos fundidos. Os resultados mostraram que ambos os operadores e técnicas de moldagem resultaram em núcleos metálicos fundidos clinicamente aceitáveis de acordo com os padrões internacionais. No ensaio clínico randomizado foi avaliada a qualidade dos núcleos metálicos fundidos em relação a sua adaptação dependendo da posição do dente no arco e a técnica de moldagem realizada. Os resultados mostraram NMFs mais curtos quando a técnica indireta foi utilizada. No entanto, independentemente da técnica todos os pinos fundidos ficaram mais curtos do que o que foi moldado, embora clinicamente aceitáveis. A técnica indireta mostrou-se mais rápida do que a técnica direta, sendo este achado especialmente importante quando planejados casos de moldagens múltiplas e/ou espaço interoclusal reduzido. Desta forma, podemos concluir que os dados do estudo *in vitro* corroboram com os dados do ECR, uma vez que independentemente da técnica de moldagem, dos operadores e da posição do dente no arco, todos os núcleos metálicos fundidos foram mais curtos do que o que foi moldado, embora clinicamente aceitáveis.

Palavras-chave: pinos de fibra de vidro; núcleos metálicos fundidos; moldagem direta e indireta.

Abstract

MORAES, Aline Pinheiro de. **Scientific evidences on the use of glass fiber posts and cast metal posts.** 2014. 133f. Thesis (PhD in Dentistry). Programa de Pós Graduação em Odontologia. Universidade Federal de Pelotas, Pelotas, Pelotas, 2014.

Traditionally, metals have been used to fabricate dental posts because of their suitable physical properties and possibility of being cast or machined into precise shapes. However, in recent decades, the increasing demand for aesthetics has led to the development of glass fiber posts. Glass fiber posts are considered an alternative to cast metal posts to restore endodontically treated teeth. Considering both types of intracanal posts, this study was divided into four parts. In the first, a narrative literature review of current concepts in the use of glass fiber posts was performed. In general, it may be said that the use of fiber posts is an important clinical option in Dentistry, but clinicians should be aware of the difficulties in achieving good adhesion within the root canal. In the second part, a systematic review evaluated if the use of silane would be beneficial to the bond strength of glass fiber posts. This review showed that although there is little evidence in the literature, silanization might improve the retention of glass fiber posts luted into root canals provided that selective physical/chemical surface treatments are applied to the post before silanization. In the third part, an *in vitro* study compared how operators (experienced or not) and intracanal impression techniques (direct or indirect) influenced the surface characteristics of the impressions and the quality of cast metal posts. Results showed that both operators and techniques resulted in clinically acceptable posts according to international standards. The fourth part of this study evaluated the accuracy of cast metal posts depending on the tooth position and impression technique performed on a randomised controlled trial. Results showed that cast metal post were shorter than their respectvive impressions for all variables tested, but resulted in clinically acceptable metal posts. However, the direct technique was more time-consuming than the indirect technique, which is especially important in cases of multiple teeth involved and/or reduced interarch space. Thus, it may be concluded that data from the *in vitro* study corroborated with the RCT, as irrespective of the impression technique, operator level of expertise or the position of the tooth in the arch all cast metal posts were shorter, but clinically acceptable.

Key-Words: glass fiber posts; cast metal posts; direct and indirect impression techniques

Sumário

1 Introdução

Retentores intrarradiculares são usados há mais de 250 anos para aumentar a retenção e fornecer estabilidade para a restauração final (ASSIF; GORFIL, 1994; MORGANO; BRACKETT, 1999) nos casos em que a estrutura dental coronária foi destruída devido à cárie, trauma ou procedimentos endodônticos muito invasivos. Metais são tradicionalmente utilizados para fabricar retentores devido as suas propriedades físicas adequadas e possibilidade de serem fundidos ou usinados em formas precisas (STEWARDSON, 2001). Uma das principais razões, apesar de equivocada, para a utilização de retentores é reforçar a estrutura radicular (SHILLINBURG et al., 1997). A principal função do retentor é reter o núcleo e, secundariamente, distribuir com uniformidade as cargas oclusais ao longo da raiz (MEZZOMO et al., 2007).

Nas últimas décadas, a crescente demanda por estética tem levado ao desenvolvimento de materiais mais estéticos, especialmente àqueles de zircônia ou fibra de vidro. Para garantir bom resultado estético, o sistema de retenção deveria ser da mesma cor do dente e ainda, refletir e transmitir luz à semelhança do dente natural, principalmente em dentes anteriores (KAKEHASHI et al., 1998; AHMAD, 1998; MICHALAKIS et al., 2004; PAUL et al., 2004). Os pinos de fibra de vidro, diferente dos pinos de zircônia, apresentam ainda a vantagem de ter módulo de elasticidade mais semelhante ao da estrutura dental quando comparado aos núcleos metálicos fundidos (NMFs). Em função disso, permitem a formação de conjunto restaurador que dissipa as tensões mecânicas de forma semelhante ao dente natural (PEGORETTI et al., 2002; MACCARI et al., 2003; FERRARI et al., 2000).

Entretanto, os NMFs são considerados até hoje o padrão-ouro em casos de necessidade de retenção intrarradicular em dentes amplamente destruídos

(ZARONE; RUSSO; SORRENTINO, 2011). Os mesmos são indicados principalmente nos casos de destruição total da porção coronária e em casos de próteses fixas extensas que necessitem retenção intrarradicular (MANNOCCI; FERRARI; WATSON, 1999; ZARONE et al., 2006). NMFs têm demonstrado desempenho satisfatório em estudos clínicos a longo prazo (WEINE et al., 1991; BERGMAN et al., 1989), além de adaptação à configuração e angulação das paredes do canal radicular e conexão ideal entre núcleo e pino, impossibilitando separação entre ambos (STEWARDSON, 2001). Suas maiores vantagens são baixo custo, não exigência de técnica ou cimentos especiais para fixação, longo histórico de utilização clínica e excelente radiopacidade. Quando considerados os efeitos de diferentes alturas do colar cervical, o chamado *efeito férula* (0,5 – 2 mm) nestes casos é necessário no mínimo 1,5 mm de estrutura dentária para garantir prognóstico favorável à restauração (LIBMAN et al., 1995). Entretanto, NMFs estão associados à estética inferior, pois podem causar corrosão metálica pigmentando a gengiva e descoloração dos dentes (STEWARDSON, 2001; ARVIDSON et al., 1978). Além disso, apresentam menor retenção, podem causar graves tipos de fraturas radiculares (TORBJORNER et al., 1995) e ainda propiciar risco de reações alérgicas (SILNESS et al., 1979). Os núcleos metálicos fundidos apresentam ainda, baixa resiliência e módulo de elasticidade não-equivalente ao da estrutura dentária (SCHWARTZ et al., 2004).

Os NMFs podem ser obtidos por meio de duas técnicas de moldagem, direta ou indireta. A técnica direta é realizada com auxílio de pinos pré-fabricados e reembasamento com resina acrílica quimicamente ativada (MIRANDA et al., 1992). Nesta técnica, as porções coronária e radicular do retentor são obtidas diretamente na boca do paciente, sendo posteriormente fundidas em ligas metálicas apropriadas. Esta técnica oferece menor tempo para confecção pela eliminação de uma fase do procedimento laboratorial. A técnica indireta também utiliza pinos pré-fabricados, no entanto, associados a um material de moldagem, sendo o mais indicado o silicone de adição (MIRANDA et al., 1994). Nesta técnica, o material leve é levado ao interior do canal com o auxílio de uma broca lêntulo ou pistola para inserção, e então se introduz o pino intracanal. Logo a seguir, uma moldeira com o material pesado e o leve é posicionada sobre o conjunto dente/pino pré-fabricado. Este mantem no interior do canal o material de moldagem e o sustenta para evitar a posterior deformação durante o vazamento do gesso. O procedimento de moldagem deve ser criteriosamente executado, de forma que não haja bolhas que possam interferir em um bom modelo de trabalho, alterando a anatomia interna do conduto no modelo de gesso (CHEE et. al., 2000). Assim, esta técnica necessita de uma etapa laboratorial adicional, acarretando maior probabilidade de imprecisão da peça fundida. No entanto, possibilita maior facilidade de confecção da porção coronária, já que é realizada sobre o modelo de gesso e possui menor tempo de sessão clínica, sendo indicada para dentes com acesso limitado e moldagens múltiplas.

Embora amplamente utilizados, poucos trabalhos laboratoriais e clínicos avaliaram o tempo necessário para execução da(s) técnica(s) ou realizaram a comparação entre operadores com diferentes níveis de aperfeiçoamento. Além disso, estudos clínicos bem delineados, seguindo princípios básicos de pesquisa clínica que permitam inferências com menor probabilidade de vieses são raros dentro dessa linha de pesquisa.

1.1 Objetivo Geral

O presente estudo tem como objetivo revisar a literatura acerca de pinos de fibra de vidro, considerando os conceitos atuais de técnicas de utilização e avaliar *in vitro* e *in vivo,* técnicas de moldagem para obtenção de NMFs com o intuito de comparar o tempo clínico entre operadores com diferentes níveis de *expertise* e a qualidade final das moldagens e, consequentemente, dos NMFs.

1.2 Objetivos Específicos

- Revisar a literatura referente aos pinos de fibra de vidro considerando as recentes mudanças na filosofia, materiais e tecnologia considerando especialmente os cimentos resinosos;
- Avaliar *in vitro* o tempo clínico entre operadores para confecção dos NMFs em cada uma das técnicas de moldagem;
- Avaliar *in vitro* as diferenças entre os NMFs confeccionados pelos diferentes operadores;
- Avaliar *in vitro* a adaptação dos NMFs;
- Avaliar *in vivo* o tempo clínico para confecção dos NMFs entre operadores em cada uma das técnicas de moldagem;
- Avaliar *in vivo* os defeitos dos NMFs confeccionados em c[illegible] uma das técnicas.

1.3 Hipótese

A hipótese nula a ser testada nos trabalhos *in vitro* e no ensaio clinico randomizado é a de que as moldagens, direta e indireta, resultarão em retentores intrarradiculares semelhantes, tanto do ponto de vista de tempo quanto do ponto de vista de qualidade, independentemente da habilidade do operador.

2 Projeto de Pesquisa

Parte 1 Current concepts on the use and adhesive bonding of glass fiber posts

Desenho experimental

Este trabalho terá por objetivo revisar e sumarizar trabalhos *in vitro* e *in vivo* sobre o uso de pinos de fibra de vidro, uma vez que estes representam uma importante opção na clínica odontológica para reconstrução de dentes tratados endodonticamente. Será realizada a busca por artigos científicos completos listados nas bases de dados Medline e ISI Web Sience de 1979-2010 utilizando-se as palavras-chaves: dentes tratados endodonticamente, pinos de fibra de vidro, cimento resinoso, adesivos, silano e odontologia. Alguns assuntos em que ainda não há consenso na literatura, como o uso de silanos e cimentos resinosos auto-adesivos serão discutidos.

O artigo será estruturado do seguinte modo: Introdução; Por que os retentores intrarradiculares são usados em odontologia? Pinos de fibra de vidro: uma alternativa; Cimentos resinosos: uma visão geral; Cimentos resinosos: autopolimerizáveis ou duais? Cimento resinoso auto-adesivo: o futuro dos cimentos odontológicos? Sistemas adesivos; Silanos; Como evitar falhas? Conclusão.

Parte 2 Influência dos operadores nas técnicas direta e indireta de moldagem intracanal para confecção dos núcleos metálicos fundidos

Desenho experimental

Este estudo *in vitro* tem por objetivo avaliar como operadores com diferentes níveis de aperfeiçoamento (10° semestre de Graduação e especialista) realizam as técnicas de moldagem intracanal, direta e indireta. Este estudo também avaliará os defeitos presentes na superfície dos NMFs e a adaptação dos NMFs. Para isso, raízes de dentes unirradiculares obtidas no Banco de Dentes do PET-FO/UFPel, serão preparadas para que sejam realizadas as moldagens. Após este procedimento, estas moldagens serão enviadas ao laboratório para obtenção dos NMFs e serão realizadas as análises de superfície utilizando-se microscópio, fotografias das moldagens e núcleos obtidos, bem como o tempo despendido para realização do procedimento.

Materiais e Métodos

Estudo piloto e seleção dos dentes

Para este estudo, será realizado um piloto com 10 raízes de dentes unirradiculares, e a partir dos dados obtidos, será feito o cálculo de “n”. Os dentes serão lavados, limpos com curetas periodontais e armazenados em solução aquosa de Cloramina T 0,5% por 7 dias para desinfecção. Os dentes terão suas raízes observadas e, aquelas que apresentarem mais de um canal, ápice incompleto, obstrução ou reabsorção interna serão excluídas para minimizar as variações anatômicas entre os dentes selecionados. Será realizada uma análise com o auxílio de uma lupa com aumento de 4x, para detecção de possíveis falhas ou fraturas; caso haja presença de trincas ou fraturas, os dentes serão descartados para minimizar qualquer fator adicional que possa afetar a magnitude de retenção do retentor cimentado.

Preparo dos dentes

Com o auxílio de uma broca diamantada em baixa rotação sob refrigeração de água (FARIA-E-SILVA et al., 2009), as porções coronal e cervical serão seccionadas a uma distância de 16 mm do ápice da raiz, objetivando padronizar o comprimento radicular. Os espécimes serão embutidos em resina acrílica e cilindros de PVC o mais paralelamente ao eixo y. Para isso, será realizada uma associação broca/canal radicular e fixação em um delineador, o qual manterá o conjunto e o cilindro em relação paralela ao eixo y e então o conjunto será alocado em dois grupos, de acordo com a técnica de moldagem a ser realizada.

Preparo endodôntico dos dentes

Todos os canais radiculares serão instrumentados (MACEDO et al., 2010). Para o alargamento dos canais nos terços médio e coronal serão utilizadas brocas Gates-Glidden (Dentsply Maillefer, Ballaigues, Switzerland) n^{o}2 a 4, sendo que o preparo apical será realizado com lima 20 e o alargamento do canal será finalizado com lima 40, ambas do tipo K-flex (DentsplyMaillefer, Petrópolis, Brasil), novos instrumentos serão utilizados a cada 5 espécimes (AL-OMARI E ZAGIBEH, 2010). Todos estes procedimentos serão executados sob irrigação com solução de hipoclorito de sódio 2,5%. Com o preparo químico-mecânico finalizado, dar-se-á a obturação do canal radicular com cones de guta-percha (Dentsply - Maillefer, Petrópolis, Brasil) e cimento endodôntico Endofill (Dentsply - Maillefer, Petrópolis, Brasil). Será empregada a técnica de condensação lateral com a utilização de um cone principal somado a cones acessórios suficientes para completa obturação do canal.

Desobturação do Canal Radicular

Concluída a obturação dos canais radiculares os dentes serão armazenados durante 24 horas em ambiente com 100% de umidade para a presa completa do cimento endodôntico. Após este período, os canais serão abordados com broca largo n^{o}3 (Dentsply - Maillefer, Petrópolis, Brasil) para desobturação dos mesmos, removendo a quantidade necessária a fim de deixar 4 mm de guta-percha remanescente na porção mais apical da raiz, mantendo o selamento apical.

Procedimentos de moldagem

Primeiramente, os canais radiculares desobturados serão isolados com vaselina sólida com auxílio de pontas de papel absorvente e, a seguir, se executarão os procedimentos de moldagem. A moldagem direta será realizada com auxílio de pinos pré-fabricados reembasados com resina acrílica quimicamente ativada (DuraLay, Reliance Dental Mfg. Co., Worth, IL, EUA) (MIRANDA et al., 1992) de forma que tanto a porção coronária como a radicular serão obtidas diretamente sobre a raiz. Para isso, será preparado em um frasco Dappen, polímero e monômero de resina acrílica, e com o auxílio de uma sonda a resina ainda fluída será inserida no interior dos canais e logo os pinos pré-fabricados umedecidos por monômero serão inseridos, os quais irão aderir à resina previamente colocada. Os excessos de resina serão acomodados ao redor dos pinos para posterior confecção do núcleo. Serão realizados movimentos de inserção e remoção do pino do interior do canal até o início da exotermia, após este será colocado em um gral com água a 37^{o}C até o término da polimerização. Será verificado se há presença de bolhas e, se necessário, será realizado o reembasamento com auxílio de pincéis (AL-OMARI E ZAGIBEH, 2010). A porção coronária terá um preparo para coroa total em um incisivo central superior, sendo a altura de 5 mm, término em chanfro, ângulos arredondados e face vestibular em dois planos. O padrão de resina será armazenado em água e então enviado ao laboratório, onde o mesmo será incluído em revestimento e fundido em metal semiprecioso.

A moldagem indireta será realizada com pinos pré-fabricados associados à silicone de adição (Futura AD - DFL Indústria e Comércio S.A., Jacarepaguá, RJ, Brasil). Nesta técnica, o material leve será levado ao interior do canal com o auxílio de pistola para inserção do mesmo, e então, com auxílio de uma pinça será introduzido o pino intracanal. Logo a seguir, uma moldeira com o material pesado e o leve será posicionada sobre o conjunto dente e pino intracanal para remoção do conjunto, após o tempo de presa determinado pelo fabricante. Será obtido um molde do canal radicular, o qual será enviado ao técnico do laboratório para execução de um modelo de gesso, sobre o qual será confeccionado o padrão de resina acrílica, que será então incluído e fundido e originará os NMFs.

Avaliação da adaptação dos NMFs e espessura da camada de cimentação simulada

Após a obtenção dos NMFs, será avaliada sua adaptação. Silicone de adição será utilizada para simular a espessura de cimento obtida durante a cimentação. A silicone de adição será manipulada de acordo com as instruções do fabricante. Cada espécime será preenchido com o material de moldagem e em seguida os NMFs, serão isolados com vaselina, serão assentados sobre os dentes com pressão apropriada e após o tempo de polimerização, os NMFs serão removidos do interior do canal juntamente com o material de moldagem (RASTOGI E KAMBLE, 2011). O silicone será cuidadosamente removido dos NMFs para mensuração da massa, com o intuito de avaliar a adaptação dos NMFs confeccionados através das diferentes técnicas de moldagem. Os moldes serão também avaliados quanto a sua espessura para simular a cimentação, com auxílio de microscópio óptico com aumento de 30X (RASTOGI E KAMBLE, 2011) e paquímetro digital, com precisão de 0,001µm, obtendo-se medidas nos terços, apical, médio e cervical.

Ensaio de resistência de união (pull-out)

Os NMFs serão cimentados com cimento resinoso auto-adesivo RelyXU100 (3M ESPE – EUA) de acordo com as recomendações do fabricante e com o auxílio de seringa centrix (DFL Ind. e Com. S.A., Rio de Janeiro, Brasil). Os espécimes serão estocados em 100% de umidade a 37^{0}C por 24 h antes do teste (MACEDO et al., 2010). O conjunto será posicionado em Máquina de Ensaios Universal (EMIC - São José dos Pinhais, SP, Brasil), de forma que a haste horizontal, anexada ao elemento superior da máquina de ensaio passe através de um orifício previamente confeccionado na região central dos NMFs (AL-OMARI E ZAGIBEH, 2010). O teste de pull-out será realizado paralelo ao longo eixo dos dentes/NMFs com uma velocidade de 0,5mm/min e a força necessária para deslocar cada NMFs será registrada em Newtons (N).

Avaliação dos operadores

Operadores com diferentes níveis de aperfeiçoamento (10° semestre e especialista) realizarão as técnicas de moldagem direta e indireta, conforme descrito anteriormente e serão avaliados em relação ao tempo que cada um levará para execução das técnicas. O tempo para realização dos procedimentos de moldagem será cronometrado e posteriormente anotado.

