

Effects of Different Light Curing Units/ Modes on the Microleakage of Flowable Composite Resins

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Objectives: The aim of this in vitro study was to evaluate the influence of different light curing units and modes on microleakage of flowable composite resins.

Methods: Eighty Class V cavities were prepared in buccal and lingual surfaces of 40 extracted human premolars with cervical wall located in dentin and the occlusal wall in enamel. These teeth were randomly assigned into two groups (n=20) and restored with different flowable composites; Group I: Esthet-X Flow, Group II: Grandio Flow. Each group was randomly divided into four subgroups; while the samples of the first subgroup were polymerized with conventional Halogen light, the rest of them were polymerized with different curing modes of Light Emitting Diode (LED). The second subgroup was polymerized with fast-curing; the third subgroup with pulse-curing and those of the fourth subgroup with step-curing modes of LED. After the samples were thermocycled and immersed in dye, they were longitudinally sectioned. Dye penetration was assessed under a stereomicroscope. Data were analyzed by Kruskal-Wallis and Mann-Whitney U tests.

Results: None of the restorations showed leakage on enamel margins. On dentin margins no significant differences were observed between flowable composite resins polymerized with halogen light ($P>.05$). While step curing mode of LED presented significant differences between the resins, the difference was insignificant when fast-curing and pulse-curing mode of LED were used. No statistically significant differences were observed between curing units for Esthet-X Flow samples. For Grandio Flow samples, only step-curing mode of LED caused statistically higher leakage scores than halogen and other curing modes of LED ($P<.05$).

Conclusions: The effect of curing units' type and curing mode on flowable composite resin leakage might be material-dependent. (Eur J Dent 2008;2:240-246)

Key words: Microleakage; Flowable composite resins; Light curing units.

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INTRODUCTION

Flowable restorative resins with a low viscosity are recommended as the material of choice for restoring Class V cavities. Flowable composites are easier to place and more self-adaptable compared to conventional restorative resin composites. However, due to its lower filler content, they demonstrate higher polymerization shrinkage¹ and have inferior mechanical properties.² The importance of perfect seal for

success and longevity of esthetic restorations has been well documented.^{3,4} However, polymerization shrinkage has remained a problem despite improvements in materials and techniques for light-cured composites.^{5,6} Stress from shrinkage results with cracked enamel rods, marginal gaps, and open margins. Microleakage around resin composite restorations occurs from these gaps and resulting in post-operative sensitivity, marginal discoloration, secondary caries, pulpal inflammation, and partial or total loss of the restoration.^{7,8} It has been reported that the inorganic filler content of the composite,^{9,10} the type of monomer, light intensity and curing cycle¹¹⁻¹³ affect the polymerization shrinkage.

Several approaches have been introduced to overcome the problem of polymerization shrinkage. The curing profile of composites was modified to improve their physical and mechanical properties and lessen polymerization shrinkage.^{14,15} Over the past few years many different light curing modes have emerged. One of them is to slow down the polymerization process by initial reduction of resin conversion.¹⁶ In this step-cure method, the composite is first cured at low intensity, then stepped up to a high intensity light.^{17,18} The purpose is to reduce polymerization stress by inducing the composite to flow in the gel state during the first application. However, the reduction in shrinkage is small and results in less composite polymerization because the lower intensity light yields lower energy levels. In pulse-delay curing, a single pause of light is applied, followed by a pause and then by a second pulse cure.^{17,19-20} The slower polymerization during the first pulse might favor the formation of extended polymer chains and hence cross-linking.²¹

Recently, LED curing lights that offer many advantages over conventional halogen curing units were introduced to clinical practice. Conventional halogen curing units have longer curing times, their components may degrade by time and may have inadequate output.^{22,23} Moreover, they induce heat.^{24,25} On the other hand, most of the energy radiated from LED light falls within the absorption spectrum of champhoroquinone photoinitiators, they are claimed to be more effective for polymerizing composite resins.^{22,26} They emit less heat and have longer life with minimal decrease in output overtime.^{25,27-29}

As the usage of LED light and different curing modes increase in daily practice, the aim of this in vitro study was to determine the effect of different light curing units/modes on the microleakage behavior of flowable composites.

