ANA CAROLINA ROCHA LIMA CAIADO

AVALIAÇÃO DA INTEGRIDADE MARGINAL E DUREZA KNOOP DE CIMENTOS RESINOSOS USADOS NA FIXAÇÃO DE PINOS DE FIBRA DE VIDRO ANATOMICAMENTE REEMBASADOS

Tese de Doutorado apresentada à Faculdade de Odontologia de Piracicaba, da Universidade Estadual de Campinas, para a Obtenção de Título de Doutor em Clínica Odontológica.

Orientador: Professor Mario Fernando De Goes

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Prof. Dr. RICARDO MARINS DE CARVALHO

Prof. Dr. NOBORU IMURA

Prof. Dr. MARCELO GIANNINI

Prof. Dr. JOSÉ FLÁVIO AFFONSO DE ALMEIDA

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RESUMO

O objetivo deste estudo foi avaliar: (1) a integridade marginal (IM) de pinos de fibra de vidro anatomicamente reembasados (PA) e pinos de fibra de vidro (PC) cimentados com diferentes materiais; (2) a dureza Knoop de cimentos resinosos duais usando a técnica PA e PC na presença e ausência de luz; e (3) a IM entre cimento resinoso autoadesivo e as paredes do canal radicular após a fixação de PC e PA reembasados com resina à base de metacrilato ou silorano. Os estudos 1 e 2 empregaram raízes de incisivos bovinos distribuídos aleatoriamente em 8 grupos de acordo com a técnica usada (PC ou PA), o cimento empregado (Rely X ARC (R) e Unicem (U), 3M ESPE), e o modo de ativação do cimento (químico (Q) ou dual (D)). No estudo 3, raízes bovinas foram distribuídas em 6 grupos de acordo com a técnica usada (PC ou PA), o material usado para reembasar o PA (resina composta à base de metacrilato ou silorano), e o modo de ativação (Q ou D). Após 48 horas, as raízes foram seccionadas longitudinalmente, polidas e demarcadas de acordo com seus terços (cervical (C), médio (M), Apical (A)). A IM entre o cimento resinoso e a dentina do canal radicular após a cimentação de pinos de fibra de vidro foi avaliada nos estudos 1 e 3. Para isso, réplicas foram confeccionadas a partir das amostras e essas foram então imersas em solvente para a confecção de novas réplicas. As amostras foram analisadas usando microscopia eletrônica de varredura (MEV) e a percentagem de margens contínuas (%) foram determinadas como uma medida de IM. No estudo 2, após o polimento as amostras, foram levadas a um microdurômetro (50g por 5 min) para obter os valores de dureza Knoop. Os estudos 1 e 3 revelaram que a IM foi estatisticamente maior para PA do que para PC antes e após imersão em solvente para todos os terços do canal radicular. No artigo 1, quando o PA foi empregado, a IM de U(73% ±36) foi maior do que para R(42% ±46). Nenhuma diferença entre cimentos foi observada quando PC foi usado (U= 8% ±15; R= 9% ±18). A IM foi maior para a ativação Q(43% ±44) do que D (22.9% ±35.5), independente da técnica ou do cimento usado. O estudo 2 revelou que a interação dos fatores (técnica, cimento e modo de ativação) foram estatisticamente significativos no terço C e M do canal (C: p= 0.0393, M: p= 0,0177), mas não no A, que foi apenas afetado pelo modo de ativação (p=0.0015). O estudo 3 mostrou que a IM não foi afetada pelo material usado para reembasar o PA nos 3 terços (C: $p<.0001$; M: $p<.0001$; A: p=0.0062) e o modo de ativação do cimento (C: p=0.9306; M: p=0.0756; A: p=0.3447). **Conclusão:** A integridade marginal foi significativamente aumentada por: (1) emprego do PA (2) ativação Q do cimento ;(3) o uso associado do pino anatômico e de um cimento auto-adesivo. O reembasamento do PA afetou a dureza knoop do cimento subjacente nos terços C e M, mas não no A; (5) O material usado para reembasar o pino anatômico não afetou significativamente a IM.

Palavras-chave: Pino de fibra de vidro, Integridade Marginal, Dureza Knoop, Cimento Resinoso.

ABSTRACT

Preformed fiber-reinforced root canal posts have increased in popularity as an alternative to metal posts. This is partly due to a modulus of elasticity that is closer to that of dentin when compared to metal posts. The employment of materials with similar mechanical properties creates a homogenous biomechanical unit which favors uniform stress distribution and reduces the incidence of root fracture and micro-leakage. In spite of positive outcomes in terms of laboratory and clinical results documented in retrospective and prospective studies, major concerns around bonding procedures still remain. The dislodging of fiber posts from the root canal continues to be the main cause of failure of fiber post–retained restorations. A chair side clinical procedure that involves the confectioning of an anatomically shaped relined post was developed to compensate the mismatch between fiber post and post space, offering a more conservative preparation for the remaining root structure. This technique has been described to compensate light limitations because the composite resin used to anatomically shape the fiber-post is light-cured immediately after relining, outside of the root canal, before cementation. Among the possible advantages of light curing the relined fiber post outside of the root canal and reducing the cement layer thickness are the increase of monomer conversion, the reduction of polymerization shrinkage, and the presence of bubbles in the cement layer. Therefore, the aim of the present study was to: (1) Compare marginal integrity of conventional and anatomically relined fiberposts to root canal dentin using scanning electron microscopy; (2) Evaluate and compare Knoop's Hardness of two dual-cure cements with for conventional and anatomically relined fiberposts in the presence and absence of light; and (3) Compare the marginal integrity between a self adhesive cement and root canal dentin after cementation of anatomic fiber posts relined with either methacrylate or silorane based composite resin. It was possible to conclude that: (1) Marginal integrity of relined fiber posts to root dentin is superior compared to conventional fiber posts; (2) The technique, activation mode and cement type were factors that affected Knoop hardness for cervical and middle root thirds. The apical third was exclusively influenced by activation mode; and (3) The material used for anatomically relining fiber posts did not significantly affect marginal integrity to root canal walls.

Key Words: Fiber Post, Marginal Integrity, Knoop's Hardness, Resin Cement.

SUMÁRIO

INTRODUÇÃO

O principal objetivo de pinos e núcleos intrarradiculares é restaurar dentes endodonticamente tratados que perderam grande parte da sua estrutura coronária. O grande desafio após a cimentação dentro do canal radicular é prover retenção para a restauração indireta definitiva (Fernandes *et al.*, 2003; Hunter *et al* 1989).

Apesar das ligas metálicas (preciosas ou alternativas) serem até recentemente o material de escolha para a fabricação de pinos e núcleos, a opção pelo uso de pinos pré-fabricados de fibra de vidro reforçados por resina tem crescido exponencialmente (Fernandes *et al.*, 2003; Hunter *et al.,* 1989). Essa mudança de atitude se deve, em grande parte, às diversas propriedades proporcionadas por esses pinos. Entre elas, o fato de que tanto a fibra de vidro quanto a resina composta que compõem esses pinos apresentam um módulo de elasticidade próximo ao da dentina (Asmussen *et al.*,1999). Quando materiais apresentam propriedades mecânicas semelhantes às do dente, uma unidade biomecânica homogênea é criada (Tay & Pashley, 2007). Esse monobloco, como foi denominado por Tay & Pashley em 2007, favorece a distribuição de forças dentro do elemento dentário (Pegoretti *et al.*, 2002). A tradução desta característica é encontrada na literatura como a redução de fraturas radiculares associadas a dentes restaurados com pinos de fibra de vidro comparados aos pinos metálicos (Ferrari *et al.*, 2000).

Além disso, o uso de adesivos/cimentos resinosos, que também apresentam módulo de elasticidade próximo ao do pino de fibra de vidro e da dentina radicular (Asmussen *et al.*, 1999), auxiliam na fixação do pino de fibra de vidro. A combinação de pino de fibra de vidro, cimento resinoso, adesivo e dentina radicular proporciona um maior selamento dos sistemas de canais radiculares quando comparado ao uso de qualquer outro cimento convencional (Zicari *et al.*, 2008; O'keefe *et al.*, 2000; Neumann *et al.* 2008; Faria-e-Silva *et al.*, 2009) . [7,10]

A qualidade da união entre o pino de fibra de vidro e a dentina radicular depende do umedecimento da resina adesiva na superfície da dentina radicular e na superfície do pino de fibra de vidro. As resinas compostas indicadas para a cimentação de pinos de fibra de vidro têm como matriz orgânica base o bis-GMA (bisfenol A-metacrilato de glicidil), UDMA (uretano dimetacrilato), TEGDMA (trietileno glicol dimetacrilato) e partículas vítreas inorgânicas que compõem entre 20% e 50% em volume do material. Apesar de este volume ser menor se comparado às resinas compostas restauradoras, o que torna o material com propriedades mecânicas também inferiores, é esta característica que proporciona a baixa viscosidade necessária para o escoamento do material tanto na superfície do pino quanto no contato com a superfície do adesivo unido à dentina do canal radicular.

Os sistemas adesivos disponíveis combinam três ou dois passos para a utilização da técnica "*etch and rinse*", e dois ou apenas um passo (todos em um) para a forma autocondicionante. Contrariamente à complexidade técnica desses sistemas adesivos tradicionais combinados aos cimentos resinosos, foram introduzidos no mercado cimentos autoadesivos. O desafio desses cimentos é produzir união com uma simples aplicação, eliminando a necessidade de pré-tratamento do substrato dentário. A simplificação dessa técnica de cimentação é particularmente tentadora quando se considera o desafio que é realizar uma técnica adesiva dentro dos canais radiculares. Por outro lado, ainda são escassos os estudos que avaliam o selamento desses cimentos quando usados para cimentar pinos de fibra de vidro (Zicari *et al*, 2008).

Entre as vantagens da característica adesiva dos cimentos resinosos está a possibilidade de uma abordagem mais conservadora das preparações do canal radicular. A opção por restaurar dentes endodonticamente tratados com pinos de fibra de vidro possibilita analisar a forma anatômica do conduto radicular para adequar o diâmetro do pino ao espaço existente (Faria-e-

Silva *et al*., 2009). O mesmo não acontece com pinos metálicos que dependem exclusivamente da retenção mecânica do pino com as paredes do canal, e exigem, portanto um preparo voltado para essa característica (Pegoretti *et al*., 2002). Além disso, a utilização de pinos de fibra de vidro com diâmetro próximo ao espaço do conduto radicular reduz a quantidade de material de cimentação e proporciona uma distribuição homogênea das tensões mecânicas por toda a estrutura dentária (Pegoretti *et al*., 2002).

