UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

FACULDADE DE ODONTOLOGIA

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

ÁREA DE CONCENTRAÇÃO CLÍNICA ODONTOLÓGICA - MATERIAIS DENTÁRIOS

Linha de Pesquisa: Biomateriais e Técnicas Terapêuticas em Odontologia

AVALIAÇÃO DE MATERIAIS RESINOSOS COM DUPLA FUNÇÃO: CIMENTAÇÃO DE PINOS RADICULARES E CONSTRUÇÃO DO NÚCLEO DE PREENCHIMENTO CORONÁRIO

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Porto Alegre, dezembro de 2016

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Dissertação apresentada como requisito obrigatório para obtenção do título de Mestre em Odontologia na área de concentração Clínica Odontológica.

Porto Alegre, 2016

CIP - Catalogação na Publicação

Walcher, Juliana Gehlen
Avaliação de materiais resinosos com dupla função: cimentação de pinos radiculares e construção do núcleo de preenchimento coronário / Juliana Gehlen Walcher. -- 2016.
49 f.

Orientadora: Susana Maria Werner Samuel.

Dissertação (Mestrado) -- Universidade Federal do Rio Grande do Sul, Faculdade de Odontologia, Programa de Pós-Graduação em Odontologia, Porto Alegre, BR-RS, 2016.

1. Técnica de pino radicular e núcleo de preenchimento coronário. 2. Pinos de fibra . 3. Cimentos resinosos. I. Werner Samuel, Susana Maria , orient. II. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

“Os que se encantam com a prática sem a ciência são como os timoneiros que entram no navio sem timão nem bússola, nunca tendo certeza do seu destino”.

Leonardo da Vinci

DEDICATÓRIA

Dedico este trabalho aos meus pais, ***Roberto*** e ***Eleonora***, que me transmitiram os mais puros valores e me ensinaram a importância de correr atrás dos meus sonhos; e aos meus demais familiares e amigos, que estiveram sempre me incentivando nesta caminhada...

AGRADECIMENTOS

À Professora ***Susana Maria Werner Samuel***, minha orientadora, pela dedicação e paciência dispensadas e pela grande oportunidade de crescimento pessoal e profissional.

Ao Professor ***Fabrício Mezzomo Collares***, pelo incentivo na incessante busca por inovação e conhecimento.

Ao Professor ***Vicente Castelo Branco Leitune***, pela atenção e apoio prestados durante todo este trabalho.

À Professora ***Carmen Beatriz Borges Fortes***, pelo acolhimento e colaboração.

A todos os colegas do ***Laboratório de Materiais Dentários (LAMAD)***, pela troca de experiências e companheirismo.

RESUMO

O desenvolvimento constante de materiais odontológicos tem possibilitado a execução de técnicas restauradoras simplificadas visando facilitar a prática clínica. Dentre eles, são apresentados materiais à base de resina com a função de cimentação de pinos radiculares e também de construção do núcleo de preenchimento coronário. Para um bom desempenho das suas funções, esses materiais devem apresentar baixa viscosidade e alta resistência. O objetivo do presente trabalho foi avaliar propriedades de materiais que apresentam essa dupla função. Os materiais testados foram: Allcem Core (FGM), Rebilda DC (VOCO) e Luxacore Z (DMG), como agentes de cimentação e preenchimento coronário (grupos teste), Rely X ARC (3M ESPE), usado apenas para cimentação (grupo controle para cimentação), e GrandioSo (VOCO), indicado apenas para preenchimento coronário (grupo controle para preenchimento). Foram realizados ensaios de resistência à flexão (n=10), grau de conversão (GC) com espectroscopia Raman (n=5), espessura de filme (n=6), escoamento (n=6) e resistência ao deslocamento por teste de push-out (n=12). A resistência à flexão e a espessura de filme foram avaliadas de acordo com a ISO 4049:2009, e o escoamento foi avaliado de acordo com a ISO 6876:2001. Para realizar o teste de push-out, foram utilizados dentes bovinos, limpos e preparados para receber pinos de fibra de vidro. Os dados foram avaliados por ANOVA de 1 via, teste de Tukey e teste-t pareado. Os cimentos teste não apresentaram diferença estatística para a resistência à flexão em relação ao controle GrandioSo, exceto Luxacore Z ($p<0,001$). O grau de conversão imediato e após 24h dos cimentos teste não mostrou diferença estatística significativa tanto em relação ao material controle para cimentação quanto ao material controle para preenchimento ($p>0,05$). Todos os materiais exibiram um GC superior após 24h ($p<0,05$), exceto Luxacore Z ($p=0,054$). Os cimentos teste não apresentaram diferença estatística na espessura de filme quando comparados ao controle Rely X ARC ($p=0,66$). O escoamento do Allcem Core foi inferior ao grupo controle para cimentação ($p=0,006$). Os valores de resistência ao deslocamento (push-out) dos cimentos teste não apresentaram diferença estatística significativa quando comparados aos valores do grupo controle para cimentação na análise de cada terço ($p>0,05$) e foram inferiores no terço apical em comparação com o cervical no Luxacore Z ($p=0,046$). O tipo de falha mais comum (variando de 86,11% a 97,22%) ocorreu na interface entre dentina e cimento, após o teste de push-out. Concluiu-se que os materiais com dupla função testados apresentaram propriedades adequadas, quando comparados a materiais de indicação restrita para cimentação ou construção do núcleo de preenchimento coronário.