Avaliação dos defeitos

Os defeitos presentes na superfície dos NMFs serão avaliados por meio de fotografias padronizadas, inspeção clínica e microscopia. As fotografias serão sempre padronizadas através da utilização de uma mesma câmera (Canon-Rebel Xti, CANON INC., Japão) ajustados sempre para mesmo foco (20x) e distância (15 cm). As fotografias serão realizadas após a moldagem direta e indireta e após fundição dos NMFs. As fotografias receberão um número a fim de realizar o cegamento da avaliação do comprimento dos NMFs. Na técnica direta, as fotos serão obtidas do retentor em resina e em metal (após a fundição), ambos dispostos sobre papel milimetrado. Na técnica indireta, será realizada fotografia da moldagem disposta sobre fundo preto, onde uma régua milimetrada será colocada na cervical do retentor intrarradicular moldado. Posteriormente a fundição, outra fotografia com o NMF disposto sobre papel milimetrado será realizada.

Análise estatística

Os dados obtidos serão analisados usando um pacote de software estatístico (versão 3.5 de SigmaStat, Chicago, IL, EUA). O nível de significância a ser considerado será α=0,05.

Parte 3 Ensaio clínico randomizado da influência da técnica de moldagem para confecção de retentores intrarradiculares

Desenho experimental

Este estudo será um ensaio clínico controlado e randomizado, em que serão avaliados operadores com diferentes níveis de aperfeiçoamento, bem como as diferenças entre moldagem direta e indireta, para obtenção de NMFs. Para isso, indivíduos com dentes tratados endodonticamente e amplamente destruídos, com necessidade de retentores intrarradiculares, serão selecionados.

Materiais e Métodos

Amostra

Serão selecionados pacientes atendidos no Projeto de Extensão de reabilitação de dentes tratados endodonticamente - ProDente, da Faculdade de Odontologia da Universidade Federal de Pelotas. Os pacientes, previamente selecionados pelo serviço de triagem da Faculdade de Odontologia da UFPel, passarão por análise e todos que se enquadrarem nos critérios de inclusão e aceitarem participar do estudo entrarão no processo de randomização. Os pacientes serão alocados em uma das intervenções, moldagem direta ou indireta através de randomização realizada em software (Excel, Microsoft).

Os critérios de inclusão serão indivíduos com boa saúde geral e bucal, que possuam dentes anteriores ou posteriores tratados endodonticamente e que necessitem de retentor intrarradicular para serem restaurados. Além disso, os pacientes deverão ter contatos oclusais posteriores simultâneos bilaterais, atendendo ao critério de oclusão mutuamente protegida. Os critérios de exclusão, não permitem neste estudo a participação de indivíduos com dentes que apresentem mobilidade maior que grau 1, dentes tratados endodonticamente que apresentem canais radiculares amplos, pacientes com doença periodontal não tratada, pacientes com alguma doença sistêmica que interfira na qualidade óssea, dentes com presença de lesão periapical e que não possa ser eliminada com tratamento endodôntico adequado, presença de problemas oclusais não tratados, utilização de próteses totais ou parciais removíveis extensas antagonistas ao dente a ser restaurado.

Procedimentos clínicos

Será realizado o preenchimento de uma ficha onde será anotado desde anamnese até os dados do dente a ser restaurado, como número de contatos proximais, presença de contato com dentes antagonistas, grau de mobilidade, profundidade de sondagem, entre outros (Apêndice A).

Os pacientes elegíveis, ou seja, aqueles que necessitam de NMFs terão suas necessidades odontológicas realizadas previamente aos procedimentos experimentais. Após o restabelecimento de condições clínicas de saúde na cavidade bucal, os pacientes receberão o tratamento endodôntico através de técnicas de rotina que incluem o uso de dique de borracha, instrumentação químico-mecânica com NaOCl 2% e limas endodônticas, obturação com guta-percha e cimento endodôntico (Endofill - Dentsply Ind. Com. Ltda, Petrópolis, RJ, Brasil) e condensação pela técnica lateral. Logo após, os dentes terão 2/3 do seu comprimento radicular desobturados, para que seja efetuada a moldagem dos canais radiculares e posterior confecção dos NMFs. Assim, será realizada a randomização dos procedimentos experimentais para assegurar a ocultação dos “tratamentos”, conforme Figura 1 a seguir:

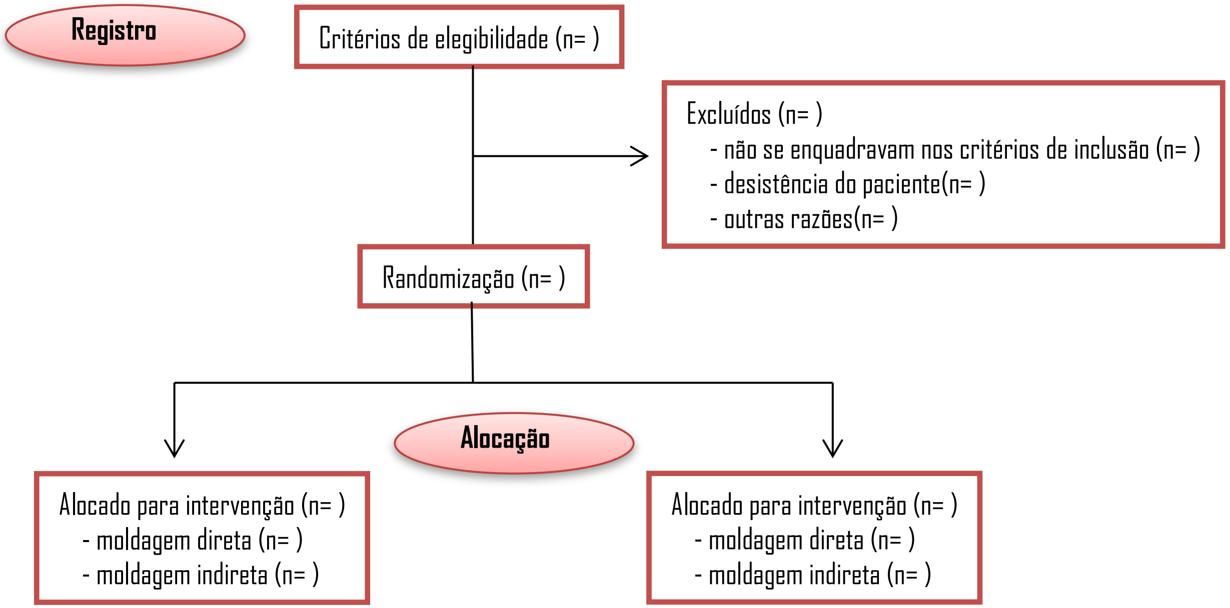

Figura 1 – Grupos de intervenção em que a alocação dar-se-á de forma randomizada.

A moldagem direta será realizada com auxílio de pinos pré-fabricados e reembasamento com resina acrílica quimicamente ativada (Duralay) (MIRANDA et al., 1992), de forma que tanto a porção coronária como a radicular serão obtidas diretamente sobre o remanescente dentário. Para isso, será preparado em um frasco Dappen polímero e monômero de resina acrílica e com o auxílio de uma sonda a resina ainda fluída será inserida no interior dos canais e logo depois serão inseridos os pinos pré-fabricados umedecidos por monômero, os quais irão aderir à resina previamente colocada. Os excessos de resina serão acomodados ao redor dos pinos para posterior confecção do núcleo. Serão realizados movimentos de inserção e remoção do pino do interior do canal até o início da exotermia e então depois este será colocado em um grau com água a 37^{o}C, até o término da polimerização. Será verificado se há presença de bolhas e, se necessário, o pino será reembasado com auxílio de pincéis (AL-OMARI E ZAGIBEH, 2010). O padrão de resina será armazenado em água e então enviado ao laboratório, onde o mesmo será incluído em revestimento e fundido em metal semiprecioso. A moldagem indireta será realizada com pinos pré-fabricados associados à silicone de adição (Futura AD-DFL Indústria e Comércio S.A.,Jacarepaguá, RJ, Brasil). Nesta técnica, o material leve será levado ao interior do canal com o auxílio de pistola para inserção do mesmo, e então, com auxílio de uma pinça, será introduzido pino intracanal pré-fabricado. Logo a seguir, uma moldeira com o material pesado e o leve será posicionada sobre o conjunto dente e pino intracanal para remoção do conjunto, após o tempo de presa determinado pelo fabricante. Será obtido um molde do canal radicular, o qual será enviado ao técnico do laboratório para execução de um modelo de gesso sobre o qual será confeccionado o padrão de resina acrílica, que será posteriormente incluído e fundido originando os NMFs.

Métodos de avaliação

Os desfechos primários a serem avaliados serão o tempo clínico entre operadores (10° semestre e especialista) em cada uma das técnicas de moldagem, bem como os defeitos dos NMFs confeccionados em cada uma das técnicas. O tempo clínico será cronometrado e anotado na ficha do paciente, sendo que nos casos de moldagem indireta serão obedecidas as recomendações do fabricante.

Os defeitos presentes na superfície dos NMFs serão avaliados por meio de fotografias padronizadas, inspeção clínica e microscopia. As fotografias serão sempre padronizadas através da utilização de uma mesma câmera (Canon-Rebel Xti, CANON INC., Japão) ajustados sempre para mesmo foco (20x) e distância (15 cm). As fotografias serão realizadas após a moldagem direta e indireta e após fundição dos NMFs. As fotografias receberão um número a fim de realizar o cegamento da avaliação do comprimento dos NMFs. Na técnica direta, as fotos serão obtidas do retentor em resina e em metal (após a fundição), ambos dispostos sobre papel milimetrado. Na técnica indireta, será realizada fotografia da moldagem disposta sobre fundo preto, onde uma régua milimetrada será colocada na cervical do retentor intrarradicular moldado. Posteriormente a fundição, outra fotografia com o NMF disposto sobre papel milimetrado será realizada. O estudo será cego.

Análise estatística

Os dados obtidos serão analisados usando um pacote de software estatístico (versão 3.5 de SigmaStat, Chicago, IL, EUA). O nível de significância a ser considerado será α=0,05.

2.1 Resultados e impactos esperados

Espera-se melhor compreender os fatores envolvidos no uso de pinos de fibra de vidro e núcleos metálicos fundidos, bem como, elucidar as melhores formas de utilização dos materiais utilizados, guiando protocolos clínicos e futuras pesquisas no mesmo campo de conhecimento.

2.2 Cronograma

Os estudos serão desenvolvidos durante o período de agosto de 2011 e agosto de 2014. O ensaio clínico randomizado será realizado até obtermos o “n” necessário, desde que haja tempo hábil para avaliação e coleta de dados e posterior análise. Após, dar-se-á a finalização dos artigos científicos os quais serão originados do presente projeto, para finalização de tese de doutorado prevista para março de 2015.

		Envio ao CEP	Levantamento Bibliográfico	Preparo das Amostras	Realização do Projeto Piloto	Execução do Projeto	Coleta de Dados	Análise Estatística	Redação e Relatórios	Defesa da Tese	Envio de Artigos para Publicação
12ºTrim	Parte 3									■	■
	Parte 4									■	■
	Parte 5						■	■	■	■	■
11ºTrim	Parte 3										
	Parte 4										
	Parte 5						■	■	■		
10ºTrim	Parte 3		■								
	Parte 4		■								
	Parte 5		■			■					
9ºTrim	Parte 3		■					■	■		
	Parte 4		■								
	Parte 5		■			■					
8ºTrim	Parte 3		■			■	■				
	Parte 4		■						■		
	Parte 5		■			■					
7ºTrim	Parte 3		■			■					
	Parte 4		■					■			
	Parte 5		■			■					
6ºTrim	Parte 3		■	■							
	Parte 4		■			■	■				
	Parte 5		■			■					
5ºTrim	Parte 3		■	■							
	Parte 4		■	■							
	Parte 5		■			■					
4ºTrim	Parte 3		■		■						
	Parte 4		■								
	Parte 5		■			■					
3ºTrim	Parte 3		■								
	Parte 4		■								
	Parte 5		■			■					
2ºTrim	Parte 3		■								
	Parte 4		■			■	■				
	Parte 5		■			■					
1ºTrim	Parte 3	■	■								
	Parte 4		■	■	■						
	Parte 5		■			■					

2.3 Considerações Éticas

A parte 2 deste projeto foi encaminhada ao Comitê de Ética em Pesquisa da FO/UFPel para utilização dos dentes humanos e aprovado sob o parecer 233/2011 (Apêndice B). A parte 4 do presente projeto foi submetida ao comitê de ética e pesquisa da Faculdade de Odontologia da UFPel e aprovado sob o parecer 122/2009 (Apêndice C).

Para a parte 3 do presente projeto, todos os pacientes elegíveis serão informados dos objetivos do estudo, riscos e benefícios associados aos procedimentos experimentais e os que aceitarem participar assinarão um termo de consentimento livre e esclarecido (Apêndice D).

3 Relatório do Trabalho de Campo

Diante do projeto de pesquisa apresentado previamente, algumas modificações foram realizadas após sugestões de professores e ideias de trabalhos, principalmente em relação ao artigo de revisão, que mediante a vasta literatura e relevância do assunto acabamos optando por escrever uma revisão narrativa ("Current concepts on the use and adhesive bonding of glass fiber posts: a review") e uma revisão sistemática direcionada ao uso do silano ("Can silanization increase the retention of glass-fiber posts? A systematic review and meta-analysis of *in vitro* studies"). Neste caso, não estava claro na literatura qual seria o real beneficio de se usar o silano na clínica odontológica e por isso surgiu a ideia de realizar esta revisão sistemática.

Para a execução do artigo *in vitro* nossa principal dificuldade foi aquisição dos materiais, que devido à demora em recebê-los demoramos mais do que o programado para executar o teste de pull-out.

Para o desenvolvimento do artigo número 4, desde meados de 2009 existe o Projeto de Extensão de Reabilitação de Dentes Tratados Endodonticamente – ProDente, que acontece às terças-feiras, durante a noite, na Faculdade de Odontologia de Pelotas, onde todos os atendimentos clínicos são realizados. Neste, alunos de graduação, pós-graduação e professores são responsáveis por todo o desenvolvimento clínico e burocrático do projeto. Ao final de cada tratamento, todos os pacientes recebem um fio dental em formato de cartão com o contato dos pesquisadores responsáveis para que estes entrem em contato sempre que julgarem necessário. Em todos os passos do projeto, pelo menos um pesquisador responsável se fez presente, desde a triagem até a última avaliação realizada. Assim, o projeto número 4 deve ser creditado a uma equipe, onde todos tem suas funções e atribuições e sem eles, nada seria possível. Importante salientar que a inclusão do número de indivíduos atendidos no projeto para este desfecho foi bastante lenta. Isto porque é realizado através de randomização (e existem múltiplos desfechos associados aos dentes) e apenas os NMFs eram inseridos no nosso trabalho para que as moldagens fossem realizadas por 2 operadores, um especialista e um aluno de graduação, uma vez que a ideia inicial era fazer uma comparação entre os dois operadores devido aos diferentes níveis de *expertise.* No entanto, optamos por trabalhar com dois operadores com o mesmo nível de expertise já que nosso trabalho in vitro nos mostrou que o nível de expertise não seria relevante para a qualidade/precisão final dos núcleos metálicos fundidos.

4 Artigo 1 – Revisão de Literatura

Current concepts on the use and adhesive bonding of glass-fiber posts in dentistry: a review

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Abstract

The aim of this study was to review and summarize the in vitro and clinical data on the use of glass-fiber posts concerning recent changes in the philosophy, materials, and technology that have impacted significantly the art and science of endodontic post placement. Original scientific papers or reviews listed in the Medline or ISI Web of Science databases from 1981 to 2013 were searched electronically using the following key words: endodontically-treated teeth, glass-fiber post, dentistry, resin cement, silane, and adhesive. The literature supports the use of a post when the remaining coronal structure is insufficient to provide retention for the restoration. Concerning which post to select, glass-fiber posts offer two important advantages: the elastic modulus is similar to that of dentin, and these posts and the respective core build-ups are cemented by an adhesive technique. However, some issues remain unclear. Randomized controlled trials are needed to confirm whether the use of silane influences the bonding and whether self-adhesive resin cements constitutes a reliable clinical option. Overall, the use of fiber posts is an important clinical option in dentistry, but clinicians should be aware of the difficulties in achieving good adhesion within the root canal.

Keywords: Adhesion; Bonding; Dentistry; Glass-fiber posts; Review

Introduction

Posts have been used to provide anchorage for dental restorations for over 250 years[104]. In the past decades, the increasing demand for aesthetics has led to the development of metal-free post-and-core systems, especially fiber-reinforced epoxy posts. To ensure a successful aesthetical outcome, the post-and-core system needs to be tooth-colored, reflecting and transmitting light similarly to a natural tooth[60, 73]. Fiber posts have been developed to improve the optical effects of aesthetic restorations[75, 25] and are widely used for restoring endodontically-treated teeth with insufficient coronal tooth structure as a core for the restoration[7, 66]. The use of posts in cases in which the tooth structure has been destroyed due to caries, trauma, or overaggressive endodontic procedures is gaining widespread acceptance among dental clinicians[3, 68].

Together with the increased use of pre-fabricated posts, especially fiber posts, an increase has also been observed in the number of publications on this subject, testing different cementation protocols, adhesive systems, and cements and discussing the indications for posts' use and the problems currently found in clinical practice. All this information should be revised and summarized to educate the dental practitioner about the current concepts and evidence for the use of fiber posts, in order to achieve the best results with the technique. Thus, the aim of this review was to discuss the current concepts for the use of glass fiber posts (GFPs) as well as the problems that may interfere with their adhesive bonding within the endodontic post space. Knowledge and control of factors affecting the posts' bond strength to root canals may ultimately improve the clinical performance of GFP-retained restorations.

Materials and Methods

Research Strategy

Original scientific papers or reviews listed in the Medline or ISI Web of Science databases from 1981 to 2012 were searched electronically using the following key words: endodontically-treated teeth, glass fiber post, dentistry, resin cement, silane, and adhesive. Papers published in all languages were selected, and the most up-to-date or relevant references were chosen. Additionally, the cross-referencing of important papers identified those of historical value, which were also selected.

Results

Although papers written in all languages were considered, all the relevant studies were written in the English language. In order to discuss each item from the clinical use perspective, the results from the literature search were divided into the following six subcategories: reasons for the use of posts in dentistry; post selection criteria: glass fiber posts; bonding systems; luting agents; post surface treatments; and critical clinical points.

Discussion

Reasons for the use of posts in dentistry

One of the main reasons for the use of posts is that they are incorrectly believed to reinforce the tooth structure. The development of epoxy posts reinforced with glass fibers derived from a need to minimize the mismatch among the elastic modulus of the post, luting agent, core material, and tooth. Fiber posts, although not actually reinforcing the tooth structure, may generate a more homogeneous stress distribution at the bonding assembly than rigid posts[100] (such as metal or zirconia posts) and thus may reduce the risk of root fractures. The potential risk is further reduced by the chemical bonding that occurs between the post and the luting cement. In addition to the favorable physical properties of GFPs, light can sometimes be transmitted through this type of post, allowing the light activation of photopolymerizable adhesive materials in the confines of the root canal[32].

The amount of remaining tooth structure after endodontic treatment or caries removal is a significant factor in determining the possibility of tooth fracture[50, 91]. Posts are used to provide retention of the core material; whether and what kind of a post is needed depends on the remaining dental structure[76]. The literature suggests that the use of fiber posts and resin composite cements might reduce the occurrence of root fractures or post debonding[19]. In general, when the remaining coronal structure is insufficient to provide retention of the restoration, the use of an intraradicular post is indicated.

Post selection criteria: glass fiber posts

In many long-term clinical studies, cast metal posts have shown good adaptability to the configuration and angulation of root canal walls as well as an ideal connection to the metal core, with no possibility of separation[104]. However, cast metal posts and cores are associated with inferior aesthetics because they do not allow light transmission. Other limitations include the risks that metal posts might corrode, causing gingival and tooth discoloration[104]; might be associated with possible biocompatibility concerns[27]; might trigger allergic reactions[99]; might offer less retention; and might lead to serious types of root fractures[109]. In addition, metal posts have low resilience and do not match the elastic modulus of the tooth structure[95]. Although carbon fiber posts were introduced as an alternative to metal posts, limitations as radiolucency, masking difficulty given all-ceramic or composite restorations, and stiffness similar to that of metal posts[6, 112] led to their replacement with white and translucent GFPs, which produce better aesthetic results[36]. Thus, GFPs have become a realistic alternative to overcome these drawbacks and are probably the most widely used and studied type of posts in dentistry[6, 73, 79].

