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Dissertação

Barreira intraorifício em dentes tratados endodonticamente: Uma revisão sistemática e meta-análise de estudos in vitro.

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Pelotas, 2021

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Dissertação apresentada à Faculdade de Odontologia da Universidade Federal de Pelotas, como requisito à obtenção do título de Mestre em Clínica Odontológica com ênfase em Endodontia.

Orientador: Prof. Dr. Evandro Piva
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Dedico este trabalho ao meu avô,
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Tem horas que é caco de vidro
Meses que é feito um grito
Tem horas que eu duvido
Tem dias que eu acredito
(Paulo Leminski)

Notas Preliminares

A presente dissertação foi redigida segundo o Manual de Normas para Dissertações, Teses e Trabalhos Científicos da Universidade Federal de Pelotas de 2019, adotando o Nível de Descrição - estrutura em “Artigo”, descrita no referido manual. Acesso em: 22/02/2021.

Resumo

ARAÚJO, Lucas Peixoto de. **Barreira intraorifício em dentes tratados endodonticamente: Uma revisão sistemática e meta-análise de estudos in vitro.** Orientador: Evandro Piva. 2021. 71 f. Dissertação (Mestrado em Clínica Odontológica com ênfase em Endodontia) – Programa de Pós-Graduação em Odontologia. Universidade Federal de Pelotas, Pelotas, 2021.

O tratamento endodontico tem como objetivo final a completa limpeza do sistema de canais radiculares e um adequado selamento em toda a sua extensão. Um selamento coronário adequado tem papel fundamental no sucesso do tratamento endodôntico. Desta forma, o objetivo principal deste estudo foi avaliar através de uma revisão sistemática a eficácia de diferentes materiais utilizados como barreira intraorifício na redução da microinfiltração coronal de dentes tratados endodonticamente. Dois revisores independentes e às cegas realizaram uma busca sistemática em cinco bancos de dados eletrônicos: PubMed/MedLine, The Cochrane Library, SciVerse Scopus, Embase e Web of Science. Os estudos incluídos foram estudos que avaliaram a redução na microinfiltração de dentes tratados endodonticamente quando colocado uma barreira intraorifício com qualquer material. Somente foram incluídos estudos in vitro publicados no idioma inglês. Um total de vinte e nove estudos in vitro foram incluídos na síntese qualitativa, e seis deles foram incluídos nas análises quantitativas. A maioria dos estudos incluídos utilizou uma barreira intraorifício colocada a uma profundidade de 3 mm. A redução da microinfiltração foi observada quando uma barreira intraorifício foi colocada em dentes tratados endodonticamente, independente do material empregado ($p<0,01$). Dentre os materiais utilizados, o agregado de trióxido mineral (MTA) e as resinas compostas apresentaram desempenho semelhante quanto à redução da microinfiltração ($p>0,05$), sendo ambos superiores estatisticamente ao subgrupo cimento de ionômero de vidro ($p<0,01$). Apesar de ensaios clínicos randomizados e bem delineados serem necessários, os resultados in vitro demonstraram que a colocação de uma barreira intraorifício pode reduzir significativamente a microinfiltração em dentes tratados endodonticamente, e o uso de biocerâmicos ou resinas compostas parecem ser os melhores materiais disponíveis para essa finalidade.

Palavras-chave: barreira intraorifício. microinfiltração. dentes tratados endodonticamente. revisão sistemática

Abstract

ARAÚJO, Lucas Peixoto de. **Intraorifice barrier in endodontically treated teeth: a systematic review and meta-analysis of in vitro studies.** Advisor: Evandro Piva. 2021. 71f. Dissertation (Masters in Clinical Dentistry with emphasis on Endodontics) – Postgraduation Program in Dentistry. Federal University of Pelotas, Pelotas, 2021.

The conventional endodontic treatment has the disinfection of the root canal system with adequate sealing of the endodontically treated teeth as its final objective. Adequate coronal sealing plays a fundamental role in the success of endodontic treatment. Thus, the main objective of this study was to evaluate, through a systematic review of the in vitro literature, the effectiveness of different materials used as an intraorifice barrier in reducing coronal microleakage of endodontically treated teeth. Two independent and blinded reviewers carried out a comprehensive search in five electronic databases: PubMed / MedLine, The Cochrane Library, SciVerse Scopus, Embase, and Web of Science. Eligible studies were studies that evaluated the use of an intraorifice barrier in endodontically treated teeth with any material of choice in reducing microleakage. Only in vitro studies published in English were included. A total of twenty-nine in vitro studies were included in the qualitative synthesis, and six of them were included in the quantitative analyses. Most of the included studies placed an intraorifice barrier at a depth of 3 mm. The microleakage reduction was observed when an intraorifice barrier was placed on endodontically treated teeth, regardless of the material used ($p \leq 0,01$). Among the materials, the mineral trioxide aggregate (MTA) and the composite resins showed similar performance in reducing microleakage ($p > 0,05$), both being statistically superior to the glass ionomer cement subgroup. Although well-designed randomized clinical trials be required, the in vitro results showed that the placement of an intraorifice barrier can significantly reduce microleakage in endodontically treated teeth, and the use of bioceramics or composite resins as intraorifice barriers seems to be the best avaiable materials for this purpose.

Keywords: intraorifice barrier, microleakage, endodontically treated teeth, systematic review

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Sumário

1 Introdução

Um selamento coronal adequado é fator decisivo para a prevenção da reinfecção pós-operatória (RAY, TROPE, 1995) em endodontia sendo que vários estudos destacam esse papel essencial na cicatrização periapical (NG et al, 2008; GOMES et al, 2015; KIRKEVANG et al, 2006; SIQUEIRA et al, 2005). No entanto, a contaminação microbiológica pode levar à falha no tratamento endodôntico por falhas na interface de restaurações temporárias ou definitivas (SIQUEIRA et al, 2008). Além disso, restaurações em resinas compostas podem falhar em até 12,4% dos casos (DEMARCO et al, 2011), sendo que as restaurações de Classe II têm um risco relativo de falha de 2,8 contra restaurações de Classe I, e esse risco é ainda maior quando mais superfícies estão envolvidas (DA ROSA et al, 2006). Além disso, a falha de restaurações adesivas como fratura, perca do material ou microinfiltração, é um problema significativo, pois é um dos principais fatores relacionados à sobrevivência de dentes tratados endodonticamente (NG et al, 2008; OLCAY et al, 2018). Assim, o uso de uma barreira intraorifício foi sugerida por Roghanizad e Jones (1996) com o objetivo de prevenir a contaminação bacteriana nos casos em que a restauração está em condições inadequadas, aumentando assim as possibilidades de previsibilidade a longo prazo do sucesso da terapia endodôntica.

A técnica de utilização de barreira intraorifício consiste em remover aproximadamente 3,0 mm da guta-percha coronária imediatamente após o término da obturação do canal radicular e preencher o espaço resultante com um material restaurador coronário. Vários materiais têm sido descritos na literatura como opções para essa técnica; e os mais comumente relatados são

cimento de ionômero de vidro, resina composta, agregado de trióxido mineral ou cimentos de fosfato de zinco. As características ideais de um material a ser utilizado como barreira intraorifício devem ser: fácil de manusear, com adesão à estrutura dentária, que evite a contaminação bacteriana, ser distinguível do dente natural e não interferir na adesão da restauração final (WOLCOTT et al, 1999).

Dessa forma, o objetivo principal deste estudo foi avaliar, por meio de uma revisão sistemática da literatura, a eficácia de diferentes materiais utilizados como barreira intraorifício na microinfiltração de dentes tratados endodonticamente. A hipótese testada foi que uma diferença significativa seria detectada na microinfiltração de dentes tratados endodonticamente com barreira intraorifício quando comparados ao grupo controle sem a barreira intraorífício.

2 Projeto

2.1 Introdução

No início dos anos de 1990, derivados do cimento Portland obtidos após purificação ou sintetizados em laboratório, passaram a ser utilizados como biomaterais ósseo-indutores ou no reparo de tecidos dentais e tem demonstrado excelentes resultados ao longo do tempo, com alta taxa de sucesso clínico (RASARATNAM, 2016). O primeiro cimento biocompatível a base de silicato de cálcio foi introduzido pela primeira vez na odontologia em 1993, quando foi desenvolvida uma nova formula, para a fabricação de um material nomeado agregado de trióxido mineral ou MTA. Este material foi composto principalmente de silicato tricálcico, silicato de di-cálcio, aluminato tri-cálcico e aluminoferrita tetra-cálcico, além de sulfato de cálcio e óxido de bismuto (LEE; MONSEF; TORABINEJAD, 1993).

O MTA tem sido um material revolucionário na área de endodontia e cirurgia. Desde a sua introdução, vários estudos demonstraram seu uso em várias aplicações clínicas (TAWIL; DUGGAN; GALICIA, 2015), entre as quais destacam o capeamento pulpar direto e indireto, pulpotomía, reparo de perfurações, selador de canais radiculares, reparo de reabsorções dentárias, fratura de raízes e revascularizações (MACWAN; DESHPANDE, 2014).

Este material também tem sido modificado com a finalidade de melhorar algumas características que não são desejáveis para algumas aplicações clinicas. Os primeiros produtos baseados em MTA apresentavam uma coloração cinza, o que gerou preocupações pela possibilidade de corar de forma permanente os tecidos dentários, neste sentido, em 2002, desenvolveu-se uma versão branca de MTA, que era muito parecida quimicamente ao comercial de coloração cinzenta, porém com redução do percentual de óxidos de alumínio ou de C_2A (DAMMASCHKE et al., 2005) conceitual. Outros dos principais inconvenientes desse material é que o tempo que precisava para endurecer, 3-4 horas, tornava seu uso dificultado para procedimentos restauradores. Para solucionar este problema, formulações como MTA Repair HP (Angelus, Londrina, Brasil) e Biodentine (Septodont, Saint-

Maur-des-Fossés, Francia) foram desenvolvidas até obter um tempo de pressa relativamente curto (cerca de 12 minutos). Nos últimos anos, uma quantidade de cimentos endodônticos bioativos à base de silicato de cálcio foram adicionados ao mercado mundial com diferentes características e composições químicas, mas com propriedades semelhantes às do MTA, que tentam suprir as dificuldades como tempo de presa, descoloração dentária, alto custo e dificuldade de manuseio do cimento (PARIROHK et al, 2018).