Palavras-chave: cimentos de resina; técnica para retentor intrarradicular; partículas inorgânicas

SUMÁRIO

1. INTRODUÇÃO

1.1. Técnica associada de pino radicular e núcleo de preenchimento coronário

Dentes submetidos ao tratamento endodôntico geralmente se apresentam severamente comprometidos por processos cariosos, restaurações prévias ou desgaste excessivo e, muitas vezes, apresentam grande perda de estrutura.[1,2] Diferentes planos de tratamento podem ser propostos na dependência da quantidade de tecido dentário remanescente. Diante de uma perda de estrutura coronária superior a 50%, pode-se indicar a colocação de um pino radicular para reter um núcleo de preenchimento, que serve como retentor para uma coroa artificial, mas sabe-se que esses pinos não têm a função de fortalecimento radicular.[3] A quantidade de tecido dentário remanescente é um fator muito importante na longevidade dos tratamentos que utilizam essa técnica. [2, 4-7]

O material utilizado para construir o núcleo de preenchimento também exerce um papel muito importante na durabilidade do tratamento.[1, 8] Deve apresentar excelentes propriedades mecânicas para resistir aos estresses gerados durante a função, promovendo distribuição equilibrada das forças e reduzindo a probabilidade de falhas em tensão ou compressão.[1] Amálgama, resina composta e ionômero de vidro vinham funcionando como agentes de preenchimento coronário, possibilitando a realização de uma restauração indireta posteriormente.[9,10] Apesar de os materiais mencionados não terem sido desenvolvidos propriamente para desempenhar essa função, eles preencheram seus requisitos devido às suas boas propriedades.[11] Referente aos núcleos metálicos, no entanto, por apresentarem um módulo de elasticidade muito superior ao da dentina, geram maior estresse na porção coronária dissipando-o diretamente à raiz, podendo levar a fraturas irreparáveis que comprometeriam o dente.[12]

Com o avanço da odontologia adesiva, materiais resistentes e com módulo de elasticidade muito próximo ao da dentina vêm sendo utilizados para construir um núcleo de preenchimento coronário.[13] Pinos não metálicos constituídos de fibra de vidro têm conquistado popularidade e apresentam a vantagem de poderem se combinar a esses compósitos de uso direto na realização dessa etapa.[14-17] Além disso, apresentam propriedades estéticas superiores, porque não geram corrosão, possibilitam maior preservação de tecido dentário sadio e têm capacidade de união à dentina através de agentes de cimentação à base de resina. A técnica que associa pino de fibra e núcleo de preenchimento em resina também é indicada em dentes com paredes radiculares finas[8,18] já que o pino, a dentina e o material de preenchimento apresentam de um módulo de elasticidade similar, concentrando menor tensão na raiz enfraquecida.[12,19] Além desses fatores que corroboram para seu uso, os pinos de fibra de vidro não resultam em reações alérgicas, como poderia ocorrer com o uso dos pinos metálicos e podem ser removidos dos canais radiculares no caso de falha endodôntica. [20,21]

A execução da técnica que utiliza pino de fibra de vidro e resina composta como material de preenchimento segue uma sequência de procedimentos apresentados na literatura: desobturação do canal radicular em baixa rotação com broca adequada ao formato do pino escolhido, preservando 4mm de material obturador como selamento apical, prova do pino e seu corte com broca diamantada em alta rotação e refrigeração preservando espaço interoclusal para a futura peça protética, assepsia do canal radicular, secagem com cones de papel absorvente, condicionamento com ácido fosfórico da dentina radicular (no caso de sistemas adesivos convencionais), secagem com cones de papel absorvente, aplicação de sistema adesivo preferencialmente de cura dual, preparo do cimento resinoso e inserção no canal radicular com auxílio de pontas aplicadoras e imediata inserção do pino selecionado silanizado. Remoção dos excessos de cimento da porção coronária do pino e remanescente dental e fotoativação por 40 segundos, aguardando-se mais 6 a 8 minutos para o término da cura química do cimento. Em seguida, prossegue-se com a construção do núcleo de preenchimento coronário em resina composta e técnica incremental, fotopolimerizando-se cada incremento, conforme instruções do fabricante.[20, 22, 23]

A seleção incorreta do agente de cimentação também pode afetar significativamente a longevidade das reabilitações que utilizam o sistema pino/ núcleo de preenchimento. Cimentos de ionômero de vidro, resina composta, fosfato de zinco e policarboxilato são os mais utilizados para cimentar pinos intrarradiculares metálicos, mas a odontologia adesiva possibilitou o uso de cimentos à base de resina para cimentar os pinos de fibra, favorecendo a adesão entre o mesmo e a raiz. Cimentos à base de resina aplicam-se à chamada técnica "monobloco", na qual dentina, pino e núcleo de preenchimento apresentam módulos de elasticidade semelhantes e funcionam como uma unidade coesiva,[23,24] fortalecendo a interface e reduzindo o risco de microinfiltrações.[12] É necessário estabelecer uma adesão eficiente tanto entre a dentina e o cimento resinoso, quanto entre o pino e o material de preenchimento, para possibilitar uma distribuição homogênea dos estresses oclusais a partir da criação de uma estrutura "monobloco".

Em decorrência de alguns fatores relacionados à estrutura da dentina radicular como a heterogeneidade na densidade e orientação dos seus túbulos, presença de *smear layer*, controle da umidade no interior do canal radicular, presença de remanescente supra-gengival adequado responsável pelo efeito de férula, alta sensibilidade da técnica adesiva e contração de polimerização inevitável nos cimentos resinosos, a razão mais comum de falha desse sistema de reabilitação tem sido a descimentação dos pinos,[17,25] no entanto a interface entre cimento resinoso e material de preenchimento também exerce um importante papel no desempenho e longevidade dos tratamentos.[26]

A adaptação do pino ao canal radicular é de grande relevância também, pelo fato de que, com emprego de uma espessura maior de cimento, eleva-se o estresse de contração induzido pela sua polimerização. O fator de configuração cavitária em raízes é muito maior que em preparos para restaurações coronárias, excedendo 200, e o estresse de contração pode exceder a resistência de união, causando descimentação do pino ou desadaptações.[6, 17]

Resinas compostas fluidas com grande conteúdo de carga inorgânica têm sido introduzidas recentemente no mercado. O seu teor de partículas e a sua contração de polimerização são comparáveis às resinas convencionais híbridas, porém mantendo a mesma viscosidade[27] e aumentando a resistência de união.[28] No entanto, se a incorporação de nanopartículas de carga no cimento levasse a um aumento na espessura de seu filme devido a um aumento na viscosidade, poderia haver prejuízo no molhamento da superfície do substrato e, consequentemente, na adesão.[29] O desenvolvimento desses materiais de baixa viscosidade e alto conteúdo de carga inorgânica tem possibilitado a execução de uma técnica restauradora em passo único, realizando a cimentação do pino radicular e a construção do núcleo de preenchimento imediatamente e com o mesmo material. As vantagens apresentadas pela técnica em passo único são: menor tempo necessário para o procedimento, menor sensibilidade técnica e redução da chance de haver possíveis incompatibilidades entre agente de cimentação e material de preenchimento, já que se utiliza apenas um material, evitando assim a existência de várias interfaces entre diferentes materiais.[30, 31]