Os fabricantes de pinos de fibra de vidro disponibilizam no mercado brocas com tamanhos equivalentes aos pinos com o intuito de tornar ainda mais precisa a adaptação do pino às paredes do canal (Faria-e-Silva *et al*.,2009). Por outro lado, na maioria das vezes, a anatomia do conduto difere muito do formato transversal do pino (Faria-e-Silva *et al*.,2009; De Deus *et al*., 2008). Clinicamente, o procedimento de cimentação tradicional produz uma região com grande volume de cimento resinoso entre pino e canal radicular. Uma das conseqüências de um volume maior de cimento é a possibilidade de se ter bolhas dentro do material que cria áreas de menor resistência (Bonfante *et al*., 2007). [13]

Apesar de estudos prospectivos e retrospectivos revelarem resultados clínicos positivos, o deslocamento de pinos de fibra de vidro continua sendo a principal falha desse tipo de restauração (Ferrari *et al*., 2000). Os fatores que podem justificar esse tipo de falha são a dificuldade da luz atingir as áreas mais profundas dentro do conduto (Bonfante *et al*., 2007; Roberts *et* al., 2004) a característica morfológica do substrato do canal radicular (Caiado *et al*., 2010), e a contração da resina composta à base de metacrilato durante a polimerização que gera altas tensões diante da geometria desfavorável do canal radicular (fator C) (Tay *et al*., 2007).

Até recentemente, as resinas compostas usadas em Odontologia Restauradora eram exclusivamente à base de metacrilato. Apesar dos esforços concentrados para melhorar suas propriedades químicas, a contração volumétrica que esses materiais apresentam continua sendo uma desvantagem. Dessa forma, diferentes abordagens foram desenvolvidas para minimizar a tensão gerada pela contração desses materiais. Entre elas podemos citar o desenvolvimento de novas fórmulas químicas como alternativa para as resinas à base de dimetacrilato e a criação de novas técnicas clínicas que buscam compensar as limitações dos materiais utilizados.

Uma nova fórmula química desenvolvida para resinas compostas pode ser encontrada na composição da resina Filtek Silorane (3M ESPE, Seefeld, Alemanha). Segundo o fabricante, essa resina contém monômeros de siloxano e oxirano. Enquanto o monômero de siloxano é responsável pela característica hidrófoba do material, o oxirano apresenta grupos funcionais que polimerizam por um mecanismo catiônico de abertura de aneis. Acredita-se que esse novo material apresenta uma contração volumétrica inferior a 1% do seu volume (Weinmann *et al.*, 2005).

Considerando especificamente as limitações da técnica convencional de cimentação dos pinos de fibra de vidro, foi também desenvolvida uma nova proposta de técnica que pode ser realizada imediatamente durante o atendimento clínico. A técnica almeja a confecção de um pino anatomicamente modelado visando compensar qualquer desadaptação entre o pino de fibra de vidro e as paredes do canal radicular. Isso pode ser feito usando uma camada de resina composta à base de metacrilato, ou mesmo de silorano, combinado com o adesivo apropriado na superfície do pino de fibra de vidro e posterior inserção no espaço do canal radicular. O resultado é a obtenção de um pino confeccionado de acordo com a anatomia do conduto radicular. O reflexo de uma maior adaptação é uma menor linha de cimentação e um menor volume de cimento (Grandini *et al.*, 2005).

Teoricamente, um menor volume de cimento entre o pino de fibra de vidro e as paredes do canal radicular pode também significar uma menor tensão gerada pela contração de polimerização do cimento e, consequentemente, uma maior integridade marginal na interface entre o cimento/adesivo e a dentina radicular.

Portanto, o primeiro capítulo deste trabalho objetiva comparar pinos de fibra de vidro cimentados convencionalmente aos pinos de fibra de vidro anatomicamente reembasados através da avaliação da integridade marginal entre pino, cimento resinoso e as paredes do canal radicular usando microscopia eletrônica de varredura.

Além disso, a técnica do pino anatômico pode ser relacionada com uma tentativa de compensar a dificuldade que a luz tem de penetrar áreas profundas dentro do canal, uma vez que o pino reembasado com resina composta é polimerizado fora do canal antes da cimentação. No entanto, pouco se sabe sobre a interferência que a luz tem ao ser transmitida pelo pino e a resina composta usada para dar anatomia do conduto ao pino, e como isso pode afetar a polimerização do cimento subjacente. Dessa forma, o segundo capítulo deste trabalho busca avaliar e comparar a dureza Knoop de dois cimentos duais usados para as técnicas convencional e anatômica, na presença e na ausência de luz.

O terceiro capítulo deste trabalho compara a integridade marginal entre cimento e a parede do canal radicular após a confecção de pinos convencionais ou pinos anatomicamente reembasados com uma resina convencional à base de metacrilato ou a resina de baixa contração à base de silorano. O principal intuito dessa comparação é avaliar se a técnica do pino anatômico é influenciada pela escolha do material usado para reembasar o pino de fibra de vidro.

O primeiro trabalho possibilita formular duas hipóteses: (1) A integridade marginal entre cimento e a parede do canal radicular é influenciada pela técnica de confecção do pino (anatômica ou convencional); e (2) O tipo de cimento (convencional ou autoadesivo) e seu modo de ativação podem influenciar a integridade marginal entre o cimento e a parede do canal radicular.

Já o segundo trabalho que avalia a dureza Knoop levanta as seguintes hipóteses: (1) a dureza Knoop dos cimentos testados é influenciada pela técnica de confecção do pino de fibra de vidro (anatômica ou convencional); e (2) a dureza Knoop é influenciada pelo tipo do cimento (convencional ou autoadesivo) empregado e seu modo de ativação.

Por fim, o terceiro trabalho que, semelhante ao primeiro avalia integridade marginal, estabelece duas hipóteses: (1) a integridade marginal entre o cimento e a parede do canal radicular é influenciada pelo tipo de resina (à base de metacrilato ou à base de silorano) usada para confeccionar o pino anatômico; e (2) a presença ou ausência de luz influencia a integridade marginal do cimento empregado com as paredes do canal quando os pinos anatômicos são reembasados com resina à base de metacrilato ou de silorano.

CAPÍTULO 1

Marginal Integrity of Glass Fiber Posts Relined with Composite Resin and Bonded with Different Resin Cements

Introduction: This study analyzed marginal integrity (MI) between resin cements and root canal walls after cementation of conventional or an anatomically relined fiber posts in self- or light-cure modes. **Methods:** Coronal portions of bovine incisors were removed and roots were endodontically instrumented. Apicies were sealed and post spaces prepared. Samples were assigned to 8 groups (n=10) according to technique used, post type (Conventional (CP) or Anatomic (AP)), cement employed (Rely X Unicem (U) or Rely X ARC (R)), and cement polymerization mode (Self-cure (SC) or Dual-Cure (DC)). After 48h, roots were longitudinally sectioned, polished, and replicas made. The same roots were solvent-immersed to remove poorly cured resin, and new replicas prepared. Post length was divided into cervical, middle, and apical thirds. Samples were analyzed under SEM, and percentages of continuous (gap-free) interface (%) (SD were determined as a measure of MI.) Data was analyzed using a three-way ANOVA and Tukey tests ($\alpha = 0.05$). **Results:** MI was statistically greater for AP than for CP in all root-thirds before, and after, solvent immersion. Using AP, U (73% ±36) presented greater marginal integrity than R (42% ±46). No significant difference in MI was observed among cements when the CP was used (U= 8% ±15; R= 9% ±18). MI was greater for SC (43% ±44)) than DC mode (22.9% ±35.5), independent of technique or cement tested. **Conclusions:** Marginal integrity was significantly enhanced by: anatomic rather than conventional posts; self-cure cementation rather and dual-cured; the combination of using anatomic posts with a self-adhesive, self-curing resin.

Key Words: Marginal Integrity, Resin cement, Root Canal

INTRODUCTION

Fiber-reinforced root canal posts (FRP) and adhesive composite cements are alternatives to metal posts and conventional luting cements to restore endodontically treated teeth having little-to-no remaining coronal tissue.(1-4) This success is partly due to cementing resins having moduli of elasticity closer to that of dentin than conventioinal luting agents, and because additional post retention may be developed using micromechanical bonding and not relying exclusively on friction.(5-9) Use of restorative materials with similar mechanical properties as the tooth creates a homogenous biomechanical unit, which favors uniform stress distribution. This uniformity reduces the potential for fracture (8) and of dentin-cement interfacial microleakage.(9)

In spite of positive laboratory and clinical results documented in retrospective (10) and prospective (11) studies, major concerns in relation to endodontic bonding procedures still remain. Application of adhesive techniques within the root canal space is particularly jeopardized because of the difficulty of photopolymerizing light to reach apical areas.(12) It is suggested that light can be transmitted through fiber posts to light-cure resin cements inside the root canal, (13) however the delivered energy density decreases in regions further from the light source.(14-15) The configuration factor developed by polymerizing a thin resin film within the canal space leers to elevated contraction stresses, and overt wall-to-wall contraction of post cements.(16-17) Moreover, most canals are elliptical in cross-section, which is not compatible with round-shaped fiber posts and drills.(18-19) When prepared canals become excessively flared, the adaptation of fiber posts to canal walls can be compromised because a thicker cement layer is developed, often times incorporating bubbles.(20-21)

An alternative, chair-side post procedure involves development of an anatomically shaped post developed by confectioning polymerizable components onto the post so as to form an anatomically shaped, custom post, thus compensating for the mismatch between fiber post and prepared post space.(20,22-23) This technique compensates for limitations imposed on the curing light because the composite resin used to anatomically shape the fiber-post is light-cured immediately after relining, outside of the root canal, before cementation.(20,22-23) Among the advantages of this technique are the increase of monomer conversion, the reduction of polymerization shrinkage, and lowering of bubble content in the resin cement.(20,22-23)

The purpose of this study was to evaluate the marginal integrity (MI) of fiber-reinforced root canal posts relined with composite resin to create an anatomical post (AP) configuration and cemented with dual-cure, self-adhesive or conventional resin cements in the presence or absence of light. Integrity was evaluated as percentage of continuous resin/dentin interface using SEM images. Three hypotheses were tested: (1) MI of posts relined with composite resin is greater than that of conventionally cemented posts; (2) Use of no light-curing will produce significantly greater MI of relined or conventional posts than when cement is dual-cured; and (3) use of self-adhesive, dual-cure resin cement will provide significantly better MI than when using conventional dual-cured resin-based cement.