O período durante o qual um material cumpre com seu uso pretendido é definido como shelf-life (WOO et al., 1996), durante este período, é esperado que o material apresente propriedades físico-químicas desejáveis para a sua correta aplicação. Com o propósito de determinar o período de vida útil de um material, e deste modo atribuir à ele uma data de validade, existem uma série de parâmetros diferentes que devem ser considerados. Um dos primeiros conceitos a considerar é que antes de chegar ao púbico alvo final, um produto deve ser muitas vezes esterilizado (utilizado algum tipo radiação ionizante), enviado através de vários canais de distribuição e sujeito a armazenagem de prateleiras em diferentes condições ambientais, sob estas condições, algumas alterações podem acontecer em um produto e, portanto, afetar seu desempenho (CLARK, 1991). Baseado nisso, os fabricantes de produtos odontológicos normalmente estipulam uma data de validade de aproximadamente 2 anos, após esse período é de se esperar que os materiais apresentem características físico-química não desejadas ou abaixo dos padrões normais (CUEVAS-SUÁREZ et al, 2019).

A vida útil de um dispositivo médico depende principalmente dos componentes dele, e de como eles reagem às condições de armazenamento como temperatura, luz e umidade, pois todos estes fatores podem influenciar as propriedades funcionais do material. De maneira geral, o produto deve ser analisado para determinar se é suscetível a algum tipo de degradação que levaria à falha funcional e ao nível de risco que a falha apresentaria (CLARK, 1991).

2.2 Justificativa

Como qualquer outro material para uso dentário, os materiais a base de biocerâmicos requerem de uma vida útil para garantir que suas propriedades físicas e mecânicas originais permaneçam iguais pelo menos até a data de validade (SAKAGUCHI; POWERS, 2012). Apesar de esses processos de degradação estarem bem documentados, a questão de quais propriedades são afetadas por esses processos, especialmente quanto ao tempo necessário para que ocorram ainda permanecem, sem nenhum estudo publicado na literatura científica até o momento.

2.3 Objetivo

2.3.1 Objetivo geral

O objetivo deste estudo é estabelecer e validar um protocolo de envelhecimento acelerado com fim de determinar o shelf-life e o prazo de validade de materiais odontológicos biocerâmicos, monitorando a estabilidade de diversas propriedades deles ao longo do tempo.

2.3.2 Objetivos específicos

- Identificar normativas, agências e normas técnicas nacionais e internacionais para a determinação do prazo de validade de materiais biocerâmicos de uso odontológico.
- Identificar os materiais biocerâmicos de maior demanda no mercado.
- Determinar um método de avaliação do prazo de validade que atualmente as indústrias odontológicas colocam nos materiais biocerâmicos disponíveis no mercado brasileiro.
- Caracterizar e avaliar inicialmente os materiais biocerâmicos a serem testados quanto a: microscopia eletrônica de varredura, difração de raios X, determinação de tamanho de partícula, resistência compressiva, tempo de presa, radiopacidade, espessura de película, escoamento e sorção e solubilidade
- Executar os protocolos de armazenagem a serem validados nos diferentes materiais biocerâmicos a serem testados.

- Caracterizar e avaliar periódicamente as propriedades selecionadas dos diferentes materiais biocerâmicos a serem testados.
- Elaborar um guia para avaliação do shelf-life e prazo de validade de materiais biocerâmicos para a sua distribuição entre as indústrias odontológicas com presença no Brasil.
- Organizar um Webinar sobre os ensaios químico-mecânicos e protocolos de armazenagem a serem realizados para determinação do prazo de validade de materiais biocerâmicos de uso odontológico.

2.3 Metodologia

O presente estudo visa caracterizar química e mecanicamente diferentes materiais para uso odontológico em função dos seguintes fatores: Modo de armazenagem: armazenagem em câmara climática com temperatura e umidade controladas e tipo de material avaliado: cimento hidráulico de silicato de cálcio para uso odontológico.

Serão realizados testes padronizados pela normativa da *International Organization for Standartization* ISO 6876:2012 e também da normativa de número 57 da *American Dental Association* (ADA) que regulam os testes para cimentos endodônticos a serem realizados que são: escoamento, radiopacidade, solubilidade, tempo de presa, tempo de trabalho e espessura de película. Serão também avaliados o pH e a liberação de íons de cálcio

Dentre os materiais a serem testados, serão escolhidos aqueles que contam com distribuição mundial e que estão consagrados na literatura como referência em estudos de alto impacto. A tabela 1 descreve os diferentes tipos de materiais que serão testados e manipulados de acordo com as recomendações do fabricante, que deverão apresentar data de fabricação não superior a 6 meses do inicio das avaliações.

Tabela 1. Informações de composição, validade, lote e período de shelf-life dos materiais.

Material	Fabricante	Composição	Validade*	Lote nº(*)	Shelf-life
MTA	Angelus®	Pó: Silicato tricálcico, silicato dicálcico, aluminato tricálcico, cal livre e óxido de bismuto. Líquido: Água destilada			
MTA Fillapex	Angelus®	Pasta base: Resina salicilato, resina natural, tungstato de cálcio, sílica nanoparticulada e pigmentos. Pasta catalisadora: Resina diluente, mineral trióxido agregado, sílica nanoparticulada e pigmentos.			
AH Plus	Dentsply Sirona®	Pasta base: Resina epóxi bisfenol-A, resina epóxi bisfenol-F, tungstato de cálcio, óxido de zircônio, sílica, pigmentos de óxido de ferro. Pasta catalisadora:, *Dibenzyldiamine , aminoadamantane, tricyclodecane-diamine,* tungstato de cálcio e óxido de zircônio.			
Bio-C Sealer	Angelus®	Silicato tricálcico, silicato dicálcico, aluminato tricálcico, óxido de cálcio, óxido de zircônia, óxido de silício, polietilenoglicol, óxido de ferro			
Bio-C Repair	Angelus®	Silicato de cálcio, óxido de cálcio, óxido de zircônio, óxido de ferro, dióxido de silício e agente dispersante			
Sealer Plus BC	MK Life®	Silicato tricálcico, silicato dicálcico, aluminato tricálcico, óxido de cálcio, óxido de zircônia, óxido de silício, polietilenoglicol, óxido de ferro			

(*) As informações de validade e lote serão registradas posteriormente à aquisição dos materiais.

1.3.1. Protocolo de armazenamento.

Os materiais serão removidos da embalagem original e armazenados em tubos falcon de 50ml e submetidos a um protocolo de armazenamento acelerado de acordo com o modelo de Arrhenius (CLARK, 1991): $r = Q_{10}^{(RT-AT/10)}$ onde r é o envelhecimento acelerado, AT é a temperatura de armazenamento recomendada pelo fabricante, RT é a temperatura aumentada, e Q_{10} é a constante de coeficiente de reação, equivalente a 2. O período de tempo de armazenamento será estabelecido de acordo com uma pesquisa de mercado realizada avaliando o tempo de validade em média dos diferentes produtos comerciais disponíveis no mercado. Durante este período, algumas propriedades químico-mecânicas serão monitoradas em tempos diferentes, sendo que, a primeira avaliação será feita uma vez recebido o produto, e a avaliação final será feita quando o produto estiver dentro do primeiro mês após o tempo da validade estabelecido pelo fabricante.

A frequência das demais avaliações estará baseada no estabelecido pela normativa Q1A(R2) do Conselho Internacional para harmonização de requisitos técnicos de produtos farmacêuticos para uso humano (INTERNATIONAL COUNCIL FOR HARMONISATION OF TECHNICAL REQUIREMENTS FOR PHARMACEUTICALS FOR HUMAN USE, 2003). O tempo de armazenamento dentro da câmara e as avaliações serão estabelecidas de acordo com o modelo proposto acima. Por exemplo, de acordo com o modelo de Arrhenius, um período de 6 meses a 40 °C, equivalem a um período de armazenagem de 18 meses a temperatura ambiente (~25 °C).

1.3.2. Caracterização dos materiais biocerâmicos.

2.3.2.1 Microscopia eletrônica de varredura e espectroscopia de energia dispersiva.

A microscopia eletrônica de varredura é utilizada para observar e analisar as propriedades estruturais da amostra, fornecendo informações sobre sua

morfologia. O microscópio eletrônico de varredura é um instrumento capaz de produzir imagens de alta resolução com aumentos de até 300.000 vezes.

As amostras dos diferentes materiais biocerâmicos serão examinadas por intermédio de microscopia eletrônica de varredura (Shimadzu SSX 550, Simadzu, Japan) do centro de Microscopia da UFPel, a 15kV, modo de elétrons secundários e a baixo vácuo a fim de analisar a morfologia e topografia das partículas que conformam os distintos materiais.

2.3.2.2 Determinação do tamanho de partícula

A determinação do tamanho médio de partícula será determinada através de medições de potencial zeta.

O potencial zeta é uma medida da magnitude da repulsão ou da atração eletrostática ou das cargas entre partículas, sendo um dos parâmetros fundamentais que afetam a estabilidade do material. A determinação da carga de superfície de amostras será realizada utilizando um instrumento Zetasizer Nano ZS (Malvern Instruments Ltd., Reino Unido), operando com laser de 633 nm, utilizando células zeta descartáveis.

2.3.2.3 Avaliação da resistência compressiva.

A resistência compressiva será avaliada conforme ao estabelecido na normativa ISO 9917-1:2007. Após a manipulação, o material será colocado em moldes de aço inoxidável (4 mm x 6 mm). 120 s após o fim da mistura, o molde será transferido para uma estufa a 37 °C durante uma hora. Os espécimes (n=10) serão removidos do molde, e imersos em água destilada e mantidos a 37 °C durante 24 horas. Decorrido esse tempo, cada amostra será colocada em uma máquina universal de ensaios mecânicos e uma carga de compressão será aplicada ao longo do eixo da amostra. A força máxima aplicada será registrada e a resistência à compressão (C) calculada em Megapascal de acordo com a seguinte fórmula: $C= 4P / \pi D^2$, onde o “P” representou a carga máxima registrada pela máquina em Newtons (N), “D” o diâmetro da amostra em milímetros (mm) e “C” a carga máxima em MPa.

