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FORMAÇÃO DE FENDAS EM RESTAURAÇÕES DE RESINA COMPOSTA: POLIMENTO IMEDIATO *VERSUS* TARDIO

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Orientador: Prof. Dr. Tiago Braga Rabello

Co-orientador: Prof. Dr. Eduardo Moreira da Silva

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Dedico este trabalho aos meus amados pais

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Se, hoje, enxergo além é por estar sobre ombros de gigantes.

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RESUMO

BARBOSA, Marianna Pires. Rio de Janeiro. 2019. *Formação de gaps em restaurações de resina composta: polimento imediato versus tardio.* Dissertação (Mestrado Profissional em Clínica Odontológica) – Programa de Pós-Graduação da Faculdade de Odontologia da Universidade Federal do Rio de Janeiro.

O objetivo deste estudo foi avaliar a influência do momento da etapa de polimento, imediato ou após sete dias, na formação de fendas em restaurações de resina composta. Cavidades cilíndricas foram preparadas nas superfícies vestibulares de incisivos bovinos. Cada cavidade foi hibridizada com um dos dois sistemas adesivos: convencional (Adper Single Bond 2) ou autocondicionante (Single Bond Universal), e restaurada usando uma das três resinas compostas: nanoparticulada (Z350), micro-híbrida (P60) e bulk-fill (ONE). As cavidades restauradas foram divididas em dois subgrupos de acordo com o tempo de polimento, imediato ou postergado por 7 dias após a restauração. Por meio da combinação dos sistemas adesivos, resinas compostas e tempos de polimento, foram criados 12 grupos (n = 5). As porcentagens de fendas marginais (%FM) foram avaliadas quantitativamente com o microscópio confocal de varredura a laser. O módulo de elasticidade das resinas compostas foi obtido por meio do teste de flexão em três pontos. Os dados foram analisados por análise de variância e pelo teste de Tukey's HDS (α = 0,05). Em relação ao sistema adesivo, a %FM foi estatisticamente maior para as cavidades restauradas com Single Bond Universal ($p<0,05$). Com relação às resinas compostas, o resultado foi o seguinte: P60 > ONE > Z350 ($p<0,05$). O tempo de polimento imediato apresentou %FM estatisticamente menor que o tardio ($p<0,05$). P60 apresentou o maior módulo de elasticidade ($p<0,05$). Foi possível concluir que o polimento imediato gera menor formação de fendas em restaurações de resina composta.

PALAVRAS-CHAVE: restauração dentária permanente, polimento dentário, resinas compostas.

ABSTRACT

BARBOSA, Marianna Pires. Rio de Janeiro, 2019. *Gap formation in composite resin restorations: immediate versus late polishing.* Dissertation (Professional Masters in Dental Clinic) – Post Graduation Program, School of Dentistry, Federal University of Rio de Janeiro.

The aim of this study was to analyze the influence of the polishing time, immediately or after seven days, in gap formation in composite resin restorations. Cylindrical cavities were prepared on buccal surfaces of bovine incisors. Each cavity was hybridized with one of the two adhesive systems: etch-and-rinse (Adper Single Bond 2) and self-etching (Single Bond Universal), and restored using one of the three composite resins: nanofilled (Z350), minifilled hybrid (P60) and bulk-fill (ONE). The cavities restored were divided in two subgroups according to polishing time, immediately or delayed by 7 days after specimen restoration. Through the combination of the adhesive systems, composite resins and polishing times, 12 groups were created (n=5). Percentages of marginal gaps (%MG) were quantitatively assessed with confocal laser scanning microscope. The flexural modulus of the composite resins was obtained from bar-shaped specimens submitted to three-point bending test. The data were analyzed by three-way ANOVA and Tukey's HSD test (α=0.05). Regarding adhesive system, %MG was statistically higher for cavities restored with Single Bond Universal ($p<0.05$). With respect to composite resins, the result was as follow: P60 > One > Z350 ($p<0.05$). Immediate polishing time presented statistically lower %MG than delayed one ($p<0.05$). P60 presented the highest flexural modulus ($p<0.05$). It was possible to conclude that immediate polishing generates less gap formation in composite resin restorations.

KEYWORDS: permanent dental restoration, dental polishing, composite resins.

SUMÁRIO

1. INTRODUÇÃO

As resinas compostas têm sido amplamente utilizadas em procedimentos restauradores estéticos diretos. No entanto, elas sofrem contração volumétrica significativa quando polimerizadas[1]. A tensão de contração de polimerização pode causar deformação das paredes da cavidade, expandir micro trincas pré-existentes em esmalte ou criar novas, e até mesmo iniciar o processo de criação de micro trincas dentro do material restaurador[2]. Na interface dente-restauração, o estresse de contração de polimerização pode levar à formação de fendas marginais[1] e, possivelmente, à microinfiltração, manchamento marginal e à sensibilidade pós-operatória[2]. Além disso, a magnitude da tensão de contração de polimerização é também depende das propriedades viscoelásticas da resina composta. Em uma dada contração de polimerização, a resina composta mais rígida produzirá maior tensão de contração e, consequentemente, aumentará a formação de fenda na interface dente-restauração[3].

O procedimento de polimento também pode influenciar a formação de fendas na interface dente-restauração[4]. A principal controvérsia em relação ao polimento de resinas compostas é quando iniciar esta etapa. Enquanto alguns fabricantes afirmam que o polimento deva ser feito imediatamente após a restauração, vários autores têm sugerido que este procedimento deva ser postergado para produzir um melhor selamento marginal da interface dente-restauração[5]. Como a reação de polimerização da resina composta não estará concluída antes das 24 horas e devido à natureza hidrofílica da resina composta[4], a contração de polimerização poderia ser parcialmente compensada pela expansão higroscópica sofrida pelo material, que resulta da sorção de água e subsequente expansão[6].

Como a presença de fendas na interface dente-restauração é considerada o primeiro sinal de falha da restauração[1,7], sua identificação poderia facilitar o prognóstico da longevidade das restaurações de resina composta[8]. Convencionalmente, testes de infiltração por penetração de corante e avaliação microscópica da interface têm sido empregados para a detecção *in vitro* destas fendas marginais. No entanto, esses métodos são altamente subjetivos e exigem o corte dos dentes para avaliar a interface dente-restauração. Essas desvantagens estimulam o uso de novas tecnologias para pesquisa de adaptação das restaurações de resina composta, como a microscopia confocal de varredura a laser, utilizada no presente estudo. A observação direta por microscopia confocal de varredura a laser fornece uma avaliação não destrutiva e não requer nenhuma preparação especial para as amostras[9].

2. PROPOSIÇÃO

O objetivo deste estudo foi avaliar a influência do momento da etapa de polimento, imediato ou após sete dias, na formação de fendas em cavidades Classe I restauradas com diferentes resinas compostas e sistemas adesivos por meio de microscopia confocal de varredura à laser 3D. Para tanto, foram testadas as seguintes hipóteses:

a) Momento da etapa de polimento

H_0 → não existe diferença na formação de fendas entre os momentos da etapa de polimento.

