LARISSA MARIA ASSAD CAVALCANTE

COMO AS TÉCNICAS RESTAURADORAS ADESIVAS PODEM INFLUENCIAR NA QUALIDADE DAS RESTAURAÇÕES ESTÉTICAS: AVALIAÇÃO DA MICRODUREZA, SELAMENTO MARGINAL E RESISTÊNCIA DE UNIÃO

Dissertação apresentada à Faculdade de Odontologia de Piracicaba, da Universidade Estadual de Campinas, para obtenção do Título de Mestre em Clínica Odontológica, Área de Dentística.

PIRACICABA
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Orientador: Prof. Dr. Luiz André Freire Pimenta
Co-orientador: Prof. Dr. Roger William Fernandes Moreira
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Com todo carinho, respeito e admiração aos meus pais
Margaret e José Inácio.
Vocês são o meu exemplo de vida, determinação e inteligência.
Pai... *Seu estímulo e força constantes me ensinam a prosseguir...*
Mãe... *Quando "crescer" quero ser igual a você.*

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SUMÁRIO

RESUMO

Neste estudo, procurou-se avaliar a influência de alguns fatores envolvidos durante os procedimentos de fotoativação sobre a adaptação marginal e microdureza de restaurações de resina composta; bem como a interferência das metodologias empregadas para estudos de resistência de união ao substrato dental. Os objetivos deste trabalho, composto por quatro artigos científicos foram: A) avaliar a microinfiltração e microdureza de restaurações de resina composta usando três técnicas de fotoativação (convencional, arco plasma de xenônio e *soft-start*) e duas diferentes resinas compostas (a microhíbrida Filtek Z250 e a compactável Surefil) (Artigo 1); B) avaliar o efeito de diferentes sistemas de luz - lâmpada halógena, luz de arco plasma de xenônio, laser de argônio e um dispositivo a base de luz emitida por diodo (LEDs) - sobre microinfiltração marginal (Artigo 2) e sobre a formação de fendas e microdureza (Artigo 3) de restaurações com margens em esmalte e em dentina, utilizando-se 3 resinas compostas indicadas para dentes posteriores – a microhíbrida Filtek Z250 e duas compactáveis Surefil e Tetric Ceram HB; C) avaliar o comportamento de dois tipos de sistemas adesivos, um de condicionamento ácido total (Single Bond) e um autocondicionante (Clearfil Liner Bond 2V) quando submetidos a dois testes de resistência de união (microtração e cisalhamento). Os resultados encontrados mostraram que as técnicas de ativação não afetaram a microinfiltração quando foi utilizada uma resina microhíbrida, entretanto, para a resina compactável, as restaurações polimerizadas com a técnica convencional apresentaram microinfiltração similar à técnica *soft-start*, e menor que aquelas polimerizadas com arco plasma de xenônio (Artigo 1). Entretanto, as resinas compostas e os sistemas de luz não interferiram na penetração do corante, não apresentando diferenças estatísticas entre as margens em esmalte e dentina (Artigo 2). Com relação a formação de fendas, não houve diferença estatística entre os sistemas de luz e as resinas compostas para os preparos cavitários com margem em

esmalte; por outro lado, para margens em dentina a resina microhíbrida apresentou as menores fendas quando comparada com as resinas compactáveis, já os sistemas de luz não apresentaram diferenças estatísticas entre si (Artigo 3). Os resultados de microdureza apontaram que a resina composta Tetric Ceram HB apresentou menores médias quando comparada com a Surefil e a Filtek Z250, entretanto, os aparelhos não apresentaram influência nos valores de dureza. Com relação à profundidade de polimerização, as superfícies de topo e meio sempre apresentaram maiores valores comparados com a superfície de base (Artigos 1 e 3). Para avaliação da resistência de união, o teste de microtração detectou diferença entre os sistemas adesivos avaliados, enquanto para o teste de cisalhamento diferenças não foram observadas (Artigo 4). Pode-se concluir, a partir dos dados destes estudos, que os sistemas de luz não interferiram diretamente na adaptação marginal e na microdureza de restaurações de resina composta, porém a formulação do material restaurador tornou-se um fator significativo de influência das variáveis analisadas, e que a escolha da metodologia a ser empregada pode influenciar na detecção dos resultados.

ABSTRACT

The development of new restorative adhesive techniques has continuously advanced resulting in huge changes in the adhesive Dentistry. Thus, in this study it was evaluated the influence of some factors involved during the photoactivation procedures on the marginal adaptation and microhardness of Class II resin composite restorations; it was also investigate the influence of the methodologies used to evaluate the bond strength of adhesive materials to the dental substrate. The aims of this study, composed of four scientific articles were: A) to evaluate the microleakage and microhardness of resin composite restorations using three polymerization techniques (conventional, plasma arc curing and soft-start) and two different resin composites (one microhybrid and one packable) (Article 1); B) to evaluate the influence of four photoactivation systems (halogen (QTH); light emitting diode (LED); argon ion laser (AL) and plasma arc curing (PAC)) on microleakage (Article 2), gap formation and microhardness (Article 3) of class II restorations – at dentin and enamel margins, using a microhybrid Filtek Z250 and two packable resin composites (SureFil and Tetric Ceram HB); C) to evaluate the behavior of two adhesive systems: the self-etching primer Clearfil Liner Bond 2V and the total-etch Single Bond when submitted to two bond strength tests: shear bond strength and microtensile. The results showed that the polymerization techniques - conventional, plasma arc curing and soft-start – did not affect the microleakage when a microhybrid resin composite was used. When a packable composite was used, restorations polymerized with Conventional technique presented similar microleakage to restoration polymerized with soft-start and lower than with plasma arc (Article 1). However, no significant differences were found in the microleakage scores among the photoactivation systems and among resin composites used, marginal adaptation was not significantly affected by location (enamel vs. cementum margins) (Article 2). Related to gap formation, there was no significant difference in gap formation among the curing systems and resin

composites at enamel margins. However at the dentin margins, the photoactivation methods did not reveal significant differences, but the microhybrid resin composite presented the best results (Article 3). No statistically significant differences were noted between KHN values of Filtek Z250 and Surefil, but Tetric Ceram HB had the lowest KHN. Occlusal and middle KHN were significantly higher than gingival KHN for all materials (Articles 1 and 3). Article 4 demonstrated that specimens used in the microtensile bond strenght test might provide a more accurate detection of differences among the adhesive systems. These findings suggested that different photoactivation systems may have no effect on the microhardness and gap formation, but the resin composite formulation were found to be a significant determinant factor; and that the methodology chosen may interfere in the detection of data.

1 INTRODUÇÃO

O avanço observado nos últimos anos com desenvolvimento de grande número de técnicas restauradoras adesivas propiciou o surgimento de uma Odontologia de mínima intervenção. Cada vez mais freqüente na Odontologia Restauradora, o uso de resinas compostas e sistemas adesivos, visam não apenas atender a demanda estética, como também promover maior conservação de tecido dental sadio e, conseqüentemente, maior resistência para o elemento dental. Entretanto, algumas características desfavoráveis inerentes ao material, tais como, contração de polimerização e deformação plástica ou elástica quando sujeitas às forças mastigatórias, podem levar a falhas nas restaurações (Burgess *et al*., 2002).

As limitações das resinas compostas são clinicamente observadas através de manchamento superficial, sensibilidade pós-operatória, desenvolvimento de cáries secundárias, inflamação e até necrose pulpar, que são sinais e sintomas da passagem de fluidos, moléculas e toxinas nas falhas produzidas entre a parede cavitária e o material restaurador (Kidd, 1976; Opdam *et al*., 1998). A falta de integridade marginal e conseqüente microinfiltração pode ser resultado direto de uma hibridização inadequada e de sistemas adesivos que não foram capazes de suportar as forças geradas durante a contração de polimerização (Mandras *et al*., 1991; Davidson *et al*., 1984). A localização das margens em esmalte ou dentina, o método de polimerização e a fonte de luz utilizada podem estar relacionados a melhor qualidade de selamento marginal (Versluis *et al*., 1998).

A fotoativação, com emissão de altas intensidades de luz, parece promover um rápido aumento da viscosidade, limitando o escoamento e interferindo na acomodação do material às paredes cavitárias (Goracci *et al*., 1996). Tem sido demonstrado experimentalmente que uma lenta reação de polimerização das resinas compostas, pode causar menos danos à interface da restauração, por

aumentar o escoamento e diminuir o estresse de contração de polimerização (Mehl *et al.*, 1997). Isto pode ser obtido através da fotoativação *soft-start* ou com baixa intensidade de luz, sem, no entanto, haver comprometimento da polimerização do material (Unterbrink & Muessner, 1995; Mehl *et al.*, 1997). Porém, alguns estudos, não observaram melhoras desta técnica quando comparada à convencional (Mehl *et al.*, 1997; Amaral *et al.*, 2002).

Características das resinas compostas como, matriz orgânica, concentração de fotoiniciadores, tamanho, tipo e quantidade de partículas de carga, a técnica de inserção e a intensidade de luz utilizada para a polimerização, também podem estar relacionadas com as propriedades físicas finais do material (Neiva *et al.*, 1998; Yap, 2000). Esses fatores parecem alterar não só a reação de contração de polimerização dos compósitos, como também a profundidade de cura e, com isso, a obtenção de um grau de polimerização adequado (Neiva *et al.*, 1998; Yap, 2000). De acordo com Silikas *et al.* em 2000, altas intensidades de luz podem levar a propriedades físicas e mecânicas superiores. Sendo assim, é grande o número de aparelhos fotopolimerizadores com diferentes tipos e intensidades de luz. Com novas propostas, o objetivo principal destas unidades de luz é o de controlar os efeitos da contração de polimerização e assegurar propriedades físicas melhores aos compósitos.

Atualmente, existem basicamente quatro diferentes sistemas de ativação por luz, utilizados para a ativação de materiais restauradores resinosos. A lâmpada halógena, luz de arco plasma de xenônio, o laser de argônio e mais recentemente os dispositivos a base de luz emitida por diodos semicondutores (LEDs). Apesar de possuírem diferentes formas na emissão de luz e de intensidades de energia (Yap & Seneviratne, 2001), esses sistemas visam melhorar as propriedades físicas e mecânicas das resinas compostas sem, no entanto, produzir grandes prejuízos à interface adesiva, entretanto, o custo benefício de cada sistema também deve ser considerado.

O sistema de lâmpada halógena é o mais freqüentemente utilizado, entretanto, a geração de calor parece ser uma das desvantagens apresentadas para esse sistema. Este aumento de temperatura, pode levar à degradação dos componentes do aparelho fotopolimerizador (Burgess *et al.*, 2002), causando modificações no espectro de emissão da luz e diminuição da sua potência com o tempo de uso. Desta forma, pode ocorrer uma diminuição na efetividade de polimerização com o aumento do tempo de uso do aparelho (Burgess *et al.*, 2002). Além disso, o feixe de luz emitido por uma lâmpada halógena emite desnecessariamente uma grande quantidade de luz para fora da região espectral de ativação da canforoquinona (Harrington & Wilson, 1995). Sendo assim, algumas unidades fotoativadoras não atingem a intensidade de luz desejada (Burgess *et al.*, 2002). Clinicamente, isso poderá implicar em insuficiente polimerização dos materiais, com diminuição das propriedades físicas e aumento do risco de falhas prematuras das restaurações (Jandt *et al.*, 2000).

Na tentativa de eliminar estas limitações observadas pelo uso da lâmpada halógena, uma alternativa é o uso do laser de argônio na polimerização de restaurações de resina composta. Uma redução de 50 a 70% no tempo de ativação deve-se ao seu feixe altamente colimado e a altíssima concentração de energia num comprimento de onda bastante favorável para a excitação do fotoiniciador canforoquinona das resinas compostas (Vargas *et al.*, 1998). Estudos sugerem que este tipo de unidade fotoativadora oferece polimerização adequada em curto período de tempo, além de proporcionar igual ou melhores propriedades físicas quando comparada à polimerização com luz halógena convencional (Powel & Blankenau, 2000). Entretanto, o aumento no grau de conversão oferecido pelo laser, pode vir acompanhado de um aumento da contração de polimerização acarretando em maior formação de fendas e infiltração marginal (Fleming & Maillef, 1999).

Também com o objetivo de reduzir o tempo clínico gasto para confeccionar as restaurações, o método baseado em luz emitida por arco plasma de xenônio,

com alta intensidade, é uma alternativa hoje existente. Apresentando alta potência de luz, de até 1800mW/cm^2, os fabricantes afirmam ser possível que as resinas compostas apresentem grau de conversão adequado em poucos segundos, refletindo em propriedades físicas e mecânicas adequadas (Peutzfeldt *et al.*, 2000; Park *et al.*, 2002). Entretanto, essa forma de polimerização mais rápida parece também gerar um excessivo estresse de contração de polimerização nas ligações adesivas, resultando em maior incidência de infiltração marginal (Brackett *et al.*, 2000).

Mais recentemente, uma opção de menor custo tem sido proposta, utilizando dispositivos a base de LEDs. Com um pico de emissão de luz ao redor de 470 nm (coincidindo com o pico de absorção da canforoquinona), o LED torna-se altamente eficiente no processo de polimerização, já que a pureza espectral obtida, permite um aproveitamento total da luz emitida (Mills *et al.*, 1999; Jandt *et al.*, 2000). Algumas vantagens oferecidas por estes aparelhos são: menor alteração térmica, maior seletividade da luz, maior tempo de vida útil e menor consumo de energia (Jandt *et al.*, 2000). Analisando as propriedades físicas e mecânicas das resinas irradiadas, a efetividade destes dispositivos têm sido atestada, obtendo resultados comparáveis com os da lâmpada halógena (Andrade *et al.*, 2001; Pimenta, 2002).

Além da variedade de sistemas de luz fotoativadoras e de resinas compostas, grandes avanços têm sido observados também no desenvolvimento dos sistemas adesivos. Assim, numerosos testes de resistência de união têm sido empregados com intuito de avaliar a efetividade das diferentes propostas de sistemas adesivos lançados no mercado. O teste de cisalhamento e de microtração são os mais freqüentemente utilizados na atualidade (Sano *et al.*, 1994), entretanto comparações relativas ao comportamento dos sistemas adesivos quando submetidos a estes dois testes de resistência de união têm sido raramente relatados na literatura.

Em função do surgimento de novas opções de fotoativação, formulações de resinas compostas e sistemas adesivos, faz-se necessário a análise constante da efetividade dos mesmos, bem como da variedade das diferentes metodologias empregadas para sua avaliação. Assim, melhoras na adaptação marginal, qualidade de polimerização e na resistência de união podem ser obtidas com conseqüente sucesso no desempenho clínico das restaurações adesivas estéticas.

2 PROPOSIÇÃO

Este trabalho, composto por quatro artigos científicos, apresentou como objetivo geral avaliar a influência de diferentes métodos de polimerização na microinfiltração, formação de fendas e microdureza de restaurações de dois tipos de resinas compostas – microhíbrida e compactável; bem como avaliar a influência dos testes de resistência de união atualmente utilizados, no comportamento de dois diferentes agentes de união. Os objetivos específicos de cada capítulo foram:

CAPÍTULO 1 – Avaliar a microinfiltração e microdureza de restaurações de resina composta usando três técnicas de polimerização – convencional, arco plasma de xenônio e s*oft-start* e duas diferentes resinas compostas – uma microhíbrida e uma compactável;

CAPÍTULO 2 – Avaliar a microinfiltração de restaurações de resina composta microhíbrida e compactável – com margens em esmalte e dentina - polimerizadas com quatro sistemas de luz – lâmpada halógena; LED; laser de argônio e arco plasma de xenônio;

CAPÍTULO 3 – Avaliar a influência de quatro sistemas de luz – lâmpada halógena; LED; laser de argônio e arco plasma de xenônio, na formação de fendas – de margens em esmalte e dentina - e na microdureza de restaurações classe II de resina composta microhíbrida e compactável;

CAPÍTULO 4 – Avaliar o comportamento de dois sistemas adesivos – um autocondicionante e um de condicionamento ácido total – quando submetidos a dois testes de resistência de união – cisalhamento e microtração.

3.1 CAPÍTULO I

INFLUENCE OF POLYMERIZATION TECHNIQUE ON MICROLEAKAGE AND MICROHARDNESS OF RESIN COMPOSITE RESTORATIONS

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SUMMARY

This study evaluated the influence of three polymerization techniques on microleakage and microhardness of class II restorations using a microhybrid (Filtek Z250) and a "packable" resin composite (SureFil). The techniques, their respective light intensities and time used in relation to the resin composites, are: Conventional (C) - 800mW/cm^2 for 40 seconds; Soft-Start (SS1) - 75mW/cm^2 for 10 seconds plus 518mW/cm^2 for 30 seconds; Soft-Start (SS2) - 170mW/cm^2 for 10 seconds plus 518mW/cm^2 for 30 seconds and Plasma Arc Curing (PAC) – 1468mW/cm^2 for 3 or 6 seconds. One hundred and fifty-two "Vertical Slot type Class II cavities" at the mesial and distal surfaces were prepared and divided into 8 groups (n=19). After the restorative procedures, the samples were thermocycled (1000 cycles at 5^{o}C and 55^{o}C), then immersed in 2% methylene blue dye solution for four hours. The microleakage was evaluated and the results analyzed by the KrusKal – Wallis and Multiple Comparisons tests. Ten samples from each group were randomly selected, embedded in polyester resin, polished and submitted to the Knoop microhardness test. ANOVA (split-plot) and Tukey´s test ($p>0.01$) revealed significant differences among depths the hardness at top surface was significantly higher followed by middle and bottom surfaces. There was no significant difference in microleakage among the techniques when microhybrid resin composite was employed. However, when using a "packable" resin composite, the conventional technique for polymerization was comparable to *Soft-Start* and better than PAC.

CLINICAL RELEVANCE

The Conventional technique for polymerization, used in association with a "packable" resin composite, provides similar resin-tooth interfacial seal as compared to *Soft-Start*, and better seal when compared to PAC, however for a microhybrid resin composite, all techniques for polymerization present the same result.

INTRODUCTION

Since their introduction to the market in the 1970s, light curing resin composites have been used for restorations, making the dentistry procedures more conservative and able to serve esthetic demand. However, some material shortcomings such as reduced wear resistance, marginal staining and excessive polymerization shrinkage as well as the sensitivity of the technique have not been eliminated despite extensive research (Leinfelder, 1995). The success of the clinical performance of light curing resin composites is directly related to adequate polymerization and light intensity, which are crucial factors in obtaining optimal physical properties (Bayne, Heyman & Swift, 1994).

During the setting process, the polymerization shrinkage of a resin composite can create forces that may disrupt the bond to cavity walls (Davidson, De Gee & Feilzer, 1984; Donly & others, 1987; Carvalho & others, 1996). This competition between contracting forces built up in the polymerizing resin and the bonds of adhesive resins to the wall of the restoration is one of the main causes of marginal failure and subsequent microleakage (Davidson & others, 1984; Mandras, Retief & Russel, 1991). Bond strength must be greater than contraction stress in order to obtain stable marginal adaptation. Microleakage permits the passage of bacteria, fluids, molecules and toxins and could encourage dentinal hypersensitivity, pulp inflammation, secondary caries and pulp necrosis (Kidd, 1976; Opdam & others, 1998).

Some studies have shown a relation exists between polymerization shrinkage and light intensity (Feilzer & others 1995; Silikas, Eliades & Watts, 2000). As a result, different light units have been introduced to the market with the aim of minimizing or controlling the polymerization shrinkage of composites.