2.3.2.4 Determinação do tempo de presa.

Os cimentos serão manipulados de acordo com as instruções do fabricante (n = 3) e colocados em anéis de alumínio para os cimentos que não requerem de úmidade para a presa (2 mm x 10 mm) e serão confeccionados moldes de gesso para os cimentos que necessitam de úmidade (1 mm x 10 mm) onde serão armazenados em câmara climática à 37º C e 95% de umidade relativa do ar por 24 hroas, de acordo com as recomendações da ISO 6876:2012. O controle do processo de endurecimento será feito com uma agulha de Gilmore com massa de 100 gramas e 2 mm de diâmetro. A agulha será baixada verticalmente sobre a superfície da amostra, repetindo-se este procedimento em intervalos de sessenta segundos até que a agulha não deixe marcas na superfície. Os valores médios serão calculados e considerados como o tempo de presa.

2.3.2.5 Radiopacidade

Será avaliada pela ISO 6876:2012, que determina que a radiopacidade seja verificada medindo a densidade radiográfica óptica equivalente a mesma espessura do alumínio. Cinco espécimes por grupo serão avaliados. Um milímetro de dentina tem a mesma radiopacidade de um milímetro de alumínio, portanto se faz necessário uma radiopacidade de no mínimo três milímetros de alumínio para cimentos biocerâmicos (TANOMARU-FILHO et al., 2013; PRÜLLAGE et al., 2016; ANSI/ADA 2000).

As amostras serão colocadas em uma placa acrílica com orifícios de diâmetro de 5 mm e 1 mm de altura sobre uma placa de vidro com superfície lisa. Sobre o conjunto será pressionada uma célula de quartzo de 1 cm revestida com uma tira de papel celofane e será padronizada a espessura das amostras de cimento até atingir três vezes o tempo necessário para atingir a presa de acordo com a recomendação do fabricante. As amostras serão posicionadas no centro da placa de fósforo Plus VISTA Scan (Dürr dental, RS, Brasil) em conjunto com a escala de alumínio (Odeme Dental Research, SC, Brasil).

O conjunto será irradiado com um aparelho de raios-X intra oral (Saevo, Ribeirão Preto, SP, Brasil) com o feixe central incidindo perpendicularmente à superfície do sensor digital, utilizando 70KV e 7mA a uma distância de 300mm por 0,2s de tempo de exposição.

Após a captura a imagem será analisada e comparada à densidade da imagem da amostra da escala de alumínio usando o software CorelDRAW® (Corel Corp) sendo feita a determinação da densidade radiográfica (radiopacidade) dos materiais através dos níveis de cinza avaliados no histograma.

2.3.2.6 Escoamento

O teste de escoamento será realizado de acordo com a ISO 6876:2012, onde cada cimento (n=5) deve ser manipulado de acordo com a recomendação do fabricante obtendo-se um volume de 0,5 mL. Cada cimento é inserido no centro de uma placa de vidro, e depois de 3 minutos do início da manipulação, é colocado sobre o cimento uma placa de vidro pesando 20g e uma carga de 100g, gerando um peso total de 120g. Após 10 minutos, o peso adicional é removido e mede-se os diâmetros maiores e menores dos discos por meio de um paquímetro digital. A normativa 57 da ADA recomenda que, cimentos endodônticos devem ter um diâmetro mínimo de 20 mm de escoamento.

2.3.2.7 Sorção e Solubilidade

O ensaio de sorção e solubilidade será adaptado da ISO 6876:2012 e de estudos prévios (VITTI et al., 2013; DA ROSA et al., 2018; ALMEIDA et al., 2018). Os espécimes (n=10) serão colocados em moldes de 6 mm de diâmetro e 1 mm de altura. Após a tomada de presa os cimentos são removidos dos moldes e limpos de qualquer partícula solta na superfície. As amostras serão pesadas em balança analítica até obter uma massa constante (m_1) e depois inseridas de forma suspensa em tubos Falcon fechados com 50 ml de água destilada por 7 dias (168h). Após os 7 dias, os corpos de prova são removidos dos frascos, lavados suavemente e secos com papel absorvente para pesar e obter uma nova massa (m_2), depois colocados em um desumidificador por 24h, e depois pesados

novamente (m_3). A solubilidade é determinada em porcentagem do peso original, calculando seguindo a fórmula (SL= [(m1 – m3)/m3] x 100) e a sorção (SR= [(m2 – m3)/m3] x 100). A normativa de número 57 da ADA recomenda que, cimentos endodônticos não devem exceder 3% em massa quando a solubilidade do material é testada.

2.3.2.8 Espessura de película

A espessura de película será avaliada de acordo com a ISO 6876:2012. SerAO confeccionadas duas placas de vidro com 5 mm de espessura medindo 15 x 15 mm de comprimento e com uma área de contato de 200 mm^2. Primeiramente, com um paquímetro digital foi aferida a espessura das duas placas de vidro sobrepostas. Os cimentos (n=5) foram manipulados e, com uma seringa, será depositado 0.05 mL do cimento no centro de uma das placas. Logo após, a outra placa será colocada sob o cimento. Após 3 minutos, uma carga vertical de 150 N será aplicada sob as placas contendo o cimento. Após 10 minutos do começo da manipulação do material, a espessura das duas placas com o material vai ser aferida com um paquímetro digital. A espessura de película é calculada pela diferença entre a espessura das placas com e sem o cimento.

2.3.2.9 Determinação do pH

A avaliação do potencial hidrogênico (pH) será realizada com um peagômetro digital (608 Analion PM Plus, Ribeirão Preto, SP, Brazil) calibrado com soluções tampões de referência. Serão confeccionados moldes de 5 mm de diâmetro e 1 mm de altura para cada grupo de amostras (n = 3). Todos os espécimes serão armazenados individualmente em tubos Eppendorf contendo 1 ml de água destilada e incubados à 37º C durante o teste.

2.3.2.10 Determinação da liberação de íons cálcio

A liberação de íons cálcio será avaliada em intervalos de tempo de 3h, 24h, 72h, 7 dias e 15 dias utilizando um medidor avançado de pH/Mv/ISE

(HI5222-01, HANNA Instruments, SP, Brasil). As amostras (n = 3) serão inseridas em moldes de 5 mm de diâmetro e 1mm de altura e armazenadas em 1.5 ml de água Milli-Q incubadas à 37º C durante o teste.

2.3.3 Análise Estatística

Para a análise estatística de cada ensaio será utilizado o software SigmaPlot 12 (Systat Inc, San Jose, CA, EUA) com 5% de significância.

2.4 Orçamento

Tabela 2 – Orçamento do estudo

Descrição	**Quantidade**	**Preço unitário (R$)**	**Preço total (R$)**
Folha A4	4 pacotes de 500 folhas	18,00	72,00
Impressão	2000	0,10	200,00
MTA Fillapex	5	85,00	425,00
AH Plus	5	300,00	1500,00
Bio-C Sealer	20	110,00	1900,00
Bio-C Repair	20	250,00	5000,00
Biodentine	5	450,00	2250,00
MTA Angelus	5	235,00	1175,00
		TOTAL	16.217,00

2.5 Cronograma

Tabela 3 – Cronograma do estudo

	2019								**2020**								
	Mês								**Mês**								
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Revisao de literatura	x	x	x	x		x	x	X	X	X	X	x					
Projeto			x	x	x												
Qualificação					x												
Testes							x	x	x	x	x	x	x				
Análise dos resultados											x	x	x	x			
Redação											x	x	x	x	x	x	
Defesa																	x

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3 Relatório do trabalho de campo

O objetivo desse relatório é apresentar as etapas que envolveram o trabalho de campo do estudo de dissertação desenvolvido durante o mestrado. O projeto de pesquisa referente a esta dissertação foi qualificado em 8 de setembro de 2019 intitulado “Avaliação da estabilidade química e mecânica de materiais odontológicos biocerâmicos como determinante do estabelecimento de prazo de validade e validação de protocolo shelf-life”, e aprovado pela Banca Examinadora composta pelos Professores Doutores Evandro Piva, Rafael Guerra Lund, Eliseu Aldrighi Münchow, e Alvaro Henrique Borges (suplente).

Devido à pandemia do vírus Sars-CoV-2, as atividades presenciais na Universidade Federal de Pelotas foram suspensas no dia 13 de março de 2020, período no qual o projeto qualificado ainda estava em fase de calibração, pré-testes e aquisição de insumos, sendo que tal suspensão foi prorrogada indeterminadamente devido ao agravamento da pandemia. Por ser um estudo laboratorial houve a impossibilidade de realizar os testes de forma presencial, tendo em vista que o mesmo envolvia diversas etapas a serem desenvolvidas no Centro de Desenvolvimento e Controle de Biomateriais da UFPel com o amparo de técnicos do laboratório. Alternativamente, foi realizado um novo projeto de pesquisa no campo da revisão sistemática, de forma a manter as atividades científicas remotamente e que minimizasse a exposição aos riscos infecto-contagiosos nesse período de pandemia. A nova temática objetivou observar através de uma revisão sistemática e meta-análise o efeito da barreira intra-orifício em dentes tratados endodonticamente in vitro

4 Artigo

Intraorifice barrier in endodontically treated teeth: A systematic review and meta-analysis of in vitro studies[1]

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ABSTRACT

Introduction: The main objective of this study was to evaluate through a systematic review and meta-analysis the efficacy of different materials as an intraorifice barrier on coronal microleakage of endodontically treated teeth in vitro. **Methods:** Two independent and blinded reviewers carried out a comprehensive search in five electronic databases: PubMed/MedLine, The Cochrane Library, SciVerse Scopus, Embase, and Web of Science. Eligible studies were studies that evaluated the use of an intraorifice barrier in endodontically treated teeth in reducing microleakage with any material of choice and with any methods employed. Only in vitro studies published in English were included. **Results:** A total of twenty-nine in vitro studies were included in the qualitative synthesis, and six of those were included in the quantitative analyses evaluating the following materials: mineral trioxide aggregate (MTA), glass-ionomer cement (GIC), and composite resin (CR). Most of the included studies placed an intraorifice barrier at a depth of 3 mm. Reduction in microleakage was observed when an intraorifice barrier was placed, irrespective of the material employed ($p \leq 0.01$). Among the materials, MTA and CR performed similarly ($p > 0.05$), both being statistically superior to the GIC subgroup ($p \leq 0.05$). **Conclusions:** Although well-designed randomized clinical trials are required, the in vitro results showed that the placement of an intraorifice barrier can significantly reduce microleakage in endodontically treated teeth, and the use of bioceramics or composite resins as intraorifice barriers seems to be the best available materials for this purpose.