H_1 → existe diferença na formação de fendas entre os momentos da etapa de polimento.

b) Resinas Compostas

H_0 → não existe diferença na formação de fendas entre as resinas compostas.

H_1 → existe diferença na formação de fendas entre as resinas compostas.

c) Sistemas adesivos

H_0 → não existe diferença na formação de fendas entre os sistemas adesivos.

H_1 → existe diferença na formação de fendas entre os sistemas adesivos.

3. METODOLOGIA ESTENDIDA

Os materiais resinosos utilizados neste estudo encontram-se na tabela 1.

Tabela 1 – Materiais e sua composição

Material (Fabricante)	Tipo	Cor	Composição
Filtek™ Z350 XT (3M ESPE, St Paul, MN, EUA)	Resina composta nanoparticulada	A3	Zirconia/sílica (78,5% peso%, 63,3 vol%) Bis-GMA, UDMA, TEGDMA, e Bis-EMA, iniciadores, estabilizantes.
Filtek™ P60 (3M ESPE, St Paul, MN, EUA)	Resina composta micro-híbrida	A3	Zircônia/silica (83 peso%, 61 vol%) Bis-GMA, UDMA, Bis-EMA, fotoiniciadores, estabilizantes.
Bulk 3M™ Filtek™ One (3M ESPE, St Paul, MN, USA)	Resina composta Bulk-fill	A3	Zircnia/sílica and a trifluoreto de itérbio consistindo de um aglomerado de partículas de 100 nm (76,5% peso%, 58,5 vol%), AUDMA, UDMA e 1, 12-dodecano-dimetacrilato, iniciadores, estabilizantes.
Adper Single Bond 2 (3M ESPE, St Paul, MN, EUA)	Adesivo convencional de dois passos	---	BisGMA, HEMA, dimetacrilatos, etanol, água, sidtema de fotoiniciadores, copolímero funcional metacrilato de ácido poliacrílico e poli-itacônico e 10% de partículas de sílica esféricas de 5nm-diâmetro
Single Bond Universal (3M ESPE, St Paul, MN, EUA)	Adesivo autocondicionante de 1 passo	---	MDP monômero fosfato, resina dimetacrilato, HEMA, copolímero 3M™ Vitrebond™, carga, etanol, água, iniciadores, silano.

* De acordo com as fichas de dados de segurança e instruções de uso do respectivo fabricante.
Bis-GMA, metacrilato bisphenolglycidil; UDMA, dimetacrilato de uretano; TEGDMA, dimetacrilato trietilenoglicol; Bis-EMA,dimetacrilato glicol A bisfenol etoxilato; AUDMA, dimetacrilato de uretano aromático, HEMA, metacrilato 2-hidroxietil; MDP, metacriloyloxidecil di-hidrogenio fosfato.

3.1. Estudo Piloto

Inicialmente, foi realizado um estudo piloto para avaliar as possibilidades de polimento da amostra. Os espécimes foram distribuídos de forma aleatória criando quatro grupos, A, B, C e D, com n=3. Em seguida, as cavidades foram hibridizadas com um sistema adesivo convencional de dois passos (Adper Single Bond 2, 3M ESPE, St Paul, MN, EUA) aplicado de acordo com as instruções do fabricante. As cavidades, foram então, restauradas com resina composta nanoparticulada (Filtek™ Z350, 3M ESPE, St Paul, MN, EUA) por meio de inserção de dois incrementos, com auxílio de uma espátula de ponta ativa plana (Suprafill # 1, SSWhite, Rio de Janeiro, RJ, Brasil). Cada incremento foi fotoativado por 40 segundos utilizando um aparelho de fotoativação do tipo LED (Radii-cal, SDI Limited, Victoria, AUS) operando com irradiância de 1.200 mW/cm². Os espécimes do grupo A e B foram polidos imediatamente após o término da restauração enquanto que os espécimes do grupo C e D foram polidos após 7 dias de armazenamento em água destilada. Dessa forma, os grupos A e C foram polidos por meio de discos de borracha (Jiffy®, Ultradent do Brasil, Indaiatuba, SP, Brasil) adaptados ao conjunto micromotor de baixa rotação e contra-ângulo instalados em um dispositivo que mantinha o conjunto fixado e paralelo ao solo e a sequência decrescente de granulação para polimento foi utilizada segundo as cores verde, amarela e branca respectivamente, durante 20 segundos por cor. Os espécimes dos grupos B e D foram polidos por meio de lixa de carbeto de silício com granulação abrasiva de 4.000 (Corundum Abrasivos, Saitama, Konosu, Miyamae, Japão) instalada em um dispositivo para polimento mecânico, (DPU 10, Struer, Dinamarca) por um minuto, com leve pressão digital. As amostras foram, imediatamente após o polimento, avaliadas quanto à rugosidade em rugosímetro (Surfteste SJ 201, Mitutoyo, Tóquio, Japão). As médias dos valores de rugosidade obtidas podem ser observadas no quadro 1.

MOMENTO DO POLIMENTO	TIPO DE POLIDOR	
	Discos de Polimento	Lixa 4.000
IMEDIATO	A - 0,16	B - 0,06
TARDIO	C - 0,24	D - 0,06

Quadro 1 – Rugosidade superficial (Ra) para os grupos do estudo piloto

Os resultados do teste de rugosidade mostraram a superioridade do polimento realizado por meio da lixa d´água 4000 em relação aos discos de polimento. Além disso, observou-se que os espécimes polidos com discos polidores não se adequavam aos requisitos para a produção de adequadas imagens por meio do microscópio confocal à laser 3D 3DLCM (LEXT OLS4001, Olympus, USA). Portanto, elegeu-se como método de polimento, a lixa 4000 instalada em dispositivo para polimento mecânico (DPU 10, Struer, Dinamarca).

3.2 Percentual de Fenda Marginal (%FM)

As superfícies vestibulares de 60 incisivos bovinos armazenados em solução aquosa de cloramina 1% por duas semanas e mantidas em água destilada por menos de três meses foram planificadas em politriz (DPU 10, Struer, Dinamarca), sob constante irrigação, utilizando-se lixas de carbeto de silício em granulação decrescente de abrasividade nas numerações 150, 400, 600 e 1200 (T223, Saint-Gobain-Norton, Guarulhos, SP, Brasil) por um minuto cada, até que se obtivesse uma superfície plana de esmalte de, aproximadamente, 10 x 10 mm. As coroas foram, então, separadas da raiz em uma máquina de corte de precisão a 300 rpm (IsoMet® 1000, Isomet, Lake Bluff, IC, EUA). Cada incisivo bovino foi, então, incluído em resina acrílica autopolimerizável incolor de presa rápida (JET, Classico, Campo Limpo Paulista SP, Brasil). Cavidades cilíndricas de 4,0 mm de diâmetro e 1,4 mm de profundidade foram preparadas em todas as superfícies planas do esmalte utilizando uma ponta diamantada (# 3053, KG Sorensen, SP, Brasil) em peça de mão de alta rotação acoplada a um dispositivo especial de alinhamento de amostras. Todos os ângulos cavo-superficiais foram terminados sem bisel. As profundidades das cavidades foram verificadas utilizando-se uma sonda periodontal milimetrada (Univeridade da Carolina do Norte, Hu-Friedy, Chicago, IL, EUA).