MATERIALS AND MEHODS

The coronal portions of eighty, freshly extracted bovine incisors were removed, leaving a 16-mm long root section. Endodontic, crown-down instrumentation was performed. Drills (Gates Glidden, SybronEndo Corporation, Orange, CA, USA) #5, 4, 3, and 2 were inserted sequentially into the canal to flare cervical and middle thirds. Apical preparation was performed using sizes 80-45 K-files (Dentsply/Maillefer, Tulsa, OK, USA). Instrumentation was performed under saline irrigation. Canal filling was not executed to avoid interference between the materials used and fiber post bonding. Apicies were externally sealed using a commercial composite resin (Z250, 3M ESPE, St. Paul, MN, USA).

Post spaces were prepared 15 mm deep using a 1.5mm diameter bur (Fibrekor post-Jeneric Pentron Incorporated, Wallingford, CT, USA). Roots were randomly assigned to eight treatment groups (n=10) according to the post technique employed (conventional or anatomic), the dual-cured cement used (conventional or adhesive), and the mode of activation (self- or dual-cure).

Post preparation

Specimens in Groups 1-4 were treated using conventional fiber posts. The post (Reforpost # 3, Angelus, Londrina, PR, Brasil) was treated with 37% phosphoric acid (3M Scotchbond etchant; 3M ESPE, St. Paul, MN, USA) for 1 min, coated with silane coupling agent (3M ESPE), and then coated with a thin layer of a light-curable resin (Scotch Bond Multipurpose Adhesive, 3M ESPE) that was applied and light exposed to a LED curing light (Elipar™ Freelight 2 LED Curing Light, 3M ESPE, Minnesota, USA) for 10s. Irradiance of light measured 1200 mW/cm^2 on a hand-held dental curing power meter (Nova, Ophir Optronics Ltd., Jerusalem, Israel)

In groups 5-8, root canals were restored using custom-made, anatomic fiber posts, the post itself being the same brand used in Groups 1-4. The canal walls were coated with a non-ionic, water-soluble polymer gel to act as a separating medium (Natrosol gel, Drogal, Piracicaba, SP, Brazil). The post was covered with composite resin paste (Filtek Z-350; Shade A2, 3M ESPE) and inserted into the canal. While still within the canal, the fiber post relined with composite resin was light-cured for 3s from the root top surface, removed while still in a pliable state, and then light-cured again for additional 40s. The root was copiously rinsed to remove all traces of the gel.

Post Cementation Procedures

Cementation protocols for all groups are described in Table 1. During all phases of post cementation, the root segment was held vertically in a mound of pliable putty (Silly Putty, Super Massa, Estrela, São Paulo, SP, Brazil), which was opaque to light, this simulating surrounding gingiva.

Sample Preparation

After 48 h, restored roots were longitudinally sectioned, using a slow-speed diamond-bladed saw (IsoMet 1000, Buehler, Lake Bluff, IL, USA) under water cooling. Only half of each tooth was used for the analysis. The cut surfaces were polished with with SiC paper (#600, #1200, #2000 grit, and specimens were ultrasonically cleaned in deionized water for 10 min between each polishing step. Polyvinyl siloxane (3M-Express, St. Paul, MN, USA) impressions of the surfaces were taken and replicated in epoxy resin (Poly/Bed®812, Nadic methyl anhydride, DMP-30, Polysciences, Inc.,Warrington, PA, USA). The length of the post inside the root canal was divided on the replicas into three equi-lenth portions using a fine tipped pencil (cervical (C), middle (M), and apical (A) thirds). After baseline impressions, the same roots were immersed in a solution of methyl ethyl ketone (MEK, 2-butanone, 99+%, Acros, Belgium) to dissolve poorly polymerized resin components and sonicated for 20 min (MaxiClean 750, Unique, Indaiatuba, SP, Brazil). The sectioned roots were immersed in 37º C deionized water for 24h to cause rehydration, and a new set of impressions and replicas was made.

The two sets of epoxy resin replicas were air-dried overnight at room temperature, sputter-coated with gold (Bal-tec SCD 050 Sputter Coater, São Paulo, Brazil), and examined in a scanning electron microscope (SEM) (JEOL JSM-5600LV, Japan) operating at 15 kV. Marginal Integrity (MI) was determined by calculating the percentage of continuous (gap-free) resin/dentin interface relative to the total interface length. Measurements were made from the captured images that were transferred to a personal computer equipped with image analysis software (IM50, v. 4.0; Leica Microsystems GmbH, Wetzlar, Germany). Data were first transformed to normality using Box-Cox transformation. Data were analyzed using a three-way ANOVA and Tukey post-hoc tests within each root-third section separately. All statistical testing was performed at a pre-set alpha of 0.05.

RESULTS

Analysis of the three-way ANOVAs revealed that marginal integrity using the anatomic composite relining technique was significantly greater than when using a conventional technique in all portions of root-thirds, before (C: p=0.0001; M: p=0.0001; A: p=0.0062) and after (C: p=0.0057; M: p=0.0001; A: p=0.0074) solvent immersion (Table II).

Marginal integrity was greater in the absence of light (43% ± 44) than in the presence of light (23% ± 35.5), independent of fiber post fabrication technique or cement type employed.

The self-adhesive cement demonstrated significantly greater marginal integrity compared to use of a conventional resin cement (Unicem 73% ±36; Rely X ARC 42% ±46, respectively) when the anatomic composite relining technique was employed (Table III). No significant difference in marginal integrity was observed between cement types when the Conventional post-fabrication method was used (Unicem 8% ± 15; Rely X ARC 7% ± 18, respectively) (Table III).

DISCUSSION

The experimental results validated the first hypothesis that posts fabricated using the anatomical technique would demonstrate significantly greater marginal adaptation. This finding was confirmed at all three root canal divisions: C: p=0.0001; M: p=0.0001; A: p=0.0062. This result agrees with a previous study,(23) which found that fiber post relining improved post retention in all root canal thirds. Also, it is important to note that marginal integrity did not change after solvent immersion when the anatomical posts were tested (Table II). This finding suggests that the smaller volume, thinner cement lining associated with relined fiber posts creates an overall greater mass of polymerized composite resin in all areas of the root canal interior. The extremely high C-factor estimated for bonding fiber-reinforced root canal posts to canal surfaces (16) is likely to be the major cause of gap formation found in the conventional post fabrication technique groups, as well as the volumetric contraction that follows polymerization of dental composites (approximately 1.5–5%) (21,24).

Although TEM examination is the best way to assess the quality of the resin-dentin inter-diffusion zone, SEM has the advantage of providing repeatable and quantitative information on its uniform formation.(20-21) Therefore, the present study employed SEM for quantitative analysis, as previously described.(21)

The second hypothesis anticipated that allowing the resin cement systems to totally self-cure would provide enhanced marginal integrity as compared to providing light and allowing the resins to undergo a dual-cure reaction was supported by the research findings. This finding was true, irrespective of method of post fabrication. The presence of a light-initiated polymerization reaction results in a rapid increase in monomer conversion of the cement, which consequently imparts high levels of internal contraction stress in this very high configuration factor situation, leading to the possibility of interfacial bonding failure. However, with the absence of light, the polymerization reaction is both slower and lower in total conversion.

The third hypothesis considered that use of a self-adhesive resin would provide superior marginal integrity over that of only a conventional resin cement, and was upheld by the experimental data, but only under certain conditions. When self-adhesive resin was used with the anatomical post, marginal integrity was always significantly greater than for conventional resin cement, however, when using the conventional post, cement type did not make a difference. Zicari et al. (2008) (6) found that although Rely X Unicem presented a promising bond strength, its sealing ability was significantly worse than other tested cements. According to authors SEM analysis revealed air bubbles at the cement–dentin interface. The fact that anatomic posts allow a thinner cement layer may explain a smaller incidence of bubbles. Higher wall-to-wall adaptation can also permits higher internal pressure during luting procedures, enhancing the quality of the resin-dentin interface bonding with the self-adhesive cement, which would be otherwise difficult to control. This can also explain why Unicem did not present the same results when the convention technique was employed.

Application of solvent and then re-evaluating marginal integrity proved to be a valuable tool. In the first tooth sectioning, if poorly cured resin were present and seemed to be filling the cement space, its presence would provide a false indication of the true bonding extent between the tooth and cementing resin. However, by subjecting the sectioned teeth to a strong organic solvent, smeared, poorly cured resin, as well as overtly unpolymerized material, were dissolved, leaving evidence of only highly polymerized resin and its relationship to the root wall to judge the extent of marginal integrity. Even though use of the self-adhesive resin, used in a self-curing mode with an anatomic fiber post fabricated provided remarkably higher marginal integrity values than all other combinations, it should be noted that resin-dentin gaps still exist. Thus, marginal integrity alone may not be sufficient to prove a higher sealing ability and stop orthograde contamination of the root via leakage of oral fluids and micro-organisms. Contemporary adhesive systems and composites are susceptible to water sorption.(21) The result of water influx would be enhanced chemical degradation and erosion caused by release of unreacted monomers that, in time, might result in massive loss of unpoylimerized composite, as well as degradation of the bonded interface, and loss of post retention.(25)

Past investigations,(20, 23) as well as the present study agree that anatomic posts are able to provide a superior quality of fit compared to the conventional cementation of fiber posts, reducing the incidence of bubbles and voids and enhancing marginal adaptation. However, it is important to emphasize that only the initial, marginal integrity of the resin-dentin interface was evaluated in this study. Long-term studies need to be performed to evaluate the durability of bonds established using the groups tested to resist influences of the harsh oral environment: pH changes, microleakage, thermocycling, water storage, etc. Ultimately, once optimal materials and methods have been established, clinical trials need to be performed to substantiate the early findings of studies such as this present one.