Conventional lamps instantly provide maximal light intensity, which causes the resin composites to harden and produces considerable increase in the viscosity of the material (Goracci, Mori & Martinis, 1996). Composites cured at low light intensity have been shown to have a better marginal adaptation (Mandras &

others, 1991; Uno & Asmussen, 1991). The theory is that a slower rate of conversion maintains a longer pre-gel phase, allowing for a better flow of the material, which, decreases contraction stress in the filling material. However, this low intensity may affect the surface hardness and may be insufficient for ensuring mechanical stability (Unterbrink & Muessner, 1995; Pimenta, 1999).

Pre-polymerization at low intensity, followed by the final cure at high intensity, can allow for the flow of resin composite during setting. This method can reduce the width and length of the marginal gaps without interfering with the physical properties of the restorations (Uno & Asmussen, 1991; Mehl, Hickel & Kunzelman, 1997).

Now available, high intensity light units based on a plasma system can reduce the long cure time and provide optimal properties in resin composite in a few seconds (Peutzfeldt, Sahafi, Asmussen, 2000; Park, Krejci & Lutz, 2002). However, the use of units with such high intensities could create more contraction forces and consequently marginal fail (Bracket, Haisch & Covey, 2000).

New methods of polymerization with varying proposals are available on the market; therefore, it is necessary to analyze the effectiveness in the control of marginal adaptation and the quality of polymerization. This study evaluated the microleakage and microhardness of Class II resin composite using three available polymerization techniques – Conventional (Optilux501, Demetron/Kerr, Danbury, CT 06810, USA), Plasma Arc Curing (PAC, APOLLO 95E Elite, DMD Corp, Westlake Village, CA 91362, USA) and Soft-Start (Variable Intensity Polymerization, BISCO Inc, Schaumburg, IL 60193, USA) - and two different resin composites - a microhybid (Filtek Z250, 3M Dental Products, St Paul, MN 55144, USA) and a packable (SureFil, Dentsply/Caulk, Milford, DE 19963, USA).

METHODS AND MATERIALS

MICROLEAKAGE TEST

Seventy-six extracted bovine incisor were initially stored in a 2% formaldehyde buffered solution (Eick & Welch, 1986; Bedran de Castro, Hara A & Pimenta LAF, 2000, Gallo *et al*, 2001), after which the debris was removed from the teeth. The crowns of the bovine teeth had been cut off 5 mm above the cement-enamel junction (CEJ) with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil).

"Vertical Slot type Class II cavities" at the mesial and distal surfaces were prepared with #245 carbide burs (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil) with a high-speed water-cooled hand piece (Kavo do Brasil AS, Joinville, SC 89221-040, Brazil). The burs were replaced after every 10 preparations to maintain uniformity. Butt-joint cavities had the following dimensions: 1.5 mm axial deep by 3 mm bucco-lingual wide and the gingival margin was located 1mm apical to the CEJ.

In all groups, enamel and dentin etching with 35% phosphoric acid (3M Dental Products, St Paul, MN 55144, USA) was performed for 15 seconds. The Single Bond (3M Dental Products, St Paul, MN 551443, USA) adhesive system was applied following manufacturer's instructions. The resin composites SureFil (Dentsply/Caulk) and Filtek Z250 (3M Dental Products) were inserted in three horizontal increments and each increment was polymerized on the occlusal surface according to the following groups (n=19):

GROUP 1: SureFil (Dentsply/Caulk) resin composite and Conventional (C) polymerization (Optilux501, Demetrom, Danbury, CT 06810, USA) for 40 seconds, each increment, showing an average intensity of 800 mW/cm^2;

GROUP 2: SureFil (Dentsply/Caulk) resin composite using Soft-Start (SS1) polymerization technique (VIP^{TM} Variable Intensity Polymerizer, Bisco, Inc., Schaumburg, IL 60193, USA) showing an average initial intensity of 75 mW/cm^2 for 10 seconds and 518 mW/cm^2 for the following 30 seconds;

GROUP 3: SureFil (Dentsply/Caulk) resin composite using Soft-Start (SS2) polymerization technique (VIP™ Variable Intensity Polymerizer, Bisco, Inc., Schaumburg, IL 60193, USA) showing an average initial intensity of 170 mW/cm^2 for 10 seconds and 518 mW/cm^2 for the following 30 seconds;

GROUP 4: SureFil (Dentsply/Caulk) resin composite using Plasma Arc Curing (PAC) polymerization technique (APOLLO 95E Elite, DMD Corp., Westlake Village, CA 91362, USA) for 6 seconds each increment, following manufacturer's instructions for this resin composite, showing an average intensity of 1468 mW/cm^2;

GROUP 5: Filtek Z250 (3M Dental Products) resin composite and Conventional (C) polymerization (Optilux501, Demetrom, Danbury, CT 06810, USA) for 40 seconds each increment, showing an average intensity of 800 mW/cm^2;

GROUP 6: Filtek Z250 (3M Dental Products) resin composite using Soft-Start (SS1) polymerization technique (VIP™ Variable Intensity Polymerizer, Bisco, Inc., Schaumburg, IL 60193, USA) showing an average initial intensity of 75mW/cm^2 for 10 seconds and 518mW/cm^2 for the following 30 seconds;

GROUP 7: Filtek Z250 (3M Dental Products) resin composite using Soft-Start (SS2) polymerization technique (VIP™ Variable Intensity Polymerizer, Bisco, Inc., Schaumburg, IL 60193, USA) showing an average initial intensity of 170 mW/cm^2 for 10 seconds and 518 mW/cm^2 for the following 30 seconds;

GROUP 8: Filtek Z250 (3M Dental Products) using Plasma Arc Curing (PAC) polymerization technique (APOLLO 95E Elite, DMD Corp., Westlake Village, CA 91362, USA) for 6 seconds each increment, following manufacturer's instructions for this resin composite showing an average intensity of 1468 mW/cm^2;

Following the restorative procedure, the teeth were stored in water at 37°C for 48 hours. All restorations were then finished with Sof-Lex (3M Dental Products) fine and ultra fine finishing disks and all specimens were then thermocycled in a thermal cycling machine (MCT2-AMM*instrumental, CA 94928, USA) for 1000 cycles at 5 ± 2°C and 55 ± 2 °C with a dwell time of 60 seconds in distilled water and a 5 seconds transfer time. Next, the apices and coronal surfaces were sealed

with epoxy resin (Araldite, Brascola Ltda, São Bernardo do Campo, SP 09771-190, Brazil) and the teeth were coated with two applications of fingernail polish up to 1 mm from the gingival margins. All teeth were immersed in a freshly prepared aqueous 2% methylene blue solution (pH 7.0) for 4 hours at 37°C and then washed in water. Finally, each tooth was sectioned vertically through the center of the restoration with a diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil) at low-speed.

Microleakage at the gingival margin was evaluated by two observers with an optical stereomicroscope (Meiji Techno Co., LTD., Iruma-gun Saitana 356, Japan) at 70x magnification and scored using the following criteria (Figure 1):

0 - No dye penetration

1 - Dye penetration that extended for less than or up to 1/3 of preparation depth

2 - Dye penetration greater than 1/3 of preparation depth, but not extending to the axial wall

3 - Dye penetration extending to the axial wall

4 - Dye penetration past the axial wall.

The results were analyzed by the Kruskal–Wallis and Multiple Comparisons tests.

KNOOP MICROHARDNESS TEST

After the microleakage evaluation, 10 sectioned restorations of each group were randomly selected and cut off with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil). Twenty-six groups of three and one group of two restorations were placed each in a ¾ inch diameter PVC ring, which was filled with self-curing polystyrene resin (Piraglass, Piracicaba, SP 13424-550, Brazil). The embedded restorations were ground on a water-cooled mechanical grinder (Maxigrind, Solotest, São Paulo, SP 01328, Brazil) using 400, 600 and 1000-grit Al_2O_3 abrasive paper (Saint-Gobain Abrasivos Ltda., Guarulhos, SP 07111150, Brazil). The restorations were polished on a mineral oil-cooled

grinder using felts with diamond pastes of 3 µm and 1 µm (Equilam, Diadema, SP 09960-500, Brazil).

The Knoop microhardness test (Microhardness Tester, Future Tech FM-1E, Future Tech Corp., Tokyo 140, Japan) was performed using a 25g load for 20 seconds. The indentations were placed at 100, 2,500 and 5,000 µm from the gingival margin, and at 100, 750 and 1,300 µm from the axial wall (Figure 2). The larger diagonal length of indentation was measured with a monitor (9M 100A Teli, Tokyo 140, Japan) and the values transformed in Knoop Hardness Numbers (KHN).

The microhardness means for each depth and for each experimental group were calculated and submitted to the ANOVA (split-plot) and Tukey's test, which was used to compare Knoop microhardness among groups, depths and resin composites.

RESULTS

MICROLEAKAGE TEST

None of the groups showed complete prevention of dye penetration. The results of statistical analysis are summarized in Table 1.

Analyzing the data, the SureFil (Dentsply/Caulk) "packable" resin composite showed better results when using the Conventional technique. The SS1 and SS2 techniques presented intermediate results, although they showed no statistical differences from PAC, which demonstrated the worst scores. The Conventional technique for polymerization provides similar resin-tooth interfacial seal as compared to Soft-Start, and better seal when compared to Plasma Arc Curing.

For Filtek Z250 (3M Dental Products) resin composite, there was no significant difference in leakage among the different methods of polymerization.

KNOOP MICROHARDNESS ANALYSIS

No significant differences in microhardness were observed between the resin composites (p=0.1701) and the C, SS1, SS2 and PAC unit polymerization techniques (p=0.7103).

The results showed no significant interaction among resin composite *vs* light units (p=0.9111), resin composites *vs* depth (p=0.3511), light unit *vs* depth (p=0,2646) and light unit *vs* resin composite *vs* depth (p=0.4173) in microhardness values.

The Tukey's test ($p<0.01$) revealed significant differences in microhardness in relation to depth/thickness of resin. Hardness at the top surface (5,000 µm) was significantly higher, followed by middle (2,500 µm) and bottom (100 µm) surface, which showed the lower KHN means (Table 2).These findings were similar for both resins and curing techniques.

DISCUSSION

Some techniques for reducing shrinkage stress and consequently marginal leakage have been suggested (Kays, Sneed & Nuckles, 1991). These include using reflexive wedges (Lutz & BarbaKow, 1992), incremental restorative techniques (Tjan, Bergh & Lidner, 1992; Applequist & Meiers, 1996) and variations in light intensity (Uno & Asmussen, 1991; Feilzer & others, 1995; Unterbrink & Muessner, 1995). A lining material with a low-modulus of elasticity such as a glass ionomer (Aboushala & others, 1996), a new generation dentin bonding (Goracci & others, 1995; Nakabaiashi & Saimi, 1996) or a flowable composite lining has also been proposed by some authors, mainly in association with the "packable" resin composite (Konstantinos, 1998; Chuang, Liu & Jin, 2001).

The influence of using different kinds of light units with varying intensities during polymerization to reduce microleakage was evaluated in this study, using the "packable" and a microhybrid resin composite.

None of the methods or restorative materials eliminate microkeakage in face of the thermal changes and differences in the coefficient of thermal expansion

between the dental tissues and the restorative material. These results were also observed in other studies (Liberman & Ben-Amar, 1996; Pimenta, 1999).

Both resins behaved differently when submitted to the same polymerization technique. While the microhybrid presented statistically similar results for all methods, “packable” did not. In association with PAC units (G4) and SS2 (G3), the “packable” was statistically different in relation to C (G1) and SS1 (G2). The “packable” presented a high elasticity modulus that can cause more strain in the interface during polymerization (Davidson & others, 1984). Another reason may be that the “packable” composite may not adapt well to the dentin bonding agent and cavity preparation walls (Meiers, Kazemi & Meier, 2001).

The high scores of microleakage found when the “packable” was compared to the microhybrid might indicate that the filler particle technology of the “packable” composite could translate into increased post-gel linear shrinkage stress directed at the margins (Meiers & others, 2001). Stress arising from post-gel polymerization shrinkage may produce defects in the composite-tooth bond, leading to bond failure and consequently post-operative sensitivity, microleakage and recurrent caries (Yap, Soh & Siow, 2002; Meiers & others, 2001). The more satisfactory results found for the microhybrid resin when compared with the “packable” in this study could be explained by the lower post-gel shrinkage as revealed by the manufactures.

Different studies have indicated that Soft-Start light curing units can be used to improve marginal integrity and to decrease the marginal gap (Uno & Asmussen, 1991; Goracci & others, 1996). However, according to our results less leakage was not observed when the Soft-Start technique was used compared to Conventional and Plasma Arc. Other studies also reported these results (Sahafi, Peutzefeldt & Asmussen, 2001; Yap & others, 2002 and Yap, Ng & Siow, 2001). For both pre-polymerizations, starting with 75 mW/cm^2 (G2 e G6) or with 170 mW/cm^2 (G3 e G7), the groups presented no statistical differences between the resins. However,

the association of the “packable” with SS2 (G3) was not similar to SS1 with microhybrid resin (G6).

The “packable” composite cured with Plasma Arc curing, showed the highest leakage scores. However it was not statistically different from the Plasma Arc with microhybrid (G8), which behaved similarly with all techniques. Several studies have shown that high and fast curing rates tend to produce excessive polymerization stresses on adhesive bonds, resulting in poor marginal adaptation along gingival or dentinal margins (Brackett & others, 2000; Uno & Asmussen, 1991; Mehl & others 1997). This study’s results seem to show that the low flow capacity of “packable” resin composite might be responsible for these values.

In this study, the microhardness of resin composites was measured in different depths as an indirect method for evaluating the relative degree of conversion (Mehl & others, 1997). The effective cure of resin composite is vital, not only to ensure optimum physical-mechanical properties (Asmussen, 1982), but also to ensure that clinical problems do not arise due to cytotoxicity of inadequately polymerized material (Caughman & others, 1991). In general, higher hardness values are an indication of more extensive polymerization (Helvatjoglou-Antoniad & others, 1991).

According to the results, the resin composites SureFil (Dentsply/Caulk) and Filtek Z250 (3M Dental Products) presented similarly when the C, SS1, SS2 and PAC unit polymerization techniques were used.

There was a significant difference in depth among the bottom (100 µm), middle (2,500 µm) and top (5,000 µm) surfaces. For all techniques microhardness was higher at the top surface. This can probably be explained as a result of the relationship between irradiation distance and effectiveness of polymerization (Pires & others, 1993). The depth of cure was reduced by increasing the distance between light tip and composite surface (Hansen & Asmussen, 1997). The degree to which light activated composite polymerizes is proportional to the amount of light to which the material was exposed (Rueggeberg, Caughman & Curtis, 1994). The top surface of the material was nearer to the light force than the subsequent resin

composite layers; in this way the light transmission did not suffer any interference and the intensity was not reduced. However at the middle and bottom surfaces the light intensity was greatly reduced due to light scattering, thus decreasing the effectiveness of polymerization (Ruyter & Oysaed, 1982). One way to compensate for this is to increase the light exposure time, which can provide better hardness results (Ota & others, 1985; Yap & others, 2001).

Although some studies demonstrated that three seconds of curing time was insufficient for optimal curing of composites when the Plasma Arc technique was used, (Park, Krejci & Lutz, 2002) the results found in this study showed similarities among C, SS1 and SS2.

Despite the great advances in light units that present new polymerization techniques, the conventional method is still preferred. Providing adequate polymerization and satisfactory infiltration scores, the Conventional method may be similar to Soft-Start and better than PAC, although each material had different characteristics.

CONCLUSIONS

The results of this study allow the authors to conclude:

1. None of the techniques could eliminate microleakage;
2. For Filtek Z250 (3M Dental Products) microhybrid resin composite, all the polymerization techniques showed similar leakage results;
3. For SureFil (Dentsply/Caulk) “packable” resin composite, only Soft-Start polymerization technique (*SS1*) with a 10-second initial intensity of 75 mW/cm^2, followed by 30-seconds at 518 mW/cm^{2,} decreased microleakage to levels similar to the Conventional technique
4. All polymerization techniques presented similar results in microhardness values, but the top surface always presented high values followed by the middle and bottom surfaces.

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TABLE 1

Results of microleakage evaluation

GROUPS	***MEDIUM RANKS***	
G5. Z250/Conventional	55.4737	**a**
G6. Z250/*SS1*	55.4737	**a**
G1. SureFil/Conventional	63.1316	**ab**
G7. Z250/*SS2*	70.0263	**abc**
G8. Z250/PAC	81.6579	**abcd**
G2. SureFil/*SS1*	87.6316	**bcd**
G3. SureFil/*SS2*	96.8947	**cd**
G4. SureFil/PAC	101.7105	**d**

Kruskal-Wallis test: Significant difference (p<0.05)
Same letters were not statistically different

TABLE 2

Means and Standart Deviations Knoop Hardness Number (KHN) for the different Cure Modes, Resin composite and Depth

Resin Composite	Cure Mode	Depth					
		Bottom(100μm)		Medium(2500μm)		Top(5000μm)	
		mean	SD	mean	SD	mean	SD
SureFil	C	100.06	25.44	107.45	13.59	112.82	11.36
SureFil	*SS1*	103.69	13.46	112.30	8.66	109.04	11.12
SureFil	*SS2*	95.94	16.12	100.64	20.73	109.13	11.76
SureFil	PAC	95.20	20.76	100.43	21.0	120.20	10.33
Z250	C	99.15	15.08	100.73	16.21	100.67	13.06
Z250	*SS1*	94.23	22.42	108.75	26.46	109.20	18.85
Z250	*SS2*	96.44	15.03	104.04	7.89	105.97	12.11
Z250	PAC	97.65	16.46	99.80	19.25	105.80	13.82
Mean		97.80 C		104.27 B		109.1A	

Tukey´s test (p<0,05) indicates statistical difference for means followed by distinct letters.