Uma vez preparadas, metade das cavidades foram hibridizadas com um adesivo convencional de dois passos (Adper Single Bond 2, 3M ESPE, St Paul, MN, EUA) e as outras trinta restantes com um sistema adesivo autocondicionante (Single Bond Universal, 3M ESPE, St Paul, MN, EUA). Ambos os sistemas adesivos foram aplicados de acordo com as instruções do fabricante. Em seguida, as cavidades foram restauradas usando uma das três resinas compostas. As resinas compostas foram inseridas em dois incrementos oblíquos utilizando um instrumento de ponta ativa plana (Suprafill #1, SSWhite, Rio de Janeiro, RJ, Brasil), com exceção da resina *bulk-fill*, que foi inserida em um único incremento. Todos os materiais resinosos foram fotoativados com uma unidade fotoativação do tipo LED (Radii-cal, SDI Limited, Victoria, AUS), operando a uma irradiância de 1200 mW/cm^2. Imediatamente após a restauração ou após armazenamento em água destilada por sete dias, os procedimentos de polimento foram realizados nas restaurações de resina composta com lixa de carbeto de silício com granulação 4.000 (Corundum Abrasivos, Saitama, Konosu, Miyamae, Japão), por um minuto, sob pressão digital, em politriz (DPU 10, Struers, Dinamarca). Pela combinação dos sistemas adesivos, resinas compostas e tempos de polimento, foram criados de forma aleatória 12 grupos de cinco espécimes cada.

A análise do %FM foi realizada por meio de microscopia confocal de varredura a laser 3D - 3DLCM (LEXT OLS4001, Olympus, EUA) operando no modo de varredura rápida XYZ, com uma lente MPLAPONLEXT utilizando um zoom de 5X. Primeiro, as imagens de cada superfície restauradora foram escaneadas. Em seguida, as imagens foram analisadas utilizando-se duas ferramentas específicas do 3DCLM, um filtro de altura que utiliza contraste de cores que permitiu identificar áreas com fendas na interface dente-resina composta e um marcador linear que permitiu medir o comprimento das fendas. O %FM foi calculado como a relação entre o comprimento da fenda e o perímetro total da cavidade usando a seguinte equação:

$$\%FM = (FM/2\pi r) \times 100,$$

onde FM é o comprimento das interfaces dente-resinas compostas com fenda e r o raio da cavidade cilíndrica.

3.3. Módulo de Elasticidade

As resinas compostas foram aplicadas em um molde bipartido de aço em forma de barra (1 x 2 x 10 mm) posicionado sobre uma placa de vidro. Após o preenchimento do molde com resina composta em excesso, a superfície do material foi coberta com uma tira de poliéster e lâmina de vidro e comprimidas com um dispositivo (500 g) para extrusão do excesso de material. Os espécimes foram fotoativados a partir da superfície em duas seções (2 x 1200 mW/cm^2 por 20 segundos). As dimensões das amostras foram registradas usando um paquímetro digital (MPI / E-101, Mitutoyo, Tóquio, Japão). Após 24 horas de armazenamento em água destilada à 37°C, os corpos de prova foram submetidos ao teste de flexão de três pontos com extensão de 6 mm entre os suportes em uma máquina universal de ensaios com carga de 50 N (DL 10000, Emic, Curitiba, PR, Brasil) à uma velocidade de 0,5 mm/minuto. O módulo de elasticidade (GPa) foi calculado a partir da porção linear da curva carga/deflexão utilizando a seguinte equação:

$$FM = l^3F/4wh^3d,$$

na qual FM é o módulo de flexão, 1 é a distância entre os suportes, F corresponde a carga aplicada, w é a largura do espécime, h é a altura do espécime e d é a deflexão gerada pela carga F. Dez espécimes foram produzidos a partir de cada resina composta.

3.4 Análise Estatística

A análise estatística foi realizada com o software Statgraphics 5.1 (Manugistics, Rockville, MD, EUA). Os dados do módulo de elasticidade foram analisados por análise de variância de um fator e teste de Tukey HSD post hoc. Os dados de formação de gap foram analisados por análise de variância de três fatores e teste de Tukey HSD post hoc. Todas as análises estatísticas foram realizadas a um nível de significância de $\alpha = 0,05$.

4. ARTIGO CIENTÍFICO

(O artigo será submetido ao periódico *Operative Dentistry*.)

Gap formation in composite resin restoration: Immediate *versus* delayed polishing.

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CONFLICT OF INTEREST

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None.

SUMMARY

The aim of this study was to analyze the influence of the polishing time, immediately or after seven days, in gap formation in composite resin restorations. Cylindrical cavities were prepared on buccal surfaces of bovine incisors. Each cavity was hybridized with one of the two adhesive systems: etch-and-rinse (Adper Single Bond 2) and self-etching (Single Bond Universal), and restored using one of the three composite resins: nanofilled (Z350), minifilled hybrid (P60) and bulk-fill (ONE). The cavities restored were divided in two subgroups according to polishing time, immediately or delayed by 7 days after specimen restoration. Through the combination of the adhesive systems, composite resins and polishing times, 12 groups were created (n=5). Percentages of marginal gaps (%MG) were quantitatively assessed with confocal laser scanning microscope. The flexural modulus of the composite resins was obtained from bar-shaped specimens submitted to three-point bending test. The data were analyzed by three-way ANOVA and Tukey's HSD test ($\alpha=0.05$). Regarding adhesive system, %MG was statistically higher for cavities restored with Single Bond Universal ($p<0.05$). With respect to composite resins, the result was as follow: P60 > One > Z350 ($p<0.05$). Immediate polishing time presented statistically lower %MG than delayed one ($p<0.05$). P60 presented the highest flexural modulus ($p<0.05$). It was possible to conclude that immediate polishing generates less gap formation in composite resin restorations.

INTRODUCTION

Composite resins have been widely used in direct esthetic restorative procedures. However, they undergo significant volumetric shrinkage when polymerized[1]. Polymerization shrinkage stress may cause deformation of the cavity walls, open pre-existing or create new enamel microcracks, and even initiate microcracking within the restorative material[2]. At the tooth-restoration interface, the polymerization shrinkage stress can lead to marginal gaps formation[1] and, possibly, microleakage, marginal discoloration and post-operative sensitivity[2]. In addition, the extent of polymerization shrinkage stress is also dependent on the viscoelastic properties of the composite resin. At a given polymerization shrinkage, the most rigid composite resin will produce a higher shrinkage stress and, consequently, increase gap formation at the tooth-restoration interface[3].

