Effect of different polymerization methods on composite microleakage

SIMONE DELIPERI, DDS, DAVID N. BARDWELL, DMD, MS & AIKATERINI PAPATHANASIOU, DDS

ABSTRACT: ***Purpose:*** To evaluate the microleakage of a condensable resin composite using a microhybrid flowable composite as a liner, cured with four different methods of polymerization. ***Methods:*** 40 freshly extracted caries-free human premolars and molars were used. MO/DO Class II standardized preparations were performed with the gingival margin placed 1 mm above the CEJ. Teeth were randomly divided into four groups. Group 1 (control group): conventional mode (Elipar Highlight), Group 2: step mode (Elipar Highlight), Group 3: ramp mode (Elipar Trilight) and Group 4: pulse mode (VIP). Preparations were etched with 32% phosphoric acid (Uni-Etch) and an adhesive system (One-Step) was used according to the manufacturer's instructions. Teeth were then restored using a 1 mm layer of flowable composite (A_2 Æliteflo LV) on the gingival and pulpal floor and condensable composite (Pyramid A2 Dentin and A1 Enamel) in 2 mm increments. Teeth were thermocycled x500 between 5°C and 55°C with a dwell of 30 seconds and then placed in a 0.5% methylene blue dye solution for 24 hours at 37°C. Samples were sectioned longitudinally and evaluated for microleakage at the gingival margin under a stereomicroscope at x30 magnification. Dye penetration was scored using an ordinal scoring system as 0: no penetration; 1: enamel penetration; 2: dentin penetration. ***Results:*** A Mann-Whitney U Test revealed a statistically significant difference between Group 1 with Groups 2, 3 and 4 ($P < 0.001$). Group 1 yielded the most microleakage. No statistically significant difference was noted between Groups 2, 3 and 4. (*Am J Dent* 2003;16:73A-76A).

CLINICAL SIGNIFICANCE: A microhybrid flowable composite was unable to reduce microleakage if not associated with a soft-start or pulse polymerization. The flowable composite reduced filler volume may result in a material more sensitive to polymerization shrinkage when a conventional mode of continuous irradiation is used.

✉: Dr. Simone Deliperi, Via Baccelli 10, Cagliari 09126, Italy. E-✉: simone.deliperi@tufts.edu

Introduction

Posterior resin composites are very popular in clinical practice due to the increasing demand for esthetics[1] and continued improvement in technology.[2,3]

Even though several types of posterior composites have been introduced into the marketplace, the ideal material has not been developed.[4-6] Manufacturers are working to improve material properties by reducing polymerization shrinkage,[7,8] simplifying dentin and enamel bonding techniques,[9,10] and improving curing methods. New light curing systems have gained popularity and may affect marginal integrity. New methods of polymerization using quartz tungsten halogen (QTH) models and the newer high intensity curing light systems (plasma arc and laser) have been introduced in an attempt to affect polymerization shrinkage.

There are three main techniques with reference to photo-curing:

Soft start polymerization - utilizes multimode QTH curing lights that start with a low intensity light and then step or ramp to a high intensity light for the final cure. The purpose of this system is to reduce the speed of conversion and increase the gel phase resulting in viscous flow and better adaptation of composites to the cavity walls.[11-13]

The pulse delay cure technique - utilizes a initial low intensity cure for a short duration to provide sufficient network formation on the top surface while delaying the gel point in the deeper resin until the final high intensity is started (enamel increment). The pulse technique uses a specific energy density for each composite at which an optimal polymerization can be achieved (Energy for Optimal Polymerization).[14-16] The rate at which energy is delivered is the power (Joule/second or Watt). The energy density is defined as the power density (power per unit area in Watt/cm^2) times the exposure time.

High intensity and fast polymerization - is based on a concept of total energy. It was introduced to decrease exposure time and have a greater depth of cure compared to conventional lights.[17]

Other research[18] show that resin formulations, rather than light type or curing mode, may be the most important factor in polymerization. The use of flowable composites to create an elastic cavity wall to absorb the shrinkage stress of subsequently applied composite was recently introduced.[19] Also notable is improvement in composite marginal adaptation with soft start polymerization.[20,21] Conversely, clinicians are attracted by the new fast curing methods, even though there is the possibility of increased resin brittleness and shrinkage. Also the narrow wavelength emitted may not correspond to the absorption band of the photoinitiators. This can result in incompletely cured resin.[22-25]

This study evaluated the microleakage of a condensable composite (Pyramid Dentin and Enamel[a]) used in conjunction with the sandwich technique of a flowable composite (Æliteflo LV[a]) in Class II restorations when different curing light sources (QTH conventional, step, ramp and pulse modes) were used.