1.2. Influência das fases orgânica e inorgânica nas propriedades dos compósitos

Algumas propriedades importantes devem ser levadas em consideração quando uma resina composta é avaliada, como dureza, grau de conversão, módulo de elasticidade, resistência à flexão e tenacidade à fratura. Dureza e grau de conversão estão associados com a profundidade de polimerização e a dureza também é uma medida do comportamento da superfície do material e prevê uma informação sobre seu polimento e resistência à abrasão. O módulo de elasticidade representa a resistência do material em se deformar elasticamente e é uma propriedade crucial dos compósitos, pois está relacionado à contração de polimerização, integridade marginal e resistência do material às cargas oclusais.[32] O módulo de elasticidade estabelece uma correlação entre conteúdo de carga inorgânica e propriedades mecânicas.[32-34] Quanto maior o conteúdo de carga, maior será o módulo de elasticidade ou rigidez e maior será a resistência do material à deformação.[35]

A contração induzida pela polimerização dos compósitos ocorre inevitavelmente durante a cura e depende da sua composição (tipos de monômeros, tipo e quantidade de carga, interações entre carga e matriz orgânica) e de fatores influentes na polimerização.[35] Em sistemas com carga, a contração é minimizada devido à redução em volume de matriz resinosa.[28, 36]

Partículas inorgânicas são comumente incorporadas às resinas fotopolimerizáveis devido à sua insolubilidade no meio oral, simples manipulação, custo moderado e habilidade de se aderir aos dimetacrilatos.[37] Elas são frequentemente funcionalizadas com grupos orgânicos reativos para que a carga e a matriz polimérica sejam interligadas por ligações covalentes entre as fases e alcancem melhor resistência. Apesar disso, tensões invariavelmente são geradas através da resina e, frequentemente, se concentram na interface resina-carga, já que essa última é a porção menos uniforme da resina. Além disso, durante a exotermia da polimerização, surge uma diferença de temperatura, levando a uma expansão térmica entre a matriz polimérica e a carga inorgânica, resultando novamente em maior acúmulo de estresse na interface resina/carga.[38] Além do tamanho, a quantidade e a distribuição das partículas também influenciam nas propriedades das resinas compostas.[37]

Como a variabilidade de monômeros presentes na matriz resinosa pode influenciar na contração de polimerização e consequentemente no desempenho dos materiais, a sua composição orgânica exerce um papel importante na determinação do estresse gerado pela polimerização. Todas as resinas à base de Bisfenol A Glicidil Metacrilato (Bis-GMA) contraem em alguma proporção e a utilização de monômeros de alto peso molecular na matriz resinosa poderia contribuir para minimizar essa contração. No entanto, essa situação ocorre em decorrência de um menor grau de conversão da resina, prejudicando consequentemente suas propriedades mecânicas.[39] Em compensação, monômeros diluentes e de baixo peso molecular, como tetraetilenoglicol dimetacrilato (TEGDMA), elevam o grau de conversão da resina, porém causam maior contração volumétrica e, consequentemente, maior estresse de contração.[35]

Limitações associadas a um baixo grau de conversão do cimento podem resultar em maior sorção e solubilidade, acelerando a degradação do material. Consequentemente, a resistência de união entre o cimento e o substrato dentário diminui, podendo levar à perda da restauração devido à descimentação, fratura ou lesões de cárie.[40] A quantidade de água absorvida pelos compósitos também depende do teor de monômeros hidrófilos. Uretano dimetacrilato (UDMA) e Bis-GMA são menos hidrófilos do que alguns outros monômeros utilizados em materiais de preenchimento, permitindo inferir que materiais que os contenham devem absorver menos água. A diferença na solubilidade dos materiais pode dever-se também às suas ligações cruzadas internas, já que a permeabilidade do polímero é inversamente proporcional à quantidade de ligações entre as cadeias poliméricas.[41]

A ISO 4049,[42] que regulamenta os materiais restauradores poliméricos, afirma que o valor mínimo de resistência à flexão dos materiais restauradores depende da sua indicação, variando de 80MPa (fotoativação intra-oral) a 100MPa (fotoativação extra-oral). A resistência à flexão de marcas comerciais varia de 61,4 a 148,9 MPa. No entanto, as propriedades mecânicas adequadas para materiais de preenchimento não foram claramente identificadas.[32]

2. OBJETIVOS

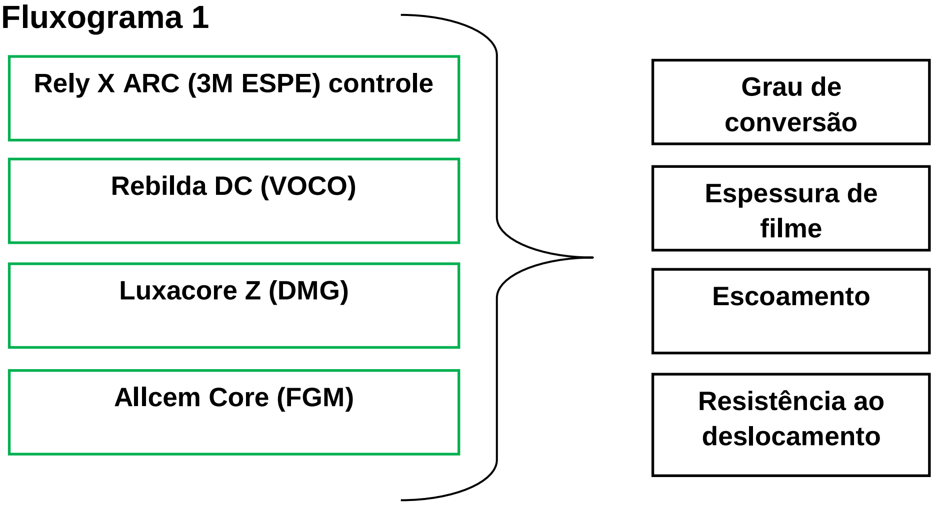
Avaliar propriedades de materiais à base de resina que exercem a função de agente de cimentação e de construção do núcleo de preenchimento coronário concomitantemente.