The polishing procedure may also influence the gap formation at the tooth-restoration interface[4]. The main controversy regarding composite polishing is when to initiate this step. While some manufacturers claim that polishing should be done immediately after restoration, several authors have been suggesting that this procedure should be delayed in order to produce a better marginal sealing of the tooth-restoration interface[5]. Because the composite polymerization reaction is not completed prior to 24 hours and due to hydrophilic nature of composite resin[4], polymerization shrinkage could be partially compensated by the hygroscopic expansion suffered by the material, that results from water sorption and subsequent swelling[6].

Since the presence of gaps at the tooth-restoration interface is considered the first sign of restoration failure[1,7], their identification could enable easier prognosis of the longevity of the composite restorations[8]. Conventionally, dye-penetration leakage tests and microscopic assessment of the interface have been employed for *in vitro* detection of these interfacial gaps. However, these methods are highly subjective, and require sectioning of the teeth to evaluate the tooth-restoration interface. These disadvantages encourage the use of newer technologies for research on adaptation of composite resin restorations, such as confocal laser scanning microscopy, used in the present study. Direct observation by confocal laser scanning microscopy provides a non-destructive evaluation and not require any special preparation for the samples[9].

Therefore, the aim of this study was to analyze the influence of two polishing times, immediately or after seven days, on the gap formation in Class I cavities restored with different composite resins, a nanoparticulate (Filtek™ Z350), one micro-hybrid (Filtek™ P60) and a bulk-fill resin (Bulk 3M™ Filtek™ One) and different adhesive systems, a two steps conventional adhesive system (Adapter Single Bond 2) and a self-etching adhesive (Single Bond Universal), by using a 3D confocal laser scanning microscope. The null hypothesis tested was that there would not be differences on gap formation between polishing times.

METHODS AND MATERIALS

The resin-based materials used in this study are shown in Table 1.

Table 1. Materials and their compositions.

Material (Manufacturer)	Type	Shade	Composition
Filtek™ Z350 XT (3M ESPE, St Paul, MN, USA)	Nanofilled composite resin	A3	Zirconia/sílica (78,5% wt%, 63,3 vol%) Bis-GMA, UDMA, TEGDMA, e Bis-EMA, initiators, stabilizers.
Filtek™ P60 (3M ESPE, St Paul, MN, USA)	Minifilled hybrid composite resin	A3	Zirconia/silica (83 wt%, 61 vol%) Bis-GMA, UDMA, Bis-EMA, photoinitiators, stabilizers.
Bulk 3M™ Filtek™ One (3M ESPE, St Paul, MN, USA)	Bulk-fill composite resin	A3	Zirconia/sílica and a ytterbium trifluoride filler consisting of agglomerate 100 nm particles (76, 5% wt%, 58,5 vol%), UDMA, UDMA and 1, 12-dodecane-dimethacrylate, initiators, stabilizers.
Adper Single Bond 2 (3M ESPE, St Paul, MN, USA)	2-step etch-and-rinse adhesive	---	BisGMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, methacrylate functional copolymer of polyacrylic and polyitaconic acids and 10% 5-nm-diameter spherical silica particles.
Single Bond Universal (3M ESPE, St Paul, MN, USA)	2-step self-etching adhesive	---	MDP phosphate monomer, dimethacrylate resins, HEMA, 3M™ Vitrebond™ copolymer, filler, ethanol, water, initiators, silane.

*According to safety data sheets and instructions for use from the respective manufacturer. Bis-GMA, bisphenolglycidil methacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethyleneglycol dimethacrylate; Bis-EMA, ethoxylated bisphenol A glycol dimethacrylate; AUDMA, aromatic urethane dimethacrylate, HEMA, 2-hydroxiethil methacrylate; MDP, methacryloyloxydecyl dihydrogen phosphate.

Percentage of Marginal GAP (%MG)

The buccal surfaces of 60 bovine incisors stored in an aqueous solution of 1% chloramine for two weeks and frozen in distilled water for less than three months were wet ground at a polishing machine (DPU 10, Struers, Denmark), with 150, 400, 600 and 1.200 grit SiC papers (T223, Saint-Gobain-Norton, Guarulhos, SP, Brazil), one minute each, until flat enamel surfaces of, approximately, 10 x 10 mm were obtained. The crowns were, then, separated from the root in a precision cutter machine at 300 rpm (IsoMet® 1000, Isomet, Manassas, VA, USA). Each bovine incisor was, then, embedded in a fast colorless autopolymerizing acrylic resin (JET Classico, Campo Limpo Paulista, SP, Brazil). Cylindrical cavities 4.0 mm diameter and 1.4 mm depth were prepared in all flat enamel surfaces using a diamond bur (#3053, KG Sorensen, SP, Brazil) in a high-speed handpiece coupled into a special sample-aligning device. Cavosurface walls were finished to a butt joint.

Once prepared, half of the cavities were bonded with an etch-and-rinse adhesive (Adper Single Bond 2, 3M ESPE, St Paul, MN, USA) and the remaining thirty with an self-etching one (Single Bond Universal, 3M ESPE, St Paul, MN, USA). Both adhesive systems were applied in accordance with the manufacturers' instructions (Table 2). Then, the cavities were restored using one of the three composite resins. The composite resins were inserted in two oblique increments using a flat-sided instrument (Suprafill #1, SSWhite, Rio de Janeiro, RJ, Brazil), except for the bulk-fill one, which was inserted in a single increment. All resin-based materials were photoactivated with a LED unit (Radii-cal, SDI Limited, Victoria, AUS) operating at an irradiance of (1200 mW/cm^2). Immediately after restoration or after storage in distilled water for seven days, polishing procedures were performed on composite restoration by wet grinding on 4.000 grit SiC paper (Corundum Abrasives, Saitama Konosu, Miyamae, Japan), for one minute at a polishing machine (DPU 10, Struers, Denmark). Through the combination of the adhesive systems, composite resins and polishing times, 12 groups of five specimens each were randomly created.

Table 2. Adhesive systems manufacturers' instructions

Material (Manufacturer)	Etch	Adhesive	Ligth-cure
Adper Single Bond 2 (3M ESPE, St Paul, MN, USA)	15 seconds total etch; 10 seconds rinse; Blot excess water using absorbent paper.	2 coats of adhesive for 15 seconds with gentle agitation; 5 seconds of gently air.	10 seconds light-cure.
Single Bond Universal (3M ESPE, St Paul, MN, USA)	---	Rub the adhesive in for 20 seconds; 5 seconds of gently air.	10 seconds light-cure.

The analysis of %MG was carried out using a 3D confocal laser scanning microscopy - 3DLCM (LEXT OLS4001, Olympus, USA) operating on scanning mode XYZ fast scan, with a lens MPLAPONLEXT using a 5X zoom. First, images of each restorative surface were scanned. After that, the images were analyzed using two specific tools of the 3DCLM, a height filter that use color contrast that allowed identify areas with gap at the tooth-composite resin interface and a linear marker that allowed measure the length of gaps, The %MG was calculated as the ratio of gap length to the entire cavity perimeter by using the follow equation:

$$\%MG = (MG/2\pi r) \times 100,$$

where MG is the length of tooth-composite resin interfaces with gap and r the cylindrical cavity radius.