FIGURE 1

Diagram of microleakage evaluation criteria

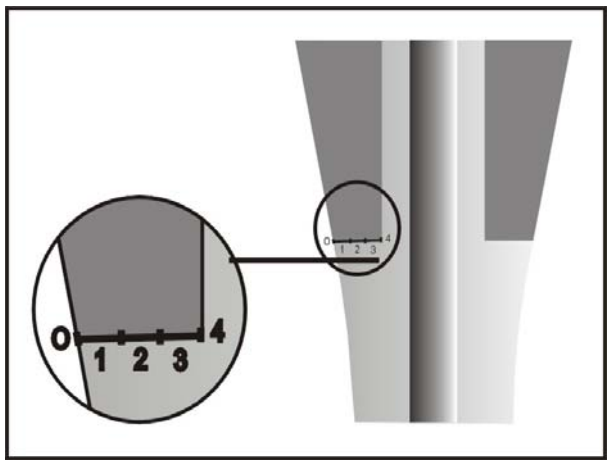
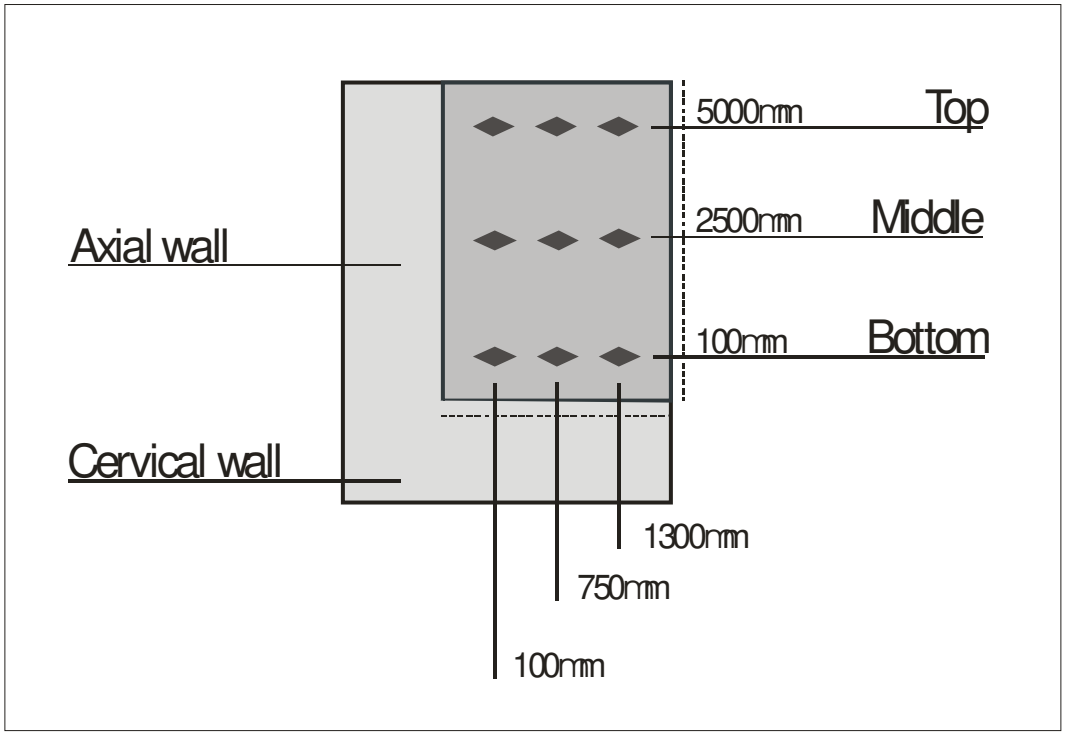


FIGURE 2

Diagram of Knoop indentation locations



3.2 CAPÍTULO II

EFFECT OF PHOTOACTIVATION SYSTEMS AND RESIN COMPOSITES ON MICROLEAKAGE OF ESTHETIC RESTORATIONS

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SUMMARY

Purpose: The purpose of this investigation was to evaluated the influence of four photoactivation systems (Quartz-Tungsten-Halogen (QTH), Light-Emitting-Diode (LED), Argon-Ion-Laser (AL) and Plasma-Arc-Curing (PAC)) on cementum/dentin and enamel marginal adaptation (measured as microleakage) of Class II restorations using a microhybrid (Filtek Z250) and two packable resin composites (SureFil and Tetric Ceram HB). *Materials and Methods:* Three hundred sixty "vertical slot Class II cavities" were prepared at the mesial surface of bovine incisors using a 245 carbide bur in high-speed. Specimens were divided into 12 groups, with each group representing one combination composite-photoactivation system. Half specimens in each group had gingival margin in enamel (n=15), and the other half in cementum/dentin (n=15). Composites were placed with Single Bond adhesive system and cured in 2mm increments according to manufacturers' recommended exposure times. After polishing, the samples were immersed in 2% methylene blue solution (pH 7.0) for 4 hours, sectioned, and evaluated (both surfaces) at the gingival margins by two examiners using a 0 to 4 marginal infiltration score system. The data were submitted to statistical analysis using the non-parametric Kruskal–Wallis test. *Results:* For both margins, no significant differences were found in the microleakage scores among the photoactivation systems and among resin composites used ($p>0.05$). Marginal adaptation was not significantly affected by location (enamel vs. cementum margins, $p>0.05$). *Conclusion:* These findings suggested that neither the light curing sources nor the resin composite types may have an effect on the microleakage scores of class II cavities, as is the case in this study.

Key words: microleakage, photoactivation system, resin composite, marginal sealing, packable resin composites.

CLINICAL RELEVANCE

The photoactivation systems and resin composite formulations may have no influence on microleakage of the restorative procedure.

INTRODUCTION

Despite the advances made over the time in composite technology, problems, such as wear, technique sensitivity, and microleakage arise when resin composites restorations are performed.

Stress arising from polymerization shrinkage is one of the most critical properties of light-activated composites (1). The competition between contracting forces built up in the polymerizing resin and the bonds of adhesive resins to the wall of the restoration may lead to marginal failure and subsequent microleakage (2,3). For this reason, bond strength must be greater than contraction stress in order to obtain stable marginal adaptation.

One of the major factors which decreases the integrity and clinical life expectancy of the esthetic restorations is gap formation and microleakage between the cavity and restorative material, especially when the gingival margin is in dentin (4). This is a problem of clinical significance because microleakage permits the passage of bacteria, fluids, molecules and toxins and could encourage dentinal hypersensitivity, pulp inflammation, secondary caries and pulp necrosis (5,6).

Curing composite depends on the composite (photoinitiator, filler type, shade and translucency), the intensity and spectral output of curing unit, and possibly the curing mode (7). Because of this relationship, different light units have been introduced to the market. Currently, there are four different types of light to polymerize resin composite: quartz tungsten halogen (QTH); plasma arc (PAC); argon ion lasers (AL) and light-emitting diodes (LED). Having different proposes, the aim of this photoactivation systems is to minimize or to control the polymerization shrinkage, to provide better physical properties and some of them to reduce the time for curing composites.

The magnitude of the stress generated in a polymerizing resin composite restoration seems to be also influenced by numerous factors related to the materials composition, technique, and cavity preparation, and the relationship among these factors dictates the exact manifestation of the shrinkage for a given restoration (7).

This study evaluated the marginal seal (measured as microleakage at enamel and cementum/dentin margins) of Class II composite restorations using four photoactivation systems: halogen (QTH); light emitting diode (LED); argon ion laser (AL) and plasma arc curing (PAC) and three different composites – a microhybrid Filtek Z250 and two packable resin composites SureFil and Tetric Ceram HB, polymerized according to the manufacturers' recommended exposure times.

METHODS AND MATERIALS

Three hundred and sixty extracted bovine incisor teeth were stored in a 1% thymol solution for one week and debrided.

The specimens were cut either 3mm apical to the cementum-enamel junction or 4mm coronal to the cementum-enamel junction, depending on gingival margin location, as illustrated in Figure 1, with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil).

In each specimen, one vertical "slot type" Class II cavity was prepared at the mesial surface with a #245 carbide bur (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil) running at a high-speed water-cooled hand piece (Kavo do Brasil AS, Joinville, SC, Brazil). The burs were replaced after every 10 preparations to maintain uniformity. The butt-joint cavities had the following dimensions: 1.5mm of axial depth by 3mm of bucco-lingual width, with the gingival margin located either 1mm apical (enamel) to or 1mm coronal (cementum/dentin) to the CEJ corresponding 4mm cervico-incisal (Figure 1).

Specimens were randomly divided into 12 groups (n=30), and each group was restored with one composite + curing device combination. Within each group, 15 specimens had gingival margins on enamel and 15 had gingival margins on cementum/dentin (Figure 1).

In all groups, enamel and dentin was etched with 35% phosphoric acid (3MESPE, St Paul, MN, USA) for 15 seconds, rinsed off for 15 seconds, and the

preps were gently air dried without desiccation of the dentin. After acid etching and washing, the adhesive system (Single Bond, 3MESPE, St Paul, MN, USA) was applied in two coats with a brush tip, lightly dried, and polymerized for 10 seconds following the manufacturer's directions. The resin composites (Table 1) SureFil (Dentsply/Caulk-Milford, DE, USA), Filtek Z250 (3MESPE, St Paul, MN, USA) and Tetric Ceram HB (Ivoclar/Vivadent INC, Amherst, NY, USA) were inserted in 2mm horizontal increments and each increment was polymerized on the occlusal surface according to the following groups:

Group 1: SureFil resin composite and argon ion laser photoactivation system (Accucure 3000, Lasermed, USA) for 20 seconds;

Group 2: SureFil resin composite and quartz tungsten halogen photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 40 seconds;

Group 3: SureFil resin composite and light emitting diode photoactivation system (Elipar^{TM} FreeLight, 3MESPE, St Paul, MN, USA) for 40 seconds;

Group 4: SureFil resin composite using plasma arc curing photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 6 seconds;

Group 5: Tetric Ceram HB resin composite with argon ion laser photoactivation system (Accucure 3000, Lasermed, USA) for 10 seconds;

Group 6: Tetric Ceram HB resin composite and quartz tungsten halogen photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 20 seconds;

Group 7: Tetric Ceram HB resin composite and light emitting diode photoactivation system (Elipar^{TM} FreeLight, 3MESPE, St Paul, MN, USA) for 20 seconds each increment;

Group 8: Tetric Ceram HB resin composite and plasma arc curing photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 3 seconds;

Group 9: Filtek Z250 resin composite with argon ion laser photoactivation system (Accucure 3000, Lasermed, USA) for 10 seconds;

Group 10: Filtek Z250 resin composite and quartz tungsten halogen photoactivation system (Optilux 501, Demetrom, Danbury, CT, USA) for 20 seconds;

Group 11: Filtek Z250 resin composite and light emitting diode photoactivation system (Elipar^{TM} FreeLight, 3MESPE, St Paul, MN, USA) for 20 seconds each increment;

Group 12: Filtek Z250 resin composite and plasma arc curing photoactivation system (APOLLO 95E Elite, DMD Corp., Westlake Village, CA, USA) for 3 seconds.

The exposure times and energy density used for each photoactivation system were according to the manufacturer's recommendations (Table 2). The power (mW) of the four light sources was measured using a power meter (Ophir Optronics Inc., Danvers, MA, USA). With a digital caliper (Mitutoyo, Japan), the diameters of the tips were measured to determine the tip areas and, dividing the power by the area, it was calculate the total intensity (mW/cm^2). The spectral distributions of the light sources were obtained using a spectrometer (USB 2000, Ocean Optics, Dunedin, FL, USA). The total intensity data and the spectral distributions of the sources were tabulated in the software Origin 6.1 (OriginLab Corp. Northampton, MA, USA) to obtain, by integrate calculus, the specific light intensity at the 450-490 nm wavelength range (Table 3).

Following the restorative procedure, the teeth were stored in water at 37°C for 48 hours. After this time, all restorations were finished with Sof-Lex (3MESPE, St Paul, MN, USA). Ten strokes of each series of disc (coarse, medium, fine and super-fine) were used. Finishing and polishing were done in only one direction with a low-speed handpiece without water spray.

After the polishing, the apices and coronal surfaces were sealed with epoxy resin (Araldite, Brascola Ltda, São Bernardo do Campo, SP, Brazil) and the teeth were coated with two applications of fingernail polish up to 1 mm from the gingival margins. All teeth were immersed in a freshly prepared aqueous 2% methylene blue solution (pH=7.0) for 4 hours at 37°C and then washed in tap water. Finally,

each tooth was sectioned vertically through the center of the restoration with a diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP, Brazil) at low-speed, obtaining two sections.

Dye penetration at the gingival margin was evaluated by two previously calibrated examiners with an optical stereomicroscope (Meiji Techno Co., LTD., Iruma-gun Saitana 356, Japan) at 70x magnification and scored using the following criteria: 0=No dye penetration; 1=dye penetration that extended for less than or up to 1/3 of preparation depth; 2=dye penetration greater than 1/3 of preparation depth, but not extending to the axial wall; 3=dye penetration extending to the axial wall and 4=dye penetration past the axial wall (Figure 2).

Each evaluator scored the microleakage of the two halves of the restoration; thus each restoration was scored four times by the two examiners. For statistical analysis, each restoration was given the highest score obtained from any of the two surfaces examined. The Weighted Kappa Test of Reproducibility evaluated the agreement among examiners. The median of the microleakage evaluation of the two examiners was submitted to the Kruskal–Wallis test at 5% level of significance in order to evaluate the differences among the experimental groups.

RESULTS

Agreement between the examiners was excellent. The Weighted Kappa estimator was 0.86.

The distribution of microleakage scores for each group – at cementum/dentin and enamel margin – is summarized in Table 4 and 5.

According to the results, none of the groups showed complete prevention of dye penetration. At the cementum/dentin (H=16.43; p=0.1256) or enamel (H=17.5760; p=0.0920) margins, Kruskal-Wallis test showed that there was no statistically significant differences observed among the four light sources and the three resin composites used in this experiment.

The Kruskal-Wallis test revealed no statistically significant difference among margins location: Enamel*Cementum/Dentin p=0.7344.

DISCUSSION

In vitro microleakage tests are numerous and diverse methods have been used to access the leakage of restorative materials (8). The most common used methodology involves exposure of the samples to a dye solution and then, viewing cross sections under a light microscope (5,9,10). A dye such as methylene blue is a realistic agent to identify the presence of a clinically relevant gap (11,12).

The influence of using different kinds of light cure systems with varying intensities during the polymerization on microleakage was evaluated in this study using a microhybrid and two packable resin composites. According to the results, none of the four photoactivation systems – QTH, AL, LED and PAC - used was capable to eliminate the marginal leakage and no differences were observed among them in the resin composites restorations.

According to some studies, the rapid rate of curing using devices with high light intensities, like PAC and AL, can produce an increase in contraction force and the magnitude of strain associate with the polymerization shrinkage (13,14,15,16). These stresses and strains can be detrimental increasing the incidence and magnitude of interfacial gaps and inferior marginal integrity (13,14,15,16). However, for these curing devices, a more marginal leakage was not observed in this study confirming previous reports (17,18,19). In spite of some researchers attributes this similar marginal seal to a relatively small degree of conversion, evaluations of Knoop hardness confirmed that PAC and AL irradiations provided an equivalent degree of cure compared to the others curing protocols (17,19). Consequently, the margins quality of PAC and AL irradiated restorations seems was not achieved at expense of compromised mechanical properties and biocompatibility.

A strong and positive correlation between polymerization contraction stress values and microleakage has been related in some studies (20,21). Several studies confirm that the amount of linear shrinkage is not influenced by the light source (22,23,24,25). This lack of relation found between the contraction polymerization and the photoactivation systems was confirmed in this study since

there are no statistical significant differences among the four light systems in microleakage at the cementum/dentin and enamel margins as demonstrate in previous studies that also evaluated the marginal seal of composite restorations (4,17,18,26,27,28).

The energy density is an important indication of the total light which the material is exposed. Calculations of energy density as the product of light intensity (in mW/cm^2) and time (in s) showed that the energy density for AL were lower than LED, PAC and QTH which showed the higher value (Table 3). These variations in energy density were probably insufficient to influence the gap formation.

Another factor that can influence the marginal seal in a resin composite restoration involves material characteristics. It has been demonstrated that the volumetric polymerization shrinkage, filler contents, elastic modulus, photoinitiator and matrix resin can greatly affect the stress formation at the resin composite and tooth interface. The flow and polymerization shrinkage were found to be significant determinants of gap formation around resin composite restorations in vitro (1). Christensen *et al*. in 1999 (29) tested fourteen different lights sources (ranging from 400 mW/cm^2 to 1900 mW/cm^2) and six different resin composites and concluded that resin formulations, rather than light type or curing mode, is the important factor in polymerization problems. Even though this influence is related in several studies, according to this study's results the both packable composites – Surefil and Tetric Ceram HB – and the microhybrid – Filtek Z250 – resin composites did not show differences regarding to dye penetration even in cementum/dentin or enamel margins. However the restorations with the microhybrid Filtek Z250 tended to display less microleakage, but the differences were not statistically significant.

Interfacial integrity evaluation by microleakage test seems to be somewhat limited, since only one parameter (dye penetration depth), evaluated at specific sites, was used to express the overall quality of the restoration's interface. The microleakage is not uniform along the interface, and as the level of complexity of the specimen increases, so does the number of potential sources of experimental

error (e.g. heterogeneity of the bonding substrate and quality of the adhesive layer) (20). These restrictions may provide a lack of more precise results when different materials were analyzed. As a result, differences due to the material in microleakage tests may not be disclosed. In this experiment no differences was detected between photoactivation systems and resin composite formulation. However further studies must be conducted in order to evaluate the long term behavior of this resin composite restorations associated with the actual available light sources.

CONCLUSIONS

Under the conditions of this in vitro study:

- None of the photoactivation methods could eliminate microleakage.
- No significant differences in the microleakage scores were found among the light sources used – AL, PAC, QTH and LED
- For enamel and cementum/dentin margins neither the resin composite formulation nor the light sources interfere in the microleakage.

ACKNOWLEDGEMENTS

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TABLE 1

Resin Composites Tested

Material	Type	Shade	Composition	Manufacturer (Batch nº)
FILTEK Z250	microhybrid	A2	Bis-GMA, UDMA, Bis-EMA, TEGDMA, filler: 60% by volume zirconia/silica	3MESPE – St Paul/USA (2PW)
SUREFIL	packable	A	Bis-GMA, UDMA, filler: 66% by volume aluminium-fluoride- boro silicate , barium, silica.	Dentsply/Caulk – Mliford/USA (010626)
TETRIC CERAM HB	packable	A2	Bis-GMA, UDMA, filler: 63% by volume barium-glass, ytterbium trifluoride, Ba-Al-fluorsilicate glass, silica.	Ivoclar/Vivadent – Liechtestein (E45007)

TABLE 2

Exposure Times and Energy Density based on total intensity values or based on the intensity values at 450-490 nm** wavelength range*

Sources	Exposure Time – Total* and at 450-490 nm** Energy Density (J/cm^2)		
	FILTEK Z250	SUREFIL	TETRIC HB
QTH	20 sec – 10.8*/5.0**	40 sec – 21.6*/10.0**	20 sec – 10.8*/5.0**
LED	20 sec – 5.4*/3.0**	40 sec – 10.8*/6.1**	20 sec – 5.4*/3.0**
PAC	3 sec – 5.4*/4.5**	6 sec – 10.9*/9.0**	3 sec – 5.4*/4.5**
AL	10 sec – 2.8*/2.0**	20 sec – 6.1*/4.1**	10 sec – 2.8*/2.0**

Time of exposure indicated by manufacturers

TABLE 3

Curing Units Tested – Total light intensity and intensity at the 450-490 nm wavelength range

Curing Units	SOURCE	Total Intensity (Mw/cm^2	Intensity at the 450-490 nm wavelength range(mW/cm^2)
Optilux 501- Demetrom, USA	QTH	541	251
EliparFreelight - 3MESPE, USA	LED	270	152
Apollo 95E - DMD Corporation, USA	PAC	1818	1516
Accucure 3000 - LaserMed, USA	AL	*277 **306	*204 **205

** 150 mW – used for Fitek Z250 and Tetric Ceram HB ** 200 mW – used for Surefil according to manufactors indication*

TABLE 4

Distribution of microleakage scores and medians for each group – dentin margins

Light unit	Resin composite	SCORES					Median
		0	1	2	3	4	
LAS	SureFil	8	6	12	2	2	2.0 A
	Tetric HB	0	9	8	6	7	1.0 A
	Filtek Z250	14	7	5	4	0	2.0 A
QTH	SureFil	10	8	6	2	0	0.5 A
	Tetric HB	8	10	4	5	3	2.0 A
	Filtek Z250	12	1	10	6	0	1.0 A
LED	SureFil	5	8	6	7	4	1.0 A
	Tetric HB	7	12	9	0	0	1.2 A
	Filtek Z250	12	2	11	5	0	1.0 A
PAC	SureFil	16	3	1	10	0	2.0 A
	Tetric HB	2	14	4	6	2	2.0 A
	Filtek Z250	11	5	9	3	2	1.0 A