Two different types of fiber-reinforced epoxy posts can be used as post-and-core systems: customized and prefabricated posts. Customized post-and-core build-ups commonly involve the use of glass or polyethylene fiber-reinforced posts that are luted directly into the root canal[78]. Prefabricated fiber posts consist of fibers either of carbon, quartz, silica, zirconia, or glass[53] embedded in an epoxy resin component with a silane coupling agent binding the fibers and resin together. Posts comprised of a mix between glass and carbon fibers are also available[103].

Retrospective[33, 34, 78] and prospective[9, 51] clinical studies have testified to the overall satisfactory performance of endodontically-treated teeth restored with fiber post-and-core systems. An important clinical remark is that the fracture of rigid posts can result in tooth loss, because it is nearly impossible to remove their apically-fixed part[56]. Fiber posts are easier to remove without the risk of root perforation because they can be burned out[114].

Prefabricated GFPs are made up of glass fibers embedded in a resin matrix and may also contain inorganic particles[59]. The fibers are pre-stressed, and, subsequently, the resin is injected under pressure to fill the spaces between the fibers, giving them solid cohesion. In most posts, epoxy resin or its derivatives are the main component of the organic phase. It has been suggested the epoxy resin may attach to methacrylate-based resin and composites through common free radicals[75], which would allow cementation using adhesive resin cements[32, 88]. However, it has also been suggested that the polymer matrix of the posts is virtually non-reactive, because the resin has a high degree of conversion and is highly crosslinked[13]. In this case, the adhesive cementation of GFPs relies on the bonding of the silane coupling agent to the inorganic glass fibers.

The advantages of GFPs cited in the introduction have contributed to their popularity. An additional advantage of GFPs is that they are readily retrievable after failure[23]. An in vitro study intimated that fiber posts are less likely to cause vertical root fractures than stainless steel posts[46]. Forces in the tooth restored with a fiber post are distributed to the restored complex in a manner that does not put stress on the vulnerable root structure[75]. A finite element analysis also showed that a GFP resulted in the lowest stress generation inside the root because the stiffness of the post is similar to that of dentin[74], whereas a metal post-and-core system transferred higher stresses to the root, which might cause a higher incidence of vertical root fractures. Hence, two important characteristics of GFPs are that (i) their elastic modulus is similar to that of dentin[6] and that (ii) these posts and the respective core build-ups are cemented with an adhesive technique[45]. These characteristics may improve the retention and mechanical performance of the restored teeth[59].

Nevertheless, the use of GFPs still presents several difficulties. Bonding to intraradicular dentin is challenging for clinicians due to the complexity and sensitivity of the technique[31, 39]. Because various resin cements and adhesives are used in clinical practice, it is imperative to know how they perform in relation to incompatibilities between adhesives and resin cements[107], which can lead to possible clinical failures.

Bonding systems

The need for the adhesive luting of GFP has engendered debates[39, 69]. It has been reported that the bonding of GFP to the dental structure may be related more to the friction of the post along the canal walls than to the adhesive bonding to root dentin[39]. The use of resin cements, however, has been found to significantly increase the retention of fiber posts and improve the fracture resistance of the bonded structures when compared to other cements[18, 22, 59, 84, 92]. Adhesive cementation has also been shown to better withstand functional forces[69], improve marginal adaption with better apical sealing[10], increase retention with reduced post length[71], and optimize the fracture patterns in case of failures[89]. Therefore, the adhesive cementation of GFPs is preferred over non-adhesive luting.

Adhesion between resin and dentin is considered to be a weak point in the bonded assembly. The type of adhesive system used in association with the resin cement is of great importance. Current adhesive systems can react with the dental structures by either etch-and-rinse or self-etch approaches. In the former, micromechanical interlocking with the root dentin is obtained by a conditioning step using phosphoric acid followed by the application of a bonding solution. The latter approach uses non-rinse acidic monomers that simultaneously condition, prime, and infiltrate the dentin, resulting in adhesion by shallow hybridization with residual hydroxyapatite.

The presence of a thick endodontic smear layer has prompted researchers to recommend a preliminary etching step to remove debris from the canal walls and increase post retention[40, 42, 115]. Acid application might also dissolve the residual canal sealer[96], although the possibility of over-etching the dentin is a potential shortcoming of etch-and-rinse systems[43]. Some studies have demonstrated similarities between bond strengths for self-etch and etch-and-rinse adhesives in different regions of coronal dentin[2, 47, 105, 108]. One study showed that a self-etch system may create a better bond to the cervical, middle, and apical thirds of the radicular dentin than an etch-and-rinse adhesive[8]. The difficulty in removing the smear layer may be a disadvantage of self-etch materials[40, 44].

Numerous authors have reported that GFP cementation with the resin cement associated with etch-and-rinse adhesive may generate greater bonding potential than self-etch adhesive[40, 44, 58, 80, 110]. This result may be explained by the fact that the acidic monomers responsible for substrate conditioning in self-etch adhesives are less effective in etching the dental structure than the phosphoric acid used in the etch-and-rinse approach. The etch-and-rinse strategy, however, requires a wet dentin substrate for optimal bonding[67], and controlling the humidity within the root canal is critical. Because the self-etch approach does not require moisture control after etching, these systems can potentially simplify the technique.

Irrespective of the type of bonding agent, limited access to curing light within the root canal may hinder the photopolymerization of the adhesives. Studies show higher bond strengths[15] and improved hybridization along the root canal[1] for self or dual-polymerized adhesives. One study also showed that the use of a self-activating adhesive combined with a dual-cure regular cement enabled the effective luting of GFPs, regardless of the amount of light transmitted through the post[111]. Therefore, the use of dual-cured adhesives seems preferable, although other investigations suggest that the use of self-cure activators might not enhance the bond strengths of GFP to root canals[8, 29]. In order to optimize the outcome of cementation procedures, the bonding system used by the clinician should be known thoroughly, and the clinical steps need to be strictly followed.

Luting agents

Contemporary resin cements may be classified into two main groups, according to the adhesive approach. In the first group (regular resin cements), the cement is used in association with an adhesive system, while in the second group (more recently introduced) the cement is self-adherent, i.e., no pre-treatment of the dental substrate using acid or primers is necessary, allowing simultaneous bonding between the intraradicular dentin and post. These latter materials are known as self-adhesive (or self-etching) resin cements and may simplify the adhesive luting procedures.

The bond properties of self-adhesive resin cements are based upon acidic functional methacrylate that may simultaneously demineralize and infiltrate the tooth substrates[82], with the additional potential to chemically bond to hydroxyapatite[35]. Studies have reported, however, limited etching potential for self-adhesive cements compared to etch-and-rinse and self-etch adhesives when luting GFPs[20, 37, 38, 58], with one investigation showing the similar bonding potentials of the combination regular resin cement-self-etch adhesive and of a self-adhesive resin cement[40]. Self-adhesive cements may also present lower degrees of C=C conversion[65] and poorer mechanical properties[90] than regular resin cements. The lower etching aggressiveness and suboptimal properties may account for the low early (immediate) interfacial strengths reported for GFPs luted with self-adhesive cements[86]. Nonetheless, in a 3-year randomized controlled clinical trial, a self-adhesive resin cement performed well with GFPs; this finding was confirmed in a 5-year simulated clinical function and subsequent linear loading[70].

Resin cements may also be classified according to their polymerization mode as photopolymerized, self-polymerized, or dual-polymerized materials. Photocured cements cannot be used for post cementation because they need the curing light to penetrate into the bulk of the material; conversely, self-cured (or chemically-cured) cements have no problems related to their polymerization in the apical areas because the curing process is initiated by a redox mechanism, which is triggered upon the mixing of the base and catalyst pastes. Self-cured materials, however, offer worse handling characteristics due to their relatively fast, uncontrolled polymerization.

Dual-cured resin cements are mostly used for luting GFPs. There materials theoretically combine the favorable properties of extended working time and the capability of reaching proper polymerization in either the presence or absence of light. It has been demonstrated, however, that the attenuated light penetration interferes with the cement polymerization toward the apical areas of the root canal[11, 21, 97], sometimes even when translucent fiber posts are used[85]. In general, the self-cure mechanism for dual-cured materials alone is not only slower but also less effective than the use of light-activation[28, 64, 83].

It is also known that self or dual-cured resins cements are not compatible with simplified adhesives (i.e., two-step etch-and-rinse or one-step self-etch agents). This incompatibility is due to the low pH of simplified adhesives, which may react to the basic tertiary amines used as self-cure co-initiators, interfering with proper polymerization[107]. Thus, non-simplified adhesives (three-step etch-and-rinse systems, for instance) should be used for bonding GFPs to root canals using regular resin cements.

The recent introduction of self-adhesive cements has allowed the luting of GFPs using a simpler approach, potentially reducing the technique sensitivity. In such a situation, the clinician should focus more on the preparation of the canal for the post and not rely on the cement itself. The limited etching capability of self-adhesive materials in the presence of the compact smear layer created within the endodontic space[38] may still be a matter of concern. In most clinical investigations, GFPs were cemented using etch-and-rinse adhesives in combination with regular self-cured[33, 55] or dual-cured[30, 33, 41, 63, 68] resin cements. Therefore, up to now, clinical studies showing the clinical performance of adhesively luted posts using self-adhesive cements (or even self-etch primers) are scarce, despite the number of recent laboratory investigations showing good results for self-adhesive resin cements[5, 26, 49, 101]. Self-adherent materials are gaining fast popularity and may represent a reliable clinical option as soon as more clinical trials indicate results comparable to regular resin cements.

Post surface treatments

Various pretreatment procedures, such as silanization, acid etching, sandblasting, tribochemical silica coating, and the application of bonding agents are currently being investigated for enhancing the bond strength of GFPs to the luting cement[12, 61, 81, 87]. Silanization is the technique used most often to achieve this goal. Silane coupling agents are bifunctional molecules, with one end of the molecule capable of reacting with inorganic glass fiber and the other with organic resin[57].

The action mechanism of silanes relies on the formation of bonds between its functional alkoxy groups and the OH-covered inorganic fibers. Improvement in the post surface wettability is another effect of silanization. The highly crosslinked polymer matrix of GFPs is virtually non-reactive[24, 48]; therefore, only the exposed fibers on the post surface could provide sites for chemical bonding with the silane molecules. The silane coupling agent most commonly used for dental applications is a pre-hydrolyzed monofunctional γ-methacryloxypropyltrimethoxysilane diluted in an ethanol-water solution.

The use of silanes to improve the bonding of resin luting agents to GFP is, however, a controversial topic[75]. Some studies reported that silanization does not have a significant effect on bond strengths of resin cements to GFPs[14, 75, 87], whereas others reported an increasing effect on bond strengths via silanization[4]. Silane coating of GFPs has also shown to increase the post-core bond strength and permit a more uniform adaptation of the composite core to the post[62]. A recent investigation has also demonstrated that the application of bonding solutions, especially combined with silane coupling agents, improves the bond strength of resin cement to the post surface[72]. However, randomized controlled trials are needed to confirm whether the use of silane influences the bond strength of GFPs.

Critical clinical points

Various factors may compromise the longevity of root-post-core-crown systems, such as humidity control inside the root canal[19]; anatomic variation and cavity configuration[39], which may lead to a non-homogeneous application of the etching and bonding procedures; incomplete cement polymerization in deeper root canal areas because of lack of light penetration, even with dual-cure cements[21]; chemical incompatibility between simplified adhesives and self or dual-cured cements[107]; and the design, length, and thickness of the post, cementation, and the quantity of remaining tooth substance[102].

Many combinations of different adhesive systems and resin cements can be used for post cementation. Adhesive procedures are technically sensitive, and the root canal environment is subjected to a number of variables that may directly affect bond strength[15]. Several factors have been described to affect the intraradicular bonding of resin-based materials[93, 95]. The histological characteristics of root dentin[31]; the presence of primary and secondary endodontic smear layers created either by endodontic instruments and modified by irrigants or by post-space calibrated burs[94]; negative clinical factors, i.e., minimal residual dentin structure; and adverse geometric factors[96][54] are consistent problems that affect bond strength within the endodontic space.

Up to now, most failures involving endodontically-treated teeth restored with fiber posts have occurred through debonding[3, 40, 113] due to stress concentration between the cement and post[16]. However, it is important to highlight that these failures are mostly reported in vitro and may not account for the clinical situation. Clinical trials dealing with GFPs usually report post debonding, traumatic post fracture, and core build-up failure with fracture of the core/tooth as the most common reasons for failure[68, 98]. The difficulty with some fiber posts is the crosslinked nature of the polymer matrix, which makes it harder for the composite resin to bond to the post[24, 48]. Yet, in most cases, the failure is not between cement and post, but between cement/adhesive and dentin.

The bond strength between the resin luting agent and post-space dentin is influenced by the distribution of resin cement in the coronal, middle, and apical third of the root during the luting procedure and by the anatomic and histologic characteristics of the root canal, including the orientation of dentin tubule[54, 52, 77]. This circumstance is probably due to the limited ability of light to diffuse along the entire length of the resin cement, thus compromising the polymerization of the cement in the most apical regions[85]. Additionally, it is difficult to control for moisture and adhesive application toward the apical region of the canal[17].

Moreover, the apical third of the root canal is the location where most of the smear layer, debris, and sealer/gutta-percha residues are found after post space preparation and acid etching[96]. The bond strength between resin cements and root dentin is generally reported to be very low. This low bond strength may not be capable of overcoming the shrinkage stresses generated during the polymerization of the resin luting agent, as a thin layer of curing resin with limited free surface for stress relief creates an undesirable scenario when C-factor is a concern[106].

Conclusion

Overall, it can be concluded from this review that the use of GFPs in clinical practice seems to be recommended to improve the retention of restorations and complete crowns in cases of great loss of tooth structure. However, in order to obtain the best results with GFP anchorage, clinicians should be aware of the difficulties in achieving good adhesion within the root canal. Clinicians should also pay attention to the selection of materials, and the manufacturers' recommendations should be thoroughly followed. More clinical research should be conducted to find out the influence of remaining tooth structure, i.e., the number of remaining walls, on the clinical performance of GFP-retained restorations. Also, state-of-the-art techniques, mainly concerning the use self-adhesive cements and silane for improving GFP retention to root canal, should be explored in future studies.

Disclosure

The authors declare that have no conflict of interest.

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5 Artigo 2 – Revisão Sistemática

Can silanization increase the retention of glass-fiber posts? A systematic review and meta-analysis of *in vitro* studies*

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Can silanization increase the retention of glass-fiber posts? A systematic review and meta-analysis of in vitro studies

ABSTRACT

Statement of Problem: The role of silanes on the bonding of resin luting agents to glass fiber posts is a controversial topic and the question still remains whether post silanization is able to improve the retention of GFPs luted into root canals.

Purpose: This study was designed to determine whether evidence exists to justify silanization of glass-fiber posts (GFPs) before cementation to increase their retention into root canals.

Material and Methods: In vitro studies that evaluated the retention of GFPs cemented into root canals or artificial substrates that used silane coupling agent as pre-treatment of the post were selected. Searches were carried out in PubMed and Scopus databases with no publication year or language limits. The last search was carried out in August, 2014. Two distinct data analyses were carried out: (i) control group (no post pre-treatment) vs. silane only, and (ii) post pre-treatment + silane vs. silane only. Pooled-effect estimates were obtained by comparing the difference between each bond strength mean value and were expressed as the weighted mean difference between groups ($P \leq 0.05$).

Results: A total of 178 papers were found and 23 were included in the review. The results were affected by the substrate into which the GFPs were luted (teeth or artificial devices). Post pre-treatment before silanization, particularly sandblasting, generally improved the retention of GFPs.

Conclusions: Silanization might improve the retention of GFPs luted into root canals provided that selective physical/chemical surface treatments are applied to the post before silanization.

Clinical implications: The improved retention of GFPs by combination of post pre-treatment and silanization is of particular interest having in mind that it could impact the clinical survival of GFP-retained restorations.

Key-words: fiber-reinforced post; dental restoration; cementation; meta-analysis; review

INTRODUCTION

Glass-fiber posts (GFPs) have been developed to improve the optical effects of aesthetic restorations [1, 2] and are widely used for restoring endodontically-treated teeth with insufficient coronal structure to serve as a core for the restoration.[3, 4] The use of GFPs in cases in which the coronal tooth structure has been destroyed due to caries, trauma, or overaggressive endodontic procedures is gaining widespread acceptance among dental clinician.[5, 6] Together with the increased use of pre-fabricated posts, particularly GFPs, an increase has also been observed in the number of studies on this subject available in the literature. These studies evaluate different cementation protocols, adhesive systems, and surface treatments for improving the bond between resin cements and GFPs. Yet, the main reason for failure of GFPs is still debonding, which occurs mainly due to the difficulties in achieving proper adhesion to the intraradicular dentin.[7]

Various surface pre-treatments of GFPs are tested in the literature. These pre-treatments can be divided in (i) physical/chemical means intended to create surface irregularities and expose the inorganic glass fibers, or (ii) chemical treatments applied to improve micromechanical and/or chemical attachment to the post.[8-12] Silanization is the most often chemical pre-treatment used. Organo-silane coupling agents are bifunctional molecules with one end of the molecule capable of reacting with inorganic glass fiber and the other end with the resin cement.[13] The role of silanes on the bonding of resin luting agents to GFPs is, however, a controversial topic.[2] Some studies reported that silanization does not have a significant effect on the bond strength between resin cements and GFPs,[2, 12, 14] whereas other studies reported improved bonding by silanization[15-17]. It is also a possibility that increased exposure of the glass fibers by physical/chemical pre-treatments could have a synergic effect with silanization to improve the retention of GFPs.

Despite the large number of in vitro studies in the literature, the question still remains whether post silanization is able to improve the retention of GFPs luted into root canals. This question cannot be easily answered due to the large variability in methods and results between primary studies. Therefore, the aim of this study was to systematically review the literature to determine whether there is in vitro evidence to justify the use of silanes to improve the bond strength of GFPs to intraradicular dentin. The hypothesis tested was that application of silane does not interfere with the retention of GFPs.

MATERIAL AND METHODS

Search strategy

This systematic review was based on the guidelines of Cochrane Handbook for Systematic Reviews of Interventions and followed the 4-phase flow diagram based in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement. [18] Two electronic databases (PubMed and Scopus) were searched to identify manuscripts that could meet the following inclusion criteria: in vitro studies that evaluated the retention (bond strength) of GFPs luted into root canals (human or bovine teeth) or into artificial devices that used silane coupling agents as pre-treatment of the post. The following search strategies were used: (glass fib* post*) AND (silane*); (endodontically-treated teeth) AND (silane*).

Screening and selection

No publication year or language limits were set. The last search was carried out in August, 2014. Reference lists of included studies were hand searched for additional articles. Excluded from the study were investigations reporting *in situ* studies, literature reviews, other types of posts that non GFPs, and studies that did not use silane coupling agents as post pre-treatment. Two reviewers (A.P.M. and R.S.O.) independently screened the titles identified in the searches. If the title indicated possible inclusion, the abstract was evaluated. After the abstracts were carefully appraised, the manuscripts considered eligible for the review, or the in case of doubt, were selected for full-text reading. In case of disagreement, a third reviewer (T.P.C.) decided if the paper should be included or not.

Data collection

The 2 reviewers extracted all data simultaneously using a standardized outline. To make identification of variables found in the papers easier, the authors categorized similar information into groups (e.g., post pre-treatment used, bond strength mean reported in the papers). In case of measurement of bond strength values for different root thirds (push-out test, for instance), the arithmetic average of the values of the thirds was used. For studies that did not report bond strength means in tables, the authors were contacted via e-mail if data were missing or when more information was needed.