Flexural Modulus

The composite resins were applied in a bar-shaped steel split mold (1 x 2 x 10 mm) positioned over a glass plate. After filling the mold to excess, the material surfaces were covered with a polyester strip and glass slide and compressed with a device (500 g) to extrude excess material. The specimens were light-cured from the top in two overlapping sections, (2 x 1200 mW/cm^2 for 20 seconds). The specimen dimensions were recorded using a digital caliper (MPI/E-101, Mitutoyo, Tokyo, Japan). After 24 hours storage in distilled water at 37°C, the specimens were submitted to three-point bending with a 6 mm span between the supports in a universal testing machine with a load cell of 50 N (DL 10000, Emic, Curitiba, PR, Brazil) at a crosshead speed of 0.5 mm/minute. The flexural modulus (GPa) was calculated from the linear portion of the load/deflection curve using the following equation:

$$FM = l^3F/4wh^3d,$$

where FM is the flexural modulus, l is the length between the supports, F is the applied load, w is the width of the specimen, h is the height of the specimen and d is the deflection at load F. Ten specimens were produced from each resin composite.

Statistical Analysis

The statistical analysis was performed with Statgraphics 5.1 Software (Manugistics, Rockville, MD, USA). The flexural modulus data were analyzed by one-way ANOVA and Tukey HSD post hoc test. The gap formation data were analyzed by 3-way ANOVA and Tukey HSD post hoc test. All statistical analyses were performed at a significance level of $\alpha=0.05$.

RESULTS

Percentage of Marginal GAP (%MG)

Immediate polishing time presented statistically lower %MG than delayed ($p<0.05$). With respect to composite resins, the result was as follow: P60 > BF One > Z350 ($p<0.05$). Regarding adhesive system, %MG was statistically higher for cavities restored with SBU ($p<0.05$). Three-way ANOVA showed statistical significance for the three independent factors (polishing time, composite resin and adhesive system), as well as for the 3-way interaction ($p<0.05$). The means of %MG for all groups are presented in Figure 1. For Z350, immediate polishing presented %MG statistically lower than that of delayed when SB2 was used ($p<0.05$). Contrarily, the %MG was statistically similar for both polishing times when SBU was used ($p>0.05$). Concerning BF One, %MG was statistically lower in immediate polishing irrespective of the adhesive system ($p<0.05$). On the other hand, for P60, regardless of the adhesive system, the polishing times did not influence %MG ($p>0.05$).

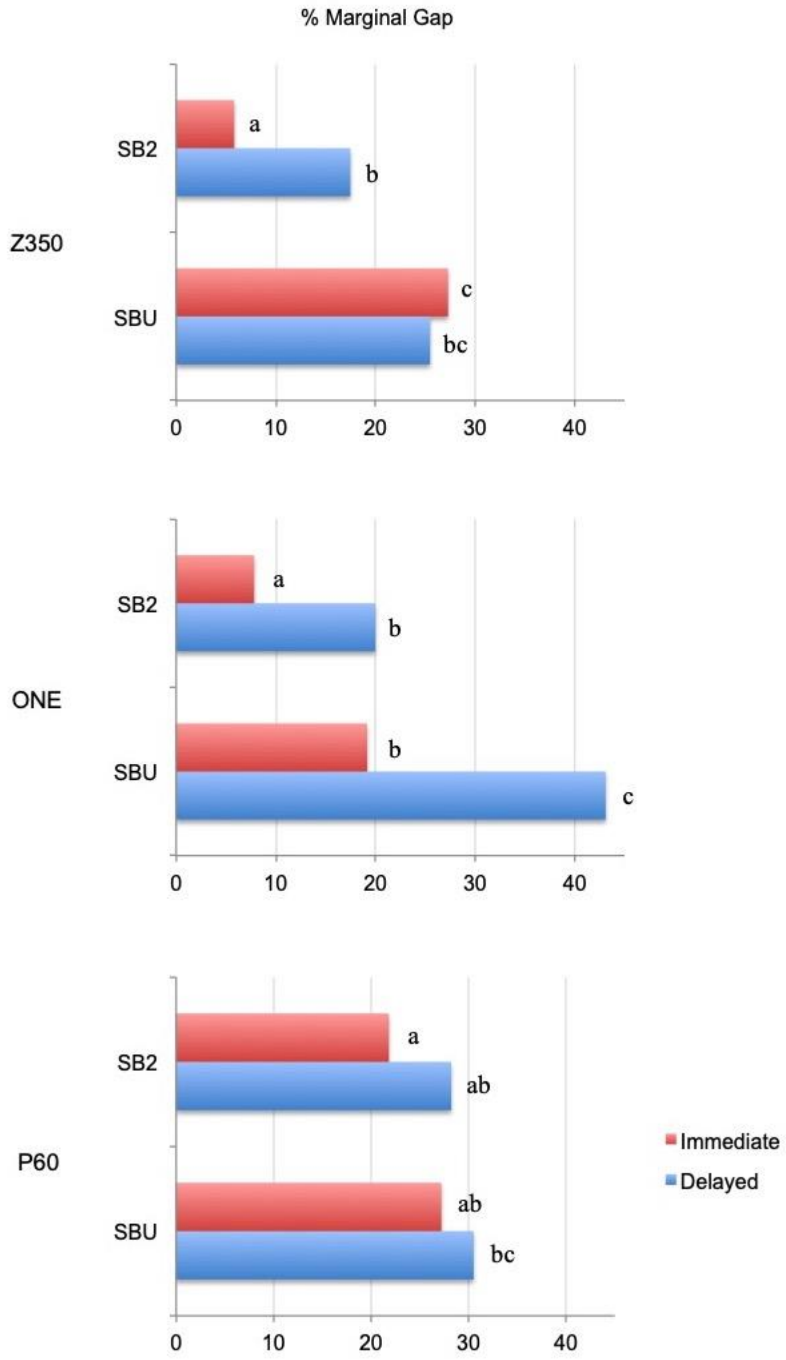

Figure 1 – For each composite resin, different letters indicate statistically significant difference ($p<0.05$).

Representative confocal laser scanning microscope images of specimens are presented in Figure 2 and 3.

