

INFLUENCE OF LIGHT INTENSITY AND CURING CYCLE ON MICROLEAKAGE OF CLASS V COMPOSITE RESIN RESTORATIONS

INFLUÊNCIA DA INTENSIDADE DE LUZ E MÉTODOS DE FOTOATIVAÇÃO NO SELAMENTO MARGINAL DE RESTAURAÇÕES CLASSE V EM RESINA COMPOSTA

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ABSTRACT

The aim of this study was to determine the effect of a softstart polymerization method from Quartz-Tungsten-Halogen (QTH) and Plasma Arc (PAC) curing units on microleakage of Class V composite resin restorations with dentin cavosurface margins. Seventy-five bovine incisors received standardized class V cavities in all dentin margins. Teeth were divided into 5 equal groups according to the curing cycle. The cavities were incrementally restored with a composite resin (Single Bond/Z-100, 3M). Light curing was applied as follows: Group I: PAC light continuous-cycle curing at 1600 mW/cm² for 3s; Group II: PAC light step-cycle curing (2s at 800 mW/cm² then 4s at 1600 mW/cm²); Group III: QTH light continuous-cycle curing at 400 mW/cm² for 40s; Group IV: QTH light ramp-cycle curing (from 100 to 600 mW/cm² in 15s followed by 25s at 600 mW/cm²); Group V: QTH light pulse-delay curing (200 mW/cm² for 3s followed by 3 min delay then 600 mW/cm² for 30s). Teeth were stored in distilled water at 37°C for 30 days and then subjected to thermocycling for 500 cycles at 5 and 55°C. Root apices were sealed and teeth coated with nail varnish before they were immersed in 0.5% fuchsine red dye solution. Teeth were then sectioned and slices were scanned with a computer scanner to determine the area of dye leakage using a computer program (Image Tools). Images of tooth slices were also visually examined under magnification and dye penetration along the tooth/restoration interface was scored. Significant differences in the degree of dye penetration and leakage were detected between groups ($p < 0.05$). Groups I and II had significantly higher values of dye penetration and leakage than groups III, IV and V. In conclusion, the use of PAC light curing in a continuous or step cycle modes resulted in increased microleakage of Class V resin composite restorations compared with medium intensity QTH light curing. Pulse, ramp and continuous-cycle curing modes with QTH light resulted in similar degrees of microleakage.

Uniterms: Composite resins; Microleakage; Polymerization; Light units.

RESUMO

Objetivo deste estudo foi determinar o efeito da polimerização gradual, mediante a utilização de aparelhos de Quartz-Tungstênio-Halógena (QTH) e Arco de Plasma de Xenônio (PAC), no selamento marginal de restaurações classe V em resina composta com margens localizadas em dentina. Setenta e cinco incisivos bovinos receberam preparos de cavidades classe V, na raiz, com o intuito de situar as margens cavitárias em dentina. Os dentes foram divididos em cinco grupos de acordo com o método de fotoativação. As cavidades, depois de condicionadas, foram tratadas com o sistema adesivo Single Bond (3M Dental) e restauradas com a resina composta Z100 (3M Dental) pela técnica incremental. A fotoativação foi realizada para cada grupo como descrito a seguir: Grupo I: PAC pelo método de fotoativação constante: 1600mW/cm² - 3s; Grupo II: PAC pelo método de fotoativação por passos (800mW/cm² - 2s, subindo automaticamente para 1600mW/cm² - 4s); Grupo III: QTH pelo método de fotoativação constante: 400 mW/cm² - 40s; Grupo IV: QTH pelo método de fotoativação em rampa: 100 a 600 mW/cm² - 15s, permanecendo a 600mW/cm² por mais 25s; Grupo V: QTH pelo método de fotoativação por pulso: 200 mW/cm² - 3s, tempo de espera de 3min.e a seguir 600mW/cm² - 30s. Os dentes foram armazenados em água destilada a 37°C por 30 dias e então submetidos à ciclagem térmica, por 500 ciclos a 5°C e 55°C. Os ápices dos dentes foram selados com resina composta e os dentes foram cobertos com duas camadas de esmalte para unha, antes da sua imersão em fucsina básica a 0,5%. Os dentes foram seccionados e os cortes foram escaneados para avaliação da área infiltrada por corante por um programa de computador (Image Tools). Os cortes foram também visualizados com lupa para a determinação do grau de penetração do corante na interface dente-restauração por escores. Diferenças estatisticamente significantes foram observadas entre os grupos quanto ao grau e à área de penetração de corante ($p < 0,05$). Os grupos I e II apresentaram valores significativamente mais altos de infiltração e penetração do corante que os grupos III, IV e V. Em conclusão, o uso da fonte de PAC, no modo constante e por passos, resultou em valores significativamente maiores de infiltração marginal quando comparados com a intensidade de luz média emitida pelos aparelhos de QTH. Os métodos de fotoativação por pulso, rampa e contínuo com a fonte de QTH resultaram num grau similar de microinfiltração.