H=16.43 p=0.1256

Medians followed by same letters are not statistically different when analyzed by Kruskal-Wallis test (alfa=0.05)

TABLE 5

Distribution of microleakage scores and medians for each group – enamel margins

Light unit	Resin composite	SCORES					Median
		0	1	2	3	4	
LAS	SureFil	10	5	11	2	2	1.5 A
	Tetric HB	0	9	9	6	6	2.0 A
	Filtek Z250	14	8	6	2	0	1.0 A
QTH	SureFil	11	9	6	0	0	0.5 A
	Tetric HB	8	11	3	6	2	1.0 A
	Filtek Z250	11	1	11	7	0	2.0 A
LED	SureFil	6	6	8	6	4	2.0 A
	Tetric HB	7	12	9	0	0	1.0 A
	Filtek Z250	13	1	12	4	0	2.0 A
PAC	SureFil	15	3	2	10	0	0.5 A
	Tetric HB	2	15	3	6	2	1.0 A
	Filtek Z250	11	5	10	2	2	1.0 A

H=17.5760 p=0.0920

Medians followed by same letters are not statistically different when analyzed by Kruskal-Wallis test (alfa=0.05)

FIGURE 1

Diagram of cavity preparations

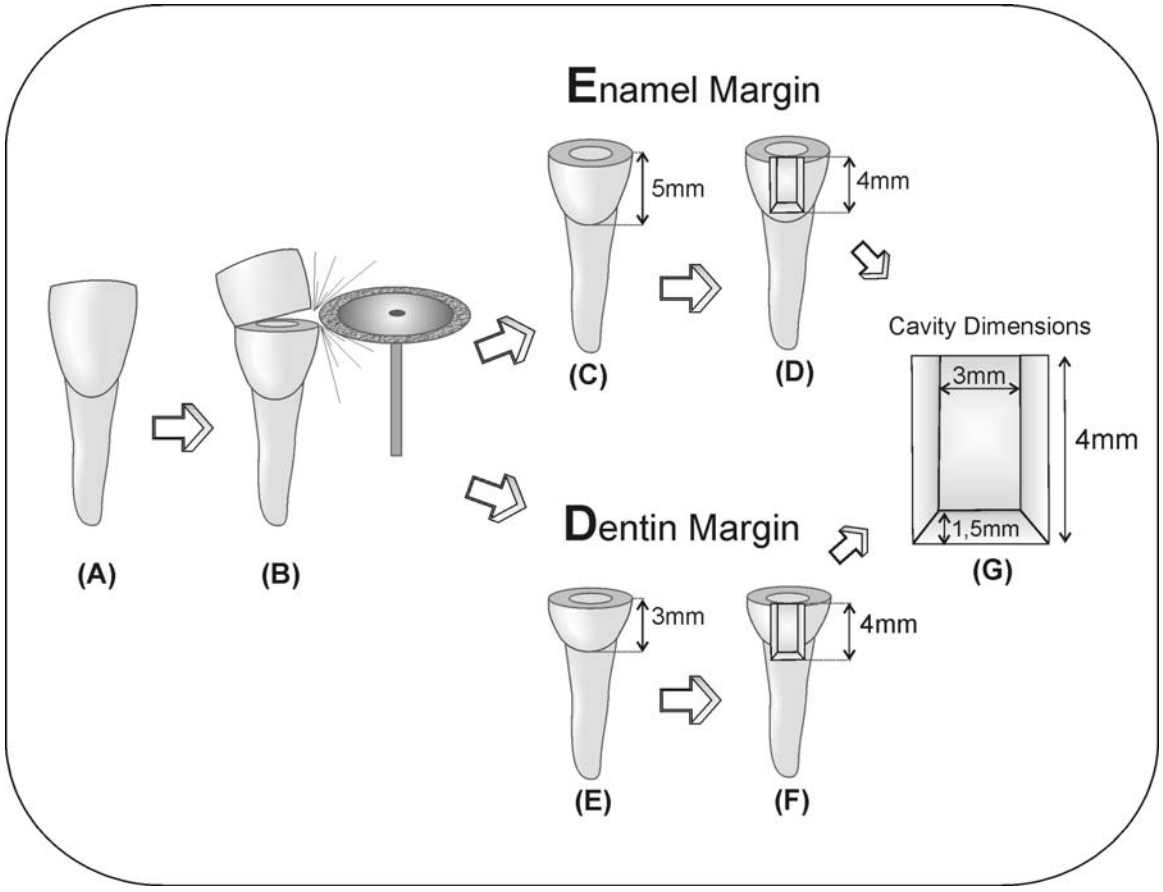
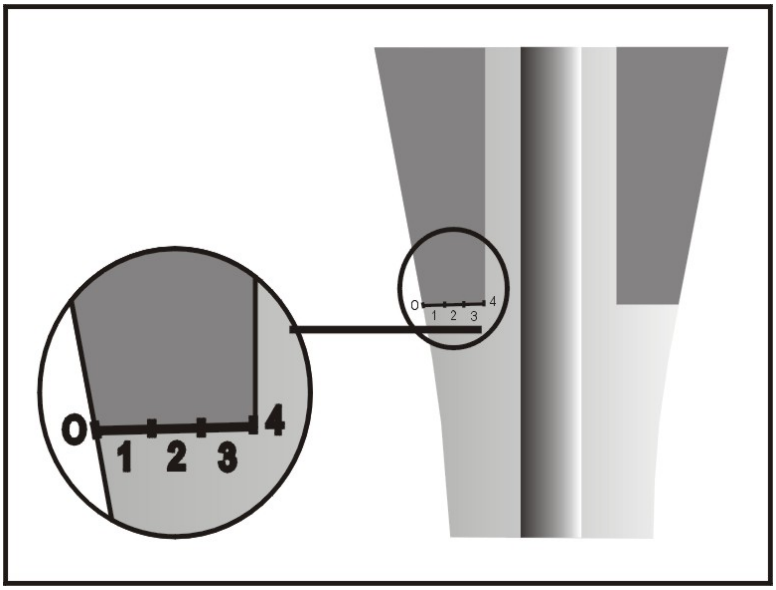


FIGURE 2

Diagram of microleakage evaluation criteria- enamel and dentin margins



LEGEND

Figure 1: *Diagram of cavity preparations*

(a): bovine incisor teeth;

(b): section of the crown;

(c): section 5 mm for enamel margins;

(d): cavity preparation at enamel margins (1mm upper enamel-cementum junction);

(e): section 3 mm for cementum margins;

(f): cavity preparation at cementum margins (1mm lower enamel-cementum junction);

(g): cavity dimensions.

3.3 CAPÍTULO III

EFFECT OF PHOTOACTIVATION METHODS ON ESTHETICS RESTORATIONS – AN EVALUATION OF GAP FORMATION AND MICROHARDNESS

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SUMMARY

The aim of this study was to evaluate the influence of four photoactivation systems (Quartz-Tungsten-Halogen (QTH), Light-Emitting-Diode (LED), Argon-Ion-Laser (AL) and Plasma-Arc-Curing (PAC)) on cementum/dentin and enamel marginal adaptation (gap formation) and microhardness of class II restorations using a microhybrid Filtek Z250 (F) and two packable composites (SureFil (S) and Tetric Ceram HB (T). Two hundred and forty "vertical slot Class II cavities" were prepared at the mesial surface of bovine incisors using a #245 carbide bur in high-speed. Specimens were divided into 12 groups, with each group representing one combination composite-photoactivation system. Half specimens in each group had gingival margin in enamel (n=10), and the other half in cementum/dentin (n=10). After polishing, epoxy replicas were processed for SEM marginal adaptation analysis, at 500x magnification. The specimens were then sectioned transversally to the dental long axis, embedded in polyester resin, polished and submitted to the Knoop microhardness test at gingival, middle and occlusal portion of the restoration. Data were analyzed for statistical significance with two-way ANOVA and Tukey's test ($p=0.05$). Results revealed no statistically significant difference in marginal adaptation among the curing systems and composites at enamel margins ($p>0.05$). At the cementum/dentin margins, there were statistically significant differences among the composites, with F resulting in better marginal adaptation when compared to S and T. However, the photoactivation system did not reveal significant differences. No statistically significant differences were noted in microhardness between F and S; however T showed significantly lower KHN ($p<0.05$). Location also influenced hardness ($p<0.01$): the KHN at occlusal and middle portions was significantly higher than those at the gingival portion. These findings suggest that different photoactivation systems may have no effect on the microhardness and gap formation, but the resin composite formulation was found to be a significant determinant factor for marginal adaptation and microhardness.

Key words: light units, marginal sealing, microhardness, resin composite, gap

CLINICAL RELEVANCE

The correct choice of restorative material and its compatibility with photoactivation systems seem to be crucial factors to reach high quality on the restorative procedure in clinical practice

INTRODUCTION

Light-activated composite materials polymerize by free radical polymerization when exposed to light at wavelengths in the 400 to 500 nm range. The photoinitiator absorbs light energy (photons) emitted from the light-curing unit or photoactivation device, and directly or indirectly initiates polymerization (Ruggeberg, 1999). Canphoroquinone is a commonly used photoinitiator that absorbs energy and reacts with a photo reducer to begin the polymerization process (Ruggeberg, 1999; Stansbury, 2000).

Polymerization shrinkage is one of the most critical properties of light-activated composites (Peutzfeldt & Asmussen, 2004). Photopolymerization shrinkage can produce a stress at the tooth-restoration interface that may lead to marginal gap formation, microleakage, possibly generating marginal discoloration, postoperative sensitivity, and secondary caries (Peutzfeldt & Asmussen, 2004).

Some studies have shown that an association exists between polymerization shrinkage, physical properties, and light intensity (Silikas, Eliades & Watts, 2000). As a result of this association, different light-curing units have been introduced to the market with the aim of minimizing or controlling the polymerization shrinkage, providing better physical properties and reducing the time for curing composites. Currently, there are basically four different types of photoactivation systems used with resin composites: quartz-tungsten-halogen (QTH); plasma arc (PAC); argon ion lasers (AL) and light-emitting diodes (LED).

The most widely used light source for curing composites are QTH lights, which have a filter to reduce output in undesired wavelengths (production in the 410 to 500 nm region of the visible spectrum)(Ruggeberg, 1999). Halogen light

bulbs generate light when electrical energy heats a small tungsten filament to extremely high temperatures (Ruggeberg, 1999; Burgess & others, 2002). Therefore, for a conventional halogen light, the larger the intensity, the more the heat production and consequently, the higher the temperature on the exposed surface (Burgess & others, 2002; Hofmann, Burkard & Klaiber, 2002).

Another category of photoactivation system is the plasma arc curing. This light curing unit, emitting high intensities, can reduce the long cure time and provide in a few seconds optimal properties in resin composite (Park, Kreijci & Lutz, 2002). However, the use of these units with such high intensities could create more contraction forces and consequently marginal fail (Brackett, Haish & Covey, 2000).

Due to the fact that the energy is primarily converted into heat, the energy conversion in these methods – QTH and PAC – is very poor. This is one of the reasons that led to the development of high-power photoactivation systems that produce only light in the wavelength needed for polymerization without further generation of heat.

The argon ion laser seemed to be an interesting alternative. Laser light is monochromatic and the photons produced are coherent and do not diverge (Ruggeberg, 1999). Thus, a great amount of energy of specific frequency can be concentrated into a very small area (Ruggeberg, 1999). In addition, this photoactivation system emits specific laser lines with wavelength specificity that closely correspond to the absorption peak of camphoroquinone (Bouschlicher, Vargas & Boyer, 1997).

The newest technology in light curing devices is the light-emitting-diode (LED) (Burgess & others, 2002). The narrow bandwidth (around 470 nm) of emitted radiation should be optimally suited for activating camphoroquinone (Burgess & others, 2002), but alternative photoinitiators absorbing at shorter wavelengths will most like not be sufficiently activated (Stansbury, 2000). Heating of irradiated objects by LED is expected to be minimal (Uhl, Mills & Jandt, 2003; Ozturk & others, 2004)

Different methods of polymerization are available on the market; therefore, it is necessary to analyze the effectiveness and the quality of polymerization. The aim of the present study was to evaluate marginal adaptation (measured as gap formation at enamel and cementum margins) and microhardness of class II composite restorations using the described photoactivation systems (QTH, PAC, AL, and LED) and three different composites – (one microhybrid and two packable composites).

METHODS AND MATERIALS

Two hundred and forty extracted bovine incisors were stored in a 1% thymol solution for one week and debrided.

The specimens were cut either 3mm apical to the cemento-enamel junction or 4mm coronal to the cemento-enamel junction, depending on gingival margin location, as illustrated in Figure 1, with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda. Barueri, SP 06442-110, Brazil).

In each specimen, one vertical “slot type” Class II cavity was prepared at the mesial surface with a #245 carbide bur (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil) running at a high-speed water-cooled hand piece (Kavo do Brasil AS, Joinville, SC 89221-040, Brazil). The burs were replaced after every 10 preparations to maintain uniformity. The butt-joint cavities had the following dimensions: 1.5mm of axial depth by 3mm of bucco-lingual width, with the gingival margin located either 1mm apical (enamel) to or 1mm coronal (cementum/dentin) to the CEJ corresponding 4mm cervico-incisal (Figure1).

In all groups, enamel and dentin was etched with 35% phosphoric acid (3MESPE, St Paul, MN 55144, USA) for 15 seconds, rinsed off for 15 seconds, and the preps were gently air dried without desiccation of the dentin. After acid etching and washing, the adhesive system (Single Bond, 3MESPE, St Paul, MN 55144, USA) was applied in two coats with a brush tip, lightly dried, and polymerized for 10 seconds following the manufacturer’s directions. The resin

composites (Table 1) Filtek Z250 (3MESPE, St Paul, MN 55144, USA), SureFil (Dentsply/Caulk-Milford, DE 19963, USA), and Tetric Ceram HB (Ivoclar/Vivadent INC, Amherst, NY 14228, USA) were inserted in 2mm horizontal increments and each increment was polymerized on the occlusal surface as specified in Table 2 which shows the exposure time, as recommended by the manufacturers, and the energy density of each photoactivation system used.

The power (mW) of the four light sources was measured using a power meter (Ophir Optronics Inc., Danvers, MA 01923, USA). With a digital caliper (Mitutoyo, Japan), the diameters of the tips were measured to determine the tip areas and, dividing the power by the area, it was calculate the total intensity (mW/cm^2). The spectral distributions of the light sources were obtained using a spectrometer (USB 2000, Ocean Optics, Dunedin, FL, 34698, USA). The total intensity data and the spectral distributions of the sources were tabulated in the software Origin 6.1 (OriginLab Corp. Northampton, MA 01060, USA) to obtain, by integrate calculus, the specific light intensity at the 450-490nm wavelength range (Table 3).

After polishing, impressions of the proximal surfaces were made with an impression material Aquasil™ (Dentsply/Caulk-Milford, DE, 19963, USA). Epoxy replicas (Buehler Epoxi Resin, IL 60044-1699, USA) were made for SEM (scanning electron microscopy) analysis to evaluate the marginal adaptation (measured as gap formation) in the gingival margins.

The epoxy replicas were sputter-coated with gold and the cervical margins were divided in three regions for SEM analysis. The margins were evaluated at x500 magnification with a SEM (JSM 5600 LV, Jeol, MA 01960, USA) and the maximum marginal gap of each region was recorded. The mean of gaps for each restoration was calculated. The data from enamel margins were submitted to Kruskal-Wallis test since it was observed many zero values and did not presented normal distribution. In contrast, the data of cementum/dentin margins were analyzed by 2-way ANOVA and Tukey's test. Meanwhile, specimens were

sectioned mesio-distally with a double-faced diamond disk (KG Sorensen Ind. Com. Ltda, Barueri, SP 06442-110, Brazil).

The hemi-restorations were placed in a ¾ inch diameter PVC ring and embedded in self-curing polystyrene resin (Piraglass, Piracicaba, SP 13424-550, Brazil). Specimens were sequentially polished on a water-cooled mechanical grinder (Maxigrind, Solotest, São Paulo, SP 01328, Brazil) using 600, 1000 and 1200-grit Al_2O_3 abrasive paper (Saint-Gobain Abrasivos Ltda., Guarulhos, SP 07111150, Brazil). The specimens were fine-polished on a mineral oil-cooled grinder using felts with diamond pastes of 6μm, 3μm and 1μm (AROTEC, Cotia, SP 06709-150, Brazil).

The Knoop microhardness test was performed using a 25g load for 20 seconds (Microhardness Tester, Future Tech FM-1E, Future Tech Corp., Tokyo 140, Japan). The indentations were placed at 100, 1900 and 3800μm from the gingival margin, and at 100, 750 and 1300 μm from the axial wall. The larger diagonal length of indentation was measured with a monitor (9M 100A Teli, Tokyo 140, Japan) and the values transformed in Knoop Hardness Numbers (KHN).

The mean KHN for each depth and for each experimental group were calculated and submitted to the ANOVA split-plot and Tukey's test, which was used to compare Knoop microhardness among groups, depths and composites.

RESULTS

MARGINAL ADAPTATION – ENAMEL MARGINS

The Kruskal-Wallis test revealed no statistically significant difference among the photoactivation methods and the composites: Laser*Composite p=0.7601; QTH*Composite p=0.4538; LED*Composite p=0.5912 and PAC*Composite p=0.2282. No statistically significant difference was observed among the resin composites and the light-curing systems Surefil*Light p=0.1568; Tetric*Light p=0.4134; Filtek Z250*Light p=0.9738. A non-parametric test was used because

the enamel margin data did not have normal distribution. The medians are shown in Table 4 and the SEM in Figure 2.

MARGINAL ADAPTATION – DENTIN MARGINS

According to the *2-Way* ANOVA and Tukey's test, there was no significant difference among the photoactivation methods used (p=0.22074); however analyzing the resin composites, the use of SureFil and Tetric Ceram HB resulted in larger gaps than Filtek Z250 witch presented better results. The means are shown in Table 5 and the SEM in Figure 3.

KNOOP MICROHARDNESS ANALYSIS

The microhardness values are listed in Table 6. For the photoactivation methods: AL, QTH, LED and PAC no statistical differences were observed (p=0.7103). No statistical significant difference was observed between FiltekZ250 and SureFil resin composites (p=0.1701), however Tetric Ceram HB presented the lower KHN means. The Tukey's test ($p<0.01$) revealed significant differences among depths. All resin composites and photoactivation devices presented the same behavior, the hardness at the top (1300 μm) and middle (750 μm) surfaces were significantly higher than the bottom (100 μm) surface.

DISCUSSION

During the setting process, the polymerization shrinkage of a resin composite can create forces that may disrupt the bond to cavity walls (Davidson, de Gee & Feilzer, 1984). This competition between contracting forces developed in the polymerizing resin and the bonds of adhesive resins to the walls of the prep is one of the main causes of marginal failure and subsequent microleakage (Davidson & others, 1984).

Dentinal adhesion has demonstrated to be more difficult and less predictable than enamel one (Swift, 1995). The difficulty in bonding to dentin is a consequence of its complex histological and variable composition (Swift, 1995). The results from this study compare favorably with the literature for enamel margins demonstrating a good seal, in contrast to the cementum/dentin margins

(Ferrari, Goracci & Garcia-Godoy, 1997; Beznos, 2001). In the marginal adaptation analysis all the samples with cervical cementum/dentin margins presented gaps, however in the teeth with cervical enamel margins it was observed that 42% of all samples had no gaps.