MATERIALS AND METHODS

Forty extracted caries-free human premolars, stored in a 0.25% mixture of sodium azide in ringer solution until the date of use were selected for the study. The teeth were cleaned with scalers and polished with pumice. Buccal and lingual Class V cavities (2.0 mm in height, 2.5 mm in mesiodistal direction and 1.5 mm in depth) were prepared with a fissure diamond (Diatech, Swiss Dental Instruments, Heerbrugg, Switzerland) in an air turbine under copious water at the cement enamel junction (CEJ). The cervical wall was located in dentin and the occlusal wall was located in enamel. Each bur was replaced every five cavity preparations. The 80 cavities of 40 teeth were etched with 34% phosphoric acid gel for 15 seconds. After the gel was rinsed for 10 seconds, the cavities were blot dried to remove excess moisture without desiccation of dentin. These teeth were randomly assigned into two groups (n=20) and then each group was divided into four subgroups (n=10) as follows;

Group I: Prime&Bond NT (Dentsply/Caulk, Milford, DE, USA) was applied to the cavity and saturated all surfaces for 20 seconds. After removing excess solvent by gently air drying for 5 seconds, it was light cured with Halogen curing unit (Hilux, Benlioglu, Ankara, Turkey) for 10 seconds. Then Esthet-X Flow (Dentsply/Caulk, Milford, DE, USA) was placed and polymerized with different light curing units/modes.

Group II: Solobond M (Voco, Cuxhaven, Germany) was applied to the cavity and let act for 30 s. Then Solobond M was dispersed with a gentle air and polymerized for 20 seconds with Halogen curing unit (Hilux, Benlioglu, Ankara, Turkey) for 10 seconds. Grandio Flow (Voco, Cuxhaven, Germany) was placed. All restorations were placed with bulk technique. Details of the restorative materials are shown in Table 1.

Each group was randomly divided into four subgroups; while the samples of the first subgroup was polymerized with conventional Halogen light (Hilux 200, Benlioglu Dental, Turkey) the rest

of them were polymerized with different curing modes of Light-emitting diode (Mini LED, Satelec, France). The second subgroup was polymerized with fast curing; the third subgroup with pulse curing and those of the fourth subgroup with step curing mode of LED. Table 2 shows the details of light curing units and modes investigated.

The restorations were finished with fine and extra-fine finishing diamond burs (Diatech Dental AG, Heerbrugg, Switzerland) used in a high-speed handpiece under constant air/water coolant and polished with sequential aluminum oxide discs (Sof-Lex, 3M, St.Paul, MN, USA).

The apex of the roots was sealed with wax and then the teeth were covered with two coats of nail varnish except for 1 mm around the margins of the restoration. The specimens were thermocycled 500 times (5-55°C) and then were immersed in 0.5% basic fuchsin for 24 hours. After rinsing, the restorations were longitudinally sectioned and dye penetration was assessed under a stereomicroscope (X40). Dye penetration was

scored for both enamel and dentin margins on a scale from 0 to 4:

- 0= no microleakage
- 1= dye penetration within 1/3 of cavity wall
- 2= dye penetration within 2/3 of cavity wall
- 3= dye penetration within last 1/3 of cavity wall up to the axial wall
- 4= dye penetration spreading along the axial wall

Microleakage data were subjected to non-parametric statistical analysis (Kruskal-Wallis and Mann-Whitney U tests) at a significance level .05.

RESULTS

Microleakage was not observed in any restorations at the enamel margins. Microleakage scores for the dentin margins are presented in Table 3. The results demonstrated no significant leakage differences among the flowable composite resins polymerized with halogen curing unit (P>.05). While fast-curing and pulse-curing modes

Table 1. Flowable composite resins and compositions.

Product	Composition	Filler Volume w/w %	Average Filler Particle Size (µm)	Volumetric Polymerization Shrinkage (%)
Esthet-X Flow (Dentsply/Caulk, Milford, DE, USA) Batch # 548012	Urethane modified Bis-GMA-adduct, BisGMA Barium fluoro amino-boro silicate glass, nanofiller silica	61	0.85-0.9	3-3.5
GrandioFlow (Voco, Cuxhaven, Germany) Batch # 441042	Bis-GMA, TEGDMA, HEDMA	80.2	SiO2-nanoparticles (40 nm) glass ceramic fillers (1 µm)	3.2

Table 2. Light curing units used in this study.

Light-curing units	Modes	Light-intensity
Halogen Hilux 200 (Hilux, Benlioglu, Ankara, Turkey)	Standard	400 mW/cm ² (40 sn)
	Fast-curing	1100 mW/cm ² (10 sn)
LED Mini LED (Mini LED, Satelec, France)	Pulse-curing	1100 mW/cm ² (10x1 sn)
	Step-curing	0-1100 mW/cm ² → 1100 mW/cm ² (10 sn) (10 sn)

of LED presented no statistical differences between the resins ($P>.05$), the difference was significant when step-curing mode of LED were used ($P<.05$). No statistically significant differences in leakage were observed between curing units/modes for Esthet-X Flow samples ($P>.05$). For Grandio Flow samples only step-curing mode of LED caused statistically higher leakage scores than halogen and other curing modes of LED ($P<.05$).