Unitermos: Resinas compostas; Microinfiltração; Polimerização; Unidades fotopolimerizadoras.

INTRODUCTION

Microleakage of direct resin composite restorations continues to be a major drawback of this type of restoration and can lead to their early failure. Factors that contribute to microleakage of resin composite restorations include type of cavosurface margin (enamel vs. dentin), type and brand of adhesive and resin composite, placement technique and degree of monomer conversion^{16,19}. A high degree of monomer conversion is essential with resin composite restorations in order to ensure optimum physical and mechanical properties^{1,6,9}. Light curing units with high light intensity were developed to help in maximizing the degree of conversion of monomers and shortening of exposure time. However, monomer conversion into polymers is always accompanied by shrinkage due to compaction of the intermolecular spacing⁷. A reduction in intermolecular distance from 0.3-0.4nm to 0.15nm on polymerization of resin composites was reported²³. A higher degree of monomer conversion into polymer results in an increase in polymerization shrinkage²³. Polymerization shrinkage can result in gap formation along the tooth/restoration interface, allowing fluids and bacteria percolation with subsequent microleakage^{5,22}.

Recently, several modified light curing cycles have been suggested as means to reduce or minimize stress buildup and subsequent gap formation at the tooth/restoration interface that occurs due to shrinkage. Some of these typically include an initial stage of curing with a low intensity light followed by a final phase of high-intensity light curing. With low light intensity, a reduced number of free radicals are released, and this extends the pre-gel state and allows time for the material to undergo some flow before the polymer network reaches the gel state²⁵. This is believed to help enhance marginal adaptation since the pre-gel stage is extended, allowing some flow of the resin molecules to occur, which helps in reducing stress buildup at the tooth/restoration interface^{12,13,15,20}.

Several methods that use a reduced initial light intensity or so-called *soft-start* polymerization have been suggested^{17,20}. These include *Step-curing* - a low intensity light applied for a specific time and immediately followed by high intensity until the end of the exposure time. *Ramp-curing* - an initial low intensity light applied for a defined period and gradually increased to a high intensity until the remaining exposure time. *Pulse-delay* - an initial low intensity light for a specific time followed by a delay of 3 to 5 minutes during which polishing of a restoration can be made; then a final exposure period at high intensity²⁵. With new sophisticated light curing units, there are multiple possibilities for curing techniques that can be confusing to the dentist to select from. Therefore, it is necessary to determine which of these curing methods and light sources are more likely to result in optimum properties of the restoration and superior marginal adaptation.

The aim of this study was to determine the effect of a softstart polymerization method from Quartz-Tungsten-Halogen (QTH) and Plasma Arc (PAC) curing units on

microleakage of Class V resin composite restorations with dentin cavosurface margins. The hypothesis was that the use of a softstart polymerization method with an initial low light intensity followed by a final phase of high-intensity light would result in improved marginal integrity.

METHODS AND MATERIALS

Seventy-five bovine incisors were employed in this study. Following extraction, the teeth were initially stored in 0.1% thymol solution¹¹ for one week. The teeth were then cleaned and examined to ensure that they were free of defects and were stored in distilled water. Total storage period did not exceed 3 months throughout the period of the investigation. Each tooth received a Class V preparation located on the root surface just below the CEJ with all preparation margins in dentin. Standardized square shaped cavities with uniform depth of 1.5mm and length and width of 4.0mm each were prepared with tungsten carbide burs # 245 (KG Sorensen Ind. Com. Ltda, São Paulo, SP, Brazil) in a high-speed handpiece with air/water spray. Preparation dimensions were checked using a digital caliper and a calibrated periodontal probe. No cavosurface bevel was prepared. Margins were subsequently finished using hand instruments.