Materials and Methods

Forty freshly extracted, caries-free human premolar and molar teeth were used in this study. The teeth were stored in physiologic saline at 4°C for 24 hours. MO/DO Class II restorations were prepared using a 330 carbide bur[b] with a high speed handpiece and copious amounts of water. The pre-

Table 1. Curing time and intensity used to polymerize flowable and condensable composites.

Group	Light system	Flowable (A2)	Condensable (A2)
1	Elipar Highlight	20 seconds, 800 mW/cm^2	40 seconds, 800 mW/cm^2
2	Elipar Highlight	10 seconds, 180 mW/cm^2 30 seconds, 800 mW/cm^2	10 seconds, 180 mW/cm^2 30 seconds, 800 mW/cm^2
3	Elipar Trilight	15 seconds, 180 –800 mW/cm^2 25 seconds, 800 mW/cm^2	15 seconds, 180 –800 mW/cm^2 25 seconds, 800 mW/cm^2
4	VIP light	20 seconds, 500 mW/cm^2	Dentin: 10 seconds, 600 mW/cm^2 Enamel: 3 seconds, 200 mW/cm^2 Final: 30 seconds, 600 mW/cm^2

pared teeth were 4 mm long, 3 mm wide and 5 mm in depth with the gingival margin not extending to the CEJ. The teeth were randomly divided into four groups:

Group 1 - Conventional light (Elipar Highlight[c]) with continuous energy output (800 mw/cm^2) for 20 seconds when curing flowable composite and 40 seconds when curing condensable composite.

Group 2 - Step light (Elipar Highlight) with a 180 mw/cm^2 intensity for 10 seconds and automatic step up to 800 mw/cm^2 for remainder of 40 seconds both for the flowable and condensable composites.

Group 3 - Ramp light (Elipar Trilight[c]) with automatic increase from 180 to 800 mw/cm^2 during the first 15 seconds and then stayed at 800 for the remainder 40 seconds both for the flowable and condensable composites.

Group 4 - Pulse light (VIP light[a]). The flowable composite was cured for 20 seconds. The condensable composite was cured with different curing times and intensities for dentin shades: 600 mw/cm^2 for 10 seconds *versus* enamel: 200 mw/cm^2 for 3 seconds. After 3 minutes of polishing and finishing, a 30-second (10 buccal, 10 lingual, 10 occlusal) final exposure at 600 mw/cm^2 was applied. Effectiveness of the lights was checked with a curing radiometer before starting each restoration. Light source was applied from an occlusal direction being careful to maintain a constant distance between the bottom of the cavity and the cusps' tips.

Each prepared tooth was etched with 32% H_3PO_4 (Uni-Etch[a]) for 15 seconds on dentin and 30 seconds on enamel, rinsed for 20 seconds and then gently blown to remove water, being careful to maintain a moist surface. An acetone-based unfilled adhesive system was used (One Step[a]) following the manufacturer's instructions. A 0.0015 inch Tofflemire metal matrix band was used to reconstruct the proximal surface and simulate clinical conditions. A 1-mm even layer of A2 flowable composite (Æliteflo LV[a]) was used in the gingival floor and cured with different times and intensities according to manufacturer's indications.

The restorations were completely filled with A2 condensable composite (Pyramid- dentin and enamel) using a vertical layering technique with each layer not being more than 2 mm thick. The curing time and the intensity were different for each group according to manufacturer's recommendation (Table 1). The restorations were finished using carbide burs (Raptor[a]) and polished with Jiffy[d] polishing cups and points.

Table 2. Summary of statistical results showing significant difference between Group 1 *vs* Groups 2, 3 and 4.

	Conventional	Step	Ramp	Pulse
Conventional	-	P= 0.002	P= 0.012	P= 0.003
Step	P= 0.002	-	N	N
Ramp	P= 0.012	N	-	N
Pulse	P= 0.003	N	N	-

After completing the restorations, the teeth were stored in physiologic saline for 24 hours at 37°C, thermocycled x500 between ±5-55° with a dwell time of 30 seconds, placed in methylene dye solution for 24 hours, then mounted in cold cure acrylic with the root immersed 1 mm below CEJ. Samples were sectioned longitudinally from mesial to distal using a low speed saw[e] and then scored for microleakage at the gingival margin using a stereomicroscope at x30. Statistical analysis was employed to evaluate the results utilizing an ordinal scoring system where 0: no penetration; 1: enamel penetration; 2: dentin penetration.

Results

The results of this study indicated that a microhybrid flowable composite was unable to decrease microleakage when a conventional curing mode was used. Group 1 yielded the most microleakage.

Step, ramp and pulse curing modes reduced microleakage of a condensable composite when used in conjunction with the sandwich technique with a microhybrid flowable composite. Statistical analysis was employed using a Kruskal Wallis one-way ANOVA by ranks, which revealed a statistical significant difference between the four groups ($P < 0.001$).