3. DELINEAMENTO

Os materiais foram divididos e avaliados conforme a sua indicação.

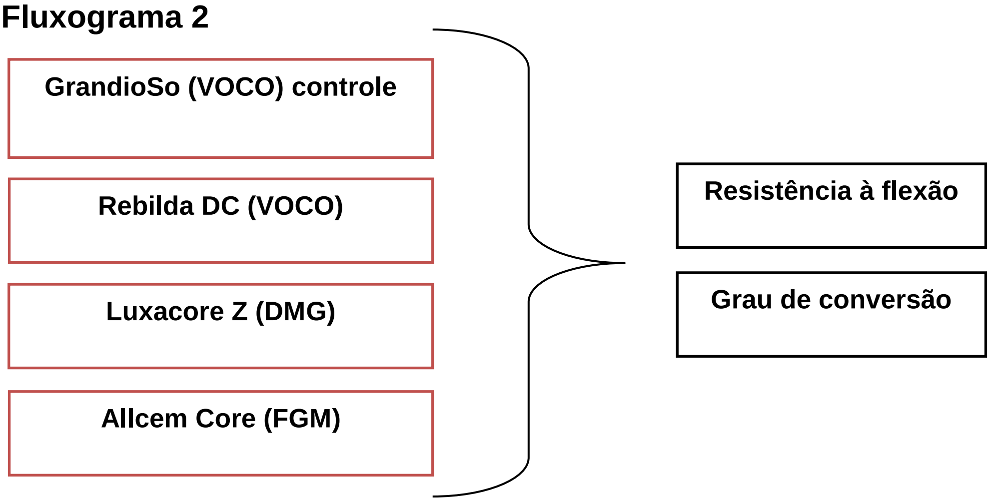
- **Agente de cimentação** - avaliação das propriedades de grau de conversão, espessura de filme, escoamento e resistência ao deslocamento pelo teste de push-out dos materiais Rebilda DC (VOCO, Germany), Luxacore Z (DMG, Hamburg, Germany) e Allcem Core (FGM, Joinville, SC, Brasil), e do material de cimentação Rely X ARC (3M ESPE, Sumaré, SP, Brasil) - (Fluxograma 1)

Fluxograma 1



- **Agente de preenchimento** - avaliação das propriedades de resistência à flexão e grau de conversão dos materiais Rebilda DC (VOCO, Germany), Luxacore Z (DMG, Hamburg, Germany) e Allcem Core (FGM, Joinville, SC, Brasil), e do material de preenchimento GrandioSo (VOCO, Germany) - (Fluxograma 2)

Fluxograma 2



4. MANUSCRITO

Esta dissertação de mestrado é composta pelo manuscrito a ser submetido para a revista Operative Dentistry:

Evaluation of core build-up cements for one-stage post endodontic restorations

Core build-up cements for one-stage post endodontic restorations

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EVALUATION OF CORE BUILD-UP CEMENTS FOR ONE-STAGE POST ENDODONTIC RESTORATIONS

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ABSTRACT

Objective: The purpose of this study was to evaluate properties of core build-up cements for one-stage post endodontic restoration. Methods: The tested materials were: Allcem Core (FGM), Rebilda DC (VOCO) and LuxaCore Z (DMG) as dual function cements; Rely X ARC (3M ESPE), used only for cementation, and GrandioSo (VOCO), used only for coronary filling. It was assessed flexural strength (n=10), immediate and 24h late degree of conversion (DC) with Raman spectroscopy (n=5), film thickness (n=6), flow (n=6) and resistance to dislodgment (RD) by push-out test (n=12). The flexural strength and the film thickness were evaluated in accordance with ISO 4049:2009 and the flow was evaluated in accordance with ISO 6876:2001. To assess the RD by push-out test, bovine teeth were prepared to receive fiber glass posts. Results: the test cements Allcem Core and Rebilda DC did not show statistic difference in flexural strength compared to GrandioSo ($p>0.05$), and Luxacore Z presented lower mean value than GrandioSo ($p<0.001$).The test cements did not present statistic difference in degree of conversion (immediate and 24h late) compared to each control material, ($p>0.05$) regardless of their indication (cementation or coronary filling). All materials tested showed a greater degree of conversion after 24h, except Luxacore Z ($p=0.054$). The test cements did not show statistic difference in the film thickness compared to Rely X ARC ($p=0.66$), and did not show statistic difference in flow compared to control Rely X ARC ($p>0.05$), except Allcem Core ($p=0.006$). The resistance to dislodgment of the test cements did not differ from the control Rely X ARC, regardless the root third ($p>0.05$). Luxacore Z showed lower mean values in the apical third compared to the coronal third (p=0.046). The most prevalent failure mode after the push-out test was at dentine/cement interface, and it varied from 86.11% to 97.22%. The most common failure mode after the push-out test was at dentine/cement interface. Conclusion: The test cements presented adequate properties when compared with their control materials for cementation and coronary filling.

Clinical Relevance

Core build-up cements may be an option to clinical practice, depending on the skills and preferences of the clinician. The composition of the test cements and their cementation and coronary filling controls are similar and they presented compatible properties in this study.