Within the limitations imposed by the conditions of testing, the following conclusions may be made:

(1) Marginal integrity of posts relined with composite resin (forming a chair-side, anatomical post) is superior compared to use of conventional, unmodified posts

(2) Limiting the dual-curable resin cement to only a self-cure cementation increased the marginal integrity of relined and conventional posts, and

(3) The highest level of marginal integrity obtained among products and methods tested was a self-adhesive cement allowed to undergo self-polymerization when delivering an anatomically modified fiber post.

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Table I. Description of Fiber post technique, Adhesive System, Luting cement, Cure Mode and Application Protocol used

Group	Fiber post technique	Adhesive System	Luting Cement	Cure Mode	Application Protocol
1	Conventional	No dentin pre-treatment	Rely X Unicem (3M ESPE)	Self-cure	No pretreatment of the canal walls was performed except the removal of excess water from the post space with absorbent paper points. The cement was inserted in the root canals using Elongation Tips (3M ESPE). The posts were cemented into the root canals with light pressure and the cement was left to self-cure for 5min from start of mix.
2	Conventional	No dentin pre-treatment	Rely X Unicem (3M ESPE)	Light-cure	Bonding procedures in Group 1 were repeated but the cement was light-cured through the cervical portion of the root for 40 s on the buccal and lingual surfaces, totalizing 80 s of light exposure.
3	Conventional	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Self-cure	Canal walls were etched with 35% phosphoric acid for 15 s, water-rinsed for 15 s and gently air dried. Excess water was removed with absorbent paper points. One coat of Scotchbond multi-purpose plus activator (3M ESPE) was applied followed by a single coat of Scotchbond multi-purpose primer, excess material was removed from the canal using paper points. One drop of Scotchbond multipurpose plus catalyst was added to the canal and to the fiber post before inserting the cement Rely X ARC using AccuDose Needle Tubes (20ga, Centrix, Shelton, Canada). The posts were placed into the root canals with light pressure and the cement was left to self-cure for 10 minutes.

4	Conventional	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Light-cure	Canal walls were etched with 35% phosphoric acid for 15 s, water-rinsed for 15 s and gently air dried. Excess water was removed with absorbent paper points. One coat of a Scotchbond multi-purpose primer was applied and dried followed by the insertion of Scotchbond multi-purpose adhesive. Excess material was removed using paper points and the adhesive was then light-cured for 10 seconds. The cement Rely X ARC was inserted in the root canal using AccuDose Needle Tubes (20ga, Centrix, Shelton, Canada) and the posts were cemented into the root canals with light pressure. The cement was then light cured through the cervical portion of the root for 40 s on the buccal and lingual surfaces, totalizing 80 s of light exposure.
5	Anatomic	No dentin Pre-treatment	Rely X Unicem (3M ESPE)	Self-cure	Group 5 followed the cementation procedures performed in Group 1
6	Anatomic	No dentin pre-treatment	Rely Unicem (3M ESPE)	Light-cure	Group 6 followed the cementation procedures performed in Group 2.
7	Anatomic	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Self-cure	Group 7 followed the cementation procedures performed in Group 3.
8	Anatomic	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Light-cure	Group 8 followed the cementation procedures performed in Group 4.

Table II. *P*-Values observed using a three-way ANOVA for percent of continuous interfaces within each third of canal depth considering three factors (cement type, conventional or anatomic post use, and use of self- or dual curing, and all interaction terms

	ROOT-THIRD LOCATION					
	CERVICAL		MIDDLE		APICAL	
Factor	Sectioned Only	Sectioned plus solvent	Sectioned Only	Sectioned plus solvent	Sectioned Only	Sectioned plus solvent
Cement	0.3342	0.9616	**0.0223**	**0.0227**	0.4125	0.8285
Post Technique	**<0.0001**	**0.0057**	**<0.0001**	**<0.0001**	**0.0062**	**0.0074**
Cure Method	0.5452	0.4422	**0.0114**	0.0616	0.2706	0.4220
Cem*Post	0.2497	0.7165	**0.0452**	**0.0115**	0.3375	0.2454
Cem*Cure	0.4370	0.5990	0.8815	0.6712	0.5763	0.4761
Post*Cure	0.1952	0.3361	0.2569	0.2941	0.2589	0.3833
Cem*Post*Cure	0.7376	0.8270	0.1326	0.2378	0.4933	0.4671

Bolded numbers indicate factors demonstrating a significant impact on marginal integrity ($p < 0.05$)

Table III. Mean (SD) percentage of gap-free interface (indicator of marginal integrity) within each root-third segment, comparing the interaction between post fabrication technique and cement type at baseline and after solvent immersion

Cement Type	At first sectioning		After solvent exposure	
	Anatomic Fiber Post	Conventional Fiber Post	Anatomic Fiber Post	Conventional Fiber Post
Conventional Resin	43 (46) Ab	9 (18) B a	28 (39) Ab	9 (18) Ba
Self-adhesive	73 (36) Aa	8 (15) B a	65 (40) Aa	5 (12) Ba

Capital letters compare marginal integrity scores only within a single cement type among the post types (rows) and lower case letters compare values within a specific post-type between the composites (columns). Similar letters indicate no significant difference between compared groups ($p > 0.05$)

CAPÍTULO 2

Knoop Hardness of Luting Resin Cements Used in Conventional or Anatomically Relined Fiber Post Techniques in the Presence or Absence of Light

ABSTRACT

Statement of Problem. Although Anatomic Posts (AP) permit better adaptation to root canal walls, thinner linings of luting cements and higher bond strength values between luting cement and root canal walls, the issue of light transmission through its relining resin must still be investigated.

Purpose. Evaluate Knoop hardness of two dual luting cements used in the cementation of AP and Conventional fiber post (CP), in the presence or absence of light.

Materials and Methods. Bovine incisors had crowns removed. Roots were endodontically prepared using saline solution. Apexes were sealed externally with composite resin and post spaces were prepared 15 mm deep. Samples were randomly assigned to 8 experimental groups (n=5) according to the technique used (AP or CP), adhesive cement employed (Rely X Unicem (U) or Scotch Bond Multipurpose + Rely X ARC (R)) and activation mode (light-cure or self-cure). After 48 h, roots were longitudinally sectioned and surfaces were polished. The length of the post inside the root canal was divided on the replicas into three (cervical- C, middle-M and apical-A thirds) using a small tip pencil and Knoop hardness number (KHN) means were obtained (50g for 5s). Data were analyzed by Three-way ANOVA and Tukey tests. The level of significance was set in advance at $\alpha = 5\%$.

Results. The interaction of all three factors (technique, luting cement and activation mode) was statistically significant at the cervical and middle thirds (cervical: p= 0.0393, Middle: p= 0,0177) but not at the apical third. The later was only significantly affected by the isolated factor Activation Mode (p=0.0015).

Conclusion. Both AP and CP techniques behave similarly in cervical and apical thirds. However, relined fiber posts significantly affect the transmission of light to the underlying luting cement in the root canal's middle third.

Clinical Implications. In all thirds (cervical, middle or apical) the presence of light was a determinant factor to increase Knoop hardness.

INTRODUCTION

The use of preformed fiber-reinforced root canal posts (FRP) have increased in popularity as an alternative to metallic posts.[1-5] Among the advantages of substituting metal for fiber and composite resin is that these materials present a modulus of elasticity that is closer to that of dentin.[3-4] When materials that present similar mechanical properties to the tooth are employed, a homogenous biomechanical unit is created. This monoblock[6] favors the uniform stress distribution within the tooth[7] and reduces the incidence of dentin-cement interface micro-leakage.[8]

Although the conventional fiber posts technique has presented favorable laboratory and clinical results documented in retrospective[09] and prospective[10] studies, great concern has been aroused in relation to the application of adhesive techniques within the root canal because of the difficulty of light to reach apical areas.[11]

An alternative to the conventional luting of fiber-posts is a chair side clinical procedure that involves the confectioning of an anatomically shaped relined post.[12-14] The main ambition of fiber post relining is to reduce the thickness of the resin cement layer.[13] A smaller volume of cement is less likely to form bubbles or voids which represent areas of weakness within the material.[12] Furthermore, the relined anatomic post adapts to the canal and therefore there is no need to try to adapt the root canal to the standardized post.[14]

In theory, the AP technique is able to partially compensate light limitations because the composite resin used to reline the fiber-post is light-cured, outside of the root canal, before cementation,[12-14] however such advantage has still not been verified. The other aspect that must be considered is how this technique influences the polymerization of the luting cement. The heart of the issue for conventional and ARFP techniques remains light transmission through the post.[13,15-18]

Considering the later, there is no information on whether light absorption through the relining resin may negatively affect the polymerization process of the layer of cement.[13]

Therefore, the purpose of this study was to evaluate Knoop hardness of two dual luting cements used in the cementation of AP or CP, in the presence or absence of light.

Three research hypotheses were tested: (1) Knoop hardness average values for both dual luting cements are different independent of the technique employed (AP or CP), (2) The activation mode (self-cure or light-cure) affect Knoop hardness values for both dual-cure luting cements tested. (3) Knoop hardness average values are influenced by the luting cement employed (conventional composite resin cement or self-adhesive composite resin cement).

MATERIALS AND MEHODS

The coronal portions of forty, freshly extracted bovine incisors were removed, leaving a 16-mm long root section. Endodontic, crown-down instrumentation was performed. Drills (Gates Glidden, SybronEndo Corporation, Orange, CA, USA) #5,4,3, and 2 were inserted sequentially into the canal to flare cervical and middle thirds. Apical preparation was performed using sizes 80-45 K-files (Dentsply/Maillefer, Tulsa, OK, USA). Instrumentation was performed under saline irrigation. Canal filling was not executed to avoid interference between the materials used and fiber post bonding. Apicies were externally sealed using a commercial composite resin (Z250, 3M ESPE, St. Paul, MN, USA).

Post spaces were then prepared 15 mm deep using a 1.5mm diameter bur (Fibrekor post- Jeneric Pentron Incorporated, Wallingford, CT, USA). The prepared roots were randomly assigned to eight experimental groups (n=5) according to the post technique employed (conventional or anatomic), the dual-cured cement used (conventional or adhesive), and the mode of activation (self- or dual-cure) Table I. The characteristics of the materials employed are listed in Table II.