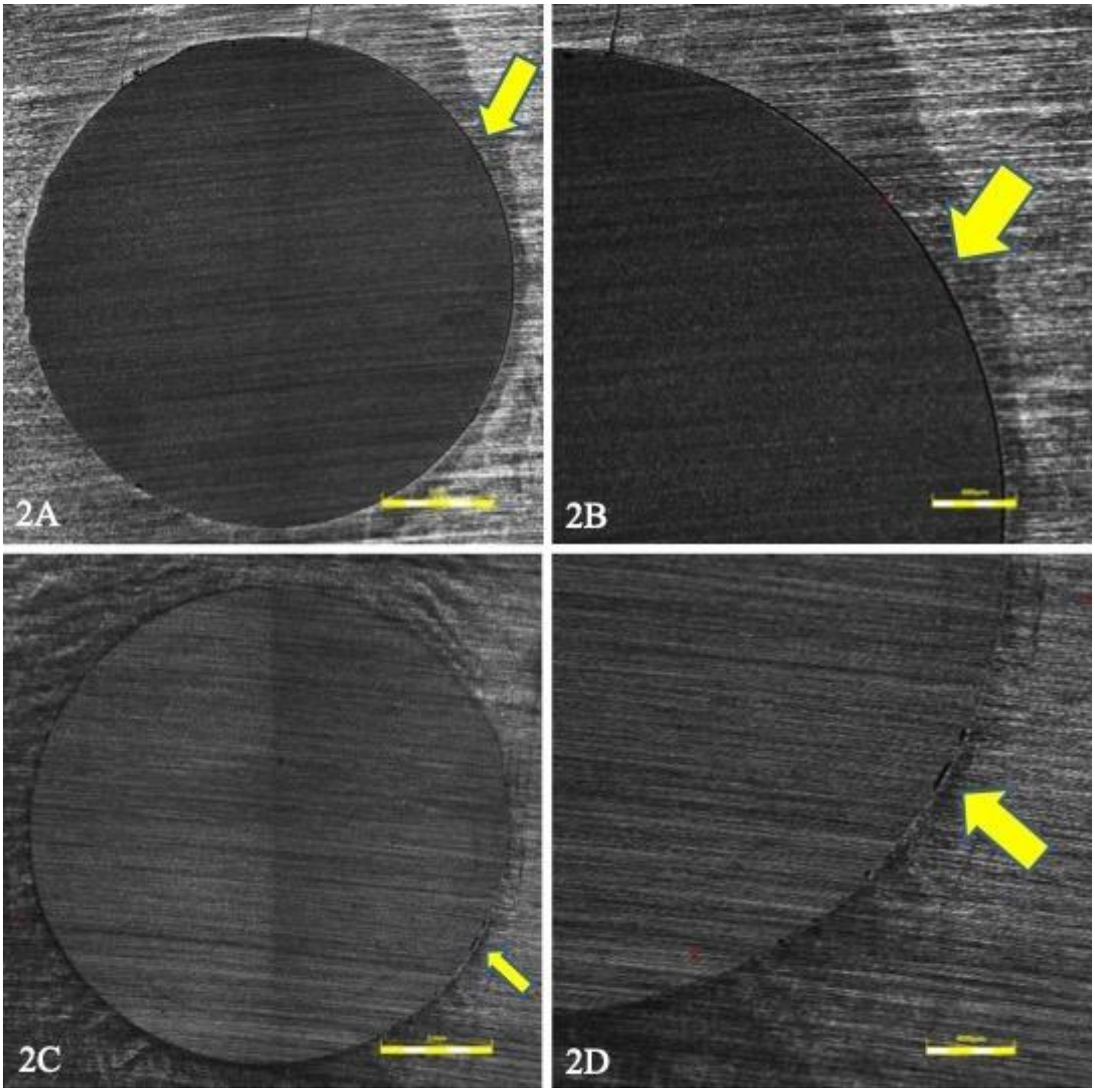

Figure 2 – 2A, confocal laser scanning microscope panoramic image showing a high %MG (yellow arrow); 2B, enlarged image of the same specimen showed as in (2A); 2C, confocal laser scanning microscope panoramic image showing a low %MG (yellow arrow); 2D, enlarged image of the same specimen showed as in (2C).

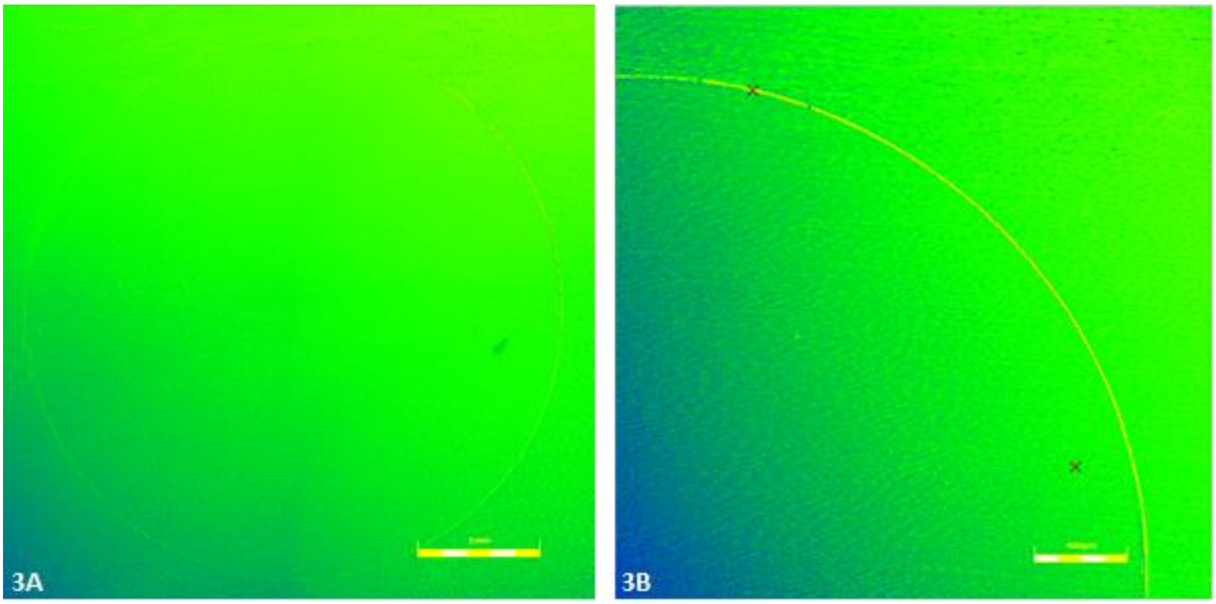

Figure 3 – 3A, confocal laser scanning microscope panoramic image showing height filter that use color contrast. 3B, enlarged image of the same specimen showed as in (3A).

Flexural Modulus

The flexural modulus of composite resins are presented in Figure 4. The Tukey's HSD test showed that P60 flexural modulus was significantly higher ($p<0.05$) than those of BF and Z350, which were not different from each other ($p>0.05$).

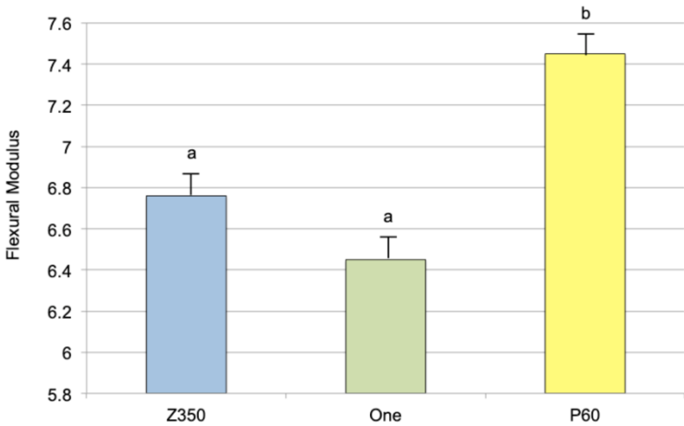

Figure 4– Means of flexural modulus (GPa) for all composite resins.
Bars with same letters are statistically similar ($p>0.05$).