INTRODUCTION

Since the 1990s, resin core buildup systems have been employed more frequently to restore endodontically treated teeth that are extensively broken down. The major advantage of this system is the possibility to enhance bond strength between the composite resin and a glass fiber post, creating a “monoblock” structure with a similar elastic modulus to dentine.[1,2,3] This unit promotes a better dissipation of the functional loads when compared to cast posts.[4]

The most common reason for failure of this system has been the post dislodgment. The root dentin structure is different from the coronary. Some factors such as heterogeneity in the density and orientation of its tubules, presence of smear layer, moisture control inside the root canal, presence of remaining coronal tooth structure, sensitivity of adhesive technique and polymerization shrinkage in resin cements can help to explain this problem.[5,6] The post adaptation into the root canal is also important because, with a higher thickness of cement, the shrinkage stress induced by its polymerization increases. Besides that, the cavitary root configuration factor is much higher than in preparations for coronary restorations, exceeding 200, and the shrinkage stress may exceed the bond strength, causing post dislodgment.[7,5]

The coronary filling material should exhibit excellent mechanical properties to withstand the stresses generated during the function and to promote an adequate distribution of masticatory loads.[8] Flowable composite resins with filler content and polymerization shrinkage similar to conventional hybrid resins have been introduced in the market. These materials allow to adhesively restore endodontically treated teeth in a one-stage post and core procedure.[9] This technique could reduce the time necessary for the clinical procedure, its sensitivity, and possible incompatibilities between the luting agent and the core build-up material.[10]

However, if the incorporation of inorganic particles into the cement leads to an increase in its viscosity, there could be damage in the wetting of the substrate surface and, consequently, in the adhesion.[11] The purpose of this study was to evaluate properties of core build-up cements for one-stage post endodontic restoration.

METHODS AND MATERIALS

Study design

The test cements Allcem Core (FGM, Joinville, SC, Brazil), Rebilda DC (VOCO, Germany), Luxacore Z (DMG, Hamburg, Germany) and the control Rely X ARC (3M ESPE, Sumaré, SP, Brazil) were submitted to tests for evaluation of degree of conversion (DC), film thickness, flow and resistance to dislodgment (RD) by push-out test. The control GrandioSo (VOCO, Germany) and the test cements Allcem Core (FGM, Joinville, SC, Brazil), Rebilda DC (VOCO, Germany) and Luxacore Z (DMG, Hamburg, Germany) were evaluated in relation to the flexural strength and degree of conversion (DC). Table 1 describes the resin based materials tested in this study. GrandioSo is indicated only for coronary filling, Allcem Core, Rebilda DC and Luxacore Z are dual function materials (cements and coronary filling agents) and Rely X ARC is indicated only for cementation.

Table 1. Materials used in this study

Material/Batch n°	**Function**	**Organic Matrix**	**Inorganic particles**
GrandioSo (VOCO) **1603228**	Filling	Bis-GMA 2,5-5% TEGDMA 2,5-5% Bis-EMA 2,5-5%	89% weight
Allcem Core (FGM) **140416**	Cementation Filling	Bis-GMA, TEGDMA, Bis-EMA	Barium aluminum silicate glass Silicon dioxide 62% weight
Rebilda DC (VOCO) **1545576**	Cementation Filling	Bis-GMA 2,5-5%, UDMA 10-25%, DDDMA 5-10%	69% weight
Luxacore Z (DMG) **733647**	Cementation Filling	Bis-GMA, UDMA	Barium glass, colloidal silica, nanocomposite, zirconium dioxide 71% weight
Rely X ARC **(3M ESPE)** **N727807**	Cementation	Bis-GMA 10-20%, TEGDMA 10-20%	Silanized ceramic 60-70% weight Silanized silica 1-10% weight

Flexural strength

Ten rectangular specimens (n=10) with 25 mm x 2 mm x 2 mm were prepared for each group (Allcem Core, Rebilda DC, Luxacore Z and GrandioSo) and stored in distilled water at 37°C for 24h before the tests, according to ISO 4049.[12] Flexural strength was determined with the 3 points test at a cross head speed of 0.75mm/min in a universal testing machine (DL2000, EMIC, São José dos Pinhais, PR, Brasil) until the specimens fracture. Flexural strength was calculated from the following equation:

$$\boldsymbol{\sigma = 3Fl / 2bh^2},$$

where F is the maximum load exerted on the specimen; l is the distance (mm) between the supports ±0.01 mm; b is the width (mm) of specimen immediately prior to testing; and h is the height (mm) of specimen measured with a digital caliper immediately prior to testing.[13]

Degree of conversion (DC)

The DC was measured by Raman spectroscopy (SENTERRA Bruker Optics, Ettlingen, Germany) using 3s of exposure, 5 coadditions, a 785nm laser with 3-5cm^{-1} resolution. Five specimens of each group (Allcem Core, Rebilda DC, Luxacore Z, GrandioSo and Rely X ARC) were prepared (n=5). 0,03g of each material was dispensed in a 4 x 1mm mold and taken to Raman to evaluate the monomer. Then the specimens were light cured for 40s with a LED (Radii, SDI, Australia) under 1200 mW/cm^2 light intensity and analised immediately and after 24h. To calculate the degree of conversion it was considered the absorbance in the spectrum peaks of aliphatic carbon bonds at 1640 cm^{-1} and aromatic carbon bonds 1610 cm^{-1} in the monomer and in the polymer spectrums, with the equation:

$$\mathbf{DC = 1 - \left(\frac{\text{absorbance } (1640\ cm^{-1}) / \text{absorbance } (1610\ cm^{-1}) \text{ polymer}}{\text{absorbance } (1640\ cm^{-1}) / \text{absorbance } (1610\ cm^{-1}) \text{ monomer}} \right) x\ 100}$$

Film thickness

There were tested 6 specimens in each group (Allcem Core, Rebilda DC, Luxacore Z and Rely X ARC) (n=6), according to ISO 4049.[12] Two glass plates with (200 ± 25) mm² and 5mm thickness were used. The thickness of paired glass plates was measured with 0,001mm accuracy (read A). Between 0,02ml and 0,1ml of the cement was mixed and dispensed in the center of the inferior plate and then covered with the other, in the same orientation from the paired glass measure. A constant load of (150 ± 2)N was applied centrally in the superior plate during (180 ± 10)s. The thickness in the same orientation from read A was measured (read B). Then the film thickness was the difference between read B and read A.

Flow

There were tested 6 specimens in each group (Allcem Core, Rebilda DC, Luxacore Z and Rely X ARC) (n=6), according to ISO 6876.[14] Two glass plates with (200 ± 25) mm² and 5mm thickness were used. 0,05 ± 0,005 ml of mixed cement was dispensed in the center of one plate and then covered with the other. It was applied a load of 100g during 10 minutes. The two largest diameters of the cement were measured, and the mean value was it´s flowability.