The resin composites present a different behavior according to the cavity margin – enamel or cementum/dentin. For enamel margins, neither the microhybrid (Filtek Z250) and the packables (SureFil and Tetric Ceram HB) nor the cure modes – AL, PAC, QTH and LED, presented statistical significant differences in mean marginal gap sizes. This satisfactory adhesion found between enamel cavity walls and restorative materials can be attributed to the enamel bond strength, which seems to be greater than contraction stress promoted for the curing process. (Meiers, Kazemi & Meier, 2001).

However, at the cementum/dentin margins the packable resin composites presented in this study the widest gaps when compared to the microhybrid resin composite. Variations in the material's composition can explain this different behavior for the gap sizes. The packable resin composite presented a high elasticity modulus, what can cause more strains in the interface during polymerization (Davidson & others, 1984). The amount of contraction stress has been determined to be dependent on the extend of the reaction, the stiffness of the composite and its ability to flow (Davidson & Feilzer, 1997; Sakaguchi & others, 1991). At the same volumetric polymerization shrinkage, a stiffer composite place higher stress on the adherence than does a resin composite of lesser stiffness (Peutzfeldt & Asmussen, 2004). The use of packable resin-based composite materials generated significantly higher maximum contraction stress and higher rate of contraction force development than a conventional hybrid resin composite (Chen & others, 2001). Thus, the poor adaptation observed for packable composites (Meiers & others. 2001) associated with the higher stress generated during the polymerization shrinkage can explain the poor results of marginal adaptation observed for these composites in this study.

Another factor that could explain the widest gaps found for SureFil and Tetric Ceram HB when compared to Filtek Z250, at the cementum/dentin margins, is that the filler particle technology of the packable composites could translate into increased post-gel linear shrinkage stress directed at the margins (Meiers & others, 2001). Stress arising from post-gel polymerization shrinkage may produce defects in the composite-tooth bond, leading to bond failure and consequently post-operative sensitivity, gap formation and recurrent caries (Meiers & others, 2001; Yap, Soh & Siow, 2002a). The more satisfactory results for the Filtek Z250 resin when compared with SureFil and Tetric Ceram HB observed in this study could be explained by the lower post-gel shrinkage as revealed by the manufactures (*Surefil High Density Posterior Restorative Manual; Filtek Z250 – Scientific Documentation; The Tetric Ceram Family – Scientific Documentation*).

The amount of linear shrinkage that occurred when a resin composite is photoactivated by different light sources seems also to be a determinant aspect to predict the success in reducing the gap formation on the resin composite restorations. The shrinkage of resin composite caused by the rapid curing with high intensity lights has been considered a disadvantage for restorative applications (Silikas & others, 2000). A more intense light source may produce faster curing and may increase the magnitude of strain and stress associated with the shrinkage (Silikas & others, 2000; Stoll & others, 2000) causing gap formation along the interface and also increasing the microleakage potential (Brackett & others, 2000). Thus, a tendency towards the increase in size of marginal gaps and microleakage could be expected with the high intensity cure modes – AL and PAC over the conventional mode QTH or LEDs (Brackett & others, 2000; Rahiotis & others, 2004). However larger marginal gaps were not observed in this investigation when the high intensity irradiation PAC and AL were used confirming previous reports regarding Class II and Class V restorations (Stoll & others, 2000; Hasegawa & others, 2001; Hofmann & others, 2003).

Several studies confirm that the amount of linear shrinkage is not influenced by the light source (Aw & Nicholls, 2001; de Gee, Feilzer & Davidson, 1993). This

lack of relation found between the contraction polymerization and the light systems was confirmed in this study since there are no statistical significant differences among the four light curing systems in gap formations at the cementum/dentin and enamel margins as demonstrate in previous studies that also evaluated the marginal seal of composite restorations (Hasegawa & others, 2001; Hofmann & others, 2003; Kubo & others, 2004; Ozturk & others, 2004; Amaral & others, 2004).

In this study, the microhardness of resin composites was measured in different depths as an indirect method for evaluating the relative degree of conversion (Mehl, Hickel & Kunzelmann, 1997). The effective cure of resin composite is vital not only to ensure optimum physical-mechanical properties, but also to guarantee that clinical problems do not arise due to cytotoxicity of inadequately polymerized material (Caughman & others, 1991), and that the material does not degrade in long term evaluation. In general, higher hardness values are an indication of more extensive polymerization (Mehl & others, 1997).

According to the results, the packable SureFil and the microhybrid Filtek Z250 presented the same behavior when the QTH, LED, AL and PAC light systems were used. However, the packable Tetric Ceram HB showed the lowest KHN means with all the activations modes.

The difference between the hardness values of restorative materials is dependent on many factors such as shade, amount of filler, refractive indices of filler and matrix, resin composite's transmission coefficient, particle type, size and loading, and the energy and wavelength of light emitted by the curing unit (Bayne, Heymann & Swift, 1994; Kawaguchi, Fukushima & Miyazaki, 1994).

The ratio of filler relative to resin is important. The higher the proportion of filler, the more difficult it is for the light to penetrate the composite (Yoon & others, 2002). The degree to which materials cure is proportional to the amount of light to which they are exposed (Yoon & others, 2002). The resin composites used presented different volume fractions of the filler - 60%; 63% and 66% respectively to Filtek Z250, Tetric Ceram HB and Surefil (*Surefil High Density Posterior*

Restorative Manual; Filtek Z250 – Scientific Documentation; The Tetric Ceram Family – Scientific Documentation). Light attenuation within resin composites is commonly attributed to scattering by filler particle (Miyazaki & others, 1991) and thought to be most valuable when the particle size is close to half the wavelength of the light (Ruyter & Oysaed, 1982). Reduction in Knoop values of the Tetric Ceram HB compared to Surefil and Filtek Z250 can be due to reduced light transmission through the higher filled composite (Bennett & Watts, 2004)

The degree of polymerization can also depended on the characteristics of the resin composite used such as the concentration of the initiator and the type and concentration of co-initiators (Hofmann & others, 2000). Although it is well known that these parameters vary between commercially available resin composites (Hofmann & others, 2000), they are usually not specified by the manufacturers. Since all resin composites employed in this study have camphorquinone as photoinitiator, the different curing behavior of Tetric Ceram HB may be associated with the use of an additional photoinitiator responding to 435 nm of wavelength (Bennett & Watts, 2004).

Calculations of energy density as the product of light intensity (in mW/cm^2) and time (in s) showed that the energy density for Argon ion Laser was the lowest for all polymerization techniques and the QTH showed the highest (Table 6). These variations in energy density were probably insufficient to influence the microhardness for Filtek Z250 and Surefil, however for Tetric Ceram HB it seems to be insufficient. This is of notable clinical significance as the Tetric Ceram HB is intended for use in the high-load wear situation of posterior cavities (Bennett & Watts, 2004). For that reason, it is recommended to increase the time curing when this resin composite is going to be used to reach higher KHN values.

There was a significant difference in depth among the bottom (100μm), middle (1,900μm) and top (3,800μm) surfaces. For all groups the microhardness was higher at the middle and top surface. This can probably be explained because of the relationship between irradiation distance and effectiveness of polymerization

(Pires & others, 1993). The depth of cure was reduced by increasing the distance between light tip and composite surface (Hansen & Asmussen, 1997). The degree of cure for a light activated composite polymerization is proportional to the amount of light to which this material was exposed (Rueggeberg, Caughman & Curtis, 1994). The top surface of the material was nearer to the light source than the subsequent resin composite layers, in this way the light transmission did not suffer any interference and the intensity was not reduced. The resin composites were inserted in 2 increments and this can explain the same results found for the top and middle surface. The middle surface received activation from the first and second increment increasing the amount of light received. However at the bottom surfaces the light intensity is greatly reduced due to light scattering, thus decreasing the effectiveness of polymerization (Ruyter & Oysaed, 1982). One way to compensate for this is to increase the light exposure time, which can provide better hardness results (Rueggeberg & others, 1994; Yap, Soh & Siow, 2002b), also curing by lingual and buccal surfaces at proximal area (Rueggeberg & others, 1994).

It has beem suggested that the top-to-bottom hardness gradient should not exceed 10-20% (hardness ratio should be greater than 0,8) for light activated resin composite to be adequately polymerized (Pilo & Cardash, 1982; Yap & others, 2002b). The hardness ratio for all groups used in the presented study was according to this calculation (Table 6).

Although some studies demonstrated that 3 seconds of curing time was not enough for optimal curing of composites when the Plasma Arc technique was used, (Hofmann & others, 2000; Park & others, 2002) the results found in this study showed similarities among AL, QTH and LED.

Despite the great advances in light units, presenting new polymerization techniques, the light sources tested did not presented significant differences in the microhardness and gap formation of class II composite restorations. These results are promising for the use of high intensities sources for curing composite as they

are compatible with the light source, the major advantage might save clinical time. On the contrary, the high costs of these devices could be considered as a limitation for use in clinics, for that reason, alternatives such as QTH or LED which present reduced costs, could be the optimal option related with cost/benefit ratio. However, the correct choice of restorative material and the technique to be used seems to be more crucial to reach high quality on the restorative procedure. Furthermore it is important for the clinicians to evaluate the composition of each material and their compatibility with the light-curing devices to improve the quality of restorations in clinical practice and consequently increasing their longevity.

CONCLUSIONS

The results of this “in vitro” study allow concluding:

- The light devices – AL, PAC, QTH and LED did not interfere on the microhardness and on the cementum/dentin and enamel gap formation of resin composites;
- For enamel margins neither the resin composite nor the light units interfere in the gap formation;
- For cementum/dentin margins the microhybrid resin composite always presented the lower gaps compared to the packable ones;
- Gap formation in enamel is lower than in cementum/dentin for all light devices and resin composite used;
- The microhardness at the top and middle surface always presented the high values than the bottom surface;
- The packable resin composite Tetric Ceram HB, presented the lowest KHN means.

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TABLE 1

Resin Composites Tested

Material	Type	Shade	Composition	Manufacturer (Batch nº)
FILTEK Z250	microhybrid	A2	Bis-GMA, UDMA, Bis-EMA, TEGDMA, filler: 60% by volume zirconia/silica	3MESPE – St Paul/USA (2PW)
SUREFIL	packable	A	Bis-GMA, UDMA, filler: 66% by volume aluminium-fluoride- boro silicate , barium, silica.	Dentsply/Caulk – Mliford/USA (010626)
TETRIC CERAM HB	packable	A2	Bis-GMA, UDMA, filler: 63% by volume barium-glass, ytterbium trifluoride, Ba-Al-fluorsilicate glass, silica.	Ivoclar/Vivadent – Liechtestein (E45007)

TABLE 2

Curing Units Tested – Total light intensity and intensity at the 450-490 nm wavelength range

Curing Units	SOURCE	Total Intensity (mW/cm^2)	Intensity at the 450-490 nm wavelength range(mW/cm^2)
Optilux 501- Demetrom, USA	QTH	541	251
EliparFreelight - 3MESPE, USA	LED	270	152
Apollo 95E - DMD Corporation, USA	PAC	1818	1516
Accucure 3000 - LaserMed, USA	AL	*277 **306	*204 **205

** 150 mW – used for Fitek Z250 and Tetric Ceram HB ** 200 mW – used for Surefil according to manufactors indication.*

TABLE 3

Exposure Times and Energy Density based on total intensity values or based on the intensity values at 450-490 nm** wavelength range*

Sources	Exposure Time – Total* and at 450-490 nm** Energy Densities (J/cm^2)		
	FILTEK Z250	SUREFIL	TETRIC HB
QTH	20 sec – 10.8*/5.0**	40 sec – 21.6*/10.0**	20 sec – 10.8*/5.02**
LED	20 sec – 5.4*/3.0**	40 sec – 10.8*/6.1**	20 sec – 5.4*/3.0**
PAC	3 sec – 5.4*/4.5**	6 sec – 10.9*/9.0**	3 sec – 5.4*/4.5**
AL	10 sec – 2.8*/2.0**	20 sec – 6.1*/4.1**	10 sec – 2.8*/2.0**

Time of exposure indicated by manufacturers.

TABLE 4

Median - Gap Formation at the Enamel Margins

SOURCE	SUREFIL	TETRIC HB	FILTEK Z250
	median	*median*	*median*
LASER	0.0 Aa	0.5 Aa	0.0 Aa
QTH	2.3 Aa	0.8 Aa	0.4 Aa
LED	2.0 Aa	1.4 Aa	0.3 Aa
PAC	0.0 Aa	1.7 Aa	0.7 Aa

*Median followed by same letters are not statistically different when analyzed by Kruskal-Wallis test (alfa=0.05). Capital letters indicate comparisons among resin composites*light source (in vertical). Small letters indicate comparisons among light source*resin composite (in horizontal).*

TABLE 5

Means and Standart Devitations (sd) Gap Formation at the Dentin Margins

SOURCE	SUREFIL	TETRIC HB	FILTEK Z250	TUKEY
	mean *(sd)*	mean *(sd)*	mean *(sd)*	
LASER	6.03 *(1.37)*	5.23 *(1.46)*	4.56 *(1.38)*	a
QTH	5.22 *(1.87)*	5.18 *(1.23)*	5.59 *(1.65)*	a
LED	4.97 *(1.35)*	6.42 *(1.94)*	4.36 *(0.90)*	a
PAC	5.86 *(1.92)*	4.90 *(1.53)*	4.61 *(2.34)*	a
TUKEY	A	A	B	

Means followed by different letters were statistically different by Tukey's test (capital letters in horizontal and small letters in vertical).

TABLE 6

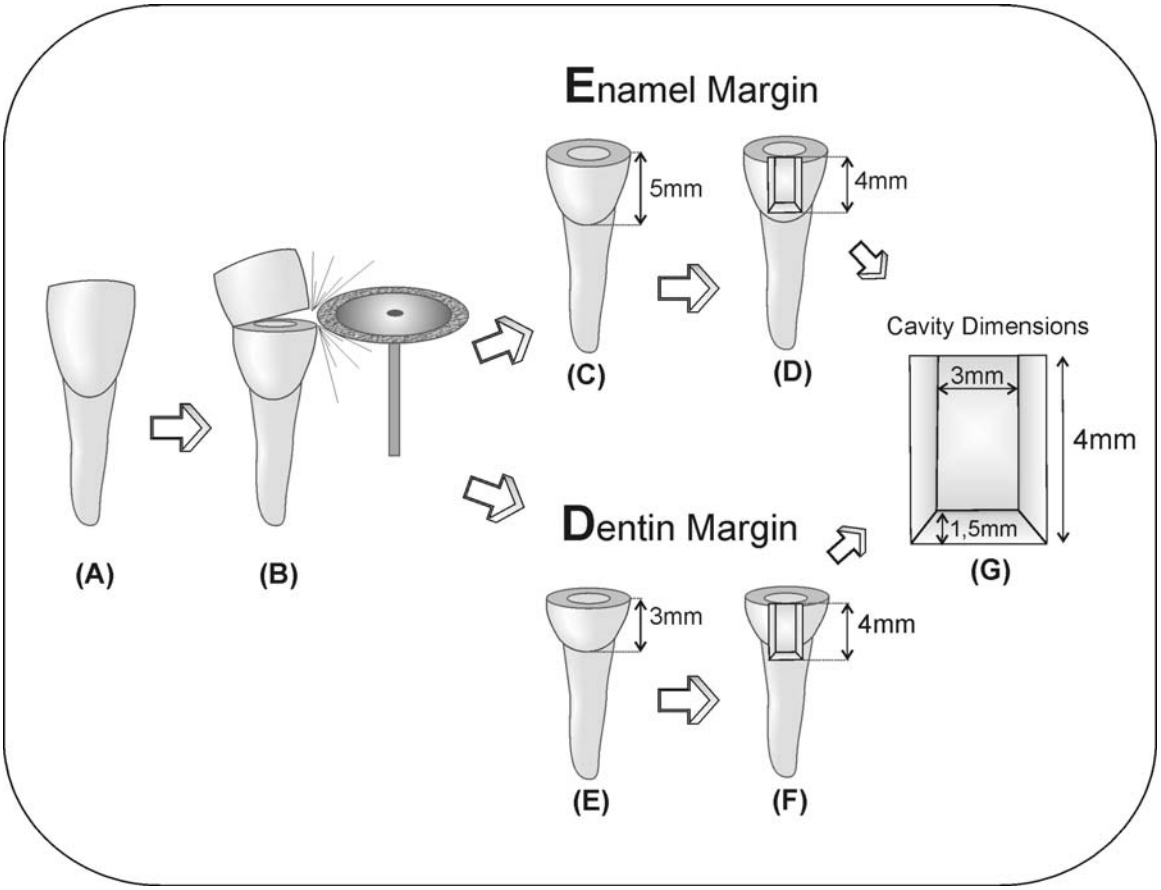
Means and Standart Devitations Knoop Hardness Number (KHN) for the Different Curing Modes, Resin composite and Depth

Sources	Composite	DEPTH OF CURE – MEANS (SD)				
		Bottom (100µm)	Middle (1900µm)	Top (3800µm)	Bottom/Top Ratio (%)	TUKEY
LASER	Surefil	118.7 (20.0)	121.7 (8.8)	123.7 (17.5)	95.95	a
	Tetric	86.5 (15.8)	88.8 (14.7)	110.7 (30.3)	78.13	b
	Z 250	105. 9 (17.9)	118.1 (16.2)	117.3 (27.3)	90.28	a
QTH	Surefil	118.9 (12.1)	128.4 (18.5)	130.4 (21.5)	91.18	a
	Tetric	84.6 (11.4)	90.7 (10.0)	93.3 (13.8)	90.67	b
	Z 250	106.9 (17.2)	117.7 (18.0)	116.8 (19.9)	91.52	a
LED	Surefil	122.1 (15.2)	120.8 (16.6)	130.7 (22.2)	93.42	a
	Tetric	92.8 (15.3)	92.8 (15.6)	95.6 (15.8)	97.07	b
	Z 250	119.6 (19.5)	119.4 (13.9)	137.4 (12.4)	82.24	a
PAC	Surefil	118.0 (16.6)	127.8 (18.6)	122.7 (15.7)	96.16	a
	Tetric	82.8 (17.1)	96.1 (14.5)	99.5 (16.2)	83.21	b
	Z 250	112.2 (15.5)	113.1 (17.0)	112.7 (16.9)	99.55	a
TUKEY		B	A	A		

Means followed by different letters were statistically different by Tukey's test (capital letters in horizontal and small letters in vertical)

FIGURE 1

Diagram of cavity preparations



LEGEND :

(a): bovine incisor teeth

(b): section of the crown

(c) :section 5 mm for enamel margins

(d):cavity preparation at enamel margins (1mm upper enamel-cementum junction)

(e):section 3 mm for cementum margins

(f): cavity preparation at cementum margins (1mm lower enamel-cementum junction)