DISCUSSION

Polymerization shrinkage of composite resin is still a major concern in restorative dentistry. One way to minimize polymerization shrinkage is to allow the flow of resin composite during setting by means of controlled polymerization. This can be done by pre-polymerization at low power density followed by final cure at high power density.³⁰ It has been claimed that slower polymerization causes an improved flow of molecules in the material, decreasing the polymerization shrinkage stress in a restoration, which is associated with less shrinkage.³¹ Therefore this technique is expected to produce better marginal integrity and sealing. It has been shown that soft-start polymerization may result lesser marginal gap, increased marginal integrity and reduced shrinkage.^{5,30,32-34} However in the present study the different light curing units and modes had no effect on Esthet-X Flow samples' leakage scores. This result agrees with those of Friedl et al³⁵ and Yap et al³⁶ who also found no significant improvement in marginal adaptation and reduction in shrinkage when a soft-start mode was used. Muangmingsuk et al³⁷ also investigated the influence of different curing methods and reported no difference between soft-

start-curing and conventional curing. In a recent study³⁸ evaluating the curing effect of a very high intensity LED and a conventional LED including soft-start modes on the microleakage of a pit and fissure sealant, no statistically significant difference in microleakage was observed. This result totally concurs with our findings as the same light curing unit was used in both studies. Similarly Fleming et al³⁹ reported that the use of a soft-start polymerization compared with a standard polymerization protocol did not offer any significant reduction in associated gingival microleakage. On the other hand step-curing modes of LED light caused a higher degree of microleakage in Grandio Flow samples in the present study. A possible explanation for this difference can be found in difference in filler content. The ratio of filler relative to resin is also important. The higher the proportion of filler, the more difficult it is for the light to penetrate the composite.²⁶ Grandio Flow has more filler/weight content than Esthet-X Flow, which are more prone to light scattering and therefore might be more sensitive for variations in light units and modes. On the other hand small particles scatter light more than large particles.⁴⁰ Therefore penetration of light to deep in the material is difficult in small particle size composite resins.⁴¹ In a study evaluating the influence of soft-start light curing exposure on polymerization shrinkage stress and marginal integrity of adhesive restorations, the effect of soft-start curing mode was found to be depend on the material itself.⁴² It might be expected that fast-curing would increase the microleakage for both flowable resins because of the generation of excess shrinkage. In the present study while

Table 3. Microleakage scores on dentin margins.

Light-curing units	Flowable composite resins									
	Grandio Flow					Esthet-X Flow				
	0	1	2	3	4	0	1	2	3	4
Halogen	9	0	0	1	0	8	1	0	1	0
LED- Fast-curing	6	4	0	0	0	10	0	0	0	0
LED- Pulse-curing	10	0	0	0	0	10	0	0	0	0
LED- Step-curing	1	3	2	2	0	10	0	0	0	0

fast-cured Grandio Flow samples showed higher microleakage, no statistically significant difference was observed between different modes of LED and also with Esthet-X Flow samples. Similar to our findings, Pradelle-Plasse et al⁴³ reported that the fast-cure mode of polymerization by LED curing unit gave results as good as those obtained with other curing protocols in terms of microleakage.

Many studies have demonstrated that pulse mode which is a kind of soft-start curing mode involving a delay significantly improved the marginal integrity.^{44,45} Similar to these findings, both flowable composite resins in this study showed no leakage when a pulse-curing mode of LED was used. The efficacy of the slow-curing method combined with the interval between two irradiations with low intensity and high intensity was reported in a study by Uno et al.⁴⁶ However, in another recent study it was concluded that different light curing modes might have no effect on the microleakage of cervical cavities.⁴⁷ Svizero et al⁴⁸ also reported that ramp and pulse-delay light curing methods did not improve marginal sealing of composite resins.

Adhesive resins might have an important role in microleakage. Grandio Flow bonded with Solobond M, Esthet-X Flow was bonded with Prime and Bond NT. Although they are both acetone contained adhesives, Prime and Bond NT is a filled adhesive with viscoelastic properties. Polymerization shrinkage might be compensated with this property of the adhesive. Moreover the thickness of the adhesive layer obtained with a filled adhesive is higher and improves ability of the interfaces to maintain adhesion and to resist dimensional changes.⁴³ This might serve as an explanation for curing modes did not have any influence on microleakage scores of Esthet-XFlow. It has been reported that the resin formulation plays major role rather than curing unit type and mode in polymerization.⁴⁹

In the present study none of the restorations, irrespective of material or curing mode, exhibited microleakage on enamel margins. This finding is consistent with previous investigations and not surprising as dentin is a less favorable bonding substrate than enamel.