Resistance to dislodgment (push-out test)

Selection and preparation of teeth

Forty-eight bovine teeth were randomly assigned in each group (Allcem Core, Rebilda DC, Luxacore Z and Rely X ARC) (n=12). Freshly extracted teeth were immediately stored fully immersed in distilled water at 4°C for no more than 6 months. To be included in this study, the following criteria had to be met: straight roots and narrow canals and a root length of at least 15mm. External debris were removed with a periodontal curette and the crown surfaces of each tooth were sectioned below the cement-enamel junction perpendicular to the long axis, using a slow-speed diamond disc under water coolant. The radicular pulp was removed using a n° 30 K-file (Maillefer-Dentsply, Ballaigues, Switzerland) and irrigation with distilled water.

Bonding of fiber posts

The post space of each root was enlarged with a n° 3 drill from the Exacto post system (Angelus, PR, Brazil), with a working length of 11mm. The n° 3 fiber post had 17 mm of length, 2 mm of cervical diameter, and 1.1 mm of apical diameter. To standardize the method, the same operator performed all of the procedures. Following post space preparations, the roots were randomly divided into 4 groups of 12 teeth each and the roots were protected with an aluminium blade to protect them from external light energy during the posts cementation. The fiber posts were cleaned with 96% ethanol and the silane (Angelus, PR, Brazil) was applied with disposable microbrush tips. Intracanal dentin was etched with 37% phosphoric acid for 15 seconds, rinsed with distilled water for 15 seconds, and then gently dried with absorbent paper points. Then a 3-step total-etch adhesive system (Scotch Bond Multi-Purpose Plus, 3M ESPE) was applied to the moist dentin with disposable microbrush tips following this steps: activator for 5 seconds, primer and solvent dry for 5 seconds, catalyst. The catalyst was also applied to the posts after they were completely dry, and immediately before cementation. Afterward, the cement was dispensed into the post space with intra oral tips from each cement system or with Centrix syringe (Centrix Inc, Shelton, CT), and the fiber post was inserted. Light activation was performed through the cervical portion of the root for 20 seconds at the buccal and lingual surfaces, for a total of 40 seconds of light exposure, with 5 mm of distance between source and root. The resin cement and adhesive were light activated with a LED (Radii, SDI, Australia) under 1200 mW/cm^2 light intensity. The power of the lightcuring unit was gauged with a radiometer (Model 100, Demetron Research Group, Danbury, CT, USA).

Push-out test

All of the roots in all of the groups were stored in 37°C distilled water for7 days, and then serially sectioned into 0.7mm thick slices in a precision cutting machine (Low Speed Saw, Buehler, Lake Bluff, IL) under constant water coolant. The slices of all roots from each group were stored in 37°C distilled water for 24 hours before push-out tests were performed. The cervical and apical diameter of the canal and the thickness of all of the slices were measured with a digital caliper. Each section was marked on its apical side and positioned on a base, with a central hole, in a universal testing machine (DL2000, EMIC, São José dos Pinhais, PR, Brazil). The push-out test was performed by applying a compressive load to the apical side of each slice by using a 0.7-mm-diameter cylindrical plunger attached to the upper portion of the testing machine. A crosshead speed of 1mm/min was applied until bond failure occurred. To express the bond strength in megapascals (MPa), the load upon failure was recorded in newtons (N) and divided by the bond area (mm^2).[6]

The sample size for push-out tests, flexural strength, degree of conversion, film thickness and flowability was calculated in accordance with other studies that used similar tests, respectively,[6,15-18] considering a study power of 80% and a significance level of 5%, with Sigma Plot 12.0.

Statistical Analysis

The normality of data was evaluated using the Shapiro-Wilk test. For flexural strength, film thickness and flow, it was used one-way ANOVA. For the immediate and after 24h DC, it was used one-way ANOVA to compare the materials in the same time and Student paired t-test to compare different times within the same material. The resistance to dislodgment data were submitted to a log transformation and to one-way ANOVA to compare different materials in the same root third, and also to compare different root thirds within the same material. The post-hoc performed was the Tukey test.

RESULTS

Flexural strength: the test cements Allcem Core and Rebilda DC did not show statistic difference compared to GrandioSo ($p>0.05$), and Luxacore Z presented lower mean value than GrandioSo ($p<0.001$) (table 2). **Degree of conversion (immediate and 24h late)**: the test cements did not present statistic difference compared to each control material ($p>0.05$), regardless of their indication (cementation or coronary filling). All materials tested showed a greater degree of conversion after 24h, except Luxacore Z ($p=0.054$) (table3). **Film thickness**: the test cements did not show statistic difference compared to Rely X ARC (p=0.66) (table 2). **Flow**: the test cements did not show statistic difference compared to control Rely X ARC (p>0.05), except Allcem Core (p=0.006) (table2). **Resistance to dislodgment**: the test cements did not present statistic difference compared to control Rely X ARC, regardless the root third (p>0.05). Luxacore Z showed lower mean values in the apical third compared to the coronal third (p=0.046) (table 4). The most prevalent failure mode after the push-out test was at dentine/cement interface, and it varied from 86.11% to 97.22% (figure 1).

Table 2. Means and standard deviation values of film thickness, flow and flexural strength.

Material/Test	**Film thickness (µm)**	**Flow (mm)**	**Flexural strength (MPa)**
Rely X ARC	26 (5.16) ^{A}	20.77 (0.93) ^{A}	-
Rebilda DC	35 (16.43) ^{A}	19.75 (1.32) ^{AB}	116.77 (17.41) ^{A}
Luxacore Z	35 (20.74) ^{A}	18.53 (1.97) ^{AB}	82.94 (18.03) ^{B}
Allcem Core	30 (6.32) ^{A}	17.60 (1.32) ^{B}	103.48 (18.08) ^{AB}
GrandioSo	-	-	125.14 (21.43) ^{A}

Significant differences within columns are written by different letters. Rely X ARC and GrandioSo are the control materials for cementation and coronary filling, respectively.