Teeth were then randomly divided into 5 equal groups (n = 15) according to the light source and curing method used. For each tooth, preparation surfaces were etched with 35% phosphoric acid (3M Dental Products Div., St. Paul, MN, USA) for 15s, thoroughly rinsed with water and gently dried with absorbent paper, leaving a slightly moist surface. A dentin bonding agent (Single Bond, 3M) was then applied following the manufacturer's instructions. Each preparation was then restored incrementally with a composite resin (Z100, 3M). Three small wedge increments were used for each restoration, and each increment was light-cured as follows: Group I: Plasma Arc (PAC) light (Apollo 95 E, DMD, Fleury d'Áude, France) applied in continuous-cycle curing mode at 1600 mW/cm² for 3s; Group II: PAC light applied in step-cycle curing mode at 800 mW/cm² for 2s followed immediately with 4s at 1600 mW/cm²; Group III: Quartz-Tungsten-Halogen (QTH) light (Digital Optilight, Gnatus, Ribeirão Preto, SP, Brazil) applied in continuous-cycle curing mode at 400 mW/cm² for 40s; Group IV: QTH light (Elipar Trilight, ESPE, Norristown, PA, USA) applied in a ramp-cycle curing mode (100 to 600 mW/cm² in 15s and 25s at 600 mW/cm²); Group V: QTH light (VIP, Bisco, Schauburg, IL, USA) applied in pulse-delay curing mode (at 200 mW/cm² for 3s followed by 3 min wait interval then 30s at 600 mW/cm²). Specimens were stored in distilled water at 37°C and all restorations were finished and polished using carbide burs with 30 blades, polishing discs (Sof-Lex, 3M) and Prisma Gloss polishing paste (Dentsply/Caulk, Petrópolis, RJ, Brazil).

After 30 days of water storage specimens were subjected to thermocycling for a total of 500 cycles at 5°C and 55°C with one minute dwell time at each temperature. The root apices of the teeth were then sealed with composite resin

and the teeth were coated with two layers of nail varnish up to 1mm from the restoration margins. Teeth were replaced in water as soon as the nail varnish dried and after 24h the teeth were immersed in 0.5% fuchsine red solution for four hours at 37°C. Specimens were then rinsed in running water for 6h before they were embedded in acrylic resin. All teeth were sectioned parallel to the long axis in 0.5mm slices with an Isomet diamond saw (Buehler, Inc., Lake Bluff, IL 60044). Immediately after slicing, the restoration areas on the most infiltrated slice were scanned using a computer scanner and the area of dye infiltration (mm) into dentin structure (gingival and apical) was determined using a computer program (Image Tools, UTHSCSH). Mean dye leakage areas were calculated for each group and data were statistically analyzed using ANOVA and Tukey test.

Dye penetration along the tooth/restoration interface was also scored by two investigators using a four-point scale as follows: 0: no dye penetration; 1: dye penetration up to ½ gingival or incisal wall; 2: dye penetration along the whole length of gingival or incisal wall; 3: dye penetration up to the center of the axial wall. Mean values for accumulative scores were calculated for each group and data were statistically analyzed using Kruskal-Wallis test.

RESULTS

The means and standard deviations for areas of dye leakage for the five groups are shown in Table 1. Groups I and II had larger dye leakage areas than the other three groups. ANOVA revealed significant differences in mean area of dye leakage between groups ($p < 0.000001$). Tukey test indicated that Groups III, IV and V had significantly smaller dye leakage areas than groups I and II. Mean scores for dye penetration along the tooth/restoration interface were also higher for Groups I and II compared with the other three. Kruskal-Wallis test revealed significant differences between groups with regard to the degree of dye penetration ($p < .000006$). Groups III, IV and V had mean accumulative scores for dye penetration that were significantly lower than those for Groups I and II.

Table 1 also shows that there is agreement between findings of both methods of microleakage assessment. Groups I and II had mean scores for dye penetration of 6 and corresponding mean areas of leakage of 7.07 and 6.99. While Groups III, IV and V had mean scores for dye penetration of 3 and corresponding mean areas of dye leakage of 3.86, 3.68 and 3.57, respectively.

DISCUSSION

The hypothesis that the use of a softstart polymerization method will result in an improved marginal integrity has been advocated by some authors^{12,13,15,20}, but was not upheld in this study.

In the present study, the application of a high intensity light showed to have a major relationship with the marginal integrity than the curing cycle. Groups I and II, light cured with PAC light, showed highest values of dye penetration and leakage, which were statistically different from those of Groups III, IV and V. This finding is in agreement with findings reported by other researchers who found a statistically significant increase in microleakage of composite resin restorations cured with the PAC light compared to those cured with QTH light^{2,28}. This might be related to the sudden polymerization shrinkage that follows curing with the PAC light. The application of a high intensity light over a short period of time causes the composite resin to quickly reach a rigid state of a high level of modulus of elasticity with consequent stress concentration at the tooth-restoration interface resulting in poor marginal adaptation^{8,13,15,26}. Additionally, the rapid development of the polymeric network promoted by high light intensity may result in shorter molecular chains with low molecular weight and less cross-linking^{25,27}.