CONCLUSIONS

Under the limitations of this in vitro study it can be concluded that the effect of curing units' type and curing (mode) methods on flowable composite resin leakage is material-dependent.

REFERENCES

1. Labella R, Lambrechts P, Van Meerbeek B, Vanherle G. Polymerization shrinkage and elasticity of flowable composites and filled adhesives. *Dent Mater* 1999;15:128-137.
2. Bayne SC, Thompson JY, Swift EJ Jr, Stamatiades P, Wilkerson M. A characterization of first-generation flowable composites. *J Am Dent Assoc* 1998;129:567-577.
3. Moncada G, Fernandez E, Martin J, Arancibia C, Mjör IA, Gordan VV. Increasing the longevity of restorations by minimal intervention? A two-year clinical trial. *Oper Dent* 2008;33:258-264.
4. Chan DC, Browning WD, Fraizer KB, Brackett MG. Clinical evaluation of the soft-start (pulse-delay) polymerization technique in Class I and II composite restorations. *Oper Dent* 2008;33:265-271.
5. Obici AC, Sinhoreti MA, de Goes MF, Consani S, Sobrinho LC. Effect of photo-activation method on polymerization shrinkage of restorative composites. *Oper Dent* 2002;27:192-198.
6. Carvalho RM, Pereira JC, Yoshiyama M, Pashley DH. A review of polymerization contraction: the influence of stress development versus stress relief. *Oper Dent* 1996;21:17-24.
7. Bergenholtz G, Cox CF, Loesche WJ, Syed SA. Bacterial leakage around dental restorations: its effect on the dental pulp. *J Oral Pathol* 1982;11:439-450.
8. Triadan H. When is microleakage a real clinical problem? *Oper Dent* 1987;12:153-157.
9. Munksgaard EC, Hansen EK, Kato H. Wall to wall polymerization contraction of composite resin versus filler content. *Scand J Dent Res* 1987;95:526-531.
10. Iga M, Takeshige F, Ui T, Torii M. The relationship between polymerization shrinkage measured by a modified dilatometer and the inorganic filler content in light cured composites. *Dent Mater J* 1991;10:38-40.
11. Unterbrink GL, Muessener R. Influence of light intensity on two restorative systems. *J Dent* 1995;23:183-189.
12. Dennison JB, Yaman P, Seir R, Hamilton JC. Effect of variable light intensity on composite shrinkage. *J Prosthet Dent* 2000;84:499-505.
13. Sakaguchi RL, Douglas WH, Peters MC. Curing light performance and polymerization of composite restorative materials. *J Dent* 1992;20:183-188.