Keywords: Intraorifice barrier. Microleakage. Endodontically treated teeth. Systematic review

1. Introduction

The conventional endodontic treatment has the disinfection of the root canal system with adequate sealing of the endodontically treated teeth as its final objective. An adequate coronal restoration prevents post-operative re-infection (1,2), and several studies reported its essential role in the healing of periapical radiolucencies (2–5). However, microbiologic contamination can lead to the failure of endodontically treated teeth through faults in the sealing ability of the temporary or definitive restoration (6). Furthermore, composite resins placed on teeth can fail in up to 12.4% of the cases (7), and Class II restorations have a relative risk of failure of 2.8 against Class I, and this risk is even higher when more surfaces are involved (8). Failure of adhesive restorations due to caries development, fracture, or marginal infiltration is of significant concern since it is one of the major factors related to the survival of endodontically treated teeth (2,9). Thus, the use of an intraorifice barrier (IOB) was primarily suggested by Roghanizad and Jones (1996) (10) with the purpose of preventing bacterial contamination in cases that the restoration is in an inadequate condition, enhancing the possibilities for predictable long-term success in endodontic therapy.

The technique consists of removing approximately 3,0 mm of the coronal gutta-percha immediately after finishing the root canal obturation and filling the resulting space with a restorative material. Several materials have been described in the literature as options for this technique, and the most commonly reported are glass-ionomer cement, composite resin, mineral trioxide aggregate, or zinc phosphate cements. The ideal characteristics of a material to be used as an intraorifice barrier must be: easy to handle, with adhesion to the dental structure, preventing bacterial contamination, to be distinguishable from the natural tooth and which does not interfere with the final restoration adhesion (11).

Since most of the evidence on this topic is based on in vitro studies, the question still remains whether the clinicians should consider placing an intraorifice barrier, and which material is best for this purpose. Nevertheless, even though microleakage studies can not properly simulate the oral environment,

positive laboratory results on reducing microleakage can be expected to perform similarly on adequate clinical conditions (12). Hence, the main objective of this study was to evaluate through a systematic review and meta-analysis the efficacy of different materials as an intraorifice barrier on coronal microleakage of endodontically treated teeth. The hypothesis tested was that a significant difference would be detected on microleakage of endodontically treated teeth with intraorifice barrier placed when compared with the positive control group without the barrier.

2. Methods

2.1. Registration and Research Question

The current systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (13). Due to the study design's nature, the protocol was registered in the Open Science Framework and is available at the following link (osf.io/qxfhy). The research question was as follows: Is the placement of an intraorifice barrier technique able to prevent microbial microleakage on endodontically treated teeth?

2.2. Eligibility criteria

Eligible studies were studies that evaluated the use of an intraorifice barrier in endodontically teeth in reducing microleakage with any material of choice and with any methods employed. Only in vitro studies published in English were included.

The exclusion criteria were studies that evaluated the use of an intraorifice barrier during intracoronary bleaching and when utilized as a barrier for post space preparation.

2.3. Search strategy

A comprehensive search in five electronic databases was carried out: PubMed/MedLine, The Cochrane Library, SciVerse Scopus, Embase, and Web of Science. The search strategy was based on the population-intervention-comparison-outcomes (PICO) strategy as follows: P: endodontically treated teeth, I: intraorifice barrier, C: no intraorifice barrier, and O: microleakage values. The specific terms utilized for the database search were chosen based on the PubMed/Medline MeSH terms as shown in table 1, and it was adapted for the other databases. The studies screened had no limit to the published year. After the identification of these articles, they were imported into Mendeley software (Elsevier, Amsterdam, NE) to remove duplicates. Additionally, the pool of studies was improved by searching the references cited by the included studies, and those were hand examined for any further eligible study.

2.4. Study selection

All articles initially found by the search strategy were screened by title and abstract by two blinded and independent reviewers (LPA and FI) utilizing the web application Rayyan (Qatar Computing Research Institute, Doha, QA) (14). The articles that clearly met the eligibility criteria and those that were uncertain were selected for full-text analysis. The initial interobserver agreement between the two examiners was calculated by Cohen's kappa coefficient ($\kappa = 0.89$). The papers that met all the eligibility criteria were included in this systematic review, and those that had any disagreement between the two reviewers were clarified through discussion with a third reviewer (WLOR).

2.5. Data extraction

Data of interest from the included studies were tabulated and interpreted by two independent reviewers (LPA and FI) in an Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA), and another reviewer (TSA) double-checked it. In case of any missing information, the corresponding author of the included study was contacted via e-mail to retrieve any missing data. If the authors did not receive any answer in two weeks, then a second e-mail was sent.

2.6. Assessment of risk of bias.

Each selected study was assessed for the methodological risk of bias using the revised Cochrane Risk of Bias tool (RoB 2.0). This tool was carefully modified according to an adaptation made from a previous systematic review of in vitro studies (15). Two revisors (LPA and FI) evaluated independently the risk of bias utilizing the following parameters: (1) sample size calculation, (2) samples with similar dimensions, (3) sample teeth were examined under a light stereomicroscope, (4) standardization of instrumentation, obturation, and intraorifice barrier space preparation, (5) comprehensible reporting of the study design, (6) sample were random allocated, (7) presence of a positive and a negative control group, and (8) statistical analysis carried out. If the authors reported the parameter, the article had a "Low risk" on that specific parameter; if it was not possible to find the information, the article received a "High risk".

2.7. Statistical Analysis

The meta-analyses were performed using Review Manager software version 5.4 (The Nordic Cochrane Centre, The Cochrane Collaboration; Copenhagen, Denmark). Initially, the global analysis was carried out using a random-effect method, and the pooled effect estimates were obtained by comparing microleakage means from each material used as an intraorifice barrier and the positive controls (no material used as a barrier). Subgroup analyses were performed considering each material: glass-ionomer cement (GIC), mineral trioxide aggregate (MTA), and composite resin. Additionally, a comparison between materials was performed as it follows: GIC vs. composite resin, GIC vs. MTA, and composite resin vs. MTA. Statistical significance was defined as a P-value ≤ 0.05 (Z test), and the statistical heterogeneity among studies was assessed using the Cochran's Q test, with a threshold P-value of 0.1, and the inconsistency test (I^2), in which values greater than 75% were considered indicative of considerable heterogeneity (16).

3. Results

3.1. Search strategy

The electronic search was conducted until December 20th, 2020, and yielded 1722 potentially relevant records. Figure 1 is a flowchart that summarizes the article selection process according to the PRISMA Statement (13). After removing the duplicates, 1224 articles were screened by titles and abstracts utilizing the web application Rayyan (Qatar Computing Research Institute); 1172 studies were excluded because they did not meet the inclusion criteria, and 52 were held on to full-text analysis. Of these 52 studies, 23 (44%) were not included; of these, 5 (9.6%) evaluated physicochemical characteristics rather than microleakage, 1 (1.9%) was a randomized clinical trial; 2 (3.8%) were in vivo studies; 2 (3,8%) were reviews related to obturation techniques; 2 (3.8%) evaluated the exposure of root canal sealers to human saliva; 9 (17.3%) did not use the barriers as intraorifice barrier but as a coronal base for restorations and 3 (5.7%) assessed the force required to fracture tooth with intraorifice barriers. The remaining 29 (54.7%) studies fulfilled all the inclusion criteria and were included in this review.

3.2. Descriptive analyses

Forty-four different materials were evaluated as an intraorifice barrier in this review, as described in Table 3. Of these, fourteen studies evaluated different types of bioceramic materials (17–30), including 11 ProRoot MTA (Dentsply Sirona, York, PA, USA), 2 MTA Angelus (Angelus, Londrina, PR, BR), 1 EndoCem ZR (Maruchi, Wonju, GO, KR), 1 Biodentine (Septodont, Saint-Maur-des-Fossés, FR), 2 Calcium-enriched Misture (Bionique Dent, Tehran, IR). Twelve studies (10,16,19,21–25,27,29-38) evaluated six different types of glass-ionomer cements and another eight types of resin-modified glass-ionomer cements, six studies (10,22,28,38,41,42) evaluated Cavit (3M ESPE), one (10) evaluated the T.E.R.M (Dentsply Sirona) temporary restorative material, three (10,24,25) evaluated Amalgam (Dentsply Sirona), 4 studies (28,29,36,43) evaluated different types of composite resins, and 10 (17,21,22,25,31,32,38–40,43) evaluated different types of flowable composites. One study (31) evaluated a self-etch, resin-based material CoroSeal (Ivoclar Vivadent), one (23) evaluated a zinc phosphate cement, ZPC Elite (GC America), two (41,43) evaluated IRM (Dentsply Sirona), another two studies (40,41) evaluated Super

EBA (Bosworth Company, IL, USA), two (35,43) evaluated C&B Metabond (Parkell, Brentwood, NY, USA) with polymethyl methacrylate powder and one (43) evaluated Amalgambond Plus (Parkell) also with polymethyl methacrylate powder. Also, another seven studies (20,23,31,32,35,36,40) evaluated different types of luting agents, which were 1 LuxaCore (DMG, Hamburg, DE), 1 DC Core LC (Kuraray), 1 DC Core chemically-cured (Kuraray), 1 Panavia F (Kuraray), 1 MaxCem (KaVo Kerr, Biberach, DE), 2 Principle cement (Dentsply Sirona), 1 Durelon (3M ESPE) and 1 Policarboksilate cement. Figure 2 summarizes the materials used in the included studies.

Among the included studies, United States was the leading country to research the topic (12 out of 29 studies, 41,3%); the sample groups ranged from 30 teeth to 188 teeth with a total of 2061 teeth in all studies and a mean of 71 teeth per study. There is a predominance in the studies samples of single-rooted teeth (24 out of 29 studies, 82%), and the depth of the intraorifice barriers ranged from 1mm to 4mm, with the majority of the studies evaluating the materials in a 3mm depth (15 out of 29 studies, 51%).

Different methodologies to assess microleakage were used (Table 2). Twelve studies evaluated microleakage by dye penetrant inspection with different types of inks (41,3%), four studies evaluated by human saliva penetration (13,7%), six studies evaluated by microbial penetration (20,6%), another six studies evaluated by a fluid filtration method (20,6%), and one evaluated the microleakage through a glucose penetration model (3,4%). The main results of each study are described in Table 3.