In spite of the difference in the curing technique, Groups III, IV and V resulted in similar lowest areas of dye leakage, 3.86, 3.68 and 3.57mm², respectively; and lowest accumulative scores for dye penetration, score of 3 for all three groups. While these values were significantly lower than those of the PAC light groups, they indicate that the use of pulse-delay curing with QTH light had little or no effect on microleakage compared with the control group under conditions of testing used in this work. This is in agreement with findings by Friedl, et al.¹⁰ (2000), who compared microleakage of Class V resin composite and polyacid-modified resin restorations when conventional QTH and softstart QTH light curing techniques were used and concluded that "softstart" did not provide better marginal adaptation. Cavalcante, et al.³ (2003) using a vertical slot type class II cavities restored with microhybrid and "packable" composites resin found out that the "packable" composite resin cured with Plasma Arc (PAC, Apollo 95E) curing showed the highest leakage scores. However, it was not statistically different from Plasma Arc with the microhybrid resin, which behaved similarly with all techniques (conventional, pulse and ramp from QTH). For

TABLE 1- Means and standard deviation values in mm² for area of dye leakage into dentin structure and mean accumulative score for dye penetration along tooth/restoration interface for the five groups. Same letters show no significant difference ($p < 0.05$) (Capital letters are used for Tukey test and small letters are used for Kruskal Wallis test)

Group	I	II	III	IV	V
Area	7.07 (4.38)a	6.99 (3.04)a	3.86 (2.63)b	3.68 (1.59)b	3.57 (2.17)b
Score	6A	6A		3 B	

H = 29.25160 P = 0.000006

all groups, the resin composites were inserted horizontally in three increments.

Luo, et al.¹⁸ (2002) reported improved marginal adaptation of Class V circular restorations made from a compomer when pulse-delay curing was used compared with conventional continuous curing. However, when a self-etching and priming procedure was used instead of conventional etching/priming procedure, both pulse-delay curing and continuous conventional curing techniques resulted in similar degrees of microleakage. This occurred even though these Class V cavities had all-enamel cavosurface margins. In the present study an etching/priming procedure was followed and all cavities had dentin cavosurface margins, which is of course more challenging for achieving marginal adaptation than enamel margins. It is interesting to note that the minimum shear bond strength values reported to be necessary for composite resins to counteract polymerization shrinkage stresses ranges from 16.8 to 24 MPa^{14,21,24}. Sometimes it is difficult to achieve this level of bond strength with certain locations on dentin surfaces. Therefore, it is possible that having dentin cavosurface margins might have influenced marginal adaptation regardless of the light curing technique used in this study.

Composite resin formulation can play an important role in the degree of polymerization shrinkage and stress development. Some commercially available materials have a tendency to result in higher polymerization shrinkage values than others^{4,29}. Among a group of 10 different composite resin materials, Z-100 had the highest value for linear shrinkage stress, as detected with the use of strain gauges³⁰. This indicates that, if other brands of resin composite materials were used in this study, it is possible that lower microleakage scores would have been encountered.

The type of curing light, PAC vs. QTH, may have not been a determining factor in this study, but rather the intensity of light emitted from each unit could be the influencing factor. Currently, there are new QTH light curing units that are capable of emitting light with intensity approaching that of the PAC light when assisted by the so called "turbo" light guide attachment. It would be important to test the effects of such QTH lights on polymerization shrinkage/microleakage of composite resins and compare them with those of the PAC light.

Findings of this study indicate a direct relationship between marginal adaptation and light intensity, irrespective of the light curing method used. Generally overall lower intensity light curing resulted in better marginal adaptation of Class V restorations. While maximizing the degree of monomer conversion and minimizing the amount of volumetric polymerization shrinkage with its subsequent stresses is highly desirable, with resin composites it is a dual goal with opposite terminals. With most current resin composite formulations, the higher the degree of monomer conversion, the higher the amount of polymerization shrinkage. However, high intensity light curing can have certain benefits that can help the dentist complete the restorative procedure in less time and perhaps ensure more thorough polymerization. Further research need to be

conducted in this respect in order to find out if certain restoration insertion and light curing techniques, including directed light application through preparation walls, can permit dentists to use high intensity light curing routinely with resin composite restorations and at the same time achieve good quality marginal adaptation without causing pulp damage from elevated temperature of the curing light.

CONCLUSIONS

- The use of PAC light either in a continuous or step cycle mode resulted in significantly higher microleakage, as evidenced by increased dye penetration and leakage compared with medium intensity QTH light curing.
- The hypothesis that the use of a softstart polymerization method with a reduced initial light intensity followed by a high light intensity would result in an improved marginal integrity was rejected.
- Pulse, ramp and continuous-cycle curing modes with QTH light resulted in similar degrees of microleakage.
- The agreement between the two methods used for assessment of microleakage, measurement of area of dye leakage and scoring of degree of dye penetration indicate reliability of the testing method used.

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