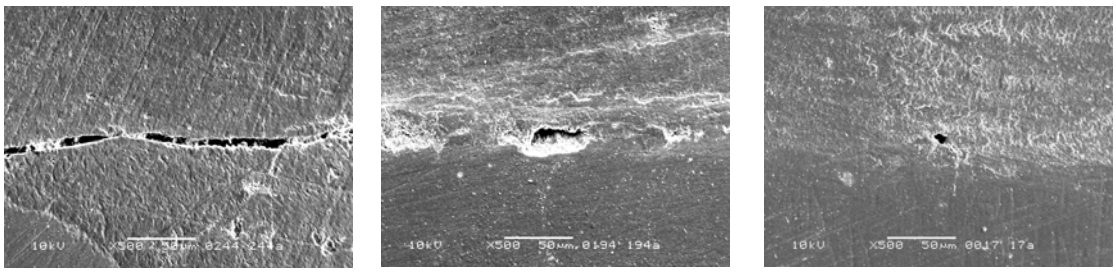
(g): cavity dimensions

FIGURE 2

PAC **ENAMEL MARGINS**

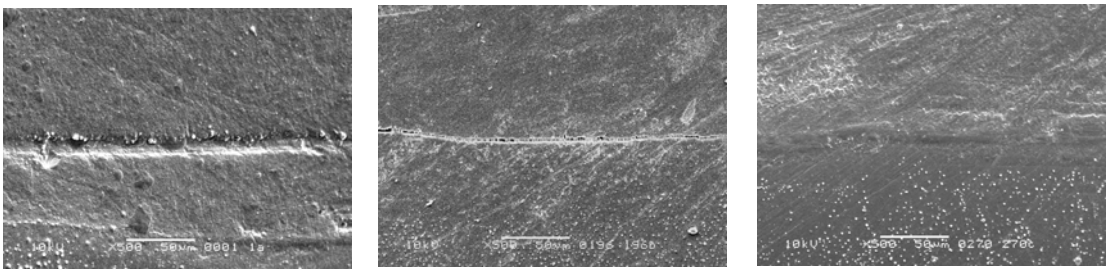
SUREFIL TETRIC CERAM HB FILTEK Z250

LED



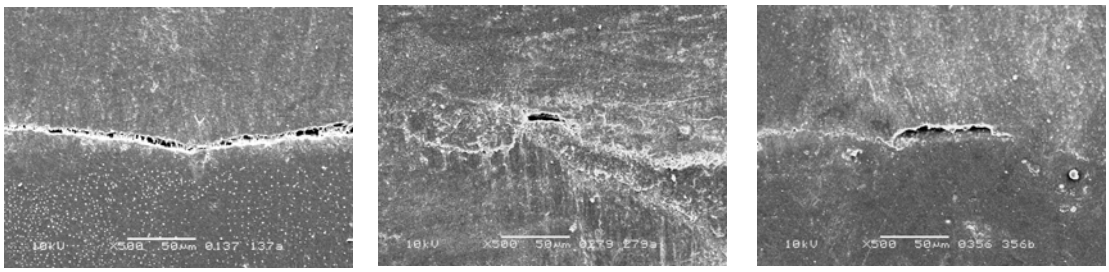
SUREFIL TETRIC CERAM HB FILTEK Z250

LASER



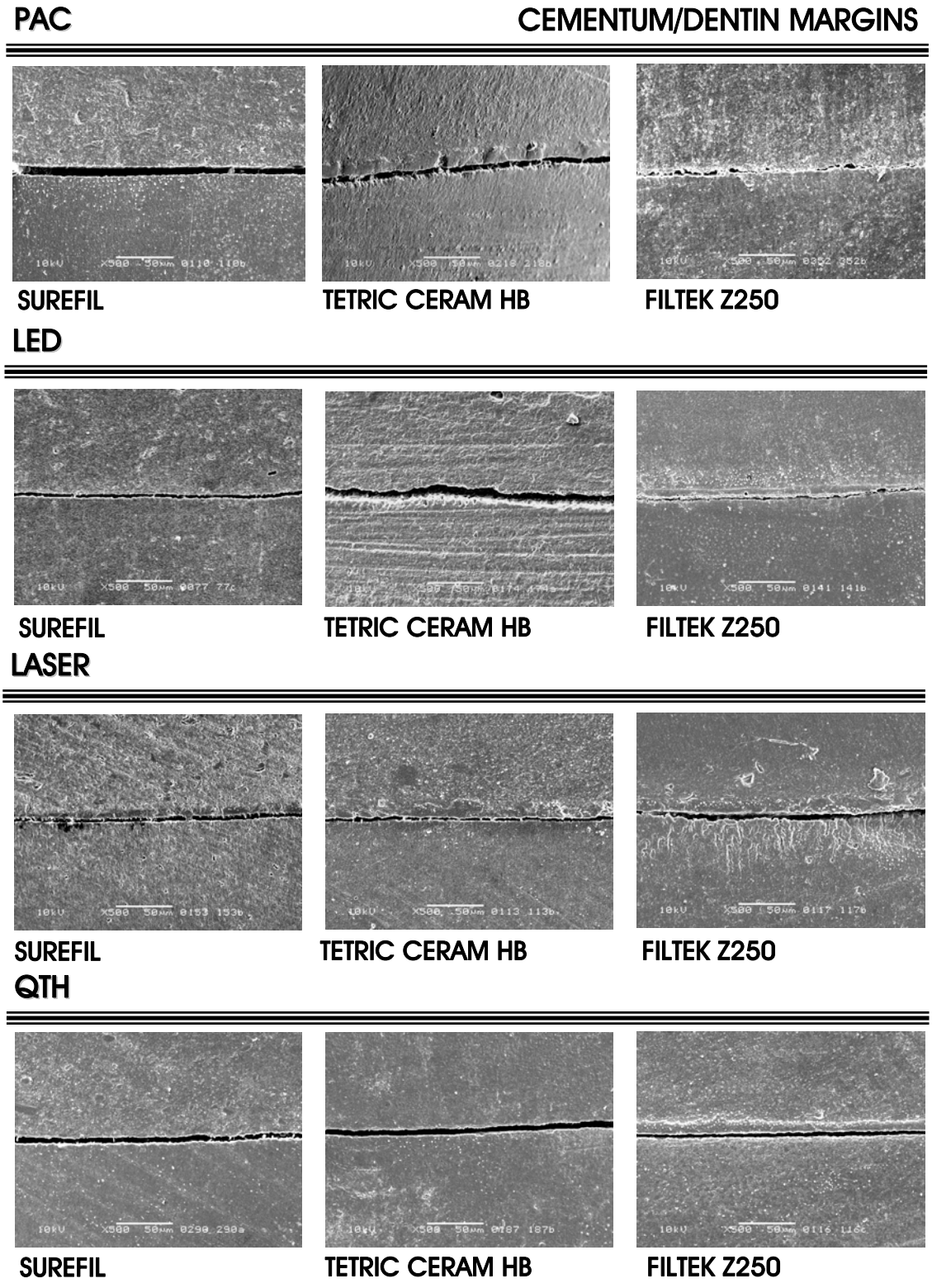
SUREFIL TETRIC CERAM HB FILTEK Z250

QTH



SUREFIL TETRIC CERAM HB FILTEK Z250

FIGURE 3


PAC
CEMENTUM/DENTIN MARGINS
SUREFIL
TETRIC CERAM HB
FILTEK Z250
LED
SUREFIL
TETRIC CERAM HB
FILTEK Z250
LASER
SUREFIL
TETRIC CERAM HB
FILTEK Z250
QTH
SUREFIL
TETRIC CERAM HB
FILTEK Z250

3.4 CAPÍTULO IV

INFLUENCE OF DIFFERENT TESTS USED TO MEASURE THE BOND STRENGTH TO DENTIN OF TWO ADHESIVE SYSTEMS

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SHORT TITLE: Influence of different bond strength tests

KEYWORDS: Microtensile bond test; shear bond test; adhesion; dentin bonding; bond strength tests; self-etching primers; one-bottle adhesive system; dumbbell specimen shape; beam specimen shape.

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ABSTRACT

Purpose: The aim of this study was to investigate the behavior of two bonding systems: self-etching primer Clearfil Liner Bond2V/ Kuraray Co. (CLB) and total-etch Single Bond/ 3M (SB) when submitted to 2 bond strength tests: Shear Bond Strength (SBS) and Microtensile (μTBS). *Materials & Methods*: Flat dentin surfaces were obtained at the facial surface of extracted bovine incisors. μTBS started with adhesive application and incremental resin composite insertion. Samples were then sliced into 1mm, slabs parallel to the long axis of the tooth. Half of the specimens from each group were trimmed in order to obtain specimens with a cross-sectional area of 1mm^2 (D), and in the other half of the group, the slabs were cut into beams with a cross section of 1mm^2 area (B). Specimens were individually fractured on a microtensile apparatus. For SBS, crown segments were embedded in polyester resin and a flat dentin surface was exposed for bonding. After adhesive and restorative procedures were accomplished, the specimens were kept in water for 24h prior to bond testing. The tests were performed in a universal testing machine. MPa values were analyzed by Tukey's test ($p<0.05$), 2-way ANOVA (μTBS) and Student's t test (SBS). *Results*: mean values (SD) on μTBS were: SB/B: 42.6 (15.1), SB/D: 35.4 (6.8), CLB/B: 14.3 (10.3) and CLB/D: 27.0 (7.9). SBS values (SD) were: SB: 17.3 (5.6) and CLB 15.9 (7.2). Beam specimens bonded with CLB presented the lowest results. SBS did not show statistical differences between groups. The results show that shear bond test seem to lack the sensitivity that is required to detect subtle differences between bonding agents or procedures.

CLINICAL SIGNIFICANCE

The "self etch" adhesive system "CLB" have shown the lowest bond strength values independently of the test used, when compared to the "total etch – one bottle" adhesive system "SB". The clinician should be award about the methodologies used to evaluate adhesive systems to make a decision of which one use in their patients

INTRODUCTION

The development of a large number of new adhesive systems available on the market shows that the adhesive dentistry has continuously advanced [1,2]. Considering this progress, it is necessary to evaluate their effectiveness [2,3].

Bond strength is the force per unit required to break a bonded assembly with failure occurring in/or near the adhesive interface [4]. The strength of bond is related to the size of the bonding area [2,3]. Therefore, to calculate bond strength it is important to control this area and know its dimensions. However, there are other variables that can influence bond testing such as substrate, etching, priming, bonding, and storing procedures [3,5,6].

Numerous bond strength tests have been employed. The shear and tensile tests are the most commonly used methods [4] and recently the microtensile bond test has been widely performed [2,7]. For shear bond strength, force is applied parallel to the interface; while for the tensile and microtensile forces are applied perpendicular to the adhesive surface [4].

The shear test uses large surfaces areas - 3 to 12mm^2 - while the microtensile test uses a bonded surface area of approximately 1mm^2. Specimens with a minimal surface area will produce a more uniform distribution of stress along the cross-sectional interface resulting in higher bond strength values [2,7,8].

The μTBS technique was introduced, in an attempt to evaluate the constancy of resin-dentin bonds, and to improve the stress distribution during the test. A number of researchers have made numerous modifications in the method, mainly in regard to the specimen shape [7,9]. Therefore it is necessary to know the effect of different specimen configurations on bond strength.

The purpose of this study was to investigate the compare of SBS with μTBS (beam (B) and dumbbell (D) specimen shapes) on the behavior of two bonding systems: the self-etching primer Clearfil Liner Bond 2V/ Kuraray (CLB) and the one-bottle total-etch acid Single Bond / 3M (SB). The null hypothesis tested was that both adhesive systems would behave similarly, independently of the test applied or specimen shapes used on μTBS.

METHODS AND MATERIALS

Eighty freshly extracted bovine incisors were collected, cleaned, and prepared for the tests. The roots were removed from the crown approximately 2mm bellow the cementoenamel junction (CEJ) using a slow-speed diamond saw under water spray. Following preparation they were randomly divided into the experimental groups.

MICROTENSILE BOND STRENGTH TEST

The buccal surfaces of 40 teeth were wet-ground flat in a mechanical grinder, with 180, 400, and 600 SiC sandpaper, in order to create flat mid-coronal dentin. These teeth were randomly assigned into two groups: 1 – Single Bond adhesive system (3M Dental Products, St Paul, MN, USA); 2 - Clearfil Liner Bond 2V self-etching primer (Kuraray Co, Osaka, Japan) applied according to the manufacturer's instructions (Table 1). Each group was divided into two subgroups (n=10) in order to prepare specimens in two different shapes: dumbbell (D) and beam (B). In all groups, a 4 mm high resin composite (Filtek Z250, 3M Dental Products, St Paul, MN, USA) build up on the bonded surface. The resin composite was cured in three increments, each increment approximately 1.30 ± 0.3mm thick, that was polymerized for 20 seconds (Optilux 501 - Demetrom/Kerr, Danbury, CT, USA). Light intensity (500 mW/cm^2) was periodically monitored with a radiometer (Demetrom/Kerr, Danbury, CT, USA). The specimens were stored in distilled water at 37^{o}C for 7 days.

DUMBBELL SHAPE

Three serial vertical slices approximately 1 mm thick, perpendicular to the bonded surface were made using a slow-speed diamond saw sectioning machine (Buehler Isomet 100™, Buehler Ltd, Lake Bluff, IL,USA). The slices were then trimmed and shaped to form an dumbbell with the narrowest portion of 1.0 ± 0.3 mm wide, using a fine finishing diamond bur #1099FF (KG Sorensen, Barueri, SP, Brazil) in a high-speed hand piece under air/water spray coolant. The interface

cross-sectional area of each specimen was constantly checked using digital calipers (Mahr GmbH Esslingen, Germany).

BEAM SHAPE

Each tooth was vertically sectioned through the resin composite and the dentin to produce a series of 1mm thick slab. Each slab was then cut into beams of $1.0 \pm 0.3mm^2$ cross-section area.

Three specimens per tooth of each shape were randomly selected from the central area for the test. The cross-sectional area of each specimen was previously measured (digital caliper Mahr GmbH Esslingen, Germany).

Specimens were then glued to an acrylic grip with a cyanoacrylate adhesive (Super Bonder, Henckel Loctite®, São Paulo, SP, Brazil). The grip with the specimen was then inserted into an acrylic device – MT Jig (trademark Fapesp # 02/0793-3), held in a Universal Testing Machine (EMIC). The tensile force was employed by a load cell of 10N at a cross-head speed of 0.5mm/min. The microtensile bond strength was calculated and expressed in MPa.

The mean values of each tooth were calculated and submitted to 2-way Analysis of Variance (ANOVA) and Tukey's multiple comparison test.

SHEAR BOND STRENGTH TEST

To obtain a flat dentin surface from the central area of the buccal surface of the crown, measuring $25mm^2$, the crowns were removed from the roots with a double faced diamond disk under water coolant (KG Sorensen, Barueri, SP, Brazil). The crowns were placed in a 2cm diameter PVC rings and oriented so that the buccal surface was faced up, and the rings were filled with self-curing polystyrene resin (Piraglass, Piracicaba, SP, Brazil). Specimens were ground on a water-cooled mechanical grinder (Maxigrind, Solotest, São Paulo, SP, Brazil) using 180, 320, 400, and 600-grit SiC sandpaper (Saint Gobain Abrasivos, Guarulhos, SP, Brazil) to expose flat mid-crown dentin.

After being polished, the dentin surfaces were covered with a piece of vinyl tape, containing a 3mm diameter hole. The teeth were randomly assigned into two

groups (n=20) for bonding of different adhesive systems tested – Single Bond/3M and Clearfil Liner Bond 2V/Kuraray Co. – applied according to the manufacturer's instructions (Table 1). A Teflon (polytetrafluoroethilene) ring mold of 3 mm diameter and 5 mm high was placed against the specimens to receive the filling material (Filtek Z250/3M). The resin composite was inserted in two increments 2.5mm thick and light-cured (Optilux 501, Demetron Kerr Co., CT, USA) for 40 seconds. An additional 20 second polymerization was performed on both sides of the resin composite cylinder. The specimens were stored in distilled water at 37°C for 7 days.

For Shear Bond Strength measurements, bonded specimens were individually positioned in a Universal Testing Machine (DL 500, EMIC Ltda, PR, Brazil) with the dentin surface parallel to the steel knife-edge. The specimens were loaded to failure at a cross-head speed of 0.5mm/min. Shear bond strengths of each specimen were calculated in MPa and data were subjected to Student's t test.

FRACTURE MODE ANALYSIS

After testing, the dentin sides of fractured specimens were observed with an optical stereomicroscope (Meiji Techno Co, LTD, Iruma-gun Saitana 356, Japan) at 70x magnification for determination of the mode of fracture. Failure mode was classified into one of four types:

Type 1: interface failure between adhesive and dentin

Type 2: total cohesive in dentin

Type 3: total cohesive in resin composite

Type 4: mixed among adhesive – resin composite – dentin

The frequency of fracture mode was expressed as percentage values for each test.

RESULTS

MICROTENSILE BOND STRENGHT TEST

The bond strength data are summarized in Table 2. During the specimens preparation only one tooth with premature failure from CLB/B (Clearfill Liner Bond

2V/Beam) group was observed, the resin composite block debonded during the specimen preparation and this specimen was removed from the experiment. Two-way ANOVA indicated that there were interactions between adhesive systems and specimens shape (p=0.0105) and identified differences between the adhesive systems and specimen shapes. Single Bond dumbbell (42.6 MPa) and beam shapes (35.4 MPa) were not statistically different. When tested in a dumbbell shape (27.0 MPa), the self-etching primer Clearfil Liner Bond 2V presented higher values of microtensile bond strength than beam shapes (14.3 MPa). The beam shape specimens showed the lowest mean and were statistically different from SB/B (Single Bond/Beam), SB/D (Single Bond/Dumbbell) and CLB/D (Clearfil Liner Bond 2V/Dumbbell).

SHEAR BOND STRENGTH TEST

The means in MPa are expressed in Table 3. According to Student's t test there was no statistically significant differences between the two materials (p=0.5217).

FAILURE MODE ANALYSIS

The failure mode was expressed in Table 4 as percentage values. Type 1 failure was the most predominant failure pattern observed in both μTBS tests – 78,5% for dumbbell and 85,2% for beam shapes. Illustration SEM of Type 1 failure is shown in Figure 1.

DISCUSSION

There is a wide range in reported results of experimental tests on bond strength of resin composite to dentin and enamel using different bonding agents [5]. The results obtained in this study, between the shear and microtensile bond strength tests, confirmed those observations. Changes in specimen geometry, loading configuration, material stiffness, bonding methods, fracture mode, stability

of dentin bonds, and testing methods provide different stress distribution at the bonded interface [3,4,5].

Shono et al. [9] reported wide differences in μTBS bond strength values, even in the same tooth. This was also observed in this study. These differences can be related to specimen preparation, material properties, regional bond differences, heterogeneity of the bond substrate, and technique sensitivity [8].

Adhesive layer thickness can vary across the bonded area [8,10]; and the presence of air bubbles or resin globules at the bonded interface may act as stress raisers during the test [8]. In the same tooth it is possible to get high or low adhesive values. When high variations are found, it is important to consider an average bond strength per tooth and not each slice value as an independent specimen. The calculation of an average for each tooth seems to give a more appropriate value, considering the regional variability inherent of each tooth.

Testing methods have never been well standardized despite a number of important recommendations have been made for both the substrate [11] and testing methods [12]. Schreiner et al. [13], comparing μTBS and SBS of five commercial dentin adhesive systems provided support for the superiority of the μTBS method over the SBS in evaluating the comparative strengths of adhesive systems. Therefore, the difficulty to standardize the test makes impossible to directly compare results presented by different bonding tests, as μTBS and SBS.

In the present study μTBS and SBS tests were also performed. However, it was not applicable to make a statistical correlation between them, once they were performed in different specimens, and this invalidates any statistical correlation attempt. However the possibility to discuss the results obtained from these two tests is the intention of this paper.

The μTBS test was created in an attempt to determine the uniformity of bond strength distribution [9] and to provide a possibility to measure regional bond

strengths of the tooth surface (i.e. upper vs. lower walls of wedge-shaped lesions, cervical vs. middle vs. applied root dentin, gingival floor vs. axial walls) [7,8,9].