Statistical analysis

Two distinct data analyses were carried out: (i) control group (untreated posts) vs. silane only, and (ii) post pre-treatment + silane vs. silane only. Every possible comparison of bond strength between groups within the articles was simulated. Pooled-effect estimates were obtained by comparing the difference between each bond strength mean value and were expressed as the weighted mean difference between groups. A P-value < 0.05 was considered statistically significant (*Z* Test).

Statistical heterogeneity of the treatment effect among studies was assessed using the Cochran's Q test, with a threshold p-value of 0.1, and the inconsistency I^2 test, in which values greater than 50% were considered indicative of high heterogeneity.[19] The analyses were carried out using random-effects model. Taking into account that the analyses of substrate used in the test could present high heterogeneity, subgroup analyses considering artificial devices or teeth as distinct substrates were carried out to explore that influence on the results. All analyses were conducted using Review Manager Software version 5.1 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration).

Assessment of risk of bias

Risk of bias of each included study was evaluated according to the description in the papers of the following parameters for the study quality assessment[20]: randomization of teeth, use of teeth free of caries or restoration, materials used according to the manufacturer's instructions, use of teeth with similar dimensions, endodontic treatment performed by the same operator, description of sample size calculation, and blinding of the operator of the testing machine. If the authors reported the parameter, the paper had a Y (yes) on that specific parameter; if it was not possible to find the information, the paper received an N (no). Papers that reported 1 to 3 items were classified as having high risk of bias, 4 or 5 items as having medium risk of bias, and 6 or 7 items as having low risk of bias. Only papers that used teeth as substrate for luting the GFPs had the risk of bias classified; the other studies had other parameters evaluated except those related to the teeth.

RESULTS

Figure 1 shows the flow diagram of the systematic review. A total of 178 papers were found and 26 were eligible for full-text analysis. The hand searches revealed 6 more papers for full-text reading. From the 32 studies, 23 papers were included in the review [2, 6, 9, 16, 21-39]. Nine studies were excluded for the following reasons: 2 did not test the bond strength, [40],[41] 2 were literature reviews, [42, 43] 1 study did not test the use of silane, [44], 3 studies used quartz-fiber posts,[45-47] and 1 did not present the group silane[48]. In the included studies, the main outcomes evaluated were type of pre-treatment, substrate used for luting the GFPs, bond strength test, and resin cement (Tables 1, 2, and 3).

Results of the meta-analyses are presented in Figures 2 and 3. The analysis between control group (untreated posts) and silane only for studies that used artificial devices (Figure 2) favored the use of silane ($P < 0.0001$), with $I^2 = 94\%$. Considering studies that used teeth as substrate, no significant difference was observed between groups ($P = 0.35$ $I^2 = 87\%$). The analysis between silane only vs. pre-treatment + silane (Figure 3) did not show significant difference between groups when artificial devices were used ($P = 0.71$, $I^2 = 81\%$), whereas the analysis favored the use of post pre-treatment + silane ($P < 0.00001$, $I^2 = 94\%$) over silane only when the GFPs were luted into teeth. The papers by Bitter *et al.* [21, 22] were not included in the analyses because the data necessary for analysis was not obtained even after an attempt of e-mail contact with the authors.

Table 3 shows that a wide variety of resin cements were used in the selected studies, with varied results reported. One study [27] reported that post silanization improved the adhesion of GFPs luted with self-adhesive resin cements, and 12 studies showed a positive effect of silane on the bond strength of posts luted with regular resin cements.[6, 22, 23, 26, 28-32, 34-36] Yet, other studies showed no significant improvement in the retention of GFPs by silanization using self-adhesive[24], regular resin cements[2, 9, 21] or both.[39] It was not possible to observe any interaction between resin cements, post silanization or other post treatments.

Risk of bias

The 9 papers that used teeth as substrate had the risk of bias classified as high.[2, 27, 30, 31, 33-35, 37,39] From the studies that used artificial devices as substrate, 11 papers[6, 9, 21-24, 26, 28, 32, 36, 38] reported that the materials were used according to manufacturers' instructions and none reported sample size calculation or if blinding of the operator of the testing machine was used (Table 4).

DISCUSSION

This systematic review is the first to summarize the in vitro data on the influence of silanization on the retention of GFPs into root canals. Several materials, surface treatments, and cementation strategies have been tested in the literature in an endeavor to increase the retention of GFPs into root canals. Analysis of all available data together could clarify the role of silane on the performance of luted GFPs, and give support for the clinician on evidence-based decision making.

Several surface pre-treatments for posts have been tested to improve the bonding between GFPs and resin cements.[10-12, 26, 41, 49-51] Pre-treatment procedures aim to generally improve the adhesion to GFPs by facilitating chemical and/or mechanical interaction between the different substrates at the bonded interface. Results of the present study indicate that silanization improves the retention of GFPs only when appropriate surface pre-treatment of the post is performed before application of silane.

This finding is explained by the fact that the glass fibers in untreated posts are covered by the highly crosslinked, low-reactive epoxy resin. Application of surface pre-treatments might expose the glass fibers, allowing more effective formation of siloxane bonds between silane and glass. The rough surface left by the surface pre-treatments may also aid in improving micromechanical retention at the post-resin cement interface.[46, 52]

Previous studies have clearly indicated the positive effect that silanization might have on the bond strength between GFPs and methacrylate-based materials.[16, 17] However, the question still unanswered was whether post silanization would have a role in improving its retention into root canals. In this study, investigations that did not lute the GFPs into dental root canals or artificial root canals were excluded, since the retention analysis was the main focus here. It was noted that silanization alone is not sufficient to improve the retention of GFPs luted into root canals, whereas the combination surface pre-treatment + silanization was able to that improve the retention into root canals.

Post debonding is the main reason for clinical failure of GFP-retained restorations.[7] This clinical failure type might result poor interaction between resin cement and intra-radicular dentin and/or poor interaction of resin cement and post. Findings of the present study indicate that when the posts were luted into natural root canals, the combination post pre-treatment + silanization significantly improved the post retention. This result is explained by a better interaction between resin cement and post surface leading to the mechanical stresses during testing to concentrate at the interface between resin cement and root dentin only. In such a scenario, the better mechanical keying at the post-cement interface does not contribute significantly with stress concentration and/or magnification during the test, leading to higher bond strength values.

In contrast to the findings from studies using extracted teeth, no significant improvement in the retention of GFPs was observed for the combination post pre-treatment + silane when the posts were luted into artificial devices. When artificial devices are used, there is no dentin-resin cement interface, in other words the resin cements used to lute the posts do not interact with dental hard tissues but rather with synthetic materials such as methacrylate-based composites. In such a scenario, the interaction of the cement with the artificial devices is expected to be improved as compared with dentin, which is acknowledged as the weakest link in adhesive bonding. In addition, the use of artificial devices usually does not have the same limitations imposed extracted teeth, such as great variability in root canal diameter and resin cement film thickness between specimens. Therefore, it is suggested that the use of artificial devices to lute GFPs should be restricted to situations where the post-cement interface is the main focus of the investigation.

Among the surface pre-treatments tested in the included studies, sandblasting stands out as the pre-treatment most often used. A total of 80% of comparisons carried out here on the effect of surface pre-treatments on the retention of GFPs into artificial devices, and ~62% of the comparisons on the retention of GFPs into root canals, used sandblasting as pre-treatment. As an overall result, the present findings indicate a positive effect of surface pre-treatments before silanization; however, this result should be mainly concentrated at the combination sandblasting + silanization on the retention of GFPs because most studies only tested that specific combination. That notwithstanding, surface pre-treatments that only selectively expose the glass fiber by chemical means could be considered the ideal situation to enhance the silanization effect. Sandblasting is known not to be selective in exposing the glass and may cause structure damage of the post, although there is no evidence whether this could affect the mechanical stability of post-and-core restored teeth.

Different mechanical tests to measure the bond strength and a wide variety of adhesives and resin cements are reported in the in vitro literature, defining a tough scenario for one seeking for comparisons between results of different studies. Authors sometimes do not follow the manufacturer's directions on the application of materials, stressing the problem of comparing studies in the literature. Systematic reviews have the advantage of analyzing the literature data together, but also suffer from the limitation that the methods employed in distinct studies differ to extents that often are difficult to predict. With that in mind, we have used a tool to assess the risk of bias of each study.

The results indicate that all selected studies present a high risk of bias, demonstrating that variables that could influence the results of the studies were not controlled by researchers, favoring the high heterogeneity of the findings in the present study. Therefore, results of the present review should be interpreted with caution considering that laboratory studies have intrinsic limitations when trying to simulate in vivo conditions. However, the improved retention of GFPs by combination of post pre-treatment and silanization is of particular interest having in mind that it could impact the clinical survival of GFP-retained restorations. Additionally, clinicians should be aware of the beneficial effects that post silanization might have on the clinical performance of restoration, particularly because post silanization is a procedure that might be overlooked in the clinical practice if regarded as of minor significance. Irrespective of the results here presented, well-designed randomized controlled clinical trials (RCTs) with long follow-up periods would provide the ultimate answer as to whether silane coupling agent could result in improved clinical success rates of GFP-retained restorations. However, it is known that RCTs cannot be used indiscriminately to support all clinical decisions. Therefore, the overall results of the present study favor the combination between post surface pre-treatment and silanization on the retention of GFPs.

CONCLUSIONS

Analysis of the in vitro literature indicates that silanization might improve the retention of glass-fiber posts luted into root canals provided that selective surface pre-treatments are applied to the post before silanization.

CONFLICTS OF INTEREST

None

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Figure 1

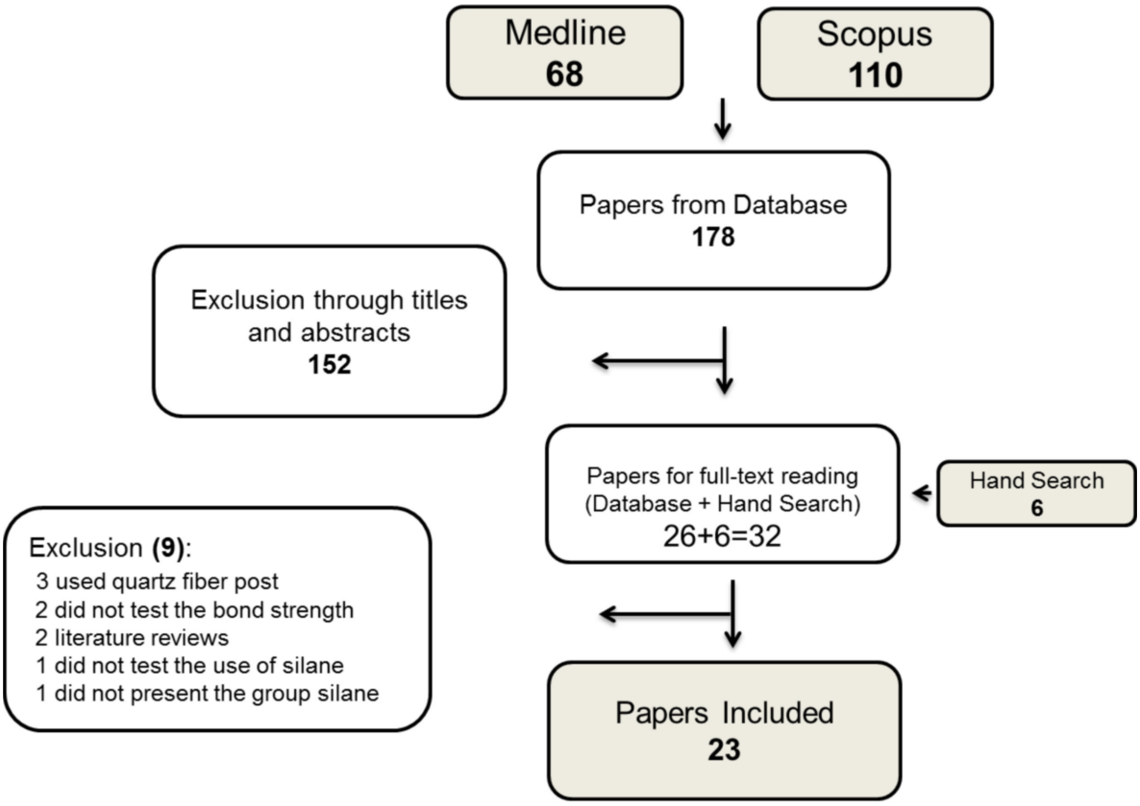
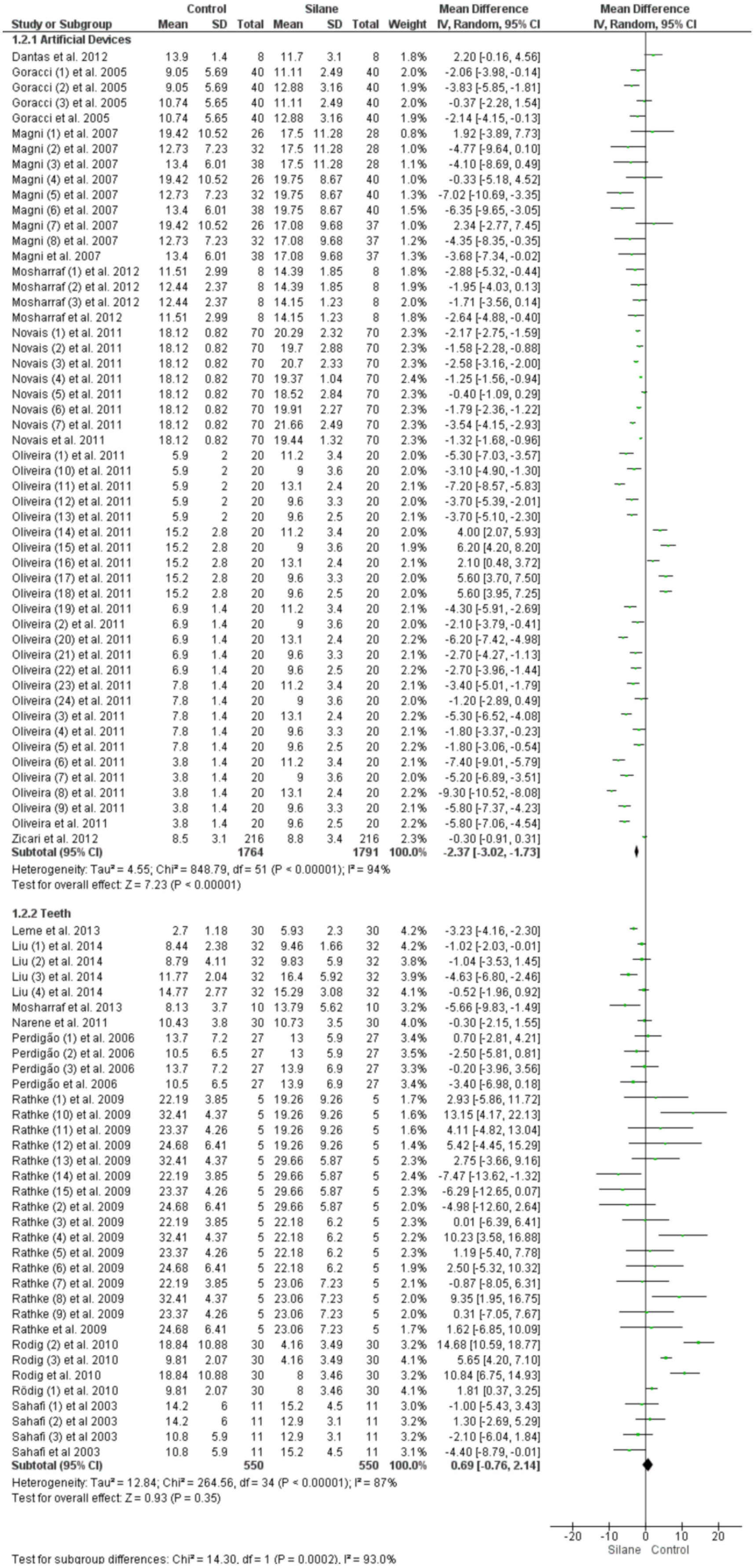

Medline
68
Scopus
110
Papers from Database
178
Exclusion through titles and abstracts
152
Papers for full-text reading (Database + Hand Search)
26+6=32
Hand Search
6
Exclusion (9):
3 used quartz fiber post
2 did not test the bond strength
2 literature reviews
1 did not test the use of silane
1 did not present the group silane
Papers Included
23