Post preparation

Specimens in Groups 1-4 were treated using conventional fiber posts. The post (Reforpost # 3, Angelus, Londrina, PR, Brazil) was treated with 37% phosphoric acid (3M Scotchbond etchant; 3M ESPE, St. Paul, MN, USA) for 1 min, coated with silane coupling agent (3M ESPE), and then coated with a thin layer of a light-curable resin (Scotch Bond Multipurpose Adhesive, 3M ESPE) that was applied and light exposed to a LED curing light (Elipar™ Freelight 2 LED Curing Light, 3M ESPE, Minnesota, USA) for 10s. Irradiance of light measured 1200 mW/cm^2 on a hand-held dental curing power meter (Nova, Ophir Optronics Ltd., Jerusalem, Israel)

In groups 5-8, root canals were restored using custom-made, anatomic fiber posts, the post itself being the same brand used in Groups 1-4. The canal walls were coated with a non-ionic, water-soluble polymer gel to act as a separating medium (Natrosol gel, Drogal, Piracicaba, SP, Brazil). The post was covered with composite resin (Filtek Z-350; Shade A2, 3M ESPE) and inserted into the canal. While still within the canal, the fiber post relined with composite resin was light-cured for 3s from the root top surface, removed while still in a pliable state, and then light-cured again for additional 40s. The root was copiously rinsed to remove all traces of the gel.

Post Cementation Procedures

Cementation protocols for all groups are described in Table I. During all phases of post cementation, the root segment was held vertically in a mound of pliable putty (Silly Putty, Super Massa, Estrela, São Paulo, SP, Brazil), which was opaque to light, this simulating surrounding gingiva.

Sample Preparation

After 48 h, roots were longitudinally sectioned, slightly away from the diameter of the post using a slow-speed diamond saw under water cooling to expose the interfaces between the post and cement and between the cement and dentin. Because of the small diameter of the post and the amount of structure lost during cutting, only one half of each tooth was available for the analysis. The cut surfaces were polished with increasingly finer grit SiC papers (#600, #1200, #2000). The specimens were ultrasonicated in deionized water for 10 min between each polishing step.

The 15mm long interface corresponding to the length of the post inside the root canal was equally divided on the samples into three using a small tip pencil. Accordingly, the segments were named cervical, middle and apical thirds and were used as a reference mark for the knoop hardness analysis.

A universal indenter tester (HMV–2, Shimadzu, Tokyo, Japan) was set at the automatic mode with 50 g of force for 15 s. Three indentation measurements were manually made in the luting cement layer at 1-mm distance from each other in all thirds (40X magnification).

Knoop hardness number (KHN, kg/mm^2) was calculated based on the indentation measurement obtained by a single operator. The arithmetic mean was calculated for each location tested. Data were first transformed to normality using Box-Cox transformation and then were analyzed by Three-way ANOVA and Tukey tests. The level of significance was set in advance at α = 5%.

RESULTS

Results show that the interaction of all three factors was statistically significant at the cervical and middle thirds (cervical: p= 0.0393, Middle: p= 0.0177) but not at the apical third (p=0.0522) (Table III). The later was only significantly affected by the factor Activation Mode (p=0.0015). Additional comparisons were made according to the results obtained by the ANOVA analysis (Tables IV, V, VI).

In the cervical third, it was possible to observe that overall both luting cements presented comparable statistical values at each experimental condition. The exception occurred for the CP in the presence of light. In this case, Unicem (62.84±2.29) presented a statistically higher value of Knoop hardness compared to Rely X ARC (52.292±3.136) (TableIV).

When Rely X ARC was analyzed according to different experimental conditions, no statistical differences were found except for AP technique in the absence of light (43.314 ±4.150) (Table IV). In this case, Rely X ARC presented a statistically smaller value for Knoop hardness compared to other groups. However, when Rely X Unicem was analyzed according to different experimental conditions, the presence of light was always associated with a higher value for Knoop hardness (Table IV).

In the middle third, the conventional technique was associated with higher values of Knoop hardness when the cement Rely X Unicem was used in all experimental conditions (Table V). The same was observed for Rely X ARC in the absence of light. However, when Rely X ARC was observed in the presence of light the opposite behavior occurred. In this case, the AP technique presented a statistically higher value for Knoop hardness (50.614±6.420) than CP (48.04±3.45).

In the apical third, the only factor that revealed statistical difference was the activation mode. Table VI shows that knoop hardness values were higher when luting cement were light-cured (46. 813 ± 5.959) than self-cured (39.479±8.067).

DISCUSSION

Although the idea of fiber post relining to compensate the limitations of conventional pre-fabricated fiber posts is a recent approach, [12-14] the question of whether a light-curing cement is adequate for the cementation of fiber posts has been constantly brought-up in literature.[13,15-17] While some authors believe that the amount of light that passes through the post and reaches its apical portion is not enough to adequately cure a light-activated resin cement,[15,17] others state that transmission through a translucent post is sufficient to induce polymerization in the apical portion.[16] If the transmission of light through the fiber post to reach the luting cement is the main issue for the conventional technique, the transmission of light through the fiber post and the pre-polymerized relining resin is that for the AP technique.

In this study, Knoop hardness was the measurement used to calculate and compare the ability that light had to reach and polymerize two dual luting cements used in the AP and CP techniques. In order to make a comparison and offer a control group, the same dual-cure cements were also tested in the absence of light (Groups1, 3, 5, and 7). An alternative method could have been used to calculate light transmission through the fiber post such as Spectrophotometric measurements of the amount of photons reaching different post levels.[15-16] However, this technique would not be able to reproduce the different clinical steps involved in the CP and AP techniques or allow the analysis of the interaction of all three factors (technique, activation mode, luting cement).

The first hypothesis that knoop hardness for both dual luting cements is influenced by the technique employed (AP or CP) was accepted for cervical and middle thirds but rejected for the apical third. Table III shows interactions between Luting cement, Technique and Activation Mode for both cervical and middle third, but not for the apical third.

When the interaction of the three factors was analyzed specifically at the cervical third it was possible to observe that overall both luting cements presented comparable statistical values at each experimental condition (Table IV). The exception was Rely X Unicem that presented a statistically higher value of Knoop hardness compared to Rely X ARC for the conventional technique in the presence of light. One of the reasons that may have influenced this result is the fact that the cement Rely X Unicem presents larger fluoraluminium silicate particle fillers (9.5µm) compared to Rely X ARC (2µm). Hence, the chance of encountering one of these particles during indentation measurements is higher for Unicem samples than Rely X ARC.

Another observation that can be made is that Rely X Unicem presented a higher Knoop hardness average value in the presence of light for both AP and CP techniques (table IV). This once again reveals that light, in the cervical third, is able to reach the layer of luting cement and enhance cure.[15-17]

In the same manner, for Rely X ARC the average value for Knoop hardness was higher in the presence of light than absence of light when the AP technique was employed. However, no difference between light-cure and self-cure activations of Rely X ARC was observed when the CP technique was used. It can be speculated that in this case, the volume of the layer of cement may have influenced the cure of the Rely X ARC cement. This implies that the amount of light transmitted in the 5mm which comprehends the cervical third is probably insufficient to overcome the polymerization obtained by the self-cure mode alone.[18]

When the interaction of the three factors was analyzed specifically at the middle third (table V) the AP technique presented statistically lower values for Knoop hardness compared to the CT. The only exception occurred when light-cured Rely X ARC was employed in the conventional technique. To explain this result it is important to understand that the middle third is extremely deficient in light transmission. When the AP technique is employed, light must be transmitted through the fiber post and the relining resin before it reaches the layer of cement. This is not the case for the CT, where light requires only to be transmitted through the fiber posts.[13]

As for the CT, light must be transmitted through the fiber post to reach a much greater volume of cement that must also be polymerized. Therefore, it is possible to comprehend that both techniques may present variables that will jeopardize Knoop hardness. This fact can probably explain why light-cured Rely X ARC employed in the conventional technique presented a statistically lower Knoop hardness value than the AP technique in the presence of light.

The apical third was exclusively influenced by the activation mode. An explanation for this result is that, although in the AP technique the fiber post is relined with composite resin along the whole length of the fiber post, towards the apical portion of the relined fiber post, the amount of relining resin is considerably reduced. As a consequence, at the apical third, there is practically no difference between the conventional fiber post and the anatomically relined fiber post. Therefore, in this region the technique was less relevant than the activation mode.

The second hypothesis tested that the activation mode (self-cure or light-cure) affects Knoop hardness values for both dual-cure luting cements tested was accepted for cervical, middle and apical thirds (table III). This once again confirms the fact that light transmission through the fiber post is directly related to higher values of Knoop Hardness of the underlying cement.

Finally, the third hypothesis that Knoop hardness average values are influenced by the luting cement employed (conventional composite resin cement or self-adhesive composite resin cement) was rejected for cervical and middle thirds but not the apical thirds (table III).

Considering the limitations of this study, it is possible to conclude that (1) The presence of light was a determinant factor to increase knoop hardness. (2) Fiber posts relined with composite resin may affect light transmission in the root canal middle third.