Table 3. Means and standard deviation values of the immediate and 24 hours late degree of conversion for all materials.

Material/Time	DC Imediate (%)	DC 24h (%)
Rely X ARC	69,15 (±8,53) ^{Aa}	88,78 (±5,22) ^{Ab}
GrandioSo	54,97 (±7,76) ^{Aa}	67,98 (±1,45) ^{Bb}
Allcem Core	62,21 (±7,68) ^{Aa}	80,24 (±2,37) ^{ABb}
Rebilda DC	58,87 (±8,06) ^{Aa}	83,58 (±6,17) ^{ABb}
Luxacore Z	63,73 (±6,54) ^{Aa}	79,22 (±6,35) ^{ABa}

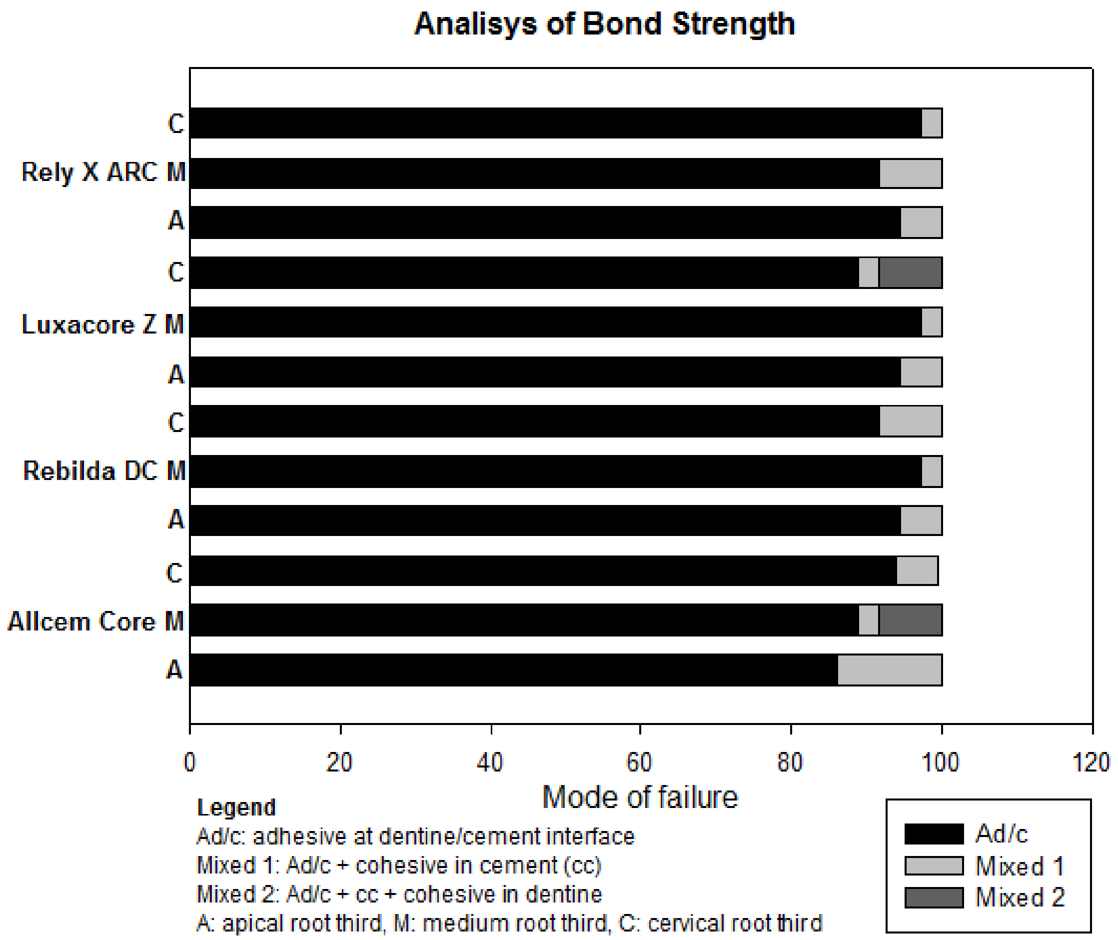
Significant differences are written by different letters (uppercase letters within column; lowercase letters within row).

Table 4. Means and standard deviation of resistance to dislodgment values between the root thirds (RT) and between different materials within the same RT, after the push-out test.

RT/Material	**Allcem Core**	**Rebilda DC**	**Luxacore Z**	**Rely X ARC**
Cervical	5.97 (2.93) ^{Aa}	5.60 (3.58) ^{Aa}	6,03 (4.31) ^{Aa}	4.32 (2.31) ^{Aa}
Medium	5.06 (3.03) ^{Aa}	5.16 (3.75) ^{Aa}	3.13 (2.58) ^{Aab}	2.50 (1.24) ^{Aa}
Apical	4.05 (2.72) ^{Aa}	3.52 (3.02) ^{Aa}	2.82 (2.11) ^{Ab}	2.85 (2.04) ^{Aa}

Significant differences are written by different letters (uppercase letters within row; lowercase letters within column).

Figure 1. Analysis of the bond strength failure for all cements and root thirds.



DISCUSSION

The most significant changes in commercial composites in recent years were modifications of the filler system. The size of filler particles incorporated into the resin matrix of commercial composites has continuously decreased, resulting in nanohybrid and nanofilled materials with improved material properties.[19] Flowable composite resins of high filler loading have been introduced and their filler content and polymerization shrinkage are comparable to those of the conventional hybrid composite resins but with the same flow behavior,[9] increasing the bond strength.[20] These materials allow to adhesively restore endodontically treated teeth in a one-stage post and core procedure.[9] There is not already a standardization for the polymeric coronary filling materials. Despite this, the flexural strength of all the test cements in this study was greater than 80 MPa, that is the minimum recommended for polymeric restorative materials.[12] GrandioSo had the higher values for flexural strength, probably because it has more content of inorganic particles,[9] compared to the other cements tested. The higher the filler content, the higher the modulus of elasticity or stiffness and the higher the resistance to deformation of the material.[21]

The degree of conversion (DC) of resin cements can be affected by multiple factors, compromising the longevity of the treatment. Some of these factors are the material composition (monomers and other components of the activation system), possible incompatibilities between the bonding system and the cement agent and the photo activation step.[22] Contrary to opaque posts, translucent fiber posts can transmit light, increasing polymerization of dual-cured resin cements and also the curing depth. However, even translucent fiber posts can reduce light transmission to less than 40% and might not guarantee sufficient polymerization of resin cements.[3] In this study, Rely X ARC reached higher 24h later DC(%) values compared to GrandioSo

($p<0.05$). The higher filler content of the second material could help to explain this result. During the polymerization process, monomers react to form a covalent bond, but the mobility of the monomer-chain can be restricted by the amount of the fillers,[5] and the reaction slows down progressively up to a moment when new bonds cannot be made.[22] Since the mechanical properties of the test cements will probably enhance with time, the tooth final preparation could be indicated at least 24h after the core build-up technique.