Figure 2



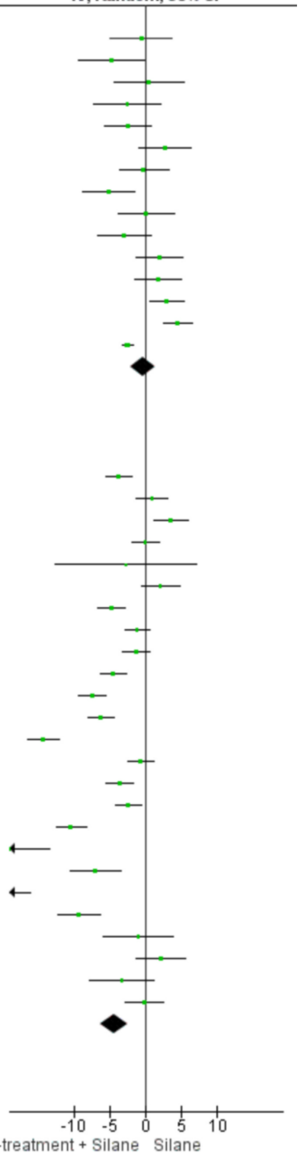
Study or Subgroup	Control Mean	Control SD	Control Total	Silane Mean	Silane SD	Silane Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Artificial Devices								
Dantas et al. 2012	13.9	1.4	8	11.7	3.1	8	1.8%	2.20 [-0.16, 4.56]
Goracci (1) et al. 2005	9.05	5.69	40	11.11	2.49	40	2.0%	-2.06 [-3.98, -0.14]
Goracci (2) et al. 2005	9.05	5.69	40	12.88	3.16	40	1.9%	-3.83 [-5.85, -1.81]
Goracci (3) et al. 2005	10.74	5.65	40	11.11	2.49	40	2.0%	-0.37 [-2.28, 1.54]
Goracci et al. 2005	10.74	5.65	40	12.88	3.16	40	1.9%	-2.14 [-4.15, -0.13]
Magni (1) et al. 2007	19.42	10.52	26	17.5	11.28	28	0.8%	1.92 [-3.89, 7.73]
Magni (2) et al. 2007	12.73	7.23	32	17.5	11.28	28	1.0%	-4.77 [-9.64, 0.10]
Magni (3) et al. 2007	13.4	6.01	38	17.5	11.28	28	1.1%	-4.10 [-8.69, 0.49]
Magni (4) et al. 2007	19.42	10.52	26	19.75	8.67	40	1.0%	-0.33 [-5.18, 4.52]
Magni (5) et al. 2007	12.73	7.23	32	19.75	8.67	40	1.3%	-7.02 [-10.69, -3.35]
Magni (6) et al. 2007	13.4	6.01	38	19.75	8.67	40	1.5%	-6.35 [-9.65, -3.05]
Magni (7) et al. 2007	19.42	10.52	26	17.08	9.68	37	1.0%	2.34 [-2.77, 7.45]
Magni (8) et al. 2007	12.73	7.23	32	17.08	9.68	37	1.2%	-4.35 [-8.35, -0.35]
Magni et al. 2007	13.4	6.01	38	17.08	9.68	37	1.3%	-3.68 [-7.34, -0.02]
Mosharraf (1) et al. 2012	11.51	2.99	8	14.39	1.85	8	1.8%	-2.88 [-5.32, -0.44]
Mosharraf (2) et al. 2012	12.44	2.37	8	14.39	1.85	8	1.9%	-1.95 [-4.03, 0.13]
Mosharraf (3) et al. 2012	12.44	2.37	8	14.15	1.23	8	2.0%	-1.71 [-3.56, 0.14]
Mosharraf et al. 2012	11.51	2.99	8	14.15	1.23	8	1.8%	-2.64 [-4.88, -0.40]
Novais (1) et al. 2011	18.12	0.82	70	20.29	2.32	70	2.3%	-2.17 [-2.75, -1.59]
Novais (2) et al. 2011	18.12	0.82	70	19.7	2.88	70	2.3%	-1.58 [-2.28, -0.88]
Novais (3) et al. 2011	18.12	0.82	70	20.7	2.33	70	2.3%	-2.58 [-3.16, -2.00]
Novais (4) et al. 2011	18.12	0.82	70	19.37	1.04	70	2.4%	-1.25 [-1.56, -0.94]
Novais (5) et al. 2011	18.12	0.82	70	18.52	2.84	70	2.3%	-0.40 [-1.09, 0.29]
Novais (6) et al. 2011	18.12	0.82	70	19.91	2.27	70	2.3%	-1.79 [-2.36, -1.22]
Novais (7) et al. 2011	18.12	0.82	70	21.66	2.49	70	2.3%	-3.54 [-4.15, -2.93]
Novais et al. 2011	18.12	0.82	70	19.44	1.32	70	2.3%	-1.32 [-1.68, -0.96]
Oliveira (1) et al. 2011	5.9	2	20	11.2	3.4	20	2.0%	-5.30 [-7.03, -3.57]
Oliveira (10) et al. 2011	5.9	2	20	9	3.6	20	2.0%	-3.10 [-4.90, -1.30]
Oliveira (11) et al. 2011	5.9	2	20	13.1	2.4	20	2.1%	-7.20 [-8.57, -5.83]
Oliveira (12) et al. 2011	5.9	2	20	9.6	3.3	20	2.0%	-3.70 [-5.39, -2.01]
Oliveira (13) et al. 2011	5.9	2	20	9.6	2.5	20	2.1%	-3.70 [-5.10, -2.30]
Oliveira (14) et al. 2011	15.2	2.8	20	11.2	3.4	20	2.0%	4.00 [2.07, 5.93]
Oliveira (15) et al. 2011	15.2	2.8	20	9	3.6	20	1.9%	6.20 [4.20, 8.20]
Oliveira (16) et al. 2011	15.2	2.8	20	13.1	2.4	20	2.1%	2.10 [0.48, 3.72]
Oliveira (17) et al. 2011	15.2	2.8	20	9.6	3.3	20	2.0%	5.60 [3.70, 7.50]
Oliveira (18) et al. 2011	15.2	2.8	20	9.6	2.5	20	2.0%	5.60 [3.95, 7.25]
Oliveira (19) et al. 2011	6.9	1.4	20	11.2	3.4	20	2.1%	-4.30 [-5.91, -2.69]
Oliveira (2) et al. 2011	6.9	1.4	20	9	3.6	20	2.0%	-2.10 [-3.79, -0.41]
Oliveira (20) et al. 2011	6.9	1.4	20	13.1	2.4	20	2.2%	-6.20 [-7.42, -4.98]
Oliveira (21) et al. 2011	6.9	1.4	20	9.6	3.3	20	2.1%	-2.70 [-4.27, -1.13]
Oliveira (22) et al. 2011	6.9	1.4	20	9.6	2.5	20	2.2%	-2.70 [-3.96, -1.44]
Oliveira (23) et al. 2011	7.8	1.4	20	11.2	3.4	20	2.1%	-3.40 [-5.01, -1.79]
Oliveira (24) et al. 2011	7.8	1.4	20	9	3.6	20	2.0%	-1.20 [-2.89, 0.49]
Oliveira (3) et al. 2011	7.8	1.4	20	13.1	2.4	20	2.2%	-5.30 [-6.52, -4.08]
Oliveira (4) et al. 2011	7.8	1.4	20	9.6	3.3	20	2.1%	-1.80 [-3.37, -0.23]
Oliveira (5) et al. 2011	7.8	1.4	20	9.6	2.5	20	2.2%	-1.80 [-3.06, -0.54]
Oliveira (6) et al. 2011	3.8	1.4	20	11.2	3.4	20	2.1%	-7.40 [-9.01, -5.79]
Oliveira (7) et al. 2011	3.8	1.4	20	9	3.6	20	2.0%	-5.20 [-6.89, -3.51]
Oliveira (8) et al. 2011	3.8	1.4	20	13.1	2.4	20	2.2%	-9.30 [-10.52, -8.08]
Oliveira (9) et al. 2011	3.8	1.4	20	9.6	3.3	20	2.1%	-5.80 [-7.37, -4.23]
Oliveira et al. 2011	3.8	1.4	20	9.6	2.5	20	2.2%	-5.80 [-7.06, -4.54]
Zicari et al. 2012	8.5	3.1	216	8.8	3.4	216	2.3%	-0.30 [-0.91, 0.31]
Subtotal (95% CI)			**1764**			**1791**	**100.0%**	**-2.37 [-3.02, -1.73]**
Heterogeneity: Tau² = 4.55; Chi² = 848.79, df = 51 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 7.23 (P < 0.00001)								
1.2.2 Teeth								
Leme et al. 2013	2.7	1.18	30	5.93	2.3	30	4.2%	-3.23 [-4.16, -2.30]
Liu (1) et al. 2014	8.44	2.38	32	9.46	1.66	32	4.2%	-1.02 [-2.03, -0.01]
Liu (2) et al. 2014	8.79	4.11	32	9.83	5.9	32	3.8%	-1.04 [-3.53, 1.45]
Liu (3) et al. 2014	11.77	2.04	32	16.4	5.92	32	3.9%	-4.63 [-6.80, -2.46]
Liu (4) et al. 2014	14.77	2.77	32	15.29	3.08	32	4.1%	-0.52 [-1.96, 0.92]
Mosharraf et al. 2013	8.13	3.7	10	13.79	5.62	10	3.2%	-5.66 [-9.83, -1.49]
Narene et al. 2011	10.43	3.8	30	10.73	3.5	30	4.0%	-0.30 [-2.15, 1.55]
Perdigão (1) et al. 2006	13.7	7.2	27	13	5.9	27	3.4%	0.70 [-2.81, 4.21]
Perdigão (2) et al. 2006	10.5	6.5	27	13	5.9	27	3.5%	-2.50 [-5.81, 0.81]
Perdigão (3) et al. 2006	13.7	7.2	27	13.9	6.9	27	3.3%	-0.20 [-3.96, 3.56]
Perdigão et al. 2006	10.5	6.5	27	13.9	6.9	27	3.4%	-3.40 [-6.98, 0.18]
Rathke (1) et al. 2009	22.19	3.85	5	19.26	9.26	5	1.7%	2.93 [-5.86, 11.72]
Rathke (10) et al. 2009	32.41	4.37	5	19.26	9.26	5	1.6%	13.15 [4.17, 22.13]
Rathke (11) et al. 2009	23.37	4.26	5	19.26	9.26	5	1.6%	4.11 [-4.82, 13.04]
Rathke (12) et al. 2009	24.68	6.41	5	19.26	9.26	5	1.4%	5.42 [-4.45, 15.29]
Rathke (13) et al. 2009	32.41	4.37	5	29.66	5.87	5	2.3%	2.75 [-3.66, 9.16]
Rathke (14) et al. 2009	22.19	3.85	5	29.66	5.87	5	2.4%	-7.47 [-13.62, -1.32]
Rathke (15) et al. 2009	23.37	4.26	5	29.66	5.87	5	2.3%	-6.29 [-12.65, 0.07]
Rathke (2) et al. 2009	24.68	6.41	5	29.66	5.87	5	2.0%	-4.98 [-12.60, 2.64]
Rathke (3) et al. 2009	22.19	3.85	5	22.18	6.2	5	2.3%	0.01 [-6.39, 6.41]
Rathke (4) et al. 2009	32.41	4.37	5	22.18	6.2	5	2.2%	10.23 [3.58, 16.88]
Rathke (5) et al. 2009	23.37	4.26	5	22.18	6.2	5	2.3%	1.19 [-5.40, 7.78]
Rathke (6) et al. 2009	24.68	6.41	5	22.18	6.2	5	1.9%	2.50 [-5.32, 10.32]
Rathke (7) et al. 2009	22.19	3.85	5	23.06	7.23	5	2.1%	-0.87 [-8.05, 6.31]
Rathke (8) et al. 2009	32.41	4.37	5	23.06	7.23	5	2.0%	9.35 [1.95, 16.75]
Rathke (9) et al. 2009	23.37	4.26	5	23.06	7.23	5	2.0%	0.31 [-7.05, 7.67]
Rathke et al. 2009	24.68	6.41	5	23.06	7.23	5	1.7%	1.62 [-6.85, 10.09]
Rodig (2) et al. 2010	18.84	10.88	30	4.16	3.49	30	3.2%	14.68 [10.59, 18.77]
Rodig (3) et al. 2010	9.81	2.07	30	4.16	3.49	30	4.1%	5.65 [4.20, 7.10]
Rodig et al. 2010	18.84	10.88	30	8	3.46	30	3.2%	10.84 [6.75, 14.93]
Rödig (1) et al. 2010	9.81	2.07	30	8	3.46	30	4.1%	1.81 [0.37, 3.25]
Sahafi (1) et al 2003	14.2	6	11	15.2	4.5	11	3.0%	-1.00 [-5.43, 3.43]
Sahafi (2) et al 2003	14.2	6	11	12.9	3.1	11	3.2%	1.30 [-2.69, 5.29]
Sahafi (3) et al 2003	10.8	5.9	11	12.9	3.1	11	3.2%	-2.10 [-6.04, 1.84]
Sahafi et al 2003	10.8	5.9	11	15.2	4.5	11	3.1%	-4.40 [-8.79, -0.01]
Subtotal (95% CI)			**550**			**550**	**100.0%**	**0.69 [-0.76, 2.14]**
Heterogeneity: Tau² = 12.84; Chi² = 264.56, df = 34 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 0.93 (P = 0.35)								

Test for subgroup differences: Chi² = 14.30, df = 1 (P = 0.0002), I² = 93.0%

Figure 3

Study or Subgroup	Silane Mean	Silane SD	Silane Total	Pre-treatment + Silane Mean	Pre-treatment + Silane SD	Pre-treatment + Silane Total	Weight	Mean Difference IV, Random, 95% CI
1.3.1 Artificial Devices								
Dantas et al. 2012	11.7	3.1	8	12.3	5.4	8	5.8%	-0.60 [-4.91, 3.71]
Magni (1) et al. 2007	17.5	11.28	28	22.23	5.63	35	5.5%	-4.73 [-9.31, -0.15]
Magni (2) et al. 2007	17.5	11.28	28	17.03	8.36	45	5.3%	0.47 [-4.37, 5.31]
Magni (3) et al. 2007	17.5	11.28	28	20.03	7.14	42	5.4%	-2.53 [-7.23, 2.17]
Magni (4) et al. 2007	19.75	8.67	40	22.23	5.63	35	6.9%	-2.48 [-5.75, 0.79]
Magni (5) et al. 2007	19.75	8.67	40	17.03	8.36	45	6.5%	2.72 [-0.91, 6.35]
Magni (6) et al. 2007	19.75	8.67	40	20.03	7.14	42	6.7%	-0.28 [-3.73, 3.17]
Magni (7) et al. 2007	17.08	9.68	37	22.23	5.63	35	6.5%	-5.15 [-8.78, -1.52]
Magni (8) et al. 2007	17.08	9.68	37	17.03	8.36	45	6.2%	0.05 [-3.91, 4.01]
Magni et al. 2007	17.08	9.68	37	20.03	7.14	42	6.3%	-2.95 [-6.74, 0.84]
Radovic et al. 2007	21.67	7.13	32	19.76	6.16	32	6.9%	1.91 [-1.35, 5.17]
Soares (1) et al. 2008	27.8	3.2	10	26.1	4.3	10	6.8%	1.70 [-1.62, 5.02]
Soares (2) et al. 2008	27.8	3.2	10	24.9	2.1	10	7.9%	2.90 [0.53, 5.27]
Soares et al. 2008	27.8	3.2	10	23.3	0.9	10	8.2%	4.50 [2.44, 6.56]
Zicari et al. 2012	8.8	3.4	216	11.3	3.9	216	9.2%	-2.50 [-3.19, -1.81]
Subtotal (95% CI)			**601**			**652**	**100.0%**	**-0.32 [-2.01, 1.36]**
Heterogeneity: Tau² = 7.99; Chi² = 75.01, df = 14 (P < 0.00001); I² = 81%								
Test for overall effect: Z = 0.38 (P = 0.71)								
1.3.2 Teeth								
Liu (1) et al. 2014	9.46	1.66	32	13.23	5.09	32	4.3%	-3.77 [-5.62, -1.92]
Liu (2) et al. 2014	9.83	5.9	32	8.95	2.39	32	4.2%	0.88 [-1.33, 3.09]
Liu (3) et al. 2014	16.4	5.92	32	12.93	3.65	32	4.2%	3.47 [1.06, 5.88]
Liu (4) et al. 2014	15.29	3.08	32	15.33	4.77	32	4.3%	-0.04 [-2.01, 1.93]
Mosharraf (1) et al. 2013	13.79	15.65	10	16.57	5.27	30	2.0%	-2.78 [-12.66, 7.10]
Mosharraf et al. 2013	13.79	5.62	30	11.72	5.07	30	4.1%	2.07 [-0.64, 4.78]
Narene (1) et al. 2011	10.73	3.5	30	15.5	4.2	30	4.3%	-4.77 [-6.73, -2.81]
Narene (2) et al. 2011	10.73	3.5	30	11.9	3.5	30	4.3%	-1.17 [-2.94, 0.60]
Narene et al. 2011	10.73	3.5	30	12.04	3.9	30	4.3%	-1.31 [-3.19, 0.57]
Rodig (1) et al. 2010	4.16	3.49	30	8.69	3.65	30	4.3%	-4.53 [-6.34, -2.72]
Rodig (2) et al. 2010	4.16	3.49	30	11.62	4.08	30	4.3%	-7.46 [-9.38, -5.54]
Rodig (3) et al. 2010	4.16	3.49	30	10.39	3.85	30	4.3%	-6.23 [-8.09, -4.37]
Rodig et al. 2010	4.16	3.49	30	18.43	4.75	30	4.3%	-14.27 [-16.38, -12.16]
Rödig (4) et al. 2010	8	3.46	30	8.69	3.65	30	4.3%	-0.69 [-2.49, 1.11]
Rödig (5) et al. 2010	8	3.46	30	11.62	4.08	30	4.3%	-3.62 [-5.53, -1.71]
Rödig (6) et al. 2010	8	3.46	30	10.39	3.85	30	4.3%	-2.39 [-4.24, -0.54]
Rödig (7) et al. 2010	8	3.46	30	18.43	4.75	30	4.3%	-10.43 [-12.53, -8.33]
Sahafi (1) et al 2003	15.2	4.5	11	34.3	8.5	11	3.2%	-19.10 [-24.78, -13.42]
Sahafi (2) et al 2003	15.2	4.5	11	22.2	3.8	11	3.9%	-7.00 [-10.48, -3.52]
Sahafi (3) et al 2003	12.9	3.1	11	34.3	8.5	11	3.3%	-21.40 [-26.75, -16.05]
Sahafi (4) et al 2003	12.9	3.1	11	22.2	3.8	11	4.1%	-9.30 [-12.20, -6.40]
Sahafi (5) et al. 2003	15.2	4.5	11	16.2	7	11	3.4%	-1.00 [-5.92, 3.92]
Sahafi (6) et al. 2003	15.2	4.5	11	13.1	3.5	11	3.9%	2.10 [-1.27, 5.47]
Sahafi (7) et al. 2003	12.9	3.1	11	16.2	7	11	3.6%	-3.30 [-7.82, 1.22]
Sahafi et al 2003	12.9	3.1	11	13.1	3.5	11	4.1%	-0.20 [-2.96, 2.56]
Subtotal (95% CI)			**586**			**606**	**100.0%**	**-4.44 [-6.32, -2.55]**
Heterogeneity: Tau² = 20.45; Chi² = 374.41, df = 24 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 4.62 (P < 0.00001)								

Mean Difference IV, Random, 95% CI



Test for subgroup differences: Chi² = 10.16, df = 1 (P = 0.001), I² = 90.2%

Table1: Characteristics of studies that used artificial devices as substrate

Author/Year	Substrate	Comparison	Bond Strength Test	Conclusion
Aksornmuang *et al.* 2004	Resin blocks	Control*, dual-cure bonding agent, dual-cure bonding agent followed by light curing for 20 s, silane coupling bonding agent, silane coupling bonding agent followed by light curing for 20 s.	Microtensile	Application of a silane coupling agent improved the bond strength of dual-cure resin core material to glass fibre posts
Bitter *et al.* 2007	Composite disk and plastic mold	4 different silane solutions	Push-out	The effects of silanization appeared to be clinically negligible.
Bitter *et al.* 2008	Plastic mold	Silane and control*	Push-out	The silanization had negligible effects.
Cekic-Nagas *et al.* 2011	Cylindrical plastic tube	Sandblasting was followed by the application of a silane; immersion in 9.6% hydrofluoric acid gel; silanization and control*	Micropush-out	Different surface treatments of fibre posts might affect the bonding capacity of resin-core systems to these posts.
Dantas *et al.* 2011	Metal matrix	Silane, hydrofluoric acid, hydrofluoric acid plus silane, plasma polymerization with argon, ethylenediamine plasma (EDA), control*	Push-out	Adhesion improvement was only observed after EDA treatment.
Debnath *et al.* 2003	Fixed bottom grip	2 different silanes using various concentrations (1, 5 and 10%)	Pull-out	5% samples had the highest strength.
Goracci *et al.* 2005	Plastic matrix	Silane and control*	Microtensile	The application of a silane onto the post surface prior to building up the core significantly increased the post–core bond strength.
Magni *et al.* 2007	Plastic matrix	Sandblasting, sandblasting + silanization, silanization, control*	Microtensile	Silanization was confirmed to be a reliabe method for improving the bond strength of resin luting agents to fiber posts.
Monticelli *et al.* 2006	Plastic matrix	Etching with potassium permanganate, treatment with 10% H2O2, treatment with 21% sodium ethoxide, etching with potassium permanganate and 10 vol.% HCl and silanization	Microtensile	Surface chemical treatments of the resin phase of fiber posts enhance the silanization efficiency of the quartz fiber phase, so that the adhesion in the post/core unit may be considered a net sum of chemical and micromechanical retention.
Mosharraf *et al.* 2012	Cylindrical plexiglass matrix	Silanization, sandblasting, treatment with 24% H2O2, and control*	Tensile	Although silanization and sandblasting can improve the TBS, there was not any significant difference between surface treatments used.
Novais *et al.* 2011	Plastic matrix	Three prehydrolyzed silanes and one 2-component silane followed by air drying temperatures, 23°C and 60°	Push-out	The use of warm air drying after silane application produced no increase in the bond strength between the fiber-reinforced composite post and the composite core. The two component silane produced higher bond strength than all prehydrolyzed silanes when it was used with air drying at room temperature.

Oliveira *et al.* 2011	Elastomer mould	Silane and control*	Shear	Silanization of glass fibre posts is not necessary when self-adhesive resin cements are used.
Radovic *et al.* 2007	Plastic matrix	Sandblasting or no pretreatment in each of the 2 groups posts received 3 types of additional ‘‘chair-side’’ treatments :Silane; adhesive; control*	Microtensile	Sandblasting may give an increase in microtensile strength to methacrylate-based glass fiber posts, eliminating the need to apply additional ‘‘chair-side’’ treatments.
Soares *et al.* 2008	Metal stubs	Silane, silane and adhesive, airborne-particle abrasion with 50-µm Al2O3 and silane, airborne-particle abrasion, silane, and adhesive	Microtensile	Treatment with silane only was sufficient as a surface treatment for adhesive bonding.
Wrbas *et al.* 2007	Artificial root canals	Silane and control*	Tensile	Silanization of fiber post surfaces seems to have no clinical relevance
Zicari *et al.* 2012	Artificial root canals	Control*; silane, or coated with silicated alumina particles	Push-out	Laboratory testing revealed that different variables like the type of post, the composite cement and the post-surface pre-treatment may influence the cement–post interface.