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TABLES

Table I. Description of Fiber post technique, Adhesive System, Luting cement, Cure Mode and Application Protocol used

Group	Fiber post technique	Adhesive System	Luting Cement	Cure Mode	Application Protocol
1	Conventional	No dentin pre-treatment	Rely X Unicem (3M ESPE)	Self-cure	No pretreatment of the canal walls was performed except the removal of excess water from the post space with absorbent paper points. The cement was inserted in the root canals using Elongation Tips (3M ESPE). The posts were cemented into the root canals with light pressure and the cement was left to self-cure for 5min from start of mix.
2	Conventional	No dentin pre-treatment	Rely X Unicem (3M ESPE)	Light-cure	Bonding procedures in Group 1 were repeated but the cement was light-cured through the cervical portion of the root for 40 s on the buccal and lingual surfaces, totalizing 80 s of light exposure.
3	Conventional	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Self-cure	Canal walls were etched with 35% phosphoric acid for 15 s, water-rinsed for 15 s and gently air dried. Excess water was removed with absorbent paper points. One coat of Scotchbond multi-purpose plus activator (3M ESPE) was applied followed by a single coat of Scotchbond multi-purpose primer, excess material was removed from the canal using paper points. One drop of Scotchbond multipurpose plus catalyst was added to the canal and to the fiber post before inserting the cement Rely X ARC using AccuDose Needle Tubes (20ga, Centrix, Shelton,

					Canada). The posts were placed into the root canals with light pressure and the cement was left to self-cure for 10 minutes.
4	Conventional	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Light-cure	Canal walls were etched with 35% phosphoric acid for 15 s, water-rinsed for 15 s and gently air dried. Excess water was removed with absorbent paper points. One coat of a Scotchbond multi-purpose primer was applied and dried followed by the insertion of Scotchbond multi-purpose adhesive. Excess material was removed using paper points and the adhesive was then light-cured for 10 seconds. The cement Rely X ARC was inserted in the root canal using AccuDose Needle Tubes (20ga, Centrix, Shelton, Canada) and the posts were cemented into the root canals with light pressure. The cement was then light cured through the cervical portion of the root for 40 s on the buccal and lingual surfaces, totalizing 80 s of light exposure.
5	Anatomic	No dentin Pre-treatment	Rely X Unicem (3M ESPE)	Self-cure	Group 5 followed the cementation procedures performed in Group 1
6	Anatomic	No dentin pre-treatment	Rely Unicem (3M ESPE)	Light-cure	Group 6 followed the cementation procedures performed in Group 2.
7	Anatomic	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Self-cure	Group 7 followed the cementation procedures performed in Group 3.
8	Anatomic	Scotch Bond Multipurpose Plus	Rely X ARC (3M ESPE)	Light-cure	Group 8 followed the cementation procedures performed in Group 4.

Materials	Mode of activation	Composition of Bonding System	Manufacturer	Batch no.
Rely X Unicem	Dual Polymerized	Silica, glass, calcium hydroxide, methacylated phosphoric acid ester, triethylene glycol dimethacylate.	3M ESPE, St. Paul, MN, USA	314601
Scotchbond Multipurpose Plus	Dual Polymerized	Primer: water, HEMA, Vitrebond copolymer Activator:ethyl alcohol, benzene sulfinic acid, sodium salt Catalyst: Bis-GMA, HEMA, benzoyl peroxide Adhesive: Bis-GMA, HEMA, tertiary amines (both for light-cure and self-cure initiators), photo-initiator	3M ESPE, St. Paul, MN, USA	Primer: 3008 Activator: 7546 Catalyst: 7547 Bond: 7543
Scotchbond Etchant		35% phosphoric acid	3M ESPE, St. Paul, MN, USA	
Rely X ARC	Dual Polymerized	Silane, treated silica filler, TEGDMA, Bis-GMA, dymethacrylate polymer	3M ESPE, St. Paul, MN, USA	3415A3

Table II. Characteristics of Materials used in this study

HEMA, 2- hydroxyethyl methacrylate; Bis-GMA, bisphenol-glycidyl methacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate.

Table III. *P*-Values observed by Three-way ANOVA for knoop hardness along the root canal thirds considering three factors (technique, luting cement, and presence or absence of light) and their interaction

Factor	Variables: Cervical	Middle	Apical
Technique	0.5469	**<.0001**	0.2955
Luting Cement	0.0287	0.7321	0.0888
Activation Mode	**<.0001**	0.0984	**0.0015**
Luting Cement* Technique	0.3444	0.1218	0.4007
Technique*Activation Mode	0.3424	0.4744	0.5082
Luting cement*Activation Mode	0.0730	0.1764	0.2652
Luting Cement* Technique* Activation Mode	**0.0393**	**0.0177**	0.0522

Table IV. Knoop hardness Average (standard deviation) and Tukey tests (5% significance) comparing the interaction between Technique and Presence/Absence of Light for both luting cements tested in the Cervical Third

	AP Technique		CP Technique	
	Presence of Light	Absence of Light	Presence of Light	Absence of Light
Rely X ARC	59.100 (4.8)aA	43.314 (4.150)bA	52.292(3.136)aB	45.560(5.247)aA
Unicem	60.606 (4.315)aA	45.680(5.879) bA	62.840(2.292)aA	44.466(5.710)bA

Lower cases compare conditions for each cement (rows) and capital letters compare cements at each experimental condition (columns). Different notations indicate significant differences ($p < 0.05$)

Table V. Knoop hardness Average (standard deviation) and Tukey tests (5% significance) comparing the interaction between Luting Cement and Presence/Absence of Light for both techniques tested in the Middle Third

	Rely X ARC		Unicem	
	Presence of Light	Absence of Light	Presence of Light	Absence of Light
AP	50.614(6.420)A	36.308(5.734)B	49.258(7.316)B	43.766(7.530)B
CP	48.04(3.45)B	48.12(5.602)A	55.174(6.956)A	47.912(2.001)A

Capital letters compare techniques at each experimental condition (columns). Different notations indicate significant differences (p <0.05)

Table VI. Average, standard deviation and Tukey Test with a 5% significance level comparing the averages of knoop hardness according to the cement activation mode in the Apical third

Activation Mode	Average	Standard Deviation	Tukey test (α=0,05)
Light-cure	46.813	5.959	A
Self-cure	39.479	8.067	B

Capital letters compare activation modes (column)

CAPÍTULO 3

Marginal Integrity of Glass Fiber Posts Relined with Methacrylate or Silorane-based Composite Resins

Statement of Problem. The extremely high C-factor estimated for bonding Glass Fiber Posts (GFP) to root canal and the high volumetric contraction that follows polymerization of dental composites is likely to be one of the major causes of gap formation between cemented posts and the root dentin substrate.

Purpose. To evaluate marginal integrity (MI) between root dentin and a dual-cure self-adhesive cement used to lute conventional (CP) or anatomically relined glass fiber posts (AP) confectioned using a low shrinkage silorane-based material or a conventional methacrylate-based composite.

Materials and Methods. Bovine incisors had crowns removed. Roots were endodontically prepared using saline solution. Apicies were externally sealed and post spaces were prepared. Samples were randomly assigned to 6 experimental groups (n=10) according to technique employed (CP or AP), the material used to confection the AP (methacrylate-based or silorane-based composite resin) and the employment or not of light during cementation procedures using a dual cure self-adhesive cement. After 48 h, roots were longitudinally sectioned, surfaces were polished and impressions were taken for replication using epoxy resin. The length of the post inside the root canal was divided on the replicas into three (cervical- C, middle-M and apical-A thirds) using a small tip pencil. After obtaining baseline impressions, roots were immersed in a solvent solution of methyl ethyl ketone and a new set of impression and replicas was made. Samples were examined by SEM. MI Values were expressed as a percentage of continuous interface (%) and standard deviation (SD). Data were analyzed by Two-way ANOVA and Tukey tests ($\alpha = 5\%$).

Results. MI was statistically greater for AP than for CP in all root-thirds before, and after, solvent immersion. MI values were not statistically different for AP groups relined with methacrylate-based or silorane-based composite resin in all thirds (C: $p<.0001$; M: $p<.0001$; A: $p=0.0062$). The presence or absence of light did not affect marginal integrity in all thirds (C: $p=0.9306$; M: $p=0.0756$; A: $p=0.3447$). Solvent immersion did not affect MI for all groups tested.

Conclusion. Although MI was significantly enhanced by anatomic rather than conventional posts, other factors such as the material used to reline the GFP, or the presence or absence of light during cementation procedures did not.

Clinical Implications. The use of GFP relined with methacrylate-based composite resin in the anatomic post technique proved to be as effective as a low shrinkage silorane-based composite resin.

INTRODUCTION

Glass Fiber Posts (GFP) have been increasingly used as an alternative to metal posts.[1-2] This popularity increase is related to the fact that GFP have a modulus of elasticity closer to that of dentin when compared to metal posts and such property is associated to a reduced risk of vertical root fracture.[3]

Although increased post retention[3], sealing ability[4] and fracture resistance have been reported when posts are cemented with composite cements,[4-5] dislodging of fiber posts from the root canal continues to be the main cause of failure of fiber post–retained restorations.[6]

The failure of union between cemented posts and root dentin can be explained by many reasons including the difficulty to light cure apical areas of root canals;[7] the incompatibility between acidic adhesives and auto/dual-cured composites;[8-10] the anatomical variations of the root;

proper moisture control for adhesive application;[11] the peculiar characteristics of the root dentin substrate;[12] the extremely high C-factor estimated for bonding Glass Fiber Posts (GFP) to root canal and the high volumetric shinkage that follows polymerization of methacrilate-based dental composites.[11,13]

Until recently, the majority of composites used in restorative dentistry have their common basis in the radical polymerization of methacrylates. Although the mechanical properties of methacrilate-based composite resins have improved, volumetric shrinkage is still a significant disadvantage.[14] Shrinkage occurs when a polymer network is formed after the conversion of monomer molecules. The van der Waals spaces between molecules are exchanged for shorter covalent bindings. This results in considerable shrinkage of the resin composite which occurs because of a closer packing of molecules. The undesirable outcome is the stress generated upon the resin-adhesive-dentin interface and the factors that directly contribute towards the magnitude of the resultant stress are the elastic modulus of the composite,[15] the polymerization conversion rate[15], and the cavity configuration[16].

Different approaches have been used to minimize the stress of resin-based restorative materials. These include not only technique adaptations such as increment placing techniques[17], the development of soft-start-polymerization[18] or the use of low-modulus intermediate layers[19], but also the attempt to create new alternative chemical formulations for dimethacrylate-based composites.[20] Unfortunately, none of these attempts have been able to offer a significant improvement.