14. Amaral CM, de Castro AK, Pimenta LA, Ambrosano GM. Influence of resin composite polymerization techniques on microleakage and microhardness. *Quintessence Int* 2002;33:685-689.
15. Cavalcante LMA, Peris AR, Amaral CM, Ambrosano GMB, Pimenta LAF. Influence of polymerization technique on microleakage and microhardness of resin composite restorations. *Oper Dent* 2003;28:200-206.
16. Davidson CL, Feilzer AJ. Polymerization shrinkage and polymerization shrinkage stress in polymer-based restoratives. *J Dent* 1997;25:435-440.
17. Asmussen E, Peutzfeldt A. Two-step curing on conversion and softening of a dental polymer. *Dent Mater* 2003;19:466-470.
18. Feilzer AJ, Dooren LH, de Gee AJ, Davidson CL. Influence of light intensity on polymerization shrinkage and integrity of restoration-cavity interface. *Eur J Oral Sci* 1995;103:322-326.
19. Rueggeberg F. Contemporary issues in photocuring. *Compend Contin Edu Dent* 1999;20[suppl 25]:S4-S15.
20. Davidson CL, de Gee AJ. Light-curing units, polymerization, and clinical implications. *J Adhes Dent* 2000;2:167-173.
21. Soh MS, Yap AU. Influence of curing modes on crosslink density in polymer structures. *J Dent* 2004;32:321-326.
22. Nomoto R, McCabe JF, Hirano S. Comparison of halogen, plasma and LED curing units. *Oper Dent* 2004;29:287-294.
23. Dunn WJ, Bush AC. A comparison of polymerization by light-emitting diode and halogen- based light-curing units. *J Am Dent Assoc* 2002;133:335-341.
24. Ozturk B, Ozturk AN, Usumez A, Usumez S, Ozer F. Temperature rise during adhesive and resin composite polymerization with various light curing sources. *Oper Dent* 2004;29:325-332.
25. Yazici AR, Müftü A, Kugel G, Perry RD. Comparison of temperature changes in the pulp chamber induced by various light curing units, in vitro. *Oper Dent* 2006;31:261-265.
26. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. *Br Dent J* 1999;186:388-391.
27. Yap AU, Soh MS. Thermal emission by different light-curing units. *Oper Dent* 2003;28:260-266.
28. Asmussen E, Peutzfeldt A. Temperature rise induced by some light emitting diode and quartz-tungsten-halogen curing units. *Eur J Oral Sci* 2005;113:96-98.
29. Owens BM. Evaluation of curing performance of light-emitting polymerization units. *Gen Dent* 2006;54:17-20.
30. Mehl A, Hickel R, Kunzelmann KH. Physical properties and gap formation of light-cured composites with and without soft-start polymerization. *J Dent* 1997;25:321-330.
31. Uno S, Asmussen E. Marginal adaptation of a restorative resin polymerized at reduced rate. *Scand J Dent Res* 1991;99:440-444.
32. Sakaguchi RL, Berge HX. Reduced light energy density decreases post-gel contraction while maintaining degree of conversion in composites. *J Dent* 1998;26:695-700.
33. Oberholzer TG, Du Preez IC, Kidd M. Effect of LED curing on the microleakage, shear bond strength and surface hardness of a resin-based composite restoration. *Biomater* 2005;26:3981-3986.
34. Santos AJ, Lisso MT, Aguiar FH, Franca FM, Lovadino JR. Effect of stepped exposure of quantitative in vitro marginal microleakage. *J Esthet Restor Dent* 2005;17:236-242.
35. Friedl KH, Schmalz G, Hiller KA, Markl A. Marginal adaptation of Class V restorations with and without "soft-start polymerization". *Oper Dent* 2000;25:26-32.
36. Yap AU, Soh MS, Siow KS. Post-gel shrinkage with pulse activation and soft-start polymerization. *Oper Dent* 2002;27:81-87.
37. Muangmingsuk A, Senawongse P, Yudhasaraprasithi S. Influence of different soft start polymerization techniques on marginal adaptation of Class V restorations. *Am J Dent* 2003;16:117-119.
38. Nalcaci A, Ulusoy N, Küçükeşmen C. Effect of LED curing modes on the microleakage of a pit and fissure sealant. *Am J Dent* 2007;20:255-258.
39. Fleming GJ, Cara RR, Palin WM, Burke FJ. Cuspal movement and microleakage in premolar teeth restored with resin-based filling materials cured using 'soft-start' polymerization protocol. *Dent Mater* 2007;23:637-643.
40. Pearson GJ. Aspects of the use and abuse of aesthetic restoratives: 1. Composite materials. *Dent Update* 1990;17:103-108.
41. Jain P, Pershing A. Depth of cure with high-intensity and ramped resin-based composite curing lights. *J Am Dent Assoc* 2003;134:1215-1223.
42. Ernst CP, Brand N, Frommator U, Rippin G, Willershausen B. Reduction of polymerization shrinkage stress and marginal microleakage using soft-start polymerization. *J Esthet Restor Dent* 2003;15:93-103.
43. Pradelle-Plasse N, Besnault C, Souad N, Colon P. Influence of new light curing units and bonding agents on the microleakage of Class V composite resin restorations. *Am J Dent* 2003;16:409-413.
44. Kanca III J, Suh BI. Pulse activation: reducing resin-based composite contraction stresses at the enamel cavosurface margins. *Am J Dent* 1999;12:107-112.

45. Luo Y, Lo EC, Wei SH, Tay FR. Comparison of pulse activation vs conventional light-curing on marginal adaptation of a compomer conditioned using a total-etch or a self-etch technique. *Dent Mater* 2002;18:36-48.
46. Uno S, Tanaka T, Natsuizaka A, Abo T. Effect of slow curing on cavity wall adaptation using a new intensity changeable light source. *Dent Mater* 2003;19:147-152.
47. Kubo S, Yokota H, Yokota H, Hayashi Y. The effect of light-curing modes on the microleakage of cervical resin composite restorations. *J Dent* 2004;32:247-254.
48. Svizero NR, D'Alpino PH, da Silva e Souza, de Carvalho RM. Liner and light exposure: Effect on in-vitro class V microleakage. *Oper Dent* 2005;30:325-330.
49. Christensen RP, Palmer TM, Ploeger BJ, Yost MP. Resin polymerization problems-are they caused by resin curing lights, resin formulation or both. *Compend Contin Educ Dent* 1999;25[suppl]:S42-54.