Table 2.

Table2: Characteristics of studies that used teeth as substrate

Author/Year	Substrate	Comparison	Bond Strength Test	Conclusion
Leme *et al.* 2013	Human roots	Control*; silane; silane and Solobond; silane and Scotchbond Adhesive; silane and Excite	Push-out	Silane application may be necessary to improve the adhesion of fiber posts
Liu *et al*. 2014	Human maxillary central incisors and canines	Control*, sandblasting, silanization, sandblasting followed by silanization	Push-out	Silanization of the post surface has no significant effect on the interfacial bond strength between the post and the resin cement
Mosharraf *et al.* 2013	Human maxillary incisors	Control*;Silanization after etching with 20% H2O2; silanization after airborne-particle abrasion; silanization	Tensile	Application of hydrogen peroxide before silanization increased the bond strength between resin cements and fiber posts.
Narene *et al.* 2011	Human root dentin	Silane, Cojet and Silane, 10% sodium ethoxide and silane and and 10% H2O2	Push-out	Cojet/Silane showed the highest bond strength
Perdigão *et al.* 2006	Human maxillary central incisors and canines	Silane and control*	Push-out	The use of a silane coupling agent did not increase the push-out bond strengths of the fiber posts used in this study.
Rathke *et al.* 2009	Human teeth	Silane and control*	Push-out	Silanization seems to be less relevant for intra-root canal bonding, but may have beneficial effects on post-to-core strengths.
Rödig *et al.* 2010	Human teeth	Control*, silanization, sandblasting + silanization and tribochemical coating	Push-out	Silanization of the posts seems to have no significant effect on bond strength.
Sahafi *et al.* 2003	Human maxillary incisors	Roughening (sandblasting, hydrofluoric acid etching), application of primer (Alloy Primer, Metalprimer II, silane), or roughening followed by application of primer (sandblasting or etching followed by primer, Cojet treatment).	Shear Bond Strength	The bond strength of resin cement could be improved by surface treatment, Cojet treatment and sandblasting were the most effective pretreatments, and etching the posts used with hydrofluoric acid cannot be recommended.
Tian *et al.* 2012	Human roots	Silane and control*	Pullout	Silanization of fiber posts does not make a difference to prevent dislocation of a post.

*control stands for no treatment

Table 3

Table3: Resin cements used in the included studies

Author/Year	Comparison	Resin Cement	Conclusion
Aksornmuang *et al.* 2004	Control*, dual-cure bonding agent, dual-cure bonding agent followed by light curing for 20 s, silane coupling bonding agent ,silane coupling bonding agent agent followed by light curing for 20 s	Clearfil DC Core (Conventional)	Application of a silane coupling agent improved the bond strength of dual-cure resin core material to glass fibre posts
Bitter *et al.* 2007	4 different silane solutions	Panavia F (Self-etch); PermaFlo DC (Conventional); VariolinK II (Conventional); RelyX Unicem (Self-adhesive)	Variolink II demonstrated a significantly higher bond strengths than the other investigated materials
Bitter *et al.* 2008	Silane and control*	Clearfil Core (Conventional); MultiCore Flow (Conventional)	Bond strengths were significantly affected by thermocycling, post type, and pretreatment, but in general not by the core material
Cekic-Nagas *et al.* 2011	Sandblasting was followed by the application of a silane; immersion in 9.6% hydrofluoric acid gel and silanization and control*	Biscore (Resin-core material); Admira (Composite resin)	The highest mean micropush-out bond strength value was achieved in DT-light post, HF-silane treatment with the Biscore core material
Dantas *et al.* 2011	Silane, hydrofluoric acid, hydrofluoric acid plus silane, plasma polymerization with argon, ethylenediamine plasma (EDA), and the control*	Rely X Unicem (Self-adhesive)	The Rely X Unicem cement showed an affinity with fiber posts treated with EDA plasma, which was observed for the highest bond strength
Debnath *et al.* 2003	2 different silanes using various concentrations (1, 5 and 10%)	Experimental resin	5% samples had the highest strength.
Goracci *et al.* 2005	Silane and control*	UnifilFlow; Tetric Flow (Flowable composites)	Any combination of post and core material, post-silanization increased the interfacial bond strength

Leme *et al.* 2013	Control*; silane; silane and Solobond; silane and Scotchbond Adhesive; silane and Excite	RelyX Unicem (Self-adhesive)	Silane application may be necessary to improve the adhesion of fiber posts luted with the self-adhesive resin cement evaluated here.
Liu *et al*. 2014	Control*, sandblasting, silanization, sandblasting followed by silanization	DMG LUXACORE Smartmix Dual, Multilink Automix, Panavia F2.0, RelyX Unicem	It can be concluded that especially when DMG LUXACORE Smartmix Dual is used, air abrasion of glass fiber posts has a significantly helpful effect on the micro push-out bond strength.
Magni *et al.* 2007	Sandblasting, sandblasting + silanization, silanization, control*	Multilink)Conventional); Variolink II (Conventional); MultiCore Flow (Conventional)	The type of luting agent did not significantly influence bond strength
Mosharraf *et al.* 2012	Silanization, sandblasting, treatment with 24% H2O2, and control*	Clearfil Photo core Composite (Composite resin)	Both silanization and sandblasting improved the bonding strength of fiber posts to composite resin core, but there were not any significant differences between these groups and control group.
Mosharraf *et al.* 2013	Control*;Silanization after etching with 20% H2O2; silanization after airborne-particle abrasion; silanization	Panavia F 2.0 (Self-etch)	Application of hydrogen peroxide before silanization increased the bond strength between resin cements and fiber posts.
Narene *et al.* 2011	Silane, Cojet and Silane, 10% sodium ethoxide and silane and and 10% H2O2	Variolink II (Conventional)	The results showed no significant differences between control group and silane treatment. The use of Cojet/Silane associated with Variolink II showed the highest bond strength
Novais *et al.* 2011	Three prehydrolyzed silanes and one 2-component silane followed by air drying temperatures, 23°C and 60°	Filtek™ Z250 Universal Restorative (Composite resin)	The use of warm air drying after silane application produced no increase in the bond strength between the fiber-reinforced composite post and the composite core.
Oliveira *et al.* 2011	Silane and control*	Maxcem Elite (MXE, Self-adhesive); RelyX Unicem clicker (UNI, Self-Adhesive); seT capsule (SET, Self-adhesive); SmartCem 2 (SC2, Self-adhesive); RelyX ARC (Conventional)	For ARC, MXE and SET, the silanated groups had higher bond strengths.

Perdigão *et al.* 2006	Silane and control*	Post Cement Hi-X Base/Catalyst (Conventional), Variolink II (Conventional), ParaPost Resin Cement (Conventional)	The use of a silane coupling agent did not increase the push-out bond strengths of the fiber posts used in this study.
Radovic *et al.* 2007	Sandblasting or no pretreatment in each of the 2 groups posts received 3 types of additional ‘‘chair-side’’ treatments :Silane; adhesive; control*	Unifil Core (Composite resin)	Sandblasting may give an increase in microtensile strength to methacrylate-based glass fiber posts, eliminating the need to apply additional ‘‘chair-side’’ treatments.
Rathke *et al.* 2009	Silane and control*	Dyract Cem Plus (Self-adhesive); Variolink II (Conventional); Panavia F 2.0 (Self-etch); RelyX Unicem (Self-adhesive)	The highest mean post-to-dentin strength was measured using the etch-and-rinse luting agent, Variolink II and the lowest mean post-to-dentin strength was measured using the etch-and-rinse luting agent, Dyract Cem Plus
Rödig *et al.* 2010	Control*, silanization, sandblasting + silanization and tribochemical coating	Variolink II (Conventional); Calibra (Conventional); Luxacore (Composite core material)	The significantly highest bond strengths were measured with the core buildup material Luxacore.
Sahafi *et al.* 2003	Roughening (sandblasting, hydrofluoric acid etching), application of primer (Alloy Primer, Metalprimer II, silane), or roughening followed by application of primer (sandblasting or etching followed by primer, Cojet treatment).	ParaPost Resin Cement (Conventional); Panavia F (Self-etch)	Panavia F had significantly higher bond strength to ground ParaPost XH, Cerapost, and dentin than did ParaPost Cement.
Soares *et al.* 2008	Silane, silane and adhesive, airborne-particle abrasion with 50-µm Al2O3 and silane, airborne-particle abrasion, silane, and adhesive	RelyX ARC (Conventional)	Treatment with silane only was sufficient as a surface treatment for adhesive bonding.
Tian *et al* . 2012	Silane and control*	ParaCore (PAR, Composite resin); Relyx Unicem (RXU, Self-adhesive); Relyx ARC (RXA, Conventional)	PAR was significantly different from RXU and RXA ($P < .05$). There was no statistically significant difference between RXU and RXA and between the use of silanization or not.
Zicari *et al.* 2012	Control*; silane, or coated with silicated alumina particles	Variolink II (Conventional); Clearfil Esthetic Cement (Conventional); RelyX Unicem (Self-adhesive)	A significantly higher push-out bond strength was recorded for the self-adhesive cement Unicem (3M ESPE)

*control stands for no treatment

Table 4

Table4: Risk of bias considering aspects reported in the materials and methods section

	Important aspects related to materials and methods section - Yes (Y) No (N) Not Applied (NA)							
Paper	**Teeth randomization**	**Teeth free of caries or restoration**	**Materials used according manufacturer's instructions**	**Teeth with similar dimensions**	**Endodontic treatment performed by the same operator**	**Sample size calculation**	**Blinding of the operator of the test machine**	**Risk of Bias**
Aksornmuang et al 2004	NA	NA	Y	NA	NA	N	N	NA
Bitter et al 2007	NA	NA	Y	NA	NA	N	N	NA
Bitter et al 2008	NA	NA	Y	NA	NA	N	N	NA
Cekic-Nagas et al 2011	NA	NA	Y	NA	NA	N	N	NA
Dantas et al 2011	NA	NA	Y	NA	NA	N	N	NA

Debnath et al 2003	NA	NA	N	NA	NA	N	N	NA
Goracci et al 2005	NA	NA	Y	NA	NA	N	N	NA
Leme et al 2013	Y	N	Y	N	Y	N	N	High
Liu *et al*. 2014	Y	N	N	N	N	N	N	High
Magni et al 2007	NA	NA	Y	NA	NA	N	N	NA

Mosharraf et al 2012	NA	NA	N	NA	NA	N	N	NA
Mosharraf et al 2013	N	Y	N	N	Y	N	N	High
Narene et al 2011	Y	Y	N	N	N	N	N	High
Novais et al 2012	NA	NA	Y	NA	NA	N	N	NA
Oliveira et al 2011	NA	NA	N	NA	NA	N	N	NA
Perdigão et al 2006	Y	N	N	N	N	Y	N	High
Radovic et al 2007	NA	NA	Y	NA	NA	N	N	NA
Rathke et al 2009	N	Y	Y	Y	NA	N	N	High
Rödig et al 2010	N	N	Y	N	Y	N	N	High
Sahafi et al 2003	N	N	Y	N	NA	N	N	High
Soares et al 2008	NA	NA	Y	NA	NA	N	N	NA
Tian et al 2012	Y	N	Y	N	N	N	N	NA
Zicari et al 2012	NA	NA	Y	NA	NA	N	N	NA

LEGENDS

Figure 1: Flow diagram of the systematic review according to the PRISMA statement.

Figure 2: Forest plot for the analysis between control group (untreated posts) and silane only. Studies that used artificial devices favored the use of silane, whereas studies that used teeth as substrate for luting the posts had no significant difference.

Figure 3: Forest plot for the analysis between silane only vs. pre-treatment + silane. No significant difference between groups was observed when artificial devices were used, whereas the analysis favored the use of post pre-treatment + silane over silane only when the posts were luted into teeth.

Artigo 3

6 – Estudo *in vitro*

Influence of operators using direct or indirect techniques for intracanal impression to fabricate cast metal posts§

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ABSTRACT

Statement of Problem: Direct and indirect techniques are used for intracanal impression and fabrication of cast metal posts. However, it is unknown if there is any difference in the quality of the casts considering the level of expertise of the operators.

Purpose: The aim of this study was to compare how operators and impression techniques influence the surface characteristics of the impressions and the quality of cast metal posts.

Material and Methods: For this in vitro study, human roots were randomly divided into four experimental groups (n=14) according to the operator (with or without expertise) and impression technique (direct or indirect). For each impression/cast post, time to obtain, length, diameter, weight, and thickness of simulated cement were calculated. Posts were luted and a pull-out bond strength evaluation was performed using a mechanical testing machine.

Results: Within the same operator, weight and thickness of the simulating cement was greater in the indirect technique ($p<0.001$ and $p=0.006$, respectively). There were no statistically significant differences between the length of the impression and the cast metal post between operators ($p=1.0$). The pull-out test did not result in statistically significant differences for both operators and techniques ($p=0.453$).

Conclusions: Within the limitations of this study, both operators and techniques resulted in clinically acceptable posts according to international standards.

Clinical implications: Both impression techniques may be used irrespective of the level of expertise of the operator, as they resulted in clinically acceptable cast metal posts. Although the indirect technique resulted in thicker cement pellicle, this may be clinically irrelevant.

Key-words: intracanal impressions technique; cast metal post; clinical chair time

INTRODUCTION

Posts have been used to provide anchorage for dental restorations in cases where the tooth structure has been destroyed due to caries, trauma, or endodontic overaggressive procedures.[1, 2] Metal alloys are traditionally used to make posts due to their suitable physical properties and possibility of being cast into precise shapes.[3] Metal posts are particularly indicated in cases of severely damaged teeth and for large fixed dental prosthesis, with high survival rates after 10 years,[4 - 7] good adaptability to the configuration and angulation of root canal walls as well as an ideal connection to the metal core, with no possibility of separation.[3, 6] Additionally, cast metal posts present as advantages low cost, long history of clinical use, excellent radiopacity, and do not require technical or special cement for fixation.

Cast metal posts can be obtained by direct or indirect impression techniques. The direct technique is performed using a prefabricated post and autopolymerizing acrylic resin,[8] which is the most popular material used for intracanal impression. In this technique, the coronal and root portions of the post are obtained directly from the patient's mouth and subsequently cast into appropriate metal alloys. The indirect technique also uses a prefabricated post but in association with a vinyl polysiloxane impression material. In this technique, the light body material is inserted into the root canal space followed by the insertion of the prefabricated post.[9] Next, a tray with the light and putty materials are used for the impression of the mouth. This technique requires an additional laboratory step, resulting in greater probability of inaccuracy of the cast. However, it allows for greater ease of preparation of the coronal portion, since it is performed outside the mouth, while other advantages are a shorter chair time,[10] and when the tooth has limited access or in cases of multiple impressions.[11 - 15]

Although evidence is available on the differences between impression techniques, the differences between operators in a clinical practice-like environment remains to be tested. Thus, the aim of this study was to compare how operators and impression techniques influence the surface characteristics of the impressions and the quality of the cast metal posts. The hypothesis tested was that neither the operator nor technique would result in differences in the quality of cast metal posts.

MATERIALS AND METHODS

Experimental design

For this in vitro study similar human premolars from a Teeth Bank (FO-UFPel) were selected. The study was approved by the local Research and Ethics Committee (protocol 233/2011). The specimens were randomly divided into four experimental groups (n=14), defined by the impression technique and operator. The main outcome evaluated was the quality of cast metal posts considering the level of expertise of the operators (undergraduate student vs experienced dentist) and impression techniques (direct vs indirect). For that, the length of each impression/cast post, diameter, weight and thickness of a simulating luting agent were calculated. Finally, posts were then luted with resin cement, and a pull-out bond strength evaluation was performed using a mechanical testing machine.

Preparation of teeth

For this study, similar premolars were selected to minimize any additional factors that could affect the retention of the cemented posts. Thus, from 80 selected teeth, 24 were discarded as they presented more than one root canal, an incomplete apex, or an obstruction within the canal system or internal root resorption. The structure of the teeth was also examined under 4x magnification to exclude teeth with cracks and fractures. Also, a pilot study was conducted to determine the number of teeth necessary for this study.

Teeth were cleaned by hand scaling and stored in 0.5% chloramine-T solution for seven days for disinfection. The crowns were removed above the cementum-enamel junction with a low-speed diamond saw under water cooling[16] in order to obtain a remaining root length of 16 mm. All canals were instrumented as described elsewhere.[17] To flare the coronal and middle third of the canal, a #2 Gates Glidden (Dentsply Maillefer, Petrópolis, Brazil) drill was inserted 12 mm into the canal, and then followed by sizes 3 and 4. The final instrumentation of the canal was established employing the size 20 to 40 files (Dentsply Maillefer). The canals were irrigated with 2.5% sodium hypochlorite solution after the use of each file and each Gates Glidden drill. New instruments were used for every five specimens. Next, root canal was obturated with gutta-percha (Dentsply Maillefer) and Sealer-26 resin sealer (Dentsply Maillefer) using lateral condensation with the use of a master cone added to accessory cones sufficient to complete obturation of the canal. The filled roots were stored in relative humidity for at least 24h to allow the resin sealer to set in an environment with 100% humidity.

After the storage period, the gutta-percha from coronal and medium thirds was removed with a largo no. 3 (Dentsply Maillefer) maintaining 4 mm of gutta-percha in the apical portion of the root canal. All steps were performed by both operators, according to the prior randomization of teeth.

Impression procedures

Root canals were isolated with petrolleum jelly with the aid of absorbent paper points before the impression procedures. Direct impression was performed using prefabricated posts relined with autopolymerizing acrylic resin[8] (Duralay; Reliance

Dental Mfg. Co., Worth, IL). For this purpose, polymer and monomer of the acrylic resin were prepared according to manufacturer's instructions, and with the aid of a probe, the still fluid resin was inserted into the canal and then the prefabricated posts embedded in monomer were inserted and bonded to the resin previously placed. Excess of acrylic resin was accommodated around the post for tailoring the core, followed by the insertion and removal of the post from the canal until early exothermy. If necessary, relining was made with the aid of a microbrush[18] and only after that the timer was turned off. The time to perform the impression techniques was considered from the beginning of isolation of the root canal until the acrylic resin polymerization.

The indirect impression was made with prefabricated posts associated with vinyl polysiloxane (AD Futura; DFL Indústria e Comércio SA, Jacarepaguá, RJ, Brazil). In this technique, the light material was placed inside the root canal, and then a plaster post was inserted. A tray with the putty and light vinyl polysiloxane was positioned in the teeth and removed after polymerization. For the indirect technique, the time was considered from the beginning of vinyl polysiloxane insertion into the root canal until the setting of the putty material.

The photographs of each impression were taken shortly after the impression procedures, and the patterns obtained by the direct technique were photographed on a graph paper while indirect impressions were photographed on black background with a ruler positioned in the cervical to apical portion of the impression. All impressions were sent to a laboratory and cast in NiCr alloy (FIT CAST-SB Plus; Talmax, Curitiba, PR, Brazil). The surface of the cast metal posts were analyzed using a microscope and standardized photographs. All photographs were taken using the same standards (20x focus, 15 cm distance on a graph paper, Canon-Rebel Xti; CANON INC., Japan).