A low shrinkage composite, commercialized as Filtek Silorane (3M ESPE, Seefeld, Alemanha) was introduced in the market as an alternative to methacrylate-based composite resins. The manufacturer claims that the new composite is based on a silorane resin that replaces the methacrilate resin matrix of dental composites.[21-22] The silorane resin consists of siloxane and oxirane functional monomers. While the siloxane monomer determines the highly hidrofobic nature of the material, the oxirane functional groups are cyclic ethers that polymerize via a cationic ring opening mechanism.[21-22] Compared to typical methacrylates that polymerize via a free-radical mechanism, the ring opening chemistry of the silorane resin has been said to reduce shrinkage of the composite below 1vol%.[22]

A different approach to minimize the resin-dentin interface stress created during the conventional luting of fiber-posts is a chair side clinical procedure that involves the confectioning of an anatomically shaped relined post.[23-24] This technique was previously described to compensate light limitations because the composite resin used to anatomically shape the fiber-post is light-cured immediately after relining, outside of the root canal, before cementation.[23-24] One of the positive outcomes of polymerizing the relined composite resin outside of the root is that most of the stress generated by monomer conversion occurs before cementation.[23-24] Only a reduced layer of cement is necessary to bond the fiber post to the root dentin substrate and the consequence is the increase of monomer conversion, the reduction of polymerization stress, and a reduced incidence of bubbles.[23-24]

Considering the different approaches that have been used to minimize the stress created between resin-dentin interfaces after polymerization, this study associated a technique adaptation and a new low shrinkage silorane-based resin. The purpose was to evaluate the Marginal Integrity (MI) of Conventional (CP) and Anatomic posts (AP) confectioned using a methacrylate-based or a silorane-based composite resin, cemented with a dual-cure self-adhesive resin cement in the presence or absence of light using Scanning electron microscopy.

Three research hypotheses were tested: (1) MI of AP is greater than that of CP; (2) MI of AP relined with a low shrinkage silorane-based composite resin is different from that found for AP relined with a conventional methacylate-based composite resin; (3) The presence or absence of light during cementation procedures influences the MI of CP or AP posts relined with either silorane-based or methacrylate based composite resins.

MATERIALS AND MEHODS

The coronal portions of sixty, freshly extracted bovine incisors were removed, leaving a 16-mm long root section. Endodontic, crown-down instrumentation was performed. Drills (Gates Glidden, SybronEndo Corporation, Orange, CA, USA) #5,4,3, and 2 were inserted sequentially into the canal to flare cervical and middle thirds. Apical preparation was performed using sizes 80-45 K-files (Dentsply/Maillefer, Tulsa, OK, USA). Instrumentation was performed under saline irrigation. Canal filling was not executed to avoid interference between the materials used and fiber post bonding. Apicies were externally sealed using a commercial composite resin (Z250, 3M ESPE, St. Paul, MN, USA).

Post spaces were then prepared 15 mm deep using a 1.5mm diameter bur (Fibrekor post-Jeneric Pentron Incorporated, Wallingford, CT, USA) in order to obtain a standardized flared canal, under water cooling. Samples were randomly assigned to 6 experimental groups (n=10) according to fiber post technique employed (CP or AP), the material used to confection the AP (methacrylate-based or silorane-based composite resin) and the employment or not of light during cementation procedures using a dual cure self-adhesive cement.

Post preparation

Specimens in Groups 1 and 2 were treated using conventional fiber posts (CP), while samples in groups 3 to 6 were treated using Anatomic posts. The description of each group can be seen in Table I. The characteristics of the materials employed are listed in Table II.

In groups 1-4, posts (Reforpost # 3, Angelus, Londrina, PR, Brazil) were treated with 37% phosphoric acid (3M Scotchbond etchant; 3M ESPE, St. Paul, MN, USA) for 1 min, rinsed and coated with silane coupling agent (3M ESPE), and then coated with a thin layer of a light-curable adhesive resin (Scotch Bond Multipurpose Adhesive, 3M ESPE) that was applied and light exposed to a LED curing light (Elipar™ Freelight 2 LED Curing Light, 3M ESPE, Minnesota, USA) for 10s. Irradiance of light measured 1200 mW/cm^2 on a hand-held dental curing power meter (Nova, Ophir Optronics Ltd., Jerusalem, Israel)

In groups 3 and 4 posts were covered with methacrylate composite resin paste (Filtek Z-350; Shade A2, 3M ESPE) and inserted into the canal coated with a non-ionic, water-soluble polymer gel (Natrosol gel, Drogal, Piracicaba, SP, Brazil). While still within the canal, the fiber post relined with composite resin was light-cured for 3s from the root top surface, removed while still in a pliable state, and then light-cured again for additional 40s. The root was copiously rinsed to remove all traces of the gel.

In Group 5 and 6, the same fiber post brand used in groups 1-4 were relined with a low shrinkage silorane-based resin (Silorane, 3M ESPE). The fiber post was treated with 37% phosphoric acid (3M Scotchbond etchant; 3M ESPE, St. Paul, MN, USA) for 1 min and rinsed. This was followed by one coat of the Filtek Silorane Primer (3M ESPE) and one coat of Filtek Silorane Adhesive, both light-cured for 10 seconds each.

After lubricating the canal walls with water-soluble polymer gel (Natrosol gel, Drogal, Piracicaba, SP, Brazil), the fiber post was covered with Filtek Silorane (Shade A2, 3M ESPE) and inserted into the canal. The relined fiber post was light-cured for 40 s inside the root canal, removed and then light-cured again for additional 40 s. Copious rinsing was done to remove lubricant gel from the root canal and relined fiber post.

All groups were cemented with Rely X Unicem (3M ESPE). No pretreatment of the canal walls was performed except the removal of excess water from the post space with absorbent paper points. The cement was inserted in the root canals using Elongation Tips (3M ESPE). The posts were cemented into the root canals with light pressure. In groups 1,3 and 5 the cement was left to self-cure for 5min from start of mix. In groups 2, 4 and 6 the cement was light cured through the cervical portion of the root for 40 s on the buccal and lingual surfaces, totalizing 80 s of light exposure.

Sample Preparation

After 48 h, roots were longitudinally sectioned, slightly away from the diameter of the post using a slow-speed diamond saw under water cooling to expose the interfaces between the post and cement and between the cement and dentin. Because of the small diameter of the post and the amount of structure lost during cutting, only one half of each tooth was available for the analysis. The cut surfaces were polished with increasingly finer grit SiC papers (#600, #1200, #2000). The specimens were ultrasonicated in deionized water for 10 min between each polishing step. Polyvinyl siloxane (3M Express, St. Paul, MN, USA) impressions of the observable surfaces were taken and the surfaces replicated with epoxy resin (Poly/Bed®812, Nadic methyl anhydride, DMP-30, Polysciences, Inc.,Warrington, PA, USA). The replica technique was used to avoid artifacts produced during the preparation for SEM examination, and to permit sequential analysis of the same specimen subjected to the treatment protocols. The 15mm long interface corresponding to the length of the post inside the root canal was equally divided on the replicas into three using a small tip pencil. Accordingly, the segments were named cervical, middle and apical thirds and were used as a reference mark for the analysis. After obtaining the baseline impressions (experimental condition 1), the original sectioned roots were immersed in a pure solution of methyl ethyl ketone (MEK, 2-butanone, 99+%, Acros, Belgium) and sonicated for 20 min (experimental condition 2). MEK is a solvent known to quickly dissolve poorly polymerized resin and has been used in studies aiming to determine the depth of cure of resin composites. In this study, MEK was used in an attempt to identify areas of poorly polymerized resin cement along the interface. The sectioned roots were then immersed in deionized water at 37 ◦C for 24h for rehydration and a new set of impression and replicas was made.

The two sets of epoxy resin replicas were air-dried overnight at room temperature, sputter-coated with gold (Bal-tec SCD 050 Sputter Coater, São Paulo, Brazil), and examined in a scanning electron microscope (SEM) (JEOL JSM-5600LV-Japan) operating at 15 kV. Marginal Integrity (MI) was determined by calculating the percentage of continuous (gap-free) resin/dentin interface relative to the total interface length. Measurements were made from the captured images that were transferred to a personal computer equipped with image analysis software (IM50, v. 4.0; Leica Microsystems GmbH, Wetzlar, Germany). Data were first transformed to normality using Box-Cox transformation. Data were analyzed using a three-way ANOVA and Tukey post-hoc tests within each root-third section separately. All statistical testing was performed at a pre-set alpha of 0.05.

RESULTS

Analysis of the three-way ANOVAs revealed that marginal integrity was significantly affected by technique in all thirds, before (C: p<.0001; M: p<.0001; A: p=0.0062) and after (C: p=0.0001; M: p<0001; A: p=0.0031) solvent immersion (Table III). The Tukey post-hoc test showed that MI for the anatomic composite relining technique (independent of the material used for its confectioning) was significantly greater than when using a conventional technique in all portions of root-thirds (Table IV). Marginal Integrity (%) did not statistically differ for samples relined with methacrylate-based or silorane-based composite resin in all thirds (Table IV).

The activation of light was not a significant factor to affect marginal integrity (Table III). Although solvent immersion reduced MI, the values were homogeneous within all tested groups.

DISCUSSION

The first hypothesis tested that MI of AP is greater than that of CP was accepted. This finding was confirmed at all three root canal divisions, independent of the material used to reline the anatomic post (Table IV). This result agrees with a previous studies[23] which found that fiber post relining improved post retention in all root canal thirds. Based on this result it can be speculated that a smaller volume of cement lining associated with relined fiber posts creates an overall greater mass of polymerized composite resin in all areas of the root canal interior.

The second research hipothesis was rejected, once Marginal Integrity (%) did not statistically differ for samples relined with methacrylate-based or silorane-based composite resin in all thirds. Although the development of contraction stress in dental composites depends on material compositional factors such as the type, content and interaction between monomers and fillers[19-20], the placement and curing technique[15,18] can also play a major role to reduce the consequences of shrinking. In this study, relined posts were light cured before cementation procedures took place. Therefore, the shrinkage of the material used to reline the post occurred before bonding procedures. In fact, the only material that was expected to contract during cementation procedures was the self-adhesive cement placed in the root canal. Once the anatomic technique was employed in all experimental groups, it was expected that the lining of cement within the root canal to be very thin. Also, since the same self-adhesive cement was used for all the experimental groups it is possible to understand why there was no significant difference between groups in relation to marginal integrity when posts were relined with silorane or methacrylate based resins.

The third hypothesis that the presence or absence of light during cementation procedures influence the marginal integrity of posts relined with either silorane-based or methacrylate based composite resins was rejected. Marginal integrity results did not change after immersion in solvent for all groups, independent of the employment or not of light during bonding procedures. This result suggests that a smaller volume of the cement lining associated with a fiber post relined with previously polymerized composite resin, independent of this material's composition, will create an overall greater mass of polymerized composite resin in the interior of the root canal (non-published results). Such finding is interesting because there appears to be a good correlation between higher degree of conversion and higher hardness, fracture toughness, and abrasive wear resistance.