3.3 Quantitative Analyses

Meta-analysis was performed with data sets of microleakage from 6 studies, considering the studies that evaluated microleakage through dye penetrant inspection methods. The global analysis using a random-effect model (Figure 3) demonstrated that the use of an intraorifice barrier had a statistically lower microleakage rate than the control groups (-5.45mm, $p \leq 0.01$). Subgroup analysis considering each material versus control also demonstrated that GICs, MTA, and composite resins presented statistically less microleakage rate than the control.

The comparison between materials showed that an intraorifice barrier with composite resin promoted a lower and statistically different microleakage than

GIC ($p \leq 0.05$), and the Cochran's values Q and I^2 test were $p \leq 0.01$ and 93% (Figure 4a). Also, MTA showed a lower and statistically different microleakage than GIC ($p \leq 0.01$), and the values of the Cochran's Q test and I^2 were $p \leq 0.01$ and 98% (Figure 4b). Finally, in the comparison between composite resin and MTA (Figure 4c) no differences were demonstrated between groups ($p=0.3$-, $I^2=98\%$).

3.4 Quality assessment

According to the parameters established for the quality assessment of the included in vitro studies, of the 29 studies included in this analysis, all studies scored poorly for the item 'sample size calculation' and in 20 of them (10,15-16,18-22,24-25,27,29,30,33,35,37–41) was observed a high risk of bias for the item 'sample teeth were examined under a light stereomicroscope for cracks or defects'. In contrast, a low risk of bias was detected in the reminiscent parameter evaluated (Supplementary 1).

4. Discussion

The present systematic review evaluated the efficacy of different materials used as intraorifice barriers to reduce coronal microleakage in endodontically treated teeth. All of the materials tested were statistically superior when compared to the gutta-percha and sealer alone; however, none of the studies showed that any material was capable of entirely prevent microleakage, only to diminish it. The results of our review demonstrated that the placement of an intraorifice barrier at a 3mm depth into the root canal obturation could improve its sealing ability, providing a more considerable period of time to maintain an adequate coronal sealing. The depth of the barrier seems to be an important factor in reducing microleakage, since some studies compared different intraorifice barrier depths, ranging from 1 mm to 4 mm, and usually, when it was placed at a 3mm depth, it had better results than when placed at 1 or 2 mm. Additionaly, a 3mm intraorifice barrier depth performed similarly when placed at a 4mm depth (11,28,33,37,42).

Some factors must be taken into consideration in the obtained results regarding methodological limitations of included studies. One of them is the degree of scientific evidence obtained by the in vitro studies that can not properly simulate the clinical oral environment, including the synergism of oral microflora, salivary pH, and masticatory stress. In the meta-analysis, it was only possible to analyze data from in vitro studies that evaluated microleakage by dye penetrant inspection with thermocycling with different inks used to assess microleakage, which were: methylene blue, rhodamine-b, india ink, and pelikan ink. Although it is easy to perform and do not require sophisticated equipment, it is a limited methodology to assess the real deepest dye penetration point that may result in an underestimation of leakage (44). Even the bacterial colonization methodologies used to assess microleakage have their own set of limitations because these types of experiment need histological confirmation in order to be valid (45). However, in the present review, it was possible to observe a similiarity of findings between the in vitro studies and in vivo studies that assessed histological findings of the effects of intraorifice barriers on periapical inflammation in dogs (46,47). In one of them (47), it was observed that the experimental group with an intraorifice barrier had 38% of the roots with periapical inflammation against 89% of the control group with gutta-percha and sealer alone, in the other study (46), no significantly different outcome was observed.

Different materials were tested as intraorifice barriers, the most frequently tested included bioceramics, glass-ionomer cements, composite resins, zinc phosphate cements, and others temporary and definitive restorative materials. The use of bioceramics in endodontics is widely appraised for its optimum characteristics regarding biocompatibility, osteoinductive capacity, ability to achieve an excellent hermetic seal due to its hygroscopic expansion capacity, forming a chemical bond with the tooth structure, antibacterial proprieties, and good radiopacity (48–50). The early generations of MTA did not have the ideal characteristics proposed for intraorifice barriers: it had discoloration potential, and it was hard to handle, demanding extra efforts to place it. However, with the recent developments in the bioceramic types of cement, those drawbacks were overcomed (51) by replacing the bismuth oxide radiopacifier with zirconium oxide or calcium tungstate, which do not cause tooth discoloration (52,53), and the handling properties were improved with the introduction of premixed bioceramics,

providing a more homogenous mixture and a putty-like consistency that only sets on an appropriate environment (54). Although none of the included studies that evaluated bioceramic materials as intraorifice barriers used those novel formulations, it can be expected to be easier to handle and place them.

Composite resins are also of daily use in endodontics for restorative procedures. It was suggested as a proper material as an intraorifice barrier due to its excellent bond properties to tooth tissues and the wide range of color palette to differentiate from the tooth color. Still, the biggest concern is with the polymerization shrinkage that can lead to marginal micro-gaps in the barrier interface, compromising the orifice seal. Flowable resin composites are also regarded as a suitable choice for an intraorifice barrier material for their better adaptation to the internal dentin walls; however, the polymerization shrinkage can be higher than the conventional resin composites due to their reduced filler that allows it to have a low viscosity (55). Another limitation of the included studies in this systematic review is that none of them evaluated the barrier with bulk-fill composite resins, which are well-described in the literature to have a reduced volumetric polymerization shrinkage and stress levels (56) and could potentially leak less as an intraorifice barrier. It is also essential to note that composite resins can have their polymerization process interfered with when in contact with eugenol-based sealers; instead, an epoxy-resin sealer is preferred when placing intraorifice barriers with composite resins (57) as observed in a few studies (31,38). Higher concentrations of sodium hypochlorite used to irrigate the root canal system can also impact the sealing ability of intraorifice barriers with resin composites because it affects the organization of collagen in the dentin extracellular matrix, which are crucial to adhesive systems perform adequately (58,59). Moreover, residual NaOCl breaks into sodium chloride and oxygen; the last one has the potential to inhibit the polymerization of adhesive materials (60). Meanwhile, it has been shown that chlorhexidine gluconate has no adverse effects on immediate composite-adhesive bonds in dentin or enamel; it even has been reported that endodontic irrigation with chlorhexidine solution significantly increased the shear bond strength to root dentin, although this mechanism is not yet completely understood, it is suggested that the adsorption of chlorhexidine by dentin may favor the resin infiltration into dentinal tubules (61–63).

Another issue to be considered when using composite resins is that most adhesive systems have acetone in the formulation. Previous studies reported that acetone-based adhesives do not polymerize well on top of gutta-percha because some components from the gutta-percha can interact with it, and this leaching can inhibit the polymerization process (32,64). Although this information seems to be irrelevant to bond coronal restorations, it is an important finding when placing intraorifice barriers because at least 1/3 of the structure to be bonded is coronal gutta-percha.

Even though bioceramics and composite resins are entirely different materials with different properties and our meta-analysis showed a high heterogeneity between the studies, the MTA subgroup was statistically similar to composite resins when used as an IOB. However, it seems that the bioceramics have some advantages against composite resins since it is easily removed with ultrasonic tips and represent less danger of procedure errors when removing it, like root perforation or ledge formation (65). Also, in contrast with composite resins, it has no polymerization shrinkage effect but has a hygroscopic expansion (66), which can potentially benefit the marginal sealability of the IOB.

Glass-ionomer cements also have most of the ideal characteristics initially proposed for IOBs (11). It is a self-adhesive material with satisfactory chemical bonding with root dentine (67), biocompatibility, thermal expansion coefficient close to teeth, and antibacterial activity mainly due to its low pH and fluoride ion release (68). Another option to be considered is the resin-modified glass-ionomer cement that can be easier to place, and its antibacterial activity is also associated with the light-curing by the release of benzine bromine and benzine iodine. One randomized clinical trial (69) evaluated the outcomes of primary root canal treatment using glass-ionomer cement as an intraorifice barrier for twelve months and it was observed no difference in periapical healing of apical periodontitis; however, it is feasible to say that the follow-up time of twelve months is insufficient to observe expressive failures in dental restorations (70), and thus failure of the endodontic treatment due to the lack of an intraorifice barrier providing an additional seal could not be investigated in this timeframe. In the metanalysis, the glass-ionomer cement was able to reduce microleakage when compared to the control group with no barriers. However, when compared to composite resins and

MTA, GICs demonstrated the worst performance in reducing microleakage than other materials.

Although the included studies showed heterogeneity among materials tested and methodologies used to evaluate microleakage, the present findings demonstrated that the placement of an intraorifice barrier can improve the coronal seal of the root canals. Furthermore, based on the results of our meta-analysis, a better seal can be achieved when bioceramics or composite resins are used as intraorifice barriers on endodotically treated teeth.

5. Conclusion

In spite of the fact that well-designed randomized clinical trials are required, the in vitro results showed that the placement of an intraorifice barrier can significantly reduce microleakage in endodontically treated teeth, and the use of bioceramics or composite resins as intraorifice barriers seems to be the best available materials for this purpose. The results of this study should be carefully interpreted since a high heterogeneity was observed among the studies, and the complexity of interpretation on microleakage findings should be taken into consideration. A call for action to carry out more extensive and long-term clinical studies regarding the placement of intraorifice barriers is desired to clinically understand the advantages of this technique.