Cast metal post assessment

Vinyl polysiloxane light body was used to simulate the thickness of the cement during the cementation. The material was handled according to the manufacturer's instructions. Each tooth was moistened with water and the root canal was filled with impression material followed by the cast metal post, which was previously isolated with pretrolleum jelly, inserted into the root canal, and held under finger pressure by the experienced (n=14) and undergraduate student (n=14) until the post was completely seated, as mimicking the clinical procedure. At the end of polymerization, cast metal posts were removed from the interior of the root canal space with the impression material. The impression material was carefully removed to measure the weight in an analytical balance with 0.01mg accuracy (AUW220D; Shimadzu, Tokyo, Japan) in order to evaluate differences between impression techniques and operators. Next, thickness measurements were made in the three thirds of the impression material: apical, middle and cervical, with the aid of a digital micrometer (Mitutoyo; Santo Amaro, SP, Brazil) accurate to 0.001 mm to assess the thickness of the simulated luting film.

Pull-out bond strength test

The cast metal posts were cemented with self-adhesive resin cement RelyX Unicem 2 (3M ESPE, St. Paul, MN) according to the manufacturer's recommendations and with the aid of a centrix syringe (Centrix syringe; DFL Ind. e Com. S.A.; Rio de Janeiro, RJ, Brazil). The specimens were stored in 100% humidity at 37^0C for 24 hours before testing.[17] The assembly was placed in a mechanical testing machine (DL500; EMIC; São José dos Pinhais, PR, Brazil) so that the horizontal rod was attached to the upper element of the testing machine by passing it through a hole previously made in the core.[18] All specimens were submitted to a tensile test until post dislodgment from the canal. The pull-out test was performed parallel to the long axis of the tooth/cast metal posts at a speed of 0.5 mm/min. The load required to displace each cast metal post was recorded in Newtons (N).

RESULTS

The results are summarized in Tables 1 and 2. All data analyzed considered a significance level set at $p<0.05$ using SigmaStat software (Systat, San Jose, Calif). Considering the time, data were ranked and analyzed with 2-way ANOVA followed by Tukey's *post hoc* test. Considering the time elapsed for the impression, both operators and techniques presented statistically significant differences ($p=0.018$). For both operators the indirect technique was more time consuming ($p<0.001$). Considering the techniques, the experienced operator was faster for both direct and indirect techniques ($p=0.026$ and $p<0.001$ respectively, Table 1).

Considering the length of the impression and the length of the metal post, the data were ranked and analyzed with Paired t-tests and showed no statistically significant differences when the operators were compared ($p=1.0$). Two-way ANOVA followed by Tukey's test showed a statistically significant difference between the techniques within the same operator, the weight (transformed by $\log_{10}$) and thickness of the vinyl polysiloxane used to simulate the cement was greater in the indirect technique ($p<0.001$ and $p=0.006$, respectively, Table 2). Although the three thirds of the impression material were collected, only mean values are shown as there were no differences between thirds for weight and thickness. For the pull-out bond strength test, data was analyzed by 2-way ANOVA and no statistically significant differences were found between operators and techniques ($p=0.453$, Table 2).

DISCUSSION

This in vitro study was designed to analyze if the operator and technique would influence on the quality of cast metal posts. Intracanal impression procedures must have great accuracy to reduce the chances of misfit of the cast metal posts. Therefore, if the first impression of the canal with small distortions is successively incorporated during all subsequent stages up to the definitive installation of the crowns[19] this may directly influence on the survival of the tooth. This may be particularly important when considering a large fixed partial denture.

In this study, the teeth were prepared trying to simulate clinical condition to obtain results as closely as possible to the clinical practice. Single-rooted teeth with a single root canal were selected to minimize anatomical variation between the selected teeth. This has to be considered, as the results may not stand for all teeth. Another possible limitation is the fact that only two operators were tested for each technique. The indirect technique was performed with vinyl polysiloxane due to its ability to accurately register the margins of the gingival tissues and sulcular area, also because it resists distortion and has excellent dimensional stability.[20] For the direct technique, acrylic resin is the most popular material used because of its easy manipulation, good dimensional stability, low cost, a reasonably long setting time, and as it produces accurate fitting of cast metal posts that require very little adjustment prior to cementation[8] and easy adjustment in the mouth as needed and less working time at the laboratory. Moreover, the direct use of acrylic resin can overcome the technically demanding nature of the indirect technique with its greater number of intermediate steps, which are usually outside dentist control. However, the indirect method is faster and easier, particularly when multiple posterior cast metal posts are necessary[21] or when operating space is limited[11-13,15,21] besides yields a shorter chair time and a more convenient and comfortable experience for the patient.[10, 22, 23]

The results of this study showed that when operators were compared, the experienced operator was faster to obtain the impressions, irrespective of the technique used, which was somewhat expected. However, when time was taken into account, the indirect technique was more time consuming for both operators, contrasting the current literature.[10,24] This may be explained by the fact that manufacturer's instructions were taken into account in the indirect technique (handling time of the material and polymerization time prior to removal), while in the direct technique it was just a matter of the curing time of the acrylic resin, and additional variables such as temperature changes experienced in the oral environment may affect the impression materials. Thus, this specific finding has to be interpreted with caution.

The impressions obtained by indirect and direct techniques were sent to the laboratory technician for casting and the comparison made was between the length of the molded posts and the cast metal posts. There were no differences between the expert and the undergraduate student irrespective of the technique, with the cast posts clinically acceptable, corroborating other studies.[8, 9, 14, 15] This result is interesting because it shows that the quality of the cast metal posts will not be compromised in relation to its length; however, this result should be interpreted with caution since only two operators were compared. This specific result cannot be compared with any previous study, as no previous investigation assessed the influence of operators regarding the techniques of impression. Yet, an interesting result is that expertise may be gained with time and should not be, in this context, the main concern of the dentist, as this study has shown that the bond strength of the post into the root canal is the same even with differences between operators. It is expected that someone with more experience takes less time to perform a clinical procedure, but if the final result is the same in terms of quality, this is not clinically relevant as expertise may be quickly achieved by clinical practice or continuing education. Additionally, clinical considerations have to be taken into account in this scenario. For instance, in the event that multiple impressions are planned, the chair time for the indirect technique is more important as it will be probably more comfortable for the patient.

Another important issue is the difference in fit and accuracy of the cast posts by measuring the weight and the thickness of the luting agent, which was evaluated in the thirds of the root canals of the impression material filling in the space between the root canal wall and the cast posts since it is known that the cementation procedure has a highly significant effect on the retention of cast metal post.[18] The indirect technique resulted in greater weight and thickness of vinyl polysiloxane used to simulate the cement film during the cementation, irrespective of the operator, which is in disagreement with the study of Pitigoi-Aron et al,[8] in which the indirect method produced a better fit and accuracy for the castings. This fact may be explained because of the alleviation performed in the standard plaster model for subsequent preparation of patterns in acrylic resin and casting by the technician. Several previous studies demonstrated that thinner cement layers present fewer voids and other defects than thicker layers, and voids within the material may act as stress concentration areas and decrease post retention predisposing the post to debonding.[25 – 28]

The thickness found in this study may be considered more than desirable if ISO standards are taken into account.[29] However, this study did not test resin cement between glass plates as to check for viscosity, but tried to be as close as possible to clinical practice using the vinyl polysiloxane as a substitute of the resin cement, as it could be removed from the assembly. Perez et al[30] corroborated this study showing that the post bond strength was not impaired by increased cement thickness.

A thin and uniform layer of cement is desirable when luting any post into root canals and the choice of self-adhesive resin cements was as it appear to have low shrinkage because of their viscoelastic properties, leading to better intimate contact of the resin cement with the root canal walls and higher frictional resistance.[31] Finally, although the pull-out bond strength was the same for all groups tested as previously shown,[18] the force applied was predominantly vertical while in the clinical practice occlusal forces are much more complex than forces applied using a simple tensile test.[32] Therefore the bond strength measured in the current investigation may not be totally correlated with clinical practice.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Impression techniques (direct or indirect) and different levels of expertise of the operators seem to have no effect on the retention of cast metal posts.
2. Although the indirect technique resulted in greater thickness of the simulated luting agent, it seems to have no influence on the metal post as regards to clinical practice.

CONFLICTS OF INTEREST

None.

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Table 1 Variables related to the posts.

			Length (mm)	
Operator	Impression Technique	Time (min)	Molded post	Cast post
Inexperienced	Direct	7.3(1.2) aB	9.9(4.1) a	9.1(3.2) a
	Indirect	17.7(0.7) bB	10.7(4.5) b	9.7(3.0) b
Experienced	Direct	6.7(1.8) aA	9.0(4.5) a	8.7(4.3) a
	Indirect	7.6(0.1) bA	10.7(4.5) b	9.4(4.1) b

Mean values (SD). Different lowercase letters refer to the comparison of techniques for the same operator. Different upercase letters refer to the same comparison technique between operators tested for each variable (time). Two-way ANOVA followed by Tukey test and paired t-test ($p<0.05$)

Table 2 Variables related to bond strength.

Operator	Impression technique	Weight (mg)	Thickness (µm)	Pull-out bond strenght (N)
Inexperienced	Direct	3.6(2.5) a	60(10) a	180(46.4) a
	Indirect	6.6(3.5) b	70(30) b	139(35.8) a
Experienced	Direct	3.5(1.9) a	70(30) a	167.4(20.1) a
	Indirect	7.4(3.7) b	100(40) b	178(64.5) a

Mean values (SD) Different lowercase letters refer to the comparison of techniques for the same operator. Two-way ANOVA followed by Tukey test ($p<0.05$).

7 Artigo 4 - Ensaio Clínico Randomizado

A randomized clinical trial on the influence of impression technique to fabricate cast metal posts§

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ABSTRACT

Objectives: A randomised clinical trial was conducted to evaluate the accuracy of cast metal posts depending on the tooth position and impression technique performed.

Methods: Endodontically treated teeth planned to receive cast metal posts and full crowns were randomised according to the impression technique (direct or indirect) and tooth position (anterior or posterior). The impression procedures were carried out by two operators and the time elapsed to perform the impression was calculated. All impressions and cast metal posts were photographed to assess any possible differences between techniques on the length of the cast metal post.

Results: Considering the length of cast metal post all resulted in shorter posts after casting compared to the moulded ones. The mean reduction for the metal posts was 2.3, 5.7, 6.3, and 7.2% for direct (anterior and posterior) and indirect techniques (anterior and posterior), respectively. Considering the time, there was a statistically significant difference between techniques and tooth position ($p=0.031$), with the direct technique presenting more time-consuming than the indirect technique ($p<0.001$) for both tooth positions, except for the indirect technique, where both tooth groups were similar considering the time for the impression ($p=0.459$).

Conclusions: Both intracanal impression techniques resulted in shorter but clinically acceptable cast posts.

Clinical Significance: As all cast posts were clinically acceptable, the choice of technique should be based on clinical experience and the extent of the rehabilitation.

Key-words: Clinical trial, intracanal impression technique, cast metal posts

INTRODUCTION

Cast posts and cores have been used to restore endodontically treated teeth[1] as one of the possible treatment options to serve as a support for a subsequent prosthetic restorative treatment.[2] Custom-fabricated cast metal posts are still regarded as the gold standard for restoring extensively damaged teeth[3-6] and for large fixed dental prosthesis, with high survival rates.[7-11] Although it may be said that glass fibre posts are similar to cast metal posts on survival[11-14] when there is insufficient ferrule (<2 mm) or a large fixed partial prosthesis, cast metal posts are commonly chosen.[15] The choice on cast metal posts is common since they will fit the irregularly shaped canal walls more intimately, their shape and structure can resist torsion forces[16] and especially because teeth with no ferrule have not been tested with glass fibre posts in large fixed partial dentures so far.

The major advantages of cast posts are low cost, not requiring technique or special cement for fixation, long history of clinical use and excellent radiopacity. However, the result of dental lost-wax casting techniques is greatly influenced by the inherent properties of the dental materials such as expansion and contraction of all materials used, including impression materials, waxes, gypsum products, plastics, and metals.[17] Distortions in the casting process result[18] in a non-uniform precementation space and absence of passivity and fitting between tooth and metal. Therefore, an adequate impression technique could influence on the clinical survival of final restorative treatment because it has a direct influence on the cast metal post retention. However, few studies compared the accuracy of the cast metal posts considering impression techniques and tooth position. The literature report that indirect technique with vinyl polysiloxane impression material reproduces the details of the root canal space[19] whilst it is faster and easier, especially when multiple posterior teeth are involved or when operating space is limited resulting in shorter clinical chair time.[20-24] Yet, direct technique is a reliable technique[24] with several advantages, including easy manipulation of the acrylic resin, dimensional stability, easy adjustment in the mouth when needed, less working time at the laboratory but with a reasonably long clinical setting time.

Thus, the aim of this randomised controlled clinical trial was to evaluate the accuracy of cast metal posts regarding adaptation and length considering the impression technique (direct or indirect) and tooth position on the arch (posterior or anterior). The hypothesis tested was that there would be no differences between impression techniques or tooth position on the time elapsed to perform the technique or on the accuracy of cast metal posts.

MATERIALS AND METHODS

Experimental design

This double-blinded (patient and evaluator), parallel-group randomised controlled trial (RCT) is part of the clinical trial registered at ClinicalTrials.gov (NCT01461239). The study was approved by the local research and ethics committee (protocol 122/2009) and followed the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines.[25] Additionally, the fulfillment of Consolidated Standards of Reporting Trials (CONSORT) Items was used.[26] Participants' oral health was assessed, and they provided written informed consent before enrolment in the study. Inclusion criterion was any endodontically treated anterior or posterior teeth with 0-0.5 ferrule height requiring cast metal post and a single metal-ceramic crown. Exclusion criteria considered teeth that did not require intraradicular retention or that for any reason could not be moulded. The main outcomes evaluated were the time to perform the impression and the quality of the posts concerning adaptation and length observed clinically, radiographically and through standardised photographs.

Sample size calculation

Under the assumption of equivalence of impression techniques, this calculation determined that 50 impressions were required to be 90% sure that the limits of a two-sided 90% confidence interval would exclude a difference of more than 18% between the direct and indirect techniques. We have also considered possible impression losses and therefore, this study included 39 patients, but 58 impressions.

Randomisation

A randomisation sequence was generated with a computerized random number generator. For treatment randomisation, a person not involved in the study wrote impression techniques (direct or indirect) on slips of paper and inserted them into plain brown envelopes. For every patient entering the clinical practice, an envelope was chosen and the technique used. Teeth were not moulded twice; every tooth was moulded with either direct or indirect technique.

Clinical Procedures

The impression procedures were carried out by two operators and the time elapsed to perform the impression techniques was registered for each impression. All procedures were performed under rubber dam isolation and all materials were used according to the manufacturers' instructions. Initially, all teeth included in the study received endodontic treatment using the crown down technique and irrigation with 2.5% NaOCl solution. Teeth were filled using the lateral condensation technique, Grossman cement (Endo-Fill; Dentsply Maillefer, Petrópolis, Brazil) and gutta-percha cones

(Dentsply; Maillefer). Then, 2/3 of the filling was removed from the root canal with #5 Gates Glidden burs (Dentsply; Maillefer).[11] Randomisation was performed to determine whether direct or indirect impression technique would be used.

For direct impression, post and core patterns were performed using acrylic resin prefabricated posts (Pinjet, Angelus Indústria de Produtos Odontológicos S/A, Brazil) relined with autopolymerizing acrylic resin (DuraLay, Reliance Dental Mfg. Co., Worth, IL, EUA).[24] For this purpose, the still fluid resin was inserted into the canal and then, prefabricated posts moistened with monomer were inserted, and bonded to the resin previously placed. Exceeding resin was accommodated around prefabricated posts for fabrication of the core. Following, insertion and removal of the posts into the root canal was performed until early exothermy and placed in water at 37^{o}C until the end of polymerization. When necessary, relining was performed.[27] After, the post and core patterns were sent for casting (Ni-Cr – Fit Cast-SB Plus; Talmax, Curitiba, PR, Brazil) in the laboratory.

The indirect impressions were made with acrylic resin prefabricated posts and vinyl polysiloxane (AD Futura; DFL Indústria e Comércio SA, Jacarepagua, RJ, Brazil). In this technique, the light material was inserted into the root canal followed by the insertion of a prefabricated post. A tray with the putty and light vinyl polysiloxane was used for post removal after the setting time. The indirect impression was poured in type IV gypsum (Durone, Dentisply; Maillefer) and sent to a dental technician to create wax patterns for casting the posts (Ni-Cr – Fit Cast-SB Plus; Talmax, Curitiba, PR, Brazil).

The time elapsed to perform the impression was considered from the beginning of isolation of the root canal (for the direct technique) until the core was finished. For the indirect technique, the time was considered from the beginning of vinyl polysiloxane insertion into the root canal until the setting of the putty material.

Evaluation of post characteristics

The characteristics of the impressions and the resulting cast metal posts were evaluated by clinical inspection and standardised images were made with a digital single lens reflex camera (Canon EOS Rebel XTi, Tokyo, Japan), with standardised focus (20 mm f/2.8VR; Canon) and at a fixed distance (15 cm) from the records. For standardisation and to provide reliability of image measurements for the direct technique, the acrylic resin patterns were photographed on graph paper, while for the indirect technique the impressions were photographed on a black background with a ruler positioned in the limit between cervical to apical portion of the intraradicular coronal post impression. Cast metal posts obtained from both direct and indirect techniques were measured with a millimetre ruler and photographed on graph paper, to ensure consistency and accuracy of measurements. Only one measurement (with the ruler) was considered, but the graph paper helped in standardisation of the measurement.

Cementation Procedures

Before cementation procedures the cast metal posts were evaluated for adaptation and length by periapical radiographs, which were taken with a parallel technique and Ultra-Speed films (Eastman Kodak Company, Rochester, NY, USA) to check the post adaptation and to evaluate if they could be cemented.

All cast metal posts were luted with self-adhesive resin cement (RelyX U200, 3MESPE St Paul, MN, USA) using a Centrix syringe (Centrix syringe; DFL Indústria e Comércio S.A., Rio de Janeiro, Brazil). Digital pressure was applied for 5 min, exceeding cement was removed, followed by light-polymerization for 40 s/surface.[11] All teeth received single metal-ceramic restorations**.**

RESULTS

From the 58 impressions performed, 5 were excluded (Figure 1). Statistical analyses were performed using SigmaStat software (Version 3.5, Chicago, IL, EUA) considering a significance level set at $p<0.05$. The results are summarised in Tables 1 and 2. Considering the moulded posts and the length of the metal post, data were analysed with Paired t-tests for intragroup comparisons and showed a statistically significant difference for all tested variables, with direct and indirect techniques for anterior teeth, and direct and indirect techniques for posterior teeth all resulting in shorter posts after casting ($p=0.04$, $p=0.02$, $p=0.04$ and $p=0.01$, respectively). The mean reduction for the metal posts was 2.3, 5.7, 6.3, and 7.2% for direct (anterior and posterior) and indirect techniques (anterior and posterior), respectively.

Considering the time, data were ranked and two-way ANOVA followed by Student-Newman-Keuls *post hoc* test showed a statistically significant difference between the techniques and tooth position ($p=0.031$), with the direct technique presenting more time consuming than the indirect technique ($p<0.001$) for both tooth groups (anterior and posterior). For the indirect technique, both tooth groups were similar with respect to time ($p=0.459$, Table 2).

DISCUSSION

The present study compared the accuracy of cast metal posts considering the impressions technique (direct or indirect) and the position of tooth on the arch and the time to obtain an impression of intrarradicular posts and the length of the molded vs cast post. To the authors' knowledge this is the first randomised controlled trial designed to compare the quality of the cast metal posts made for intracanal impression conducted based on the assumed equivalence of the techniques. Both intracanal impression techniques resulted in shorter but clinically acceptable metal posts. The hypothesis tested was that there would be no difference between impression techniques on the quality of metal posts. Thus, the hypothesis was accepted.