The Mann Whitney U test for two independent samples revealed statistical significant difference between Group 1 with Group 2 (P= 0.002), Group 3 (P= 0.012) and Group 4 (P= 0.003). No statistical significant difference was found among Groups 2, 3, and 4 when compared to each other (Table 2).

Discussion

In 1984, Davidson & De Gee[26] stressed the importance of composite flow in the direction of cavity walls to allow for its internal adaptation during the early setting phase. Others[27-29] pointed out that the relief of polymerization stress through composite flow is reached with the use of low light energy; conversely they recorded higher polymerization shrinkage with higher light energy. Miyazaki *et al*[30] demonstrated improved physical properties of composites cured with low intensity and slow polymerization *versus* higher intensity and faster polymerization. Since then, many studies reported improved marginal adaptation and physical properties of composites cured with the soft start polymerization.[11-13,20,21,31-34] A variant of the soft start polymerization, called pulse delay technique, was introduced with encouraging results.[14-16]

No previous study has investigated the microleakage of a condensable composite used in conjunction with the sandwich technique of a flowable when cured with a conventional, soft-start, or pulse technique. Flowable composite has been advocated to improve marginal adaptation of posterior composite due to their ability to act as an elastic stress absorbing layer for subsequently applied composite increments.[19,35,36] On the other hand, there is evidence in the literature that the ability of flowable composite to seal the cavosurface margin is questionable. Their decreased viscosity is achieved by reducing the filler volume so they are less rigid but shrink and wear more than conventional composite.[37-42]

The results of this study indicated that the ability of flowable composite to reduce microleakage was related to the polymerization methods. When cured with a soft start polymerization, either step or ramp, microleakage at the gingival margin was significantly reduced compared with the conventional mode. This may be explained by a very short pre-gel phase and a sudden polymerization of flowable and condensable composites. Conversely, the use of low intensity for 10-15 seconds may delay the gel point giving a further possibility for the composite resin to flow. It may be assumed that the elasticity effect of flowable composites was less important than the effect of soft start polymerization in this study, because the flowable composite was able to reduce microleakage only when using a soft-start or pulse polymerization. The pulse polymerization was also effective in reducing microleakage. This mode uses a soft start polymerization just for the final enamel increment with the attempt to reduce the enamel fractures outside the restoration margin, while using a conventional mode for the other increments with a specific energy density (power density x times) for each composite. The specific energy used with the pulse mode may be responsible for the different results obtained with the pulse and the conventional mode which both use a continuous irradiation for Æliteflo LV and Pyramid Dentin. As a matter of fact, the reduced microleakage associated with the pulse mode may be related to the reduced power density used to cure flowable and condensable composites. The pulse group was not significantly different from the step and ramp mode; this means that the same result can be achieved with different curing modes using Æliteflo LV and Pyramid Dentin and Enamel.

When cured with a soft start polymerization, improved marginal integrity (from 11-30%), depending on the composites tested, has been reported.[31,32] These results may be explained by increased concentration of photoinitiators in certain composites, so that they require shorter exposure time to get the same degree of conversion at the same intensity. The gel point is anticipated (the time for the composite to flow) even with a soft start polymerization.The lower modulus of elasticity of flowable composite was considered responsible for this different behavior using a soft start polymerization by other authors.[32] The combination of Æliteflo LV and Pyramid was able to withstand the increased energy density required for the soft start polymerization compared to the pulse one, *i.e.* the energy and time required to cure composites with the soft start polymerization was superior than the ones required for the pulse mode.

These considerations seem to support the theory that a specific energy density is required for each composite at which an ideal compromise of reduced stress and optimal physical properties may be achieved. To completely use the advantage of the soft start and pulse polymerization with all composites, each manufacturer's light should provide a complete list of ideal curing time and intensity for the more popular composites on the market. In this way, improved marginal adaptation and reduced stress at the cavosurface margin may be obtained since clinicians would not be estimating appropriate curing times and intensities.

a. Bisco, Schaumburg, IL, USA.
b. Brasseler, Savannah, GA, USA.
c. 3M ESPE, St. Paul, MN, USA.
d. Ultradent Products, South Jordan, UT, USA.
e. Buehler, Lake Bluff, IL, USA.

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Dr. Deliperi is a Clinical Instructor, Department of Conservative Dentistry, University of Cagliari, Cagliari, Italy, and a Visiting Instructor and Research Associate, Postgraduate Esthetic Dentistry, Tufts University School of Dental Medicine, Boston, Massachusetts, USA; Dr. Bardwell is Associate Clinical Professor, Restorative Dentistry, and Director, Postgraduate Esthetic Dentistry, Tufts University School of Dental Medicine, Boston, Massachusetts USA. Dr Papathanasiou is in private practice in Athens, Greece, and is a Visiting Assistant Professor, Department of Prosthodontics and Operative Dentistry, Tufts University School of Dental Medicine, Boston, Massachusetts, USA.

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