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Figures and Tables

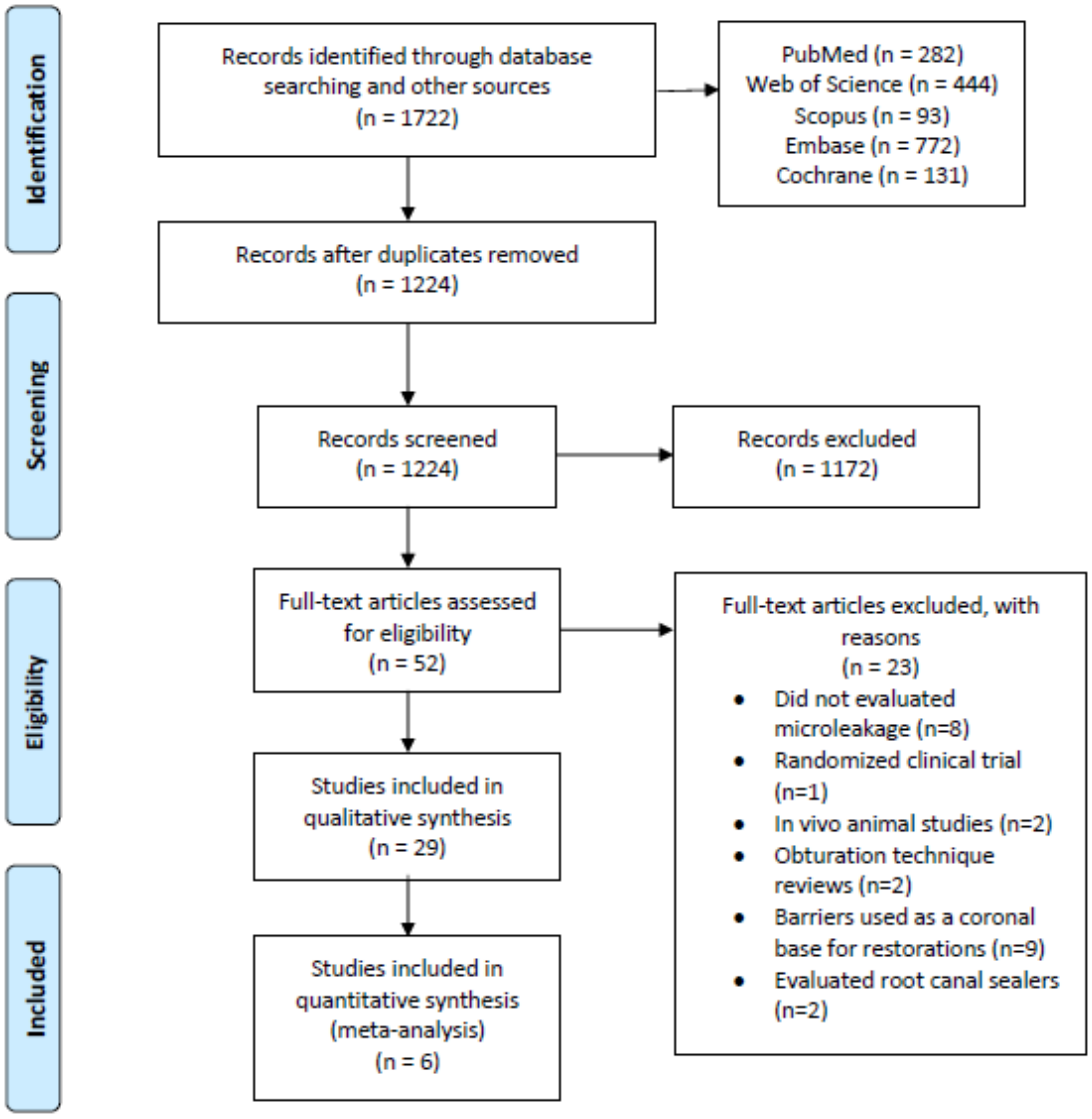


Figure 1. Search flowchart according to the PRISMA Statement.

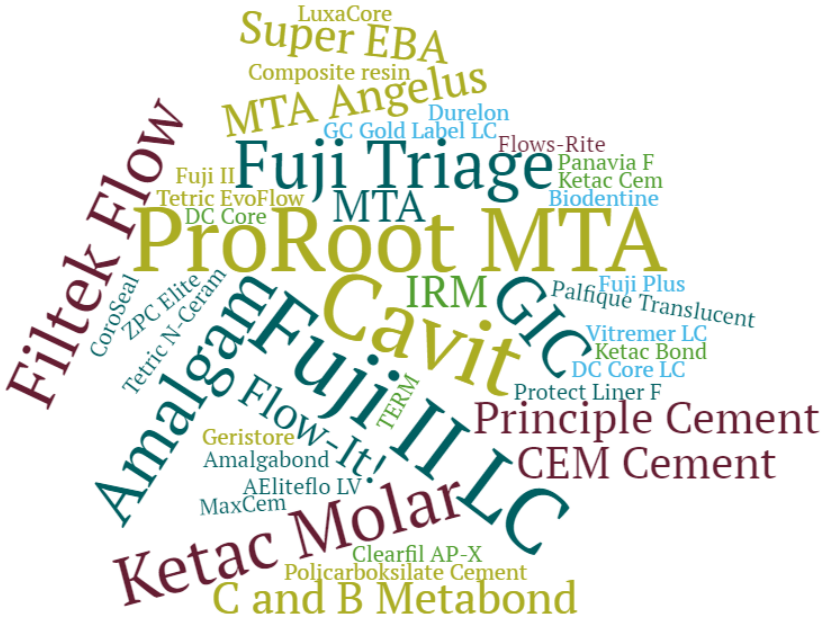


Figure 2. Word cloud representing the materials used as IOBs. The larger font means the materials were used with a greater frequency.

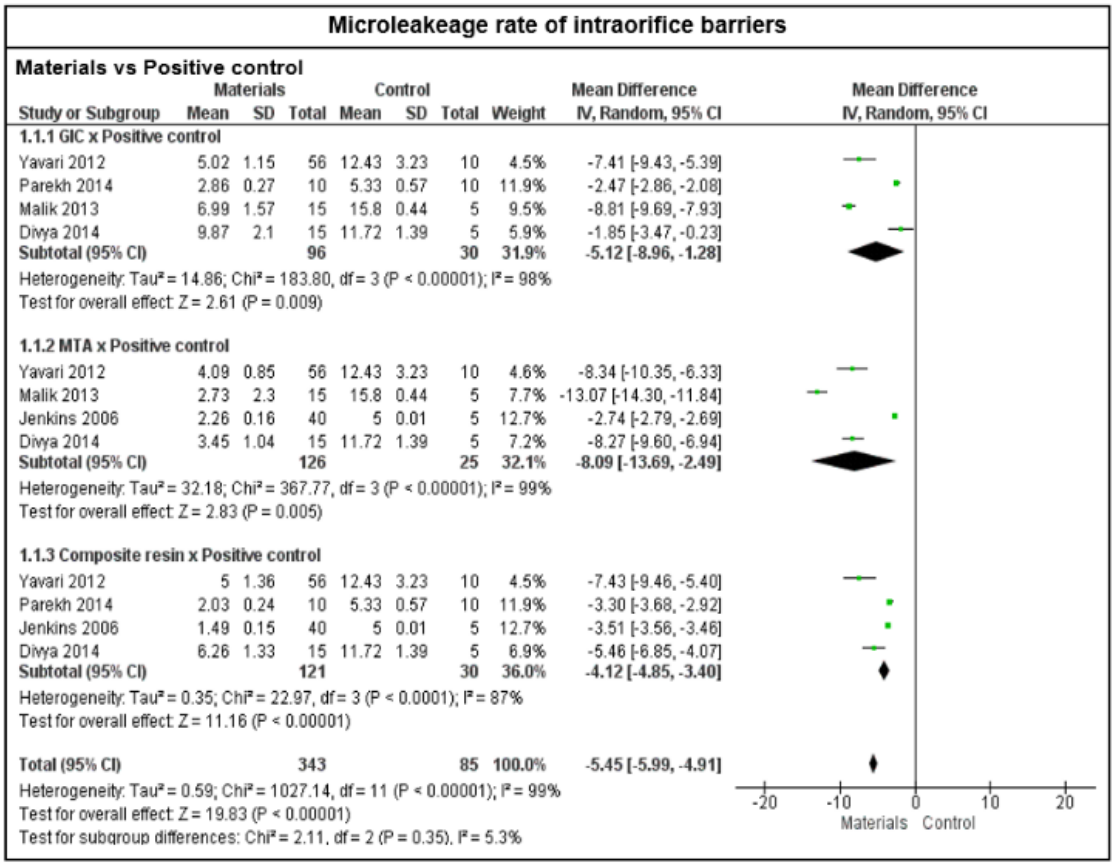


Figure 3. Results for the analysis of the microleakage of different materials against the positive control groups using a random-effects model. All materials used as IBs were significantly different from the control groups ($p \leq 0.05$).

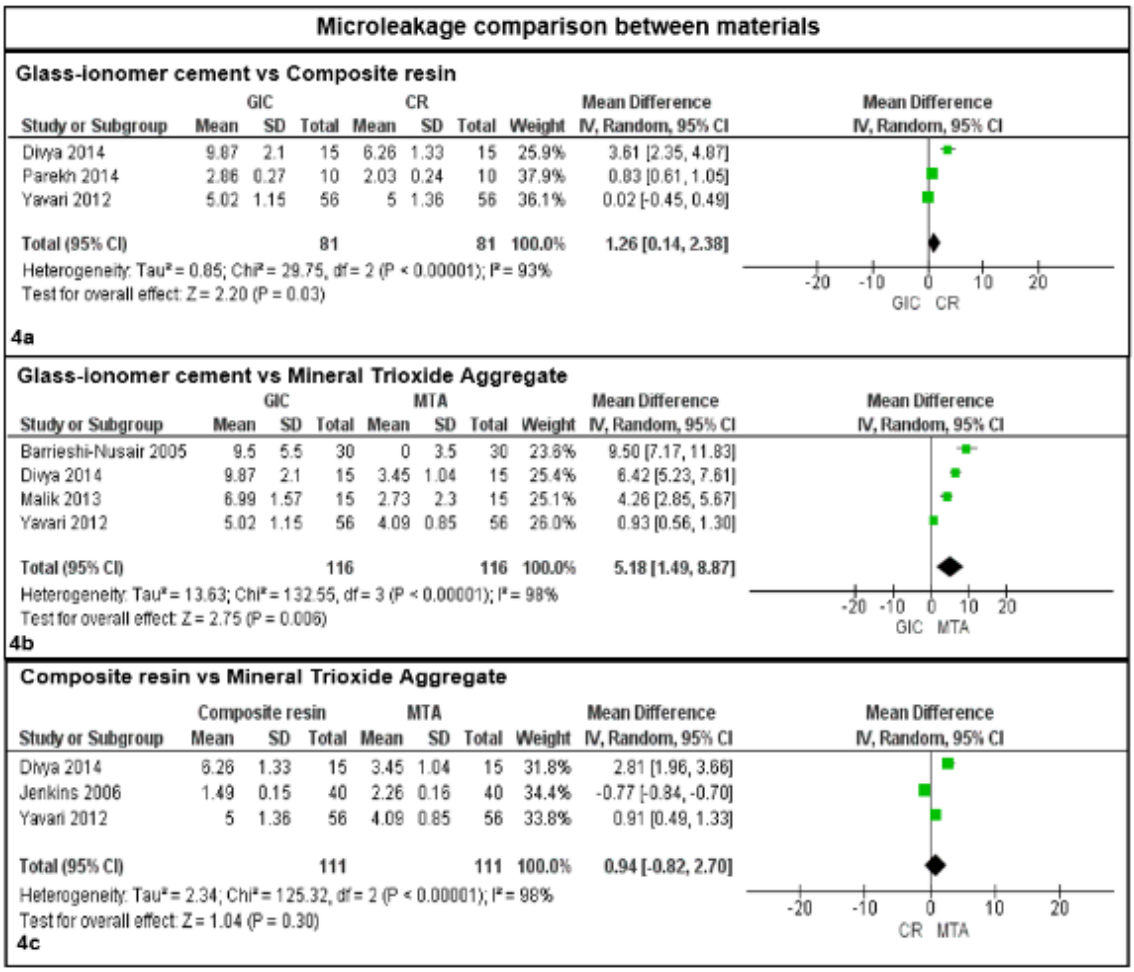


Figure 4. Summary of meta-analysis findings comparing Glass-ionomer cement, Composite Resin, and Mineral Trioxide Aggregate against each other using a random-effects model. The only analysis which showed a statistical difference was Glass-ionomer cement vs. Mineral Trioxide Aggregate, observing a superiority to the MTA ($p \leq 0.05$).