DISCUSSION

Marginal adaptation has been described as one of the most important factors that influence the clinical outcome of a composite resin restoration[10]. Also, even considering that the clinical protocol to build up composite resin restorations is well accepted by the clinicians, there is still no consensus regarding the best time in which the steps of finishing and polishing of these restorations have to be done[1,5,6]. Thereby, the present study focused on the influence of polishing time (immediate or delayed by 7 days) on gap formation at the tooth-composite resin interfaces. The choice of the restorative materials for evaluating this response was thought to cover all possibilities available for the clinical practice.

The null hypothesis of the present study was rejected, polishing time had influenced on marginal gap formation, immediate polishing leaded to %MG statistically lower than delayed polishing.

Although some studies had evaluated the gap width[11-13], the presence or absence of marginal gaps at the tooth-composite resin interfaces is more clinically relevant than gap width[1]. The gap formed, regardless of width, is an open door to oral fluids and is capable of degrading the dentin-composite interface. In addition, it is more reliable to evaluate the marginal gap length along the restorations margins. Reduced gap length could result in reduced length of the margins that are submitted to degradation by oral fluids or penetration of bacteria[1]. Therefore, similar to previous studies[1,9,14,15], the present work measured the length of the gap along cavity margins and it was calculated as a percentage of the entire cavity margins length. For this evaluation of the gap formation in composite resin restorations was used a 3D confocal laser scanning microscope. This non-destructive method allows analyzing percentage of marginal gap in two moments, before and after the artificial aging in future work. To the best of these authors knowledge, this is the first study using this tool to evaluate the gap formation at the tooth-composite resin interfaces.

The primary aim of dental adhesives is to provide retention to composite fillings. In addition, a good adhesive should be able to withstand shrinkage stress from composite resin e, consequently, prevent gap formation along the restoration's margins[16]. Comparing to etch-and-rinse adhesives, one disadvantage of the self-etching adhesives is the reduction in enamel bonding efficacy, which was also observed with the universal adhesives[17]. Self-etch and universal adhesives have a less acidic composition compared with phosphoric acid, thus reducing their potential to demineralize the mineral phase of enamel and, consequently, to create appropriate micro-retentive porosities[17-19]. The present study confirms the previous literature since the %MG was statistically higher for cavities restored with Single Bond Universal. In addition, this fact could explain the absence of significant difference among polishing times for Z350 when Single Bond Universal was used. The high %MG caused by the weak bond strength provided by universal adhesive might has overpassed any benefits offered by polishing time.

Among composite resins, the %MG was higher for cavities restored with P60. This find can be explained by the highest flexural modulus presented by P60. Flexural modulus is directly related to polymerization stress, a phenomenon explained by a parallel to Hooke's law[20], in which polymerization stress is the product of polymerization shrinkage versus flexural modulus. According to this law, there is less relation between polymerization shrinkage and shrinkage stress, but rather, a significant relation between the latter and flexural modulus[21]. Thus, although the increasing filler contents cause reduction of the volumetric shrinkage, high filler contents lead to higher flexural modulus, which result in increased polymerization shrinkage stress[22-24]. Although the flexural modulus of Z350 and ONE were not different from each other (Figure 2), the %MG of ONE was higher than that of Z350. According to Ilie[25], ONE has addition fragmentation monomers (AFA) in its composition. This monomer has a reactive site that cleaves through an addition-fragmentation mechanism during the polymerization reaction, which may concur to a high degree of conversion. Allied to the possible high translucency showed by bulk-fill composite resins[26], we can hypothesize that ONE reached a higher degree of conversion than Z350, which could have contributed to a high polymerization stress inside its bulk. In other words, this could create a high stress at the tooth-composite resin interface that could support the higher %MG presented by this composite resin.

In the present study, two different polishing times were used for investigation, immediate and delayed by 7 days. The %MG was significantly reduced when restorations were polished immediately. These results agree with previous study[5]. Even after polymerization, the surface layer of composite resin restoration is resin-rich[27]. This reactive surface can potentiate the inward and outward movement as well as the entrapment of water molecules within the composite bulk and reflects the water sorption and the solubility phenomena. Swelling, plasticization and softening, hydrolysis, release of unreacted monomers and lixiviation of fillers and ions from their surfaces are results of both phenomena[28], all of them being capable of compromising the physicomechanical stability and gap formation of the composite resin restorations. Shintani and others[27] demonstrated that the values of water sorption and solubility were lower for polished composite resin specimens than those without any polishing procedure. Consequently, it might be advisable to perform the polishing of composite resin surface immediately to improve the long-lasting performance of restorations.

CONCLUSION

The results of this study did not support the null hypothesis. It was possible to conclude that there is a difference in the %MG formation between polishing times. Immediate polishing presented %MG statistically lower than delayed polishing.

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5. CONCLUSÃO

Com base nos resultados estatísticos obtidos, pode-se concluir que:

a) Existe diferença na formação de fendas entre os momentos da etapa de polimento.

O polimento imediato apresentou percentual de formação de fendas estatisticamente menor que o polimento realizado 7 dias após o término da restauração.

Rejeitada a hipótese nula (H_0).

b) Existe diferença na formação de fendas entre as resinas compostas.

A resina micro-híbrida Filtek™ P60 apresentou percentual de formação de fendas estatisticamente maior do que a resina bulk-fill Bulk 3M™ Filtek™ One e essa percentual maior do que a resina nanoparticulada Filtek™ Z350.

Rejeitada a hipótese nula (H_0).

c) Existe diferença na formação de fendas entre os sistemas adesivos.

O sistema adesivo autocondicionante Single Bond Universal apresentou percentual de formação de fendas estatisticamente maior do que o sistema adesivo convencional de dois passos Adper Single Bond 2.

Rejeitada a hipótese nula (H_0).

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ANEXO

Operative Dentistry Guide for Authors
New Instructions as of 20 September 2008

Operative Dentistry requires electronic submission of all manuscripts. All submissions must be sent to Operative Dentistry using the Allen Track upload site. Your manuscript will only be considered officially submitted after it has been approved through our initial quality control check, and any problems have been fixed. You will have 6 days from when you start the process to submit and approve the manuscript. After the 6 day limit, if you have not finished the submission, your submission will be removed from the server. You are still able to submit the manuscript, but you must start from the beginning. Be prepared to submit the following manuscript files in your upload:

- A Laboratory or Clinical Research Manuscript file must include:
    - a title
    - a running (short) title
    - a clinical relevance statement
    - a concise summary (abstract)
    - introduction, methods & materials, results, discussion and conclusion
    - references (see Below)
    - The manuscript **MUST NOT** include any:
        - identifying information such as:
            - Authors
            - Acknowledgements
            - Correspondence information
        - Figures
        - Graphs
        - Tables
- An acknowledgement, disclaimer and/or recognition of support (if applicable) must in a separate file and uploaded as supplemental material.
- All figures, illustrations, graphs and tables must also be provided as individual files. These should be high resolution images, which are used by the editor in the actual typesetting of your manuscript. Please refer to the instructions below for acceptable formats.
- All other manuscript types use this template, with the appropriate changes as listed below.