Also, the smaller the volume of cement present in the canal, the smaller the amount of energy (physical or chemical) to form the polymer network. For instance, when there is a smaller layer of cement and this material is light-cured, the same amount of photons will be absorbed by a proportionally smaller amount of photosensitizers that will then be raised to the excited state. These will help form more free radicals to initiate and propagate the polymerization process which will consequently occur in a more intense mode.

The consequence of a reduced volume of self-adhesive cement will also result in a reduction of bubbles within the cement layer and a greater wall-to-wall adaptation.[23] The later is due to a higher internal pressure during luting procedures, enhancing the quality of the resin-dentin interface bonding with the self-adhesive cement, which would be otherwise difficult to control in conventional fiber post luting technique.

Past investigations have described the clinical steps to create the anatomic post as a relatively simple procedure.[23-24] The same studies have also agree that anatomic posts are able to provide a superior quality of fit compared to the conventional cementation of fiber posts, reducing the incidence of bubbles and voids and enhancing marginal adaptation. The results of the present study add to such information by proving that the material used to confection the anatomic post or the activation mode used are not as important as the technique itself to reduce the consequences of polymer shrinking. Still, it is important to emphasize that only the initial marginal integrity of the resin-dentin interface was evaluated in this study. Future studies, mainly prospective clinical trials are necessary to further indicate fiber post relining procedures in the clinical practice.

CONCLUSION

Marginal integrity between root canal and adhesive cement was not dependent on the material used to reline the glass fiber post, or the activation mode during cementation procedures, but on the technique employed.

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TABLES

Table I. Description of groups according to technique, relining materials, adhesive cement and activation mode

Group	Technique	Relining Material	Cement	Cure Mode
1	CP	___	Rely X Unicem (3M ESPE)	Self-cure
2	CP	___	Rely X Unicem (3M ESPE)	Light-cure
3	AP	Silorane	Rely X Unicem (3M ESPE)	Self-cure
4	AP	Silorane	Rely X Unicem (3M ESPE)	Light-cure
5	AP	Z350	Rely X Unicem (3M ESPE)	Self-cure
6	AP	Z350	Rely X Unicem (3M ESPE)	Light-cure

Table II. Characteristics of Materials used in this study

Materials	Mode of activation	Composition	Manufacturer	Batch no.
Filtek Z350	Light	Resin: Bis-GMA, Bis-EMA, UDMA, TEGDMA Filler: Zirconia, sílica	3M ESPE, St. Paul, MN, USA	6018A2
Filtek Silorane	Light	Resin: Silorane Filler: Quartz and yttrium fluoride	3M ESPE, St. Paul, MN, USA	4762A2
Silorane Primer	Light	15–25% 2-hyroxyethyl methacrylate (HEMA); 15–25% bisphenol-a-diglycidyl ether dimethacrylate (BIS-GMA); 10–15% water; 10–15% ethanol; 5–15% phosphoric acid-methacryloxy-hexylesters; 8–12% silane treated silica; 5–10% 1.6-hexanediol dimethacrylate; <5% copolymer of acrylic and itaconic acid; <5% (dimethylamino) ethyl methacrylate; <3% DL-camphorquinone; <3% phosphine oxide.	3M ESPE, St. Paul, MN, USA	4763P
Silorane Adhesive	Light	70–80% Substituted dimethacrylate; 5–10% Silane treated silica; 5–10% triethylene glycol dimethacrylate (TEGDMA); <5% Phosphoric acid-methacryloxy-hexylesters; <3% DL-camphorquinone; <3% 1.6-hexanediol dimethacrylate.	3M ESPE, St. Paul, MN, USA	4763B
Rely X Unicem	Dual Polymerized	Liquid: methacrylated phosphoric acid ester, dimethacrylates, photo-initiator, stabilizer Powder: glasspowder, silica, calciumhydroxide, initiator, pigment, polymer	3M ESPE, St. Paul, MN, USA	314601
Scotch Bond Multipurpose Adhesive	Dual	Bis-GMA, HEMA, tertiary amines (both for light-cure and self-cure initiators), photo-initiator	3M ESPE, St. Paul, MN, USA	7543

Table III. *P*-Values observed by Two-way ANOVA for percent of continuous interfaces along the root canal thirds considering two factors (Technique and Activation Mode) and their interaction

	ROOT-THIRD LOCATION					
	CERVICAL		MIDDLE		APICAL	
Factor	Sectioned Only	Sectioned plus solvent	Sectioned Only	Sectioned plus solvent	Sectioned Only	Sectioned plus solvent
Technique	<.0001	0.0001	<.0001	<.0001	0.0062	0.0031
Activation Mode	0.9306	0.9279	0.0756	0.3190	0.3447	0.5645
Technique*Activation Mode	0.1331	0.1148	0.4637	0.8302	0.7534	0.8250

Table IV. Mean (SD) percentage of gap-free interface (indicator of marginal integrity) within each root-third segment, comparing the interaction between post fabrication techniques.

Technique	ROOT-THIRD LOCATION		
	CERVICAL	MIDDLE	APICAL
Conventional	20.4 (23.5) B	7.7(15.0) B	8.4(15.4) B
Silorane	73.7 (34.6) A	73.5 (28.5) A	46.6 (41.2) A
Methacrylate	70.6 (30.5) A	73.4 (35.9) A	34.0 (31.0) A

Capital letters compare marginal integrity scores among the post types (columns). Similar letters indicate no significant difference between compared groups ($p > 0.05$)

CONSIDERAÇÕES GERAIS

Tecnicamente, os passos clínicos para a confecção do pino anatômico podem ser considerados relativamente simples (Grandini *et al.*, 2005). Além disso, as vantagens alcançadas com o pino anatômico parecem superar a inconveniência de acrescentar um passo extra de reembasamento do pino de fibra de vidro com resina composta antes da cimentação.

Investigações recentes revelam que pinos anatomicamente reembasados com resina possibilitam uma maior adaptação do pino de fibra de vidro às paredes do canal, diminuindo assim a incidência de falhas e bolhas no cimento (Grandini *et al.*, 2005). A Literatura também revela que maiores valores de resistência da união são obtidos com a cimentação de pinos anatômicos comparados a pinos convencionais em todos os terços do canal radicular (Faria-e-Silva *et al.*, 2009). Da mesma forma, o estudo apresentado no primeiro capítulo deste trabalho revela que a integridade marginal obtida após a cimentação de pinos de fibra de vidro reembasados com resina (pino anatômico) é superior à obtida com a cimentação convencional de pinos de fibra de vidro (pino convencional) independente do terço radicular, aceitando a primeira hipótese formulada. Outro fator analisado no primeiro trabalho foi a influência do modo de ativação e do cimento empregado (convencional ou autoadesivo) na integridade marginal. Os resultados revelaram que a ativação química foi estatisticamente superior à ativação dual, enquanto a combinação do uso de pinos anatômicos e cimentos autoadesivos apresentaram os maiores valores de integridade marginal.

Além de uma maior adaptação marginal, o uso de pinos anatomicamente reembasados com resina e fotopolimerizados fora da boca antes da cimentação torna possível compensar parcialmente as limitações de luz inerentes à técnica de cimentação dos pinos de fibra dentro de canais radiculares. Por outro lado, não há estudos na literatura que comparam a transmissão de luz através de um pino de fibra convencional ou o pino de fibra reembasado com resina composta

(Grandini *et al*., 2005). O trabalho apresentado no Capítulo 2 compara a dureza Knoop de dois cimentos duais usados para cimentar pinos de fibra nas técnicas convencional e anatômica, na presença e ausência de luz. O estudo revela que a interação dos fatores técnica, método de ativação e cimento foi estatisticamente significativa para os terços cervical e médio. Já para o terço apical, o único fator significativo foi o método de ativação do cimento. É possível especular que no terço apical do pino reembasado não há uma quantidade expressiva de resina reembasada como acontece no terço cervical e médio. Por esse motivo o pino anatômico e o convencional, na pratica, não apresentam diferenças que possam influenciar na transmissão de luz para essa região e prejudicar a dureza Knoop do cimento.

O terceiro e último capítulo deste estudo compara a integridade marginal entre cimento e a parede do canal radicular após a confecção de pinos convencionais ou pinos anatômicos usando uma resina convencional à base de metacrilato ou uma resina de baixa contração à base de silorano. Como no primeiro trabalho, foi possível concluir que pinos anatômicos apresentam maior integridade marginal comparado aos pinos convencionais. Além disso, a hipótese apresentada de que a resina (à base de metacrilato ou silorano) usada para reembasar o pino anatômico não influencia a integridade marginal entre o cimento e a parede do canal radicular foi aceita. A avaliação realizada através de microscopia eletrônica de varredura revelou que a escolha do material para reembasar o pino de fibra não foi um fator significativo para aumentar a integridade marginal. Dessa forma, apesar de a resina composta à base de silorano apresentar uma menor contração volumétrica, a polimerização do pino reembasado fora do canal, antes da cimentação, foi capaz de superar a maior contração inerente à resina composta à base de metacrilato.

Apesar da integridade marginal e a dureza Knoop serem variáveis importantes para considerar a qualidade da reconstrução do dente com pinos de fibra de vidro, novas investigações devem ser realizadas para que haja uma verdadeira comprovação da superioridade do uso de pinos anatômicos comparados aos pinos de fibra convencionais na clínica diária. Estudos clínicos randomizados prospectivos devem ser elaborados e executados para que o clínico comprove a longevidade de pinos de fibra de vidro anatômicos.

CONCLUSÃO

A avaliação conjunta dos três estudos apresentados neste trabalho revela que:

(1) A integridade marginal de pinos anatômicos é superior comparado aos pinos convencionais.

(2) A ativação química foi estatisticamente superior à ativação dual independentemente do cimento empregado. A combinação do uso de pinos anatômicos e cimentos autoadesivos apresentaram os maiores valores de integridade marginal.

(3) A combinação dos fatores técnica, método de ativação e cimento influenciaram significativamente os valores de dureza Knoop nos terços cervical e médio. Já para o terço apical, o método de ativação foi o único fator de influência significativa para a dureza Knoop.

(4) A avaliação realizada através de microscopia eletrônica de varredura revelou que a escolha do material (resina composta à base de metacrilato ou silorano) não foi um fator significativo para aumentar a integridade marginal dos pinos de fibra de vidro anatomicamente reembasados.

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