Although we found differences between the moulded and cast post lengths, it may be said that they are clinically irrelevant, with a mean of 2.3, 5.7, 6.3 and 7.2% length reduction (or 0.3, 0.7, 0.6, 0.7 mm) for direct (anterior and posterior teeth) and indirect techniques (anterior and posterior teeth), respectively. These results showed that metal posts fabricated with the direct technique presented less differences between moulded and cast posts, but without statically significant difference. The indirect technique presented a higher percentage of shortage probably because the dental technician performs a relief in the plaster model on which the acrylic resin pattern is made, resulting in greater probability of inaccuracy of the cast. However, this result did not influence the clinical practice, since all the posts were considered clinically acceptable and were not repeated, as previously shown.[24,28-30] A previous clinical study compared direct and indirect techniques with regard to survival probability with no statistically significant differences.[9] Therefore, what probably is likely to influence the clinical practitioner decision on which technique to choose is his/her technical skill and the case to be executed.

The use of acrylic resin can overcome the technically demanding nature of the indirect technique with its greater number of intermediate steps, which are usually out of the dentist control. However, it is more time consuming, as also corroborated by our results and is quite difficult to apply when the interarch space is minimal.[24] Conversely, direct fabrication technique of posts and cores has shown lower survival probability compared to the indirect technique.[9] The reason of this finding could be the difficulty of building up a post and core intraorally with the same precision of indirect fabrication on a model. However, it is clearly shown /indicated that direct fabrication of posts requires a greater degree of operators' skill. Although the study of Balkenhol[9] has stated that the indirect fabrication of post and cores is a way to ensure long-term success, all the teeth included in this study are in loco after 4 years of follow-up.

The indirect technique is considered to be technically demanding, with its extra number of intermediate steps. However, if a stable impression and accurate material is used and meticulous laboratory procedure followed, it can give results comparable to those obtained by direct technique,[27] which is in accordance to the findings of this study. Additionally, in some cases where multiple teeth are involved or interarch space reduced, the indirect technique usually is the technique of choice. This study showed that the indirect technique is faster than the direct technique due to less time-consuming for the practitioner, corroborating previous studies.[20-24]

Finally, posterior and anterior teeth may instead have differences. As clinical access to posterior teeth is more difficult, there was the idea s of separating into groups of teeth with the aim of having clinically practical results for better impression especially in cases of multiple impressions. Although we have not performed multiple impressions which can be considered a limitation of this work it seems obvious that multiple indirect impressions are less time-consuming than direct ones, especially in posterior teeth. Nevertheless, our study has shown no difference in the time to anterior and posterior teeth in the indirect technique.

CONCLUSION

Although the indirect technique presented shorter posts compared to the direct technique, all resulted in shorter but clinically acceptable metal posts. The indirect technique proved to be faster than the direct technique, which is especially important in cases of multiple teeth involved and/or reduced interarch space.

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Table 1 - Variables related to the length of posts.

		Length (mm)		Mean reduction
Technique	Teeth	Moulded Post	Cast Post	(%)
Direct	Anterior	10.3±2.1b	10±2.0a	2.3
	Posterior	11.3±3.1b	10.6±3.4a	5.7
Indirect	Anterior	9.8±2.8b	9.2±2.5a	6.3
	Posterior	7.8±2.4b	7.1±1.9a	7.2

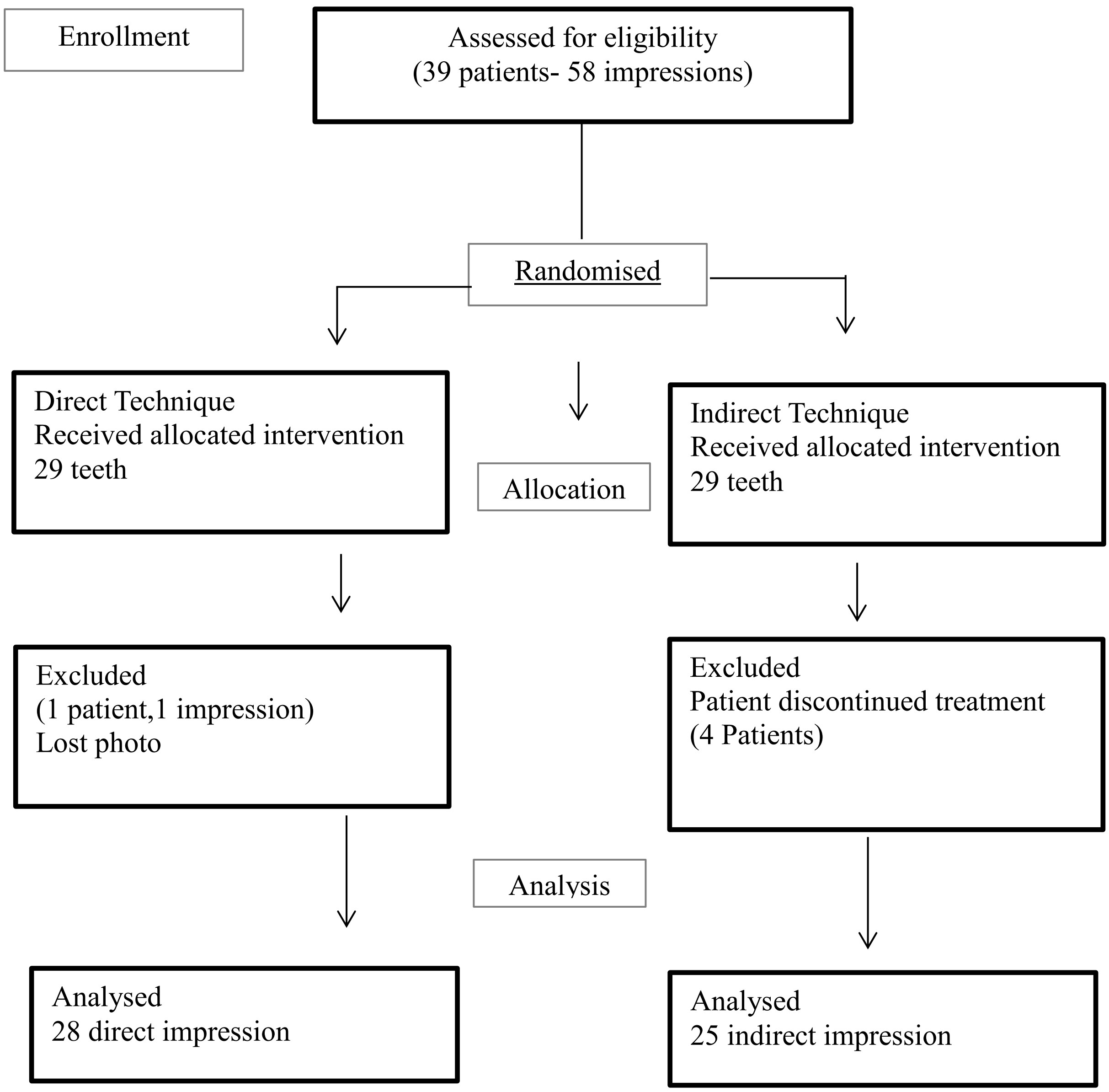
Values are mean±SD. Different letters represent the difference between moulded and cast post for the same impression technique and teeth group (Paired t-tests, $p<0.05$).

Table 2 - Variables related to time of impression techniques.

Technique	Teeth	Time (min)
Direct	Anterior	20±11.2*b
	Posterior	38.2±18.3b
Indirect	Anterior	7.3±0.6a
	Posterior	7.5±1.0a

Values are mean±SD. *Represents statistically significant differences between anterior and posterior teeth within the same impression technique. Different letters represent statistically significant differences between techniques within the same teeth group. Two-way ANOVA, followed by SNK test ($p<0.05$).

Fig. 1 – Flowchart



8 Conclusões

Diversos fatores estão relacionados ao sucesso clínico de procedimentos protéticos restauradores. Desta forma, os resultados desta tese permitem concluir que: I) o uso de pinos de fibra de vidro é uma importante opção clínica, mas deve-se ter especial atenção às dificuldades de se obter uma boa adesão ao longo do canal radicular; II) embora haja pouca evidência na literatura, a silanização pode melhorar a retenção de pinos de fibra de vidro quando tratamentos físicos/químicos seletivos são aplicados ao pino antes da silanização; III) técnicas de moldagem intracanal (direta ou indireta) e diferentes níveis de *expertise* dos operadores parecem não ter efeito na retenção dos núcleos metálicos fundidos; IV) a técnica indireta de moldagem intracanal produziu núcleos metálicos fundidos mais curtos comparada a técnica direta, mas todos os pinos foram clinicamente aceitáveis. Entretanto, a técnica indireta mostrou-se mais rápida do que a técnica direta, sendo este achado especialmente importante quando se têm situações clínicas mais complexas.

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Apêndices

Apêndice A

Ficha do Paciente

Faculdade de Odontologia - UFPel

Projeto de Extensão

1. Paciente: ____

2. Data Nascimento:___/____/________3. Sexo: ______

4. Endereço:____

____
_

5. Telefones: Residencial:______________Celular:________________
Trabalho:______________ Parente próximo:_______________

Aluno atendente : ____

Questionário de saúde
Sofre de alguma doença: ( ) Sim ( ) Não - Qual(is)____________________

Está em tratamento médico atualmente? ( ) Sim ( ) Não.

Gravidez: Sim ( ) Não ( ) Usa anticoncepcional? ( ) Sim ( ) Não

Faz reposição hormonal? ( ) Sim ( ) Não

Fumante?: Sim ( ) Não ( )

Está fazendo uso de alguma Medicação? ( ) Sim ( ) Não

Qual(is)? ____

Nome do Médico Assistente/telefone: _____________________________

Teve alergia? ( ) Sim ( ) Não -Qual(is) ________________________________

Já foi operado? ( ) Sim ( ) Não -Qual(is) ______________________________

Teve problemas com a cicatrização? Sim ( ) Não ( )

Teve problemas com a anestesia? Sim ( ) Não ( )

Teve problemas de Hemorragia? Sim ( ) Não ( )

Sofre de alguma das seguintes doenças ?

Febre Reumática: Sim ( ) Não ( ); Problemas Cardíacos: Sim ( ) Não ( )

Problemas Renais: Sim ( ) Não ( ); Problemas Gástricos: Sim ( ) Não ( )

Problemas Respiratórios: Sim ( ) Não ( ); Diabetes: Sim ( ) Não ( )

Problemas Alérgicos: Sim ( ) Não ( ) Hipertensão Arterial: Sim ( ) Não ( );

Problemas Articulares ou Reumatismo: Sim ( ) Não ( );

Hábitos: ________________________________

Antecedentes Familiares: ____

HIGIENE BUCAL (utiliza):

( ) fio / fita dental ( ) interdental ( ) escova macia / média / dura

( ) unitufo / bitufo ( ) palito ( ) creme dental: ______________________

- CARACTERÍSTICAS DOS DENTES A SEREM TRATADOS NO PROJETO ProDENTE

Dentes tratados (número)		
N faces restantes		
N contatos proximais		
Contato com antagonista **(sim ou não)**		
Suporte periodontal **(anotar a inserção óssea em mm / desvios normalidade)**		
Perda de Inserção **6 sítios** **(mm)**	**MV** **V** **DV** **ML** **L** **DL**	**MV** **V** **DV** **ML** **L** **DL**

Profund. **de sondagem** **6 sítios** **(mm)**	**MV** **V** **DV** **ML** **L** **DL**	**MV** **V** **DV** **ML** **L** **DL**
Presença de mobilidade **(0 ou 1)**		
Comprimento do remanescente radicular (mm)		
Sangramento à sondagem (sim ou não)		
Uso de pino **(sim ou não)**		
Tipo de pino **(Fibra, NMF)**		
Tipo de Cimento **(RelyX U100)**		
Comprimento cimentado (mm)		
Comprimento coronário do pino (mm)		
Diâmetro do pino **(0.5; 1.)**		
Tipo de restauração final **(metalo-cerâmica)**		
Tipo de Cimento para coroa **(RelyX U100)**		

- TRATAMENTO ENDODÔNTICO

Realizado no ProDente? (   ) sim (   ) não

OBS: Se o tratamento for realizado no ProDente, preencher ficha específica.

Desenhe o remanescente dentário:

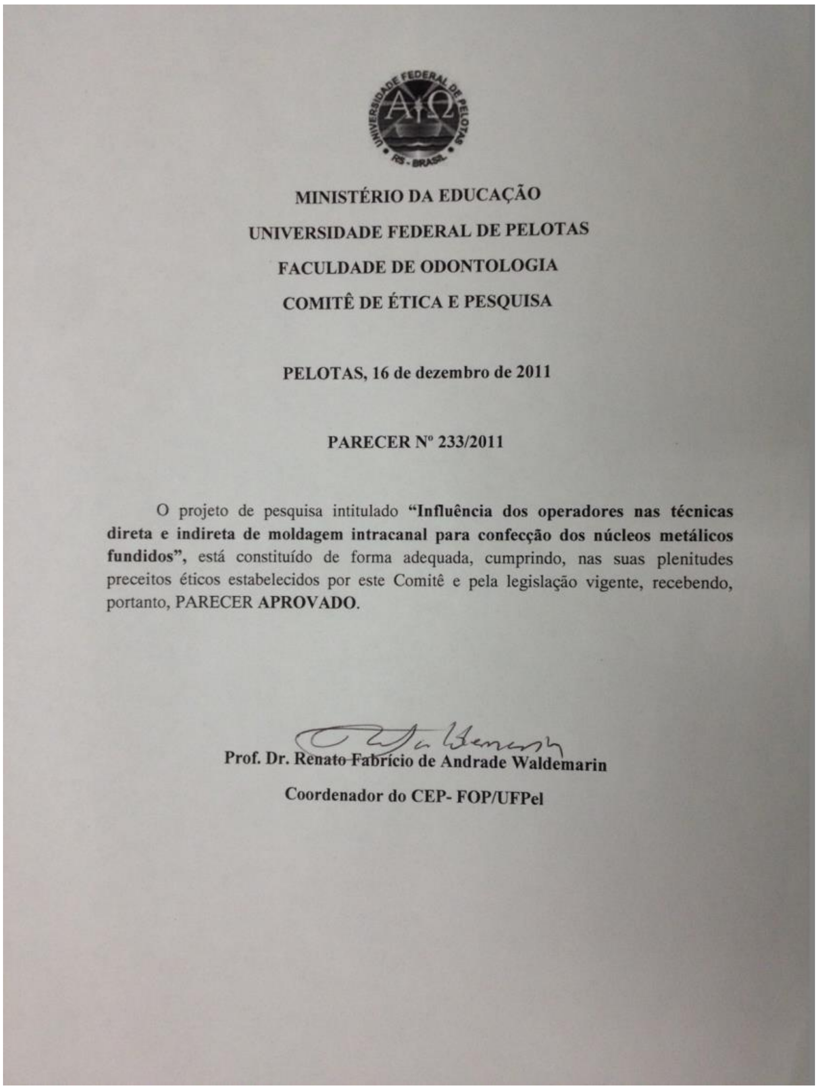
Desenhe o remanescente dentário:

Procedimentos (DATAR; descrever DETALHADAMENTE os procedimentos)

Data	**Procedimento**	**Material (is) utilizado (s)**	**Visto Prof.**

Apêndice B

Parecer do Comitê de Ética



MINISTÉRIO DA EDUCAÇÃO

UNIVERSIDADE FEDERAL DE PELOTAS

FACULDADE DE ODONTOLOGIA

COMITÊ DE ÉTICA E PESQUISA

PELOTAS, 16 de dezembro de 2011

PARECER Nº 233/2011

O projeto de pesquisa intitulado **"Influência dos operadores nas técnicas direta e indireta de moldagem intracanal para confecção dos núcleos metálicos fundidos"**, está constituído de forma adequada, cumprindo, nas suas plenitudes preceitos éticos estabelecidos por este Comitê e pela legislação vigente, recebendo, portanto, PARECER **APROVADO**.

Prof. Dr. Renato Fabrício de Andrade Waldemarin

Coordenador do CEP- FOP/UFPel

Apêndice C

Parecer do Comitê de Ética

MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DE PELOTAS
FACULDADE DE ODONTOLOGIA
COMITÊ DE ÉTICA EM PESQUISA

PELOTAS, 05 de novembro de 2009.

PARECER Nº 122/2009

O projeto de pesquisa intitulado **COMPARAÇÃO DO SUCESSO DE DUAS ESTRATÉGIAS DE CIMENTAÇÃO DE PINOS REFORÇADOS POR FIBRA DE VIDRO: ENSAIO CLÍNICO RANDOMIZADO MULTICÊNTRICO** está constituído de forma adequada, cumprindo, na suas plenitudes preceitos éticos estabelecidos por este Comitê e pela legislação vigente, recebendo, portanto, **PARECER FAVORÁVEL** à sua execução.

Prof º. Marcos Antonio Torriani
Coordenador do CEP/FO/UFPel

Prof. Marcos A. Torriani
Coordenador
Comitê de Ética e Pesquisa

Apêndice D

Termo de Consentimento Livre E Esclarecido

UNIVERSIDADE FEDERAL DE PELOTAS

FACULDADE DE ODONTOLOGIA

Termo de Consentimento Livre e Esclarecido

Por meio deste termo o(a) senhor(a) está sendo convidado a participar do projeto de pesquisa intitulado “Retentores intrarradiculares utilizados em prótese dentária: dos núcleos metálicos fundidos aos pinos de fibra de vidro”. Este trabalho tem por objetivo comparar duas técnicas de moldagem intracanal e avaliar, se uma é melhor que a outra.

Procedimentos: Para a moldagem do conduto radicular (canal) para obtençãodos núcleos metálicos fundidos e sua posterior cimentação, você será submetido aos seguintes procedimentos: (1) isolamento absoluto: consiste na colocação de uma borracha ao redor do dente, para evitar que entre saliva na região; (2) preparo do canal: com um broca específica será removida a obturação existente dentro do canal radicular, para que o retentor possa ser moldado; (3) cimentação: será levado para dentro do canal o cimento (colagem) e em seguida colocado o retentor; (4) polimerização: o retentor e o cimento serão iluminados por uma luz específica durante 40 s, para o endurecimento do cimento.

Os custos para a colagem do retentor são de nossa responsabilidade;os custos da prótese, de sua responsabilidade, conforme tabela vigente do Laboratório de Prótese.

Riscos do paciente: para a obtenção do retentor intracanal, você estará sujeito aos seguintes riscos: (1) perfuração da raiz do dente, o que pode ser contornado ou pode levar a perda do dente (extração); (2) algum tipo de reação alérgica aos utilizados.

Benefícios: (1) Você receberá acompanhamento odontológico de qualidade antes e durante a pesquisa; (2) a cimentação destes retentores para segurar a prótese é uma técnica que gera vantagens para o sucesso da prótese ao longo do tempo.

Ao aceitar participar do estudo o senhor (a) autoriza a execução dos procedimentos por parte dos alunos do programa, autoriza o uso dos dados sobre suas características e condições orais e o uso de imagens (Rx e fotografias), quando necessárias. Os pesquisadores se comprometem em manter sigilo e anonimato sobre os seus dados, ficando esses dados confidenciais apenas acessíveis para os pesquisadores e para você. O material com seus dados e imagens ficará sob os cuidados da Profa. Tatiana Pereira Cenci, armazenados no 2º andar do prédio da Faculdade. Após dez anos da primeira consulta o material contendo seus dados e imagens será incinerado.

Lembramos que o senhor (a) tem total autonomia em decidir participar ou não da pesquisa, podendo, inclusive, desistir do estudo em qualquer momento.

Por esse termo, eu ____, RG nº __________________________ aceito participar do projeto descrito nesse termo e autorizo a realização dos procedimentos descritos acima e a utilização de dados e imagens referentes a minha pessoa pelos pesquisadores envolvidos no estudo.

Pelotas, ____/____/______

____

Assinatura do paciente

______________________________ ______________________________

Nome do professor | Assinatura do professor

Qualquer dúvida, o(a) senhor(a) pode entrar em contato com a pesquisadora responsável: Tatiana Pereira Cenci (8111-4509); ou entrar em contato com o comitê de ética em pesquisa da Universidade Federal de Pelotas: http://www.foufpel.com.br ou 3222-6690.