Table 1 – Search strategy used in PubMed (MEDLINE)

	Search Terms
#3	Search #1 AND #2
#2	Seach “Coronal Microleakage” OR “Coronal Sealing” OR “Coronal Seal” OR “Coronal Barrier” OR “Intra-coronal Barrier” OR “Intracoronal Barrier” OR “Intraorifice Barrier” OR “Intra-orifice Barrier” OR “Intraorifice Seal” OR “Intra-orifice Seal” OR “Orifice Seal” OR “Orifice Barrier” OR “Intracanal Barrier” OR “Intra-canal Barrier” OR “Intracanal Sealing” OR “Intra-canal Sealing” OR “Barrier Materials” OR “Cervical Barrier”
#1	Search **“**Tooth, Nonvital” [mesh] OR “Tooth, nonvital” OR “Nonvital Tooth” OR “Tooth, Devitalized” OR “Devitalized Tooth” OR “ Tooth, Pulpless” OR “Pulpless Tooth” OR “Teeth, Pulpless” OR “Pulpless Teeth” OR “Teeth, Devitalized” OR “Devitalized Teeth” OR “Teeth, Nonvital” OR “Nonvital Teeth” OR “Teeth, Endodontically-Treated” OR “Endodontically-Treated Teeth” OR “Teeth, Endodontically Treated” OR “Tooth, Endodontically-Treated” OR “Endodontically-Treated Tooth” OR “Tooth, Endodontically Treated” or “root canal therapy” [mesh] OR “Root canal therapy” OR “Canal Therapies, Root” OR “Canal Therapy, Root” OR “Root Canal Therapies” OR “Therapies, Root Canal” OR “Therapy, Root Canal” OR “Endodontics” [mesh] OR “Endodontics” OR “Endodontology”

Table 2 - Demographic data of the included studies

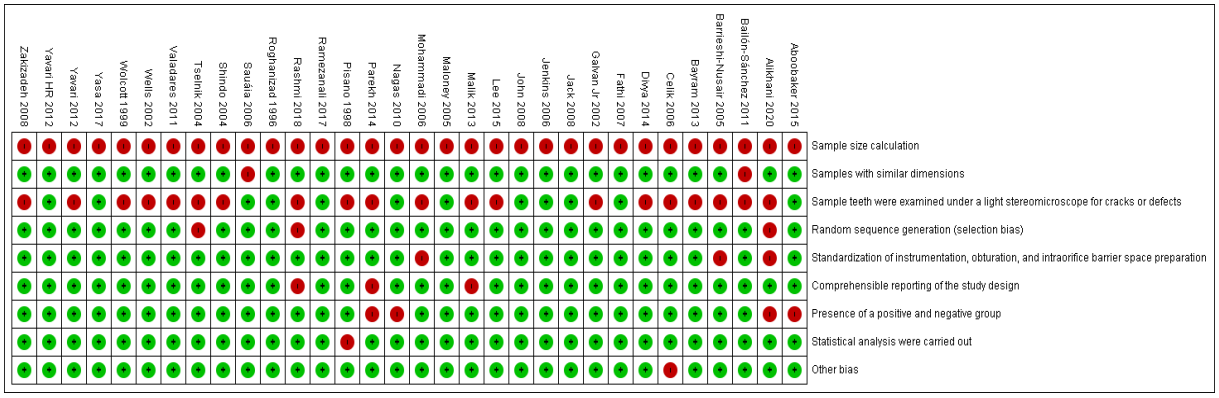
Study	Year	Country	Methodology	Number of teeth (per group)	Tooth group
Roghanizad	1996	United States	2% methylene blue dye penetration	94 (28)	Maxillary incisors
Yavari	2012	Iran	2% methylene blue dye penetration	188 (56)	Single-rooted premolars
Malik	2013	India	2% methylene blue dye penetration	70 (30)	Single-rooted premolars
Lee	2015	South Korea	1% methylene blue dye penetration	70 (10)	Single-rooted premolars
Alikhani	2020	Iran	2% methylene blue dye penetration	45 (15)	Single-rooted teeth
Shindo	2004	Japan	2% methylene blue dye penetration	100 (15)	Single-rooted teeth
Parekh	2014	India	Rhodamine-B dye penetration	40 (10)	Single-rooted premolars
Pisano	1998	United States	Human saliva penetration	74 (20)	Single-rooted teeth
Zakizadeh	2008	United States	Human saliva penetration and Micro-CT evaluation	50 (10)	Single-rooted teeth
Yavari	2012	Iran	Human saliva penetration	70 (15)	Single-rooted premolars
Tselnik	2004	United States	Human saliva penetration	78 (18)	Single-rooted teeth
Wolcott	1999	United States	Proteus vulgaris penetration	110 (25)	Single-rooted teeth
Barrieshi-Nusair	2005	Kuwait	Pelikan ink penetration	70 (30)	Single-rooted teeth
Jenkins	2006	United States	India ink penetration	130 (40)	Single-rooted teeth
Sauáia	2006	Brazil	India ink penetration	80 (20)	Maxillary and mandibular molars
Divya	2014	India	India ink penetration	70 (15)	Single-rooted premolars
Ramezanali	2017	Iran	India ink penetration	76 (22)	Single-rooted premolars
Galvan	2002	United States	Fluid filtration model	52 (10)	Mandibular molars
Wells	2002	United States	Fluid filtration model	62 (15)	Maxillary and mandibular molars
Maloney	2005	United States	Fluid filtration model	30 (10)	Single-rooted premolars
Jack	2008	United States	Fluid filtration model	34 (15)	Single-rooted teeth
John	2008	United States	Fluid filtration model	40 (10)	Single-rooted teeth
Bayram	2013	Turkey	Fluid filtration model	50 (10)	Maxillary incisors
Mohammadi	2006	Iran	Enterococcus faecalis penetration	51 (15)	Single-rooted teeth
Fathi	2007	United States	Enterococcus faecalis penetration	55 (15)	Single-rooted teeth
Valadares	2011	Brazil	Enterococcus faecalis penetration	70 (20)	Single-rooted teeth
Rashmi	2018	India	Enterococcus faecalis penetration	100 (20)	Single-rooted teeth
Celik	2006	Turkey	Sthapylococcus epidermitis penetration	60 (10)	Single-rooted premolars
Bailón-Sanchéz	2011	Spain	Glucose penetration	42 (10)	Single-rooted teeth

Table 3 – Main results of the included studies

Study	Experimental Groups	Intraorifice barrier depth	Control Groups	Main results of the included studies
Roghanizad	Cavit (3M ESPE), TERM (Dentsply), Amalgam (Dentsply)	3 mm	5 positive (no barrier) and 5 negative controls (nail varnish and sticky wax)	A 3mm intraorifice barrier of Amalgam prevented leakage in 96,4% of the cases, and it was significantly better than Cavit and TERM.
Yavari	Flow-It (Pentron), GC Gold Label LC (GC America), ProRoot MTA (Dentsply)	3 mm	10 positive (no barrier) and 10 negative controls (nail varnish and sticky wax)	A 3mm intraorifice barrier of ProRoot MTA was statistically superior to GIC or Composite Resin to minimize recontamination of the remaining gutta-percha.
Malik	Fuji II GIC (GC America), ProRoot MTA (Dentsply)	4 mm	5 positive (no barrier) and 5 negative controls (nail varnish and sticky wax)	A 4mm intracanal plug of ProRoot MTA exhibited a lower mean leakage than Fuji II GIC, and it may be used to minimize microleakage in endodontically treated teeth.
Lee	ProRoot MTA (Dentsply), EndoCem Zr (Maruchi), MTA Angelus (Angelus), LuxaCore (DMG), Fuji II LC (GC America), ZPC Elite (GC America)	3 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	All materials allowed infiltration of dye. However, a 3mm intraorifice barrier of ProRoot MTA showed significantly smaller penetration and less variation than the other materials.
Alikhani	Fuji II LC (GC America)	1, 2, and 3 mm	None	The findings indicated that a 3mm depth of Fuji II LC intraorifice barrier showed the highest preventive effect on coronal microleakage in endodontically treated teeth.
Shindo	Protect Liner F (Kuraray), Panavia F (Kuraray), DC Core light-cured (Kuraray), DC Core chemically cured (Kuraray), Super EBA (Bosworth), Ketac (3M ESPE)	4 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	A 4mm intraorifice barrier of Panavia Liner F and Panavia F had the highest sealing ability than the other materials.
Parekh	Fuji II LC (GC America), Tetric N-Flow (Ivoclar Vivadent), Fuji II LC+Tetric N-Flow	3,5mm	5 positive controls (no barrier)	Tetric N-Flow has shown more leakage than Fuji II LC + Tetric N-Flow and Fuji II LC groups when used as intraorifice barriers.
Pisano	Cavit (3M ESPE), IRM (Dentsply), Super EBA (Bosworth)	3,5 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	A 3,5mm intraorifice barrier of Cavit leaked the least when compared to the other included materials.