The flow and film thickness are also important properties of resin cements. The flowable composites can be easily inserted into small cavities and are expected to exhibit better adaptation to the internal cavity wall compared to the conventional restorative composites which are more viscous.[9] Within a thick cement film, more monomers are available to react and to convert into polymers, generating a higher polymerization shrinkage.[23] As is known, the C-factor of the root canal is higher than it is in coronary restorations, exceeding 200, and the shrinkage stress could exceed the bond strength, causing debonding or gaps and voids.[7] The film thickness did not differ among the tested cements ($p>0.05$). Rely X ARC had superior flow mean value than Allcem Core ($p<0.05$), maybe due to a lower amount of inorganic particles.[9] However, their values are in accordance with the standards.[12,14]

In this study, the cement was inserted into the post space using a syringe to minimize the inclusion of air bubbles, as it has been observed that bubbles are noted if a post does not fit well into the post space and, consequently, the cement layer is thicker. Those bubbles are responsible for decreasing bond strength and, consequently, predisposing posts to dislodgment.[7] This gradual loss of retention is exacerbated by the polymerization shrinkage of cementing agents.[5] Some studies also reported that the reduction of bond strength from de cervical to the apical root third can be attributed to various factors.[23] There are the less dense structure of the root dentine tubules, the configuration in the apical portion of the root canal system,[20] apical sclerosis, the higher cavity configuration factor, the difficulty of visualization and access to the apical part of the root canal as well as restricted flow of the resin core materials.[1,24,25]

Push-out tests are recommended to determine the bond strength of fiber posts to root dentin because they are able to distribute stress more homogeneously, produce less variability in mechanical testing results, fewer pretest failures, and lower standard deviation.[23,26] Fiber posts conventionally have a circular cross section, whereas oval root canal configurations are prevalent, which raises questions on the adaptation of conventional posts to oval root canals. Sound dental tissue has to be sacrificed when performing circular post placement in oval-shaped root canals to adapt the shape of the canal to that of the circular post. This procedure also decreases root strength.[27,2] Maybe this can explain some dentine cohesive fails after the push-out test, because some canals have an oval configuration, requiring more prepare of sound tooth before the post placement. The test cements did not show statistic difference in the mean bond strength for all root thirds, compared with the control Rely X ARC. It was not statistic difference between the root thirds within the same material, except Luxacore Z, that exhibited a higher mean value for the cervical root third compared to the apical root third ($p<0.05$). This result can be attributed to the composition of this material, because the high opacity of the zirconia particles can reduce the light transmission during the photoactivation and consequently the final degree of conversion, reducing the mechanical properties of the material.[28]

Some limitations of this study can be depicted as follows: no aging condition was performed on the tooth, which could lead to a less realistic clinical behavior. The long-term evaluation of dentin–resin bond strength in vitro studies is usually performed by water storage.[29] The root canals were not endodontically treated before the post space preparation, because remnants of sealers, eugenol, gutta-percha, and other intracanal medicine might interfere in the adhesive process, thus reducing bond strength.[23] Eugenol-based sealer reduces the immediate push-out bond strength of fiber posts luted to root canal with resin cement, regardless of the type of adhesive system or resin cement used.[29]

CONCLUSION

Since the core build-up cements presented, in this study, similar properties to their cementation and coronary filling controls, they could be an option to the clinical practice, depending on the skills and preferences of the clinician.

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5. CONSIDERAÇÕES FINAIS

O desenvolvimento tecnológico vem aprimorando dia a dia os materiais odontológicos, qualificando a prática clínica. Um equilíbrio entre as fases orgânica e inorgânica pode permitir que alguns materiais à base de resina disponham de adequadas propriedades reológicas necessárias a um agente de cimentação, mas que também sejam resistentes mecanicamente para suportar os esforços mastigatórios. Os materiais com dupla função de cimentação e construção do núcleo de preenchimento coronário testados nesse estudo foram introduzidos pela indústria com a intenção de facilitar a prática clínica. Como vantagens, algumas etapas durante o tratamento poderiam ser eliminadas com a possibilidade de utilizar o mesmo material para executar duas etapas em sequência. O apelo da indústria é de que o excesso de cimento que extravasa para a porção coronária do pino após a sua inserção no interior do canal durante a cimentação seja aproveitado para iniciar a construção do núcleo de preenchimento. Entretanto, para que essa classe de materiais seja clinicamente aceita, deve apresentar longevidade na cimentação e na resistência aos esforços mastigatórios. No que se refere às habilidades do operador, poderia haver dificuldade no emprego desses materiais durante a construção do núcleo de preenchimento coronário, devido a sua fluidez característica, o que poderia indicar o uso de matrizes conformadoras para a realização dessa etapa, representando uma desvantagem para alguns profissionais.

No que se refere às propriedades avaliadas neste estudo, foi possível observar a potencialidade dos cimentos teste para uso clínico com o intuito de reduzir etapas durante o procedimento adesivo e qualificar a interface de união entre agente de cimentação e agente de preenchimento, uma vez que se trata de um mesmo material. Entretanto, tendo em vista que a literatura é carente de estudos desses materiais, a realização de uma avaliação clínica longitudinal, que avalie a durabilidade dos mesmos, poderá corroborar os achados deste trabalho.

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