Complete the online form which includes complete author information and select the files you would like to send to Operative Dentistry. Manuscripts that do not meet our formatting and data requirements listed below will be sent back to the corresponding author for correction.

GENERAL INFORMATION

- All materials submitted for publication must be submitted exclusively to Operative Dentistry.
- The editor reserves the right to make literary corrections.
- Currently, color will be provided at no cost to the author if the editor deems it essential to the manuscript. However, we reserve the right to convert to gray scale if color does not contribute significantly to the quality and/or information content of the paper.

- The author(s) retain(s) the right to formally withdraw the paper from consideration and/or publication if they disagree with editorial decisions.
- International authors whose native language is not English must have their work reviewed by a native English speaker prior to submission.
- Spelling must conform to the American Heritage Dictionary of the English Language, and SI units for scientific measurement are preferred.
- While we do not currently have limitations on the length of manuscripts, we expect papers to be concise; Authors are also encouraged to be selective in their use of figures and tables, using only those that contribute significantly to the understanding of the research.
- Acknowledgement of receipt is sent automatically. If you do not receive such an acknowledgement, please contact us at editor@jopdent.org rather than resending your paper.
- **IMPORTANT:** Please add our e-mail address to your address book on your server to prevent transmission problems from spam and other filters. Also make sure that your server will accept larger file sizes. This is particularly important since we send page-proofs for review and correction as .pdf files.

REQUIREMENTS

- **FOR ALL MANUSCRIPTS**

  1. **CORRESPONDING AUTHOR** must provide a WORKING / VALID e-mail address which will be used for all communication with the journal.
     NOTE: Corresponding authors MUST update their profile if their e-mail or postal address changes. If we cannot contact authors within seven days, their manuscript will be removed from our publication queue.
  2. **AUTHOR INFORMATION** must include:
     - full name of all authors
     - complete mailing address for each author
     - degrees (e.g. DDS, DMD, PhD)
     - affiliation (e.g. Department of Dental Materials, School of Dentistry, University of Michigan)
  3. **MENTION OF COMMERCIAL PRODUCTS/EQUIPMENT** must include:
     - full name of product
     - full name of manufacturer
     - city, state and/or country of manufacturer
  4. **MANUSCRIPTS AND TABLES** must be provided as Word files. Please limit size of tables to no more than one US letter sized page. (8 ½ ” x 11”)
  5. **ILLUSTRATIONS, GRAPHS AND FIGURES** must be provided as TIFF or JPEG files with the following parameters
     - line art (and tables that are submitted as a graphic) must be sized at approximately 5” x 7” and have a resolution of 1200 dpi.
     - gray scale/black & white figures must have a minimum size of 3.5” x 5”, and a maximum size of 5” x 7” and a minimum resolution of 300 dpi and a maximum of 400 dpi.
     - color figures must have a minimum size of 2.5” x 3.5”, and a maximum size of 3.5” x 5” and a minimum resolution of 300 dpi and a maximum of 400 dpi.

    - color photographs must be sized at approximately 3.5” x 5” and have a resolution of 300 dpi.

- **OTHER MANUSCRIPT TYPES**
  1. **CLINICAL TECHNIQUE/CASE STUDY MANUSCRIPTS** must include:
     - a running (short) title
     - purpose
     - description of technique
     - list of materials used
     - potential problems
     - summary of advantages and disadvantages
     - references (see below)
  2. **LITERATURE AND BOOK REVIEW MANUSCRIPTS** must include:
     - a running (short) title
     - a clinical relevance statement based on the conclusions of the review
     - conclusions based on the literature review…without this, the review is just an exercise
     - references (see below)

- **FOR REFERENCES**

  REFERENCES must be numbered (superscripted numbers) consecutively as they appear in the text and, where applicable, they should appear after punctuation. The reference list should be arranged in numeric sequence at the end of the manuscript and should include:

  1. Author(s) last name(s) and initial (ALL AUTHORS must be listed) followed by the date of publication in parentheses.
  2. Full article title.
  3. Full journal name in italics (no abbreviations), volume and issue numbers and first and last page numbers complete (i.e. 163-168 NOT attenuated 163-68).
  4. Abstracts should be avoided when possible but, if used, must include the above plus the abstract number and page number.
  5. Book chapters must include chapter title, book title in italics, editors’ names (if appropriate), name of publisher and publishing address.
  6. Websites may be used as references, but must include the date (day, month and year) accessed for the information.
  7. Papers in the course of publication should only be entered in the references if they have been accepted for publication by a journal and then given in the standard manner with “In press” following the journal name.
  8. **DO NOT** include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.

EXAMPLES OF REFERENCE STYLE

- Journal article: two authors

  Evans DB & Neme AM (1999) Shear bond strength of composite resin and amalgam adhesive systems to dentin *American Journal of Dentistry* **12(1)** 19-25.

- Journal article: multiple authors
  Eick JD, Gwinnett AJ, Pashley DH & Robinson SJ (1997) Current concepts on adhesion to dentin *Critical Review of Oral and Biological Medicine* **8(3)** 306-335.
- Journal article: special issue/supplement
  Van Meerbeek B, Vargas M, Inoue S, Yoshida Y, Peumans M, Lambrechts P & Vanherle G (2001) Adhesives and cements to promote preservation dentistry *Operative Dentistry* **(Supplement 6)** 119-144.
- Abstract:
  Yoshida Y, Van Meerbeek B, Okazaki M, Shintani H & Suzuki K (2003) Comparative study on adhesive performance of functional monomers *Journal of Dental Research* **82(Special Issue B)** Abstract #0051 p B-19.
- Corporate publication:
  ISO-Standards (1997) ISO 4287 Geometrical Product Specifications Surface texture: Profile method – Terms, definitions and surface texture parameters *Geneve: International Organization for Standardization* **1st edition** 1-25.
- Book: single author
  Mount GJ (1990) *An Atlas of Glass-ionomer Cements* Martin Duntz Ltd, London.
- Book: two authors
  Nakabayashi N & Pashley DH (1998) *Hybridization of Dental Hard Tissues* Quintessence Publishing, Tokyo.
- Book: chapter
  Hilton TJ (1996) Direct posterior composite restorations In: Schwarts RS, Summitt JB, Robbins JW (eds) *Fundamentals of Operative Dentistry* Quintessence, Chicago 207-228.
- Website: single author
  Carlson L (2003) Web site evolution; Retrieved online July 23, 2003 from: http://www.d.umn.edu/~lcarlson/cms/evolution.html
- Website: corporate publication
  National Association of Social Workers (2000) NASW Practice research survey 2000. NASW Practice Research Network, 1. 3. Retrieved online September 8, 2003 from:http://www.socialworkers.org/naswprn/default