Zakizadeh	Amalgam, Fuji Plus LC (GC America), Geristore (DenMat), ProRoot MTA (Dentsply)	2 mm	5 positive (no barrier) and 5 negative controls (sticky wax)	A 2mm intraorifice barrier of Fuji Plus might be an effective barrier against saliva contamination for a limited time.
Yavari	ProRoot MTA (Dentsply), Amalgam, Filtek Flow (3M ESPE), CEM Cement (BioniqueDent)	3 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	A 2mm intraorifice barrier of MTA and CEM cement are more effective than amalgam or composite resin in preventing saliva leakage in endodontically treated teeth.
Tselnik	Gray MTA, White MTA, Fuji II LC (GC America)	3 mm	5 positive (no barrier) and 5 negative controls (epoxy resin)	Intraorifice barriers of MTA and Fuji II LC in a 3mm depth provided an acceptable coronal seal for up to 90 days in vitro.
Wolcott	Ketac-Bond (3M ESPE), Vitrebond (3M ESPE), Trial Glass Ionomer (GC America)	2 and 3 mm	5 positive (no barrier) and 5 negative controls (epoxy resin)	The intraorifice seal provided by the Vitrebond was significantly better than the seal in teeth without intraorifice barriers ($p < 0.05$).
Barrieshi-Nusair	ProRoot MTA (Dentsply), Glass Ionomer Cement	4 mm	5 positive (no barrier) and 5 negative controls (sticky wax)	Mineral trioxide aggregate, when placed coronally in 4mm thickness over gutta-percha, seals the canal content significantly more than does glass ionomer.
Jenkins	Cavit (3M ESPE), ProRoot MTA (Dentsply), Tetric (Ivoclar Vivadent)	1, 2, 3, and 4 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	The results of this study indicated that, at all depths, Tetric demonstrated a significantly better seal than either MTA or Cavit.
Sauáia	Cavit (3M ESPE), Vitremer LC (GC America), Flow-It (Pentron)	3 mm	10 positive (no barrier) and 10 negative controls (nail varnish)	The results showed that Cavit sealed significantly better than Vitremer and Flow-It when used as intraorifice filling materials at a 3mm depth.
Divya	Composite resin, Gray MTA, White MTA, Glass Ionomer Cement	4 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	None of the materials prevented the microleakage completely. However, the groups restored with MTA showed significantly better results in preventing microleakage than the other groups.
Ramezanali	MTA Angelus (Angelus), CEM Cement (BioniqueDent), Biodentine (Septodont)	3 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	There were no statistical differences between the experimental groups. However, CEM cement at 3mm depth exhibited the least microleakage. CEM cement, Biodentine, and MTA effectively provide an efficient seal when used as intra-orifice barriers in endodontically treated teeth.
Galvan	Amalgambond Plus with PMMA powder (Parkell), C&B Metabond with PMMA powder (Parkell), Æliteflo LV composite (BISCO), Palfique translucent composite (Tokuyama), IRM (Dentsply)	Pulpal floor and 3mm	1 positive (no barrier) and 1 negative control (cyanoacrylate)	All four adhesive resins effectively decreased coronal microleakage, with Amalgambond producing the best seal at all times. IRM, however, demonstrated extensive leakage at 1 and 3 months.

Wells	Principle cement (Dentsply) and C&B Metabond (Parkell)	Pulpal floor and 2mm	1 positive (no barrier) and 1 negative control (nail varnish)	The seal provided by C&B Metabond was superior to the seals produced by Principle. However, by 1 week, there were no significant differences among the seals.
Maloney	Fuji Triage (GC America)	1 and 2 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	Teeth with Fuji Triage intracoronal barriers leaked significantly less than teeth without barriers. There was no significant difference between the 1 and 2 mm barriers. However, there was a trend towards less fluid movement when the thicker barrier was placed.
Jack	Resilon and Epiphany (Resilon Research), Fuji Triage (GC America)	2 mm	2 positive (no barrier) and 5 negative controls (nail varnish)	The placement of a 2 mm Triage glass ionomer intraorifice barrier after gutta-percha obturation resulted in significantly more resistance to fluid movement than the other groups.
John	Fuji Triage (GC America), Gray MTA, White MTA	2 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	No statistically significant difference in fluid flow leakage was found between the experimental groups. Both Fuji Triage and MTA provide superior intraorifice seal than the control group.
Bayram	CoroSeal (Ivoclar Vivadent), Ketac Molar Easymix (3M ESPE), Filtek Flow (3M ESPE), Polikcarboksilate cement	2 mm	5 positive (no barrier) and 5 negative controls (nail varnish)	CoroSeal at a 2 mm intraorifice depth was the most effective material among the other groups in reducing the coronal leakage when compared to Flowable Composite, Fissur Sealant, and Policarboksilate Cement.
Mohammadi	Gray MTA, White MTA, Principle cement (Dentsply)	3 mm	3 positive (no barrier) and 3 negative controls (epoxy resin)	The results indicated that MTA, when placed coronally in 3mm thickness over gutta-percha, significantly reduced bacterial penetration.
Fathi	Ketac Cem (3M ESPE), Clearfil AP-X (Kuraray), Maxcem (Kerr)	2 mm	5 positive (no barrier) and 5 negative controls (inoculated with sterile BHI broth)	There was no statistically significant difference in the bacterial penetration of Ketac-Cem, Clearfil Protect Bond/Clearfil AP-X, and Maxcem as intracoronal barriers by 120 days.
Valadares	Cavit,(3M ESPE)	2 and 3 mm	25 positive (no barrier) and 5 negative controls (cyanoacrylate)	Applying a 3mm intraorifice barrier of Cavit practically eliminated microleakage from E.faecalis in the apical third of the root canal system.
Rashmi	ProRoot MTA (Dentsply), Fuji II LC (GC America), Flows-rite (PulpDent)	3 mm	20 positive (no barrier) and 20 negative controls (epoxy resin)	Based on this study, it can be concluded that 3mm of Fuji II LC provided a better intraorifice seal than MTA and flowable resin composite.
Celik	Ketac Molar Easymix (3M ESPE), Durelon (3M ESPE), Vitrebond (3M ESPE), Filtek Flow (3M ESPE)	1 mm	15 positive (no barrier) and 5 negative controls (nail varnish)	1mm intraorifice barrier of Ketac Molar Easymix demonstrated statistically less leakage than the flowable resin composite group.
Bailón-Sanchéz	ProRoot MTA (Dentsply), Cavit (3M ESPE), Tetric EvoFlow (Ivoclar Vivadent)	4 mm	6 positive (no barrier) and 6 negative controls (nail varnish)	ProRoot MTA, Cavit, and Tetric EvoFlow demonstrated similar leakage values when used as an intraorifice barrier at a 4 mm depth.



Supplementary figure. Review authors' judgements about each risk of bias item for each included in vitro study

5 Consideraçõs finais

. Apesar de ensaios clínicos randomizados e bem delineados serem necessários, os resultados in vitro demonstraram que a colocação de uma barreira intraorifício pode reduzir significativamente a microinfiltração em dentes tratados endodonticamente, e o uso de biocerâmicos ou resinas compostas parecem ser os melhores materiais disponíveis para essa finalidade.

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Apêndice A – Nota da Dissertação

Barreira intraorifício em dentes tratados endodonticamente: Uma revisão sistemática e meta-análise de estudos in vitro.

A presente dissertação de mestrado visou analisar por meio de uma revisão sistemática da literatura, a eficácia na redução da microinfiltração de dentes tratados endodonticamente ao utilizar uma barreira intraorifício. A partir da análise de estudos da área, foi possível obter um panorama das evidências científicas disponíveis sobre o tema. Devido a maior parte das evidências disponíveis serem estudos laboratoriais realizadas em condições semelhantes, foi possível realizar uma meta-análise dos estudos in vitro. A redução da microinfiltração proporcionada pela colocação de barreiras intraorifício em dentes tratados endodonticamente pode ser um ponto chave para a previsibilidade do sucesso a longo prazo dos tratamentos endodônticos

Campo da pesquisa: Clínica Odontológica, Endodontia.

Candidato: Lucas Peixoto de Araújo, Cirurgião-dentista pela Universidade Federal de Pelotas (2018) e Especialista em Endodontia pelo Instituto Educacional Odontológico do Mercosul (2020)

Data da defesa e horário: 26/03/2021 as 14h.

Local: Sala online de webconferência do Programa de Pós-graduação em Odontologia da Universidade Federal de Pelotas.

Membros da banca: Prof. Dr. Rafael Guerra Lund, Prof. Dr. Caio Cézar Randi Ferraz, Prof. Dr. Carlos Enrique Cuevas Suárez (suplente), Profª. Drª. Nádia de Souza Ferreira (suplente)

Orientador: Prof. Dr. Evandro Piva
Co-orientador: Prof. Dr. Wellington Luiz de Oliveira da Rosa

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Apêndice B – Súmula do currículo do candidato

Súmula do currículo

Lucas Peixoto de Araújo nasceu em 24 de outubro de 1994, em Rio Grande, Rio Grande do Sul, Brasil. Ingressou na Faculdade de Odontologia da Universidade Federal de Pelotas (FO-UFPel) em 2013, tendo sido graduado cirugião-dentista em 2018. Em 2018 ingressou no Mestrado do Programa de Pós-graduação em Odontologia da Universidade Federal de Pelotas (UFPel), área de concentração Endodontia, sob orientação do Prof. Dr. Evandro Piva. É especialista em Endodontia pelo Instituto Educacional Odontológico do Mercosul sob orientação da Profª Drª Fernanda Graziela Côrrea Signoretti e co-orientação do Prof. Dr. Alexandre Augusto Zaia. Durante o período de mestrado foi bolsista da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Apresenta 1 artigo publicado, 1 artigo aceito para publicação, 1 artigo submetido, 1 livro publicado e 15 resumos publicados em anais de congressos. Atualmente, é professor visitante do curso de especialização em Endodontia do Instituto Educacional Odontológico do Mercosul e foi aprovado na seleção para o doutoramento em endodontia na Universidade Estadual de Campinas.

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CUBA, K.D.; ARAÚJO, L.P.; MASOTTI, A.S.; TORRIANI, M.A. **Manual de propedêutica odontológica para clínica cirúrgica**. 1. ed. Lucas Peixoto de Araújo, 2020. v. 1. 82p. http://dx.doi.org/10.29327/520748