For the μTBS test each configuration (D and B) and adhesive system used presented a number of ten teeth per group. From each tooth three samples were randomly selected from the central area and the average bond strength was calculated in MPa. The results obtained for dumbbell specimen shapes did not reveal any statistical differences between the two adhesive systems. When SBS test was performed, the self-etching CLB and the total-etch SB also presented statistically similar results, but with lower means compared with μTBS. The failure mode observed in this study might suggest that both microtensile shapes were able to provide a higher percentage of adhesive failures when compared with SBS test. Furthermore, the dumbbell shape produced 10.3% of mixed pattern failure, which could explain the statistical significant difference observed in CLB that showed lowest values in microtensile bond strength. (Table 4).

The inverse relationship between bond strength and bonded cross-sectional area has been shown in studies that employed the microtensile test [2,8,14]. A possible explanation for this observation is that small cross-sectional areas improve stress distribution during the test. Another reason may be due to the distribution of defects in the material, since larger specimens probably contain more defects than small ones [2,8]. Further explanation for this fact might also be a higher stress production at the interface during the preparation of specimens [15].

Beam configuration specimens present different results according to the adhesive systems evaluated. The use of the self-etching primer CLB resulted in the lowest bond strength values and it was the only group that lost samples (1/10). The total-etch SB adhesive system values were statistically different from the self-etching CLB. However, the discrepant results found between the adhesive systems SB and Clearfil Liner Bond 2V seem not to be attributed to a more sensitive technique, revealing differences between the materials.

Despite the faster preparation and standardization of the area with the beam specimens, their slicing procedure might have an adverse effect, producing more tension at the interface than the dumbbell shape. Whereas the dumbbell shape suffers just one saw cut, the beams were cut twice. The use of high speed in the preparation of the dumbbell samples, for trimming the constriction, seems to produce less stress at the interface than the second cut suffered by the beams in their preparation.

The depth of dentin demineralization caused by the self-etching primers was limited to 0.5-1µm rather than the typical 4-5µm resin infiltrated layers that are reached with bonding systems that use separate etching and priming procedures [10]. These differences among the hybrid layer, mainly in regard to their thickness and tag pattern, created by this two bonding systems can also have an effect on the values found for the beam specimen shape.

Zheng et al [16], observed a relationship between adhesive thickness and microtensile bond strength. Thick adhesive layers would tend to allow some displacement during load application that would improve stress distribution during testing. When compared in this study, the CLB bond strengths obtained in the SBS test and µTBS test in dumbbell shape, were not significantly statistically different. However the self-etching primer CLB, when used in beam shape, had a different performance and the group presented the lowest bond strength values. Though many works did not find a correlation between bond strengths and interfacial morphology for the adhesive systems [10,17], this relation probably exists. The hybrid layer of the self-etching primer CLB might not be sufficiently strong to withstand the stress applied at the interface during the preparation of beam specimens and µTBS test performance.

Different test modes in the same experiment or among different experiments may present a variety bond strength values. The same material when used by different operators can behave differently, even when submitted to the same restorative procedures [9].

The results show that using the Shear Bond Strength test, differences among the materials may not be disclosed. Specimens used in the μTBS test might provide a more accurate detection of differences among the adhesive systems and permit the researchers to evaluate regional bond strengths of tooth surface offering versatilities that cannot be achieved by a conventional bond strength method as SBS.

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TABLE 1

Adhesive systems studied, with respective manufacturer, composition, batch number and procedures

MATERIAL	MANUFACTURER	COMPONENTS	PROCEDURES
Single Bond (SB)	3M Dental Products Division, St. Paul, MN, USA	Bis-GMA, HEMA, polyalkenoic copolymer, ethanol, water Batch# 1FH	etch for 15s (phosphoric ac 35%); rinse 15s; air dried gently; apply 2 coats of the adhesive; gently dry for 5s; light cure for 10s
Clearfil Liner Bond 2V (CLB)	Kuraray Co., Ltd., Osaka, Japan	Primer A: MDP, HEMA, water, photoinitiator, accelarator Batch#00073C Primer B: HEMA, water, accelarator Batch#00073B Bond: MDP, demethacrylates, photoinitiator, accelarator, microfiller Batch#00120B	mix primer A and B, apply 30s; air dried gently; apply bond and air gently; light cure for 20s

TABLE 2

Dentin microtensile bond strengths for adhesive systems and specimen shapes

ADHESIVE SYSTEM	μTBS – MPa			
	Beam		Dumbbell	
	Mean *(sd)*	n	Mean *(sd)*	n
Single Bond (SB)	42.6 (15.1) **Aa**	10	35.4 (6.8) **Aa**	10
Clearfil Liner Bond 2V (CLB)	14.3 (10.3) **Bb**	9	27.0 (7.9) **Aa**	10

Means values with the same letter are not significantly different by Tukey's test (p<0.05) – capital letters on horizontal and lower-case on vertical.

TABLE 3

Statistical analysis of shear bond strength for the adhesive systems tested

ADHESIVE SYSTEM	Mean *(sd)*	n
Single Bond (SB)	17.3 (5,6)	20
Clearfil Liner Bond 2V(CLB)	15.9 (7.2)	19

**(p=0.5217)*

TABLE 4

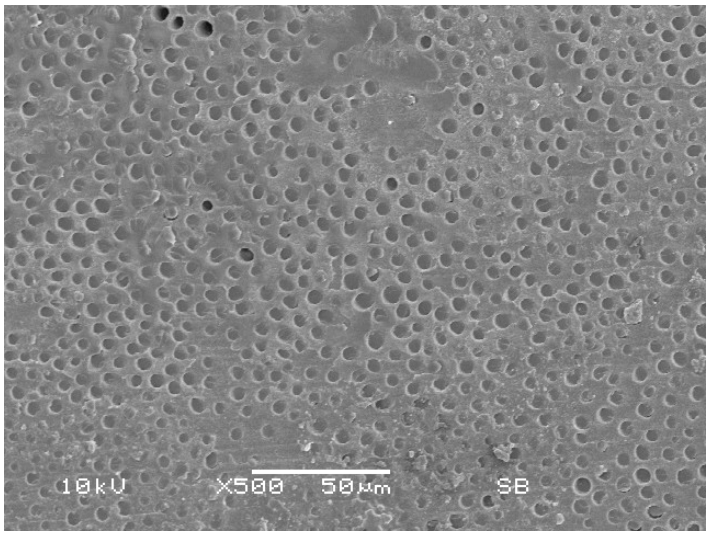
Modes of failure of each test.

FAILURE MODE	µtbs		SBS
	dumbbell	beam	
Interface	78.5%	85.2%	67.5%
Dentin	9.5%	5.6%	22.5%
Resin	1.7%	9.3%	---
Mixed*	10.3%	---	10%

**Adhesive-Dentin-Resin*

FIGURE 1

SEM photomicrograph illustrating a Type 1 failure: interface failure between adhesive resin and dentin (some tubules are opened while in some areas the tubules remain filled by the bonding resin).



4 CONSIDERAÇÕES GERAIS

Estudos têm demonstrado divergências sobre a influência das fontes de luz ou das técnicas de fotoativação utilizadas para polimerização de compósitos sobre o selamento marginal e a microdureza das restaurações com resina composta. Os resultados apresentados neste trabalho dividido em quarto capítulos oferecem informações consistentes que permitem afirmar que a formulação do compósito utilizado apresentou maior influência nas características finais da restauração do que a técnica ou a fonte de ativação utilizada.

No capítulo 1, verificou-se que as técnicas de fotoativação que utilizam baixa intensidade de luz inicial (*soft-start 1* e *soft-start 2*) provavelmente não foram capazes de diminuir o estresse de contração de polimerização das resinas compostas e apresentaram resultados de microinfiltração marginal semelhantes aos da técnica convencional. Desta forma, não foram observadas vantagens na utilização destas técnicas quando comparada com a convencional. Para a resina composta microhíbrida, todas as técnicas de fotoativação produziram resultados de microinfiltração que não diferiram estatisticamente entre si. A técnica que associa fonte de luz de Arco Plasma de Xenônio e resina composta compactável, entretanto, gerou os maiores escores de penetração de corante. Esta diferença de escores não foi detectada no capítulo 2, que também avaliou a microinfiltração marginal. De acordo com os resultados obtidos, a fonte de luz, o tipo de compósito ou a localização das margens, em esmalte ou dentina não afetaram de forma diferente a penetração do corante.

Os resultados controversos obtidos nos capítulos 1 e 2 podem ser justificados pela metodologia empregada. O teste de microinfiltração marginal vem sendo utilizado por muitos anos e em inúmeros trabalhos relatados na literatura (Taylor & Lynch, 1992). Apesar de considerada uma metodologia consagrada, este teste apresenta limitações que podem gerar resultados controversos, mesmo quando realizados em um mesmo laboratório e pelo mesmo operador. A

penetração do corante não é uniforme ao longo de toda interface adesiva e, como a análise é feita por meio de secções que nem sempre se apresentam nas mesmas regiões (variações milimétricas resultantes de cada corte), os valores de escores atribuídos podem ser os responsáveis pelas diferenças observadas nos resultados. Assim, uma deficiência de resultados precisos é observada quando distintos materiais são avaliados e diferenças entre os mesmos podem não ser detectadas (Calheiros *et al.*, 2004).

No capítulo 3, a adaptação marginal foi avaliada através do teste de formação de fendas com microscopia eletrônica de varredura. Os resultados deste capítulo mostram a influência do tipo de compósito sobre a adaptação marginal de restaurações com margem em dentina. A resina microhíbrida sempre apresentou as menores fendas (em µm) quando comparada às compactáveis. Entretanto, para as restaurações com margens em esmalte não foi detectada diferença entre as fontes de luz, nem entre o tipo de compósito. Provavelmente, isto pode ter ocorrido em função da melhor eficácia comprovada dos sistemas adesivos no esmalte; a união obtida pode ter sido suficiente para resistir às tensões geradas pela contração de polimerização das resinas compostas.

A metodologia utilizada para avaliação da formação de fendas parece apresentar valores mais precisos com relação à adaptação marginal, já que toda a margem cervical da restauração é avaliada, ao contrário do teste de microinfiltração marginal, onde a avaliação restringe-se a secções pré-estabelecidas.

A avaliação da qualidade de polimerização das restaurações de resina composta foi realizada através do teste de microdureza. Nos capítulos 1 e 3, as técnicas de fotoativação e as fontes de luz, respectivamente, não interferiram nos resultados de dureza dos compósitos utilizados. A resina microhíbrida Filtek Z250 e a compactável Surefil, apresentaram comportamento semelhante nos dois capítulos. No capítulo 3, a resina compactável Tetric Ceram HB apresentou dureza

inferior às outras duas resinas testadas, o que pôde ser explicado pela composição do material.

No capítulo 4, procurou-se verificar a influência de duas diferentes metodologias para se avaliar a resistência de união de dois sistemas adesivos em dentina. Existe uma grande variação nos resultados relatados em testes experimentais no que diz respeito a valores obtidos através de testes de resistência de união (∅ilo, 1993). De acordo com os resultados obtidos no capítulo 4, as variações referentes à configuração dos corpos-de-prova para o teste de microtração podem interferir no resultado, sendo que o formato de palito parece detectar maior diferença entre os materiais testados. Além disso, a possibilidade de se realizar mensurações em diferentes regiões de um mesmo dente é uma vantagem inerente ao teste (Pashley *et al.*, 1999). Entretanto, algumas limitações, como por exemplo, a possibilidade de gerar um alto estresse na interface adesiva durante a confecção das amostras, podem interferir nos resultados finais de desempenho dos materiais testados (Shono *et al.*, 1997). Assim, os resultados obtidos no capítulo 4, com relação aos materiais avaliados, o sistema adesivo autocondicionante apresentou os menores valores de resistência de união, quando comparado com o sistema adesivo de condicionamento ácido total para a configuração de “palitos”.

Diante da coletânea e análise dos resultados obtidos neste estudo composto por quatro capítulos, pôde se observar que: as fontes de luz e técnicas de fotoativação, ao contrário do tipo de compósito utilizado, parecem não interferir diretamente na adaptação marginal e na microdureza de restaurações de resina composta; e que a metodologia empregada parece ter papel importante na detecção de variações entre os diferentes materiais testados.

Desta forma, com relação aos sistemas de fotoativação empregados, apesar das novas tecnologias disponíveis, a lâmpada halógena ainda mostrou-se comprovadamente eficaz e segura. Muita atenção deve ser dada à composição das resinas compostas utilizadas, buscando sempre materiais que apresentem

propriedades físicas e mecânicas adequadas e cientificamente comprovadas. Quanto aos sistemas adesivos, o condicionamento ácido total apresentou os melhores valores de resistência de união, usado na configuração de palitos, o que o torna, teoricamente, mais capaz de suportar as forças produzidas pela contração de polimerização das resinas compostas e, desta forma, gerar melhor selamento marginal das restaurações adesivas.

5 CONCLUSÕES

Diante dos quatro capítulos deste trabalho, pôde-se concluir que:

- Os sistemas de luz e/ou técnicas de fotoativação não apresentaram interferência na adaptação marginal e microdureza de restaurações de resina composta, porém a formulação do material restaurador tornou-se um fator de influência significativo das variáveis testadas;

- Para avaliação da resistência de união, o teste de microtração detectou diferença entre os sistemas adesivos avaliados, enquanto para o teste de cisalhamento diferenças não foram observadas. Quanto aos materiais testados, o sistema adesivo autocondicionante, usado na configuração de palitos, apresentou os menores valores de resistência de união.

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APÊNDICE 1

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Influence of Polymerization Technique on Microleakage and Microhardness of Resin Composite Restorations

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Clinical Relevance

The conventional technique for polymerization, used in association with a "packable" resin composite, provides similar resin-tooth interfacial seal to Soft-Start and better seal when compared to PAC; however, for a microhybrid resin composite, all techniques for polymerization present the same result.

SUMMARY

This study evaluated the influence of three polymerization techniques on microleakage and microhardness of Class II restorations using a microhybrid (Filtek Z250) and a "packable" resin composite (SureFil). The techniques, their respective light intensities and time used in relation to the resin composites, are: Conventional (C)—800mW/cm² for 40 seconds; Soft-Start (SS1)—75mW/cm² for 10 seconds plus 518mW/cm² for 30 seconds; Soft-Start (SS2)—170mW/cm² for 10 seconds plus 518mW/cm² for 30 seconds and Plasma Arc Curing (PAC)—1,468mW/cm² for three or six seconds. One hundred and fifty-two "Vertical Slot type Class II cavities" at the mesial and distal surfaces were prepared and divided into eight groups (n=19). After the restorative procedures, the samples were thermocycled (1,000 cycles at 5°C and 55°C), then immersed in 2% methylene blue dye solution for four hours. The microleakage was evaluated and the results analyzed by the Kruskal–Wallis and Multiple Comparisons tests. Ten samples from each group were randomly selected, embedded in polyester resin, polished and submitted to the Knoop microhardness test. ANOVA (split-plot) and Tukey's test ($p<0.01$) revealed significant differences among depths: the hardness at the top surface was significantly higher followed by the middle and bottom surfaces. There was no significant difference in microleakage among the techniques when microhybrid resin composite was employed. However, when using a "packable" resin composite, the conventional technique for polymerization was comparable to Soft-Start and better than PAC.

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INTRODUCTION

Since their introduction to the market in the 1970s, light curing resin composites have been used for restorations, making dental procedures more conservative and able to serve esthetic demand. However, some material shortcomings, such as reduced wear resistance, marginal staining and excessive polymerization shrinkage and the sensitivity of the technique, have not been eliminated despite extensive research (Leinfelder, 1995). The success of the clinical performance of light curing resin composites is directly related to adequate polymerization and light intensity, which are crucial factors in obtaining optimal physical properties (Bayne, Heymann & Swift, 1994).

During the setting process, polymerization shrinkage of a resin composite can create forces that may disrupt the bond to cavity walls (Davidson, de Gee & Feilzer, 1984; Donly & others, 1987; Carvalho & others, 1996). This competition between contracting forces built up in the polymerizing resin and the bonds of adhesive resins to the wall of the restoration is one of the main causes of marginal failure and subsequent microleakage (Davidson & others, 1984; Mandras, Retief & Russel, 1991). Bond strength must be greater than contraction stress in order to obtain stable marginal adaptation. Microleakage permits the passage of bacteria, fluids, molecules and toxins and could encourage dentinal hypersensitivity, pulp inflammation, secondary caries and pulp necrosis (Kidd, 1976; Opdam & others, 1998).

Some studies have shown a relation between polymerization shrinkage and light intensity (Feilzer & others, 1995; Silikas, Eliades & Watts, 2000). As a result, different light units have been introduced into the market to minimize or control the polymerization shrinkage of composites.

Conventional lamps instantly provide maximal light intensity, which causes the resin composites to harden and produce a considerable increase in viscosity of the material (Goracci, Mori & Casa de'Martinis, 1996). Composites cured at low light intensity have been shown to have a better marginal adaptation (Mandras & others, 1991; Uno & Asmussen, 1991). The theory is that a slower rate of conversion maintains a longer pre-gel phase, allowing for a better flow of the material, which decreases contraction stress in the filling material. However, this low intensity may affect the surface hardness and may be insufficient for ensuring mechanical stability (Unterbrink & Muessner, 1995; Pimenta, 1999).

Pre-polymerization at low intensity, followed by the final cure at high intensity, can allow for the flow of resin composite during setting. This method can reduce the width and length of marginal gaps without interfering with the physical properties of the restorations (Uno & Asmussen, 1991; Mehl, Hickel & Kunzelmann, 1997).

Now available, high-intensity light units based on a plasma system can reduce the long cure time and provide optimal properties in resin composite in a few seconds (Peutzfeldt, Sahafi & Asmussen, 2000; Park, Krejci & Lutz, 2002). However, the use of units with such high intensities could create more contraction forces and, consequently, marginal failure (Brackett, Haisch & Covey, 2000).

New methods of polymerization with varying intensities and curing times are on the market; therefore, it is necessary to analyze the effectiveness in the control of marginal adaptation and the quality of polymerization. This study evaluated the microleakage and microhardness of Class II resin composites using three available polymerization techniques—Conventional (Optilux501, Demetron/Kerr, Danbury, CT 06810, USA), Plasma Arc Curing (PAC, APOLLO 95E Elite, DMD Corp, Westlake Village, CA 91362, USA) and Soft-Start (Variable Intensity Polymerization, BISCO Inc, Schaumburg, IL 60193, USA) and two different resin composites—a microhybid (Filtek Z250, 3M Dental Products, St Paul, MN 55144, USA) and a "packable" (SureFil, Dentsply/Caulk, Milford, DE 19963, USA).

METHODS AND MATERIALS

Microleakage Test

Seventy-six extracted bovine incisors were initially stored in a 2% formaldehyde buffered solution (Eick & Welch, 1986; de Castro, Hara & Pimenta, 2000; Gallo & others, 2001), after which debris was removed from the teeth. The crowns of the bovine teeth were cut off 5 mm above the cement-enamel junction (CEJ) with a double-faced diamond disk (KG Sorensen Ind Com Ltda, Barueri, SP 06442-110, Brazil).

"Vertical Slot type Class II cavities" at the mesial and distal surfaces were prepared with #245 carbide burs (KG Sorensen Ind Com Ltda) with a high-speed water-cooled handpiece (Kavo do Brasil AS, Joinville, SC 89221-040, Brazil). The burs were replaced after every 10 preparations to maintain uniformity. Butt-joint cavities had the following dimensions: 1.5 mm axial deep by 3 mm bucco-lingual wide and the gingival margin was located 1 mm apical to the CEJ.

In all groups, enamel and dentin etching with 35% phosphoric acid was performed for 15 seconds. Single Bond (3M Dental Products) adhesive system was applied following manufacturer's instructions. The resin composites SureFil (Dentsply/Caulk) and Filtek Z250 (3M Dental Products) were inserted in three horizontal increments and each increment was polymerized on the occlusal surface according to the following groups (n=19):

GROUP 1: SureFil (Dentsply/Caulk) resin composite and Conventional (C) polymerization technique for 40 seconds, each increment, showing an average intensity of 800 mW/cm²;

GROUP 2: SureFil (Dentsply/Caulk) resin composite using Soft-Start (SS1) polymerization technique (Variable Intensity Polymerizer, BISCO, Inc) showing an average initial intensity of 75 mW/cm² for 10 seconds and 518 mW/cm² for the subsequent 30 seconds;

GROUP 3: SureFil (Dentsply/Caulk) resin composite using Soft-Start (SS2) polymerization technique (Variable Intensity Polymerizer, BISCO, Inc) showing an average initial intensity of 170 mW/cm² for 10 seconds and 518 mW/cm² for the subsequent 30 seconds;

GROUP 4: SureFil (Dentsply/Caulk) resin composite using Plasma Arc Curing (PAC, APOLLO 95E Elite, DMD Corp) polymerization technique (APOLLO 95E Elite, DMD Corp) showing an average intensity of 1,468 mW/cm² for six seconds each increment, following manufacturer's instructions for this resin composite;

GROUP 5: Filtek Z-250 (3M Dental Products) resin composite and Conventional (C) polymerization (Optilux501, Demetron/ Kerr) for 40 seconds each increment, showing an average intensity of 800 mW/cm²;

GROUP 6: Filtek Z250 (3M Dental Products) resin composite using Soft-Start (SS1) polymerization technique (Variable Intensity Polymerizer, BISCO, Inc) showing an average initial intensity of 75mW/cm² for 10 seconds and 518mW/cm² for the subsequent 30 seconds;

GROUP 7: Filtek Z250 (3M Dental Products) resin composite using Soft-Start (SS2) polymerization technique (Variable Intensity Polymerizer, BISCO, Inc) showing an average initial intensity of 170 mW/cm² for 10 seconds and 518 mW/cm² for the subsequent 30 seconds;

GROUP 8: Filtek Z250 (3M Dental Products) resin composite using the Plasma Arc Curing (PAC, APOLLO 95E Elite, DMD Corp) polymerization technique showing an average intensity of 1,468 mW/cm² for three seconds for each increment, following the manufacturer's instructions for this resin composite.

Following the restorative procedure, the teeth were stored in water at 37°C for 48 hours. All restorations were then finished with Sof-Lex (3M Dental Products) fine and ultra fine finishing disks and all specimens were thermocycled in a thermal cycling machine (MCT2-AMM instrumental, CA 94928, USA) for 1000 cycles at 5 ± 2°C and 55 ± 2°C with a dwell time of 60 seconds in distilled water and a five-second transfer time. Next, the apices and coronal surfaces were sealed with epoxy resin (Araldite, Brascola Ltda, São Bernardo do Campo, SP 09771-190, Brazil) and the teeth were coated with two applications of fingernail polish up to 1 mm from the gingival margins. All teeth were immersed in a freshly prepared aqueous 2% methylene blue solution (pH 7.0) for four hours at 37°C, then washed in water. Finally, each tooth was sectioned vertically through the center of the restoration with a diamond disk (KG Sorensen Ind Com Ltda) at low speed.

Microleakage at the gingival margin was evaluated by two observers with an optical stereomicroscope (Meiji Techno Co, LTD, Iruma-gun Saitana 356, Japan) at 70x magnification and scored using the following criteria (Figure 1):

0 - No dye penetration.

1 - Dye penetration that extended up to 1/3 of preparation depth.

2 - Dye penetration greater than 1/3, up to 2/3 of preparation depth.

3 - Dye penetration extending to the axial wall.

4 - Dye penetration past the axial wall.

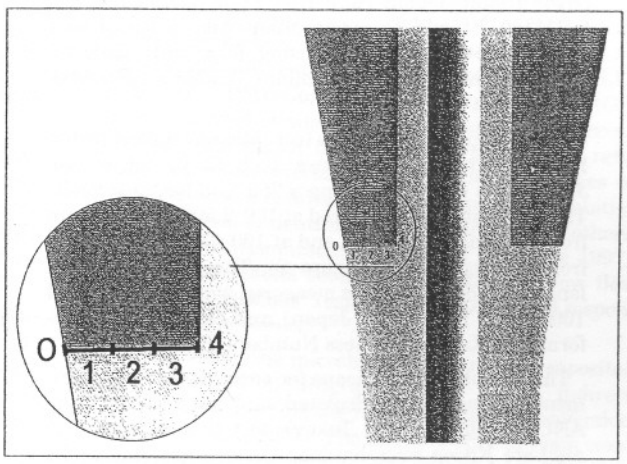

Figure 1. *Diagram of microleakage evaluation criteria.*

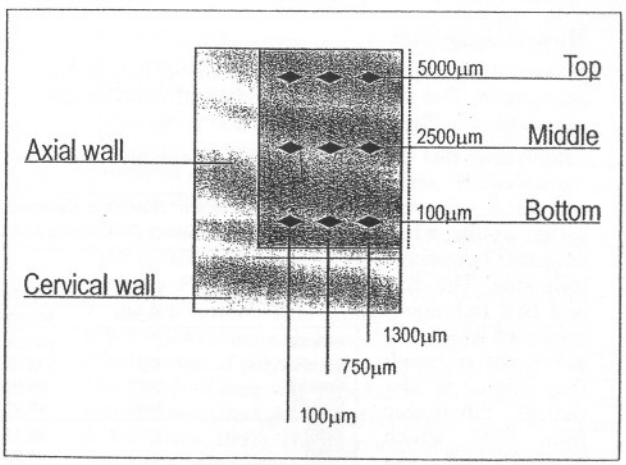

Figure 2. *Diagram of Knoop indentation locations.*

The results were analyzed by the Kruskal–Wallis and Multiple Comparisons tests.

Knoop Microhardness Test

After the microleakage evaluation, 10 sectioned restorations of each group were randomly selected and cut off with a double-faced diamond disk (KG Sorensen Ind Com Ltda). Twenty-six groups of three and one group of two restorations were placed in a 3/4 inch diameter PVC ring filled with self-curing polystyrene resin (Piraglass, Piracicaba, SP 13424-550, Brazil). The embedded restorations were ground on a water-cooled mechanical grinder (Maxigrind, Solotest, São Paulo, SP 01328, Brazil) using 400, 600 and 1000-grit Al_2O_3 abrasive paper (Saint-Gobain Abrasivos Ltda, Guarulhos, SP 07111150, Brazil). The restorations were polished on a mineral oil-cooled grinder using felts with diamond pastes of 3 µm and 1 µm (Equilam, Diadema, SP 09960-500, Brazil).

The Knoop microhardness test (Microhardness Tester, Future Tech FM-1E, Future Tech Corp, Tokyo 140, Japan) was performed using a 25g load for 20 seconds. The indentations were placed at 100, 2,500 and 5,000 µm from the gingival margin, and at 100, 750 and 1,300 µm from the axial wall (Figure 2). The larger diagonal length of indentation was measured with a monitor (9M 100A Teli, Tokyo 140, Japan) and the values transformed to Knoop Hardness Numbers (KHN).

The microhardness means for each depth and experimental group was calculated and submitted to the ANOVA split-plot and Tukey's test that was used to compare Knoop microhardness among groups, depths and resin composites.

RESULTS

Microleakage Test

None of the groups showed complete prevention of dye penetration. The results of the statistical analysis are summarized in Table 1.

Analyzing the data, the SureFil (Dentsply/Caulk) "packable" resin composite showed better results when using the Conventional technique. The SS1 and SS2 techniques presented intermediate results, although they showed no statistical differences from PAC, which demonstrated the worst scores. The Conventional technique for polymerization provided a similar resin-tooth interfacial seal to that of Soft-Start (Variable Intensity Polymerization, BISCO Inc) and a better seal when compared to Plasma Arc Curing (PAC, APOLLO 95E Elite, DMD Corp).

For Filtek Z250 (3M Dental Products) resin composite, there was no significant difference in leakage among the different methods of polymerization.

Knoop Microhardness Analysis

No significant differences in microhardness were observed between the resin composites (p=0.1701) and the C, SS1, SS2 and PAC unit polymerization techniques (p=0.7103).

The results showed no significant interaction among the resin composites vs light units (p=0.9111), resin composites vs depth (p=0.3511), light units vs depth (p=0,2646) and light units vs resin composite vs depth (p=0.4173) in microhardness values.

The Tukey's test (p<0.01) revealed significant differences in microhardness in relation to depth/thickness of resin. Hardness at the top surface (5,000 µm) was significantly higher, followed by the middle (2,500 µm) and bottom (100 µm) surface, which showed lower KHN means (Table 2). These findings were similar for both resins and curing techniques.

Table 1: *Results of Microleakage Evaluation*

Groups	Medium Ranks	
G5. Z250/Conventional	55.4737	a
G6. Z250/SS1	55.4737	a
G1. SureFil/Conventional	63.1316	ab
G7. Z250/SS2	70.0263	abc
G8. Z250/PAC	81.6579	abcd
G2. SureFil/SS1	87.6316	bcd
G3. SureFil/SS2	96.8947	cd
G4. SureFil/PAC	101.7105	d

Kruskal-Wallis test: Significant difference (p<0.05)
Same letters were not statistically different

Table 2: *Means and Standard Deviations Knoop Hardness Number (KHN) for the Different Cure Modes, Resin Composite and Depth*

Resin Composite	Cure Mode	Depth					
		Bottom (100 µm)		Medium (2,500 µm)		Top (5,000 µm)	
		Mean	SD	mean	SD	mean	SD
SureFil	C	100.06	25.44	107.45	13.59	112.82	11.36
SureFil	SS1	103.69	13.46	112.30	8.66	109.04	11.12
SureFil	SS2	95.94	16.12	100.64	20.73	109.13	11.76
SureFil	PAC	95.20	20.76	100.43	21.0	120.20	10.33
Z250	C	99.15	15.08	100.73	16.21	100.67	13.06
Z250	SS1	94.23	22.42	108.75	26.46	109.20	18.85
Z250	SS2	96.44	15.03	104.04	7.89	105.97	12.11
Z250	PAC	97.65	16.46	99.80	19.25	105.80	13.82
Mean		97.80 C		104.27 B		109.1A	

Tukey's test (p<0,05) indicates statistical difference for means followed by distinct letters

DISCUSSION

Some techniques for reducing shrinkage stress and, consequently, marginal leakage have been suggested (Kays, Sneed & Nuckles, 1991). These include using reflective wedges (Lutz, Krejci & Barbakow, 1992), incremental restorative techniques (Tjan, Bergh & Lidner, 1992; Applequist & Meiers, 1996) and variations in light intensity (Uno & Asmussen, 1991; Feilzer & others, 1995; Unterbrink & Muessner, 1995). A lining material with a low-modulus of elasticity, such as a glass ionomer (Aboushala, Kugel & Hurley, 1996), a new generation of dentin bonding (Goracci, Mori & Bazzucchi, 1995; Nakabayashi & Saimi, 1996) or a flowable composite lining has also been proposed by some authors, mainly in association with the "packable" resin composite (Ferdianakis, 1998; Chuang, Liu & Jin, 2001).

The influence of using different kinds of light units with varying intensities during polymerization to reduce microleakage was evaluated in this study using a "packable" and a microhybid resin composite.

None of the methods or restorative materials eliminate microleakage in the face of thermal changes and differences in the coefficient of thermal expansion between dental tissues and the restorative material. These results were also observed in other studies (Liberman, Gorfil & Ben-Amar, 1996; Pimenta, 1999).

Both resins behaved differently when subjected to the same polymerization technique. While the microhybrid presented statistically similar results for all methods, the "packable" did not. In association with PAC units (G4) and SS2 (G3), the "packable" was statistically different in relation to C (G1) and SS1 (G2). The "packable" presented a high elasticity modulus that can cause more strain in the interface during polymerization (Davidson & others, 1984). Another reason may be that the "packable" composite may not adapt well to the dentin bonding agent and cavity preparation walls (Meiers, Kazemi & Meier, 2001).

The high microleakage scores that were found when the "packable" was compared to the microhybrid might indicate that the filler particle technology of the "packable" composite could translate into increased post-gel linear shrinkage stress directed at the margins (Meiers & others, 2001). Stress arising from post-gel polymerization shrinkage may produce defects in the composite-tooth bond, leading to bond failure and, consequently, post-operative sensitivity, microleakage and recurrent caries (Yap, Soh & Siow, 2002; Meiers & others, 2001). The more satisfactory results found for the microhybrid resin when compared with the "packable" in this study could be explained by the lower post-gel shrinkage as revealed by the manufacturers.

Different studies have indicated that Soft-Start (Variable Intensity Polymerization, BISCO Inc) light curing units can be used to improve marginal integrity and decrease marginal gap (Uno & Asmussen, 1991; Goracci & others, 1996). However, according to the results of this study, less leakage was not observed when the Soft-Start technique (Variable Intensity Polymerization, BISCO Inc) was used compared to Conventional and Plasma Arc (PAC, APOLLO 95E Elite, DMD Corp). Other studies also reported these results (Sahafi, Peutzfeldt & Asmussen, 2001; Yap & others, 2002; Yap, Ng & Siow, 2001). For both pre-polymerizations, starting with 75 mW/cm² (G2 e G6) or 170 mW/cm² (G3 e G7), the groups presented no statistical differences between the resins. However, the association of the "packable" with SS2 (G3) was not similar to SS1 with the microhybrid resin (G6).

The "packable" resin composite cured with Plasma Arc (PAC, APOLLO 95E Elite, DMD Corp) curing showed the highest leakage scores. However, it was not statistically different from Plasma Arc (PAC, APOLLO 95E Elite, DMD Corp) with the microhybrid (G8), which behaved similarly with all techniques. Several studies have shown that high and fast curing rates tend to produce excessive polymerization stresses on adhesive bonds, resulting in poor marginal adaptation along gingival or dentinal margins (Brackett & others, 2000; Uno & Asmussen, 1991; Mehl & others 1997). This study's results seem to show that the low flow capacity of "packable" resin composite might be responsible for these values.

In this study, the microhardness of resin composites was measured in different depths as an indirect method for evaluating the relative degree of conversion (Mehl & others, 1997). The effective cure of resin composite is vital, not only to ensure optimum physical-mechanical properties (Asmussen, 1982), but also to ensure that clinical problems do not arise due to cytotoxicity of inadequately polymerized material (Caughman & others, 1991). In general, higher hardness values are an indication of more extensive polymerization (Helvatjoglou-Antoniadi & others, 1991).

According to the results, the resin composites SureFil (Dentsply/Caulk) and Filtek Z250 (3M Dental Products) presented similarly when the C, SS1, SS2 and PAC unit polymerization techniques were used.

There was a significant difference in depth among the bottom (100 µm), middle (2,500 µm) and top (5,000 µm) surfaces. For all techniques, microhardness was higher at the top surface. This can probably be explained as a result of the relationship between irradiation distance and effectiveness of polymerization (Pires & others, 1993). The depth of cure was reduced by increasing the distance between the light tip and composite surface (Hansen & Asmussen, 1997). The degree to which light activated composite polymerizes is proportional to the amount of light to which the material is exposed (Rueggeberg, Caughman & Curtis, 1994). The top surface of the

material was nearer to the light force than the subsequent resin composite layers; in this way, light transmission did not suffer any interference and the intensity was not reduced. However, at the middle and bottom surfaces the light intensity was greatly reduced due to light scattering, thus, decreasing the effectiveness of polymerization (Ruyter & Oysaed, 1982). One way to compensate for this is to increase the light exposure time, which can provide better hardness results (Ota & others, 1985; Yap & others, 2001).

Although some studies demonstrated that three seconds of curing time was insufficient for optimal curing of composites when the Plasma Arc (PAC, APOLLO 95E Elite, DMD Corp) technique was used (Park & others, 2002), the results found in this study showed similarities among C, SS1 and SS2 for the microhybrid resin composite.

Despite the great advances in light units that present new polymerization techniques, the conventional method is still preferred. Providing adequate polymerization and satisfactory infiltration scores, the Conventional method may be similar to Soft-Start (Variable Intensity Polymerization, BISCO Inc) and better than PAC, although each material had different characteristics.

CONCLUSIONS

The results of this study allow the authors to conclude:

1. None of the techniques could eliminate microleakage;
2. For Filtek Z250 (3M Dental Products) microhybrid resin composite, all the polymerization techniques showed similar leakage results;
3. For SureFil (Dentsply/Caulk) "packable" resin composite, only the Soft-Start polymerization technique (SS1) (Variable Intensity Polymerization, BISCO Inc) with a 10-second initial intensity of 75mWcm², followed by 30 seconds at 518mW/cm², decreased microleakage to levels similar to the Conventional technique;
4. All polymerization techniques presented similar results in microhardness values, but the top surface always presented high values followed by the middle and bottom surfaces.

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APÊNDICE 2

University of Campinas
Piracicaba School of Dentistry

November, 2004

To

Dr. Harald O. Heymann,

Editor-in-Chief

Dear Dr. Harald O. Heymann,

We are submitting the manuscript entitled **EFFECT OF PHOTOACTIVATION SYSTEMS AND RESIN COMPOSITES ON MICROLEAKAGE OF ESTHETIC RESTORATIONS** to be appraisal by the referees of Journal of Esthetic and Restorative Dentistry. The material contained in the article has not been published previously and is not under consideration by another journal.

Thank you in advance for your consideration

Sincerely,

Larissa Maria Assad Cavalcante
Alessandra Resende Peris
André Vicente Ritter
Edward Swift Jr.
Luiz André Freire Pimenta

APÊNDICE 3

University of Campinas
Piracicaba School of Dentistry

December, 2004

To

Dr. Michael A. Cochram

Editor

Dear Dr. Michael Cochram,

We are submitting the manuscript entitled **EFFECT OF PHOTOACTIVATION SYSTEMS ON RESIN COMPOSITE RESTORATIONS - AN EVALUATION OF MARGINAL ADAPTATION AND MICROHARDNESS** to be appraisal by the referees of Operative Dentisty. The material contained in the article has not been published previously and is not under consideration by another journal.

Thank you in advance for your consideration

Sincerely,

Larissa Maria Assad Cavalcante

Alessandra Resende Peris

Gláucia Maria Bovi Ambrosano

André Vicente Ritter

Edward Swift Jr.

Luiz André Freire Pimenta

APÊNDICE 4

----- Forwarded message from godoy@nova.edu -----
Date: Wed, 4 Aug 2004 19:45:41 -0400
From: godoy@nova.edu
Reply-To: godoy@nova.edu
Subject: Manuscript Accepted
To:lpimenta@fop.unicamp.br

Dear Dr. Pimenta:
I am pleased to inform you that your revised manuscript "Influence of different tests used to measure the bond strength to dentin of two adhesive systems" has been accepted for publication in the American Journal of Dentistry.

Before publication you will receive page proofs for your approval.
Sincerely,

Prof. Dr. Franklin Garcia-Godoy
Editor, American Journal of Dentistry

----- End forwarded message -----