Effect of LED Curing on Marginal Integrity of an Ormocer–based Sealant

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ABSTRACT

Purpose: The purpose of this study was to investigate the microleakage of a light cured, ormocer-based fissure sealant when photopolymerized with 2 different light emitting diode (**LED**) curing units and a conventional quartz-tungsten halogen (**QTH**) light-curing unit.
Methods: Thirty freshly extracted, unerupted human third molars from 9 adolescent were randomly assigned into 3 groups (N=10/group). Pits and fissures were acid etched for 30 seconds, rinsed for 15 seconds with an air-water spray, and air-dried. An ormocer-based fissure sealant material (Admira Seal) was applied to all fissures. In group 1, the sealant was photopolymerized with a Smart Light LED curing unit (Dentsply) for 10 seconds. Another LED curing unit (Elipar II) and a conventional QTH curing unit (Hilux) were used in groups 2 and 3 for 10 and 30 seconds, respectively. Specimens were immersed in 0.5% basic fuchsin for 24 hours, sectioned and examined under a stereomicroscope, and scored for marginal microleakage.
Results: Statistical analysis of microleakage scores revealed no significant difference among the groups tested (*P*>.05, Kruskal-Wallis test).
Conclusion: The tested LED curing units may provide reduction in total application time without comprising marginal integrity of the ormocer-based sealant.
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Preventive measures, including improved oral hygiene and use of fluoride agents, have proven effective in reducing the prevalence of smooth surface caries.[1] Consequently, a decline in dental caries has been reported over the last decades.[2,3] This decline, however, is not uniform for all tooth surfaces.[4,5] The high caries susceptibility of pit and fissure surfaces of posterior teeth has been recognized for many years.[6] The complex morphology of the occlusal surface hinders the mechanical removal of the bacterial plaque and reduces the effects of preventive measures.[7] Studies have shown that pit and fissure caries account for 85% to 88% of childhood caries in populations with an overall low caries risk.[8,9]

Introduction of the acid-etch technique and the development of resin materials have made fissure sealing an effective method for the prevention of occlusal caries.[10] The dental literature contains a plethora of evidence regarding the effectiveness of fissure sealants against pit and fissure caries when the sealant is retained *in situ* and has remained intact without deterioration or microleakage at the resin/tooth interface.[11,12]

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Basically, commercially available fissure sealant products are classified into 2 broad categories: self-curing materials (chemical cure); and light-curing materials.[13] The early ultraviolet light-initiating systems have been abandoned, but the visible light cure-initiated and self-curing types have been available since 1970. The self-curing sealants have drawbacks, such as short working time and air bubble entrapments upon mixing. On the other hand, with light cured sealants, it is possible to control the working time, the risk of entrapping air bubbles is minimal, and the on-demand polymerization takes a relatively short amount of time.[5,14]

Conventionally, quartz-tungsten–halogen (**QTH**) lights, which have a power density ranging between 600-800 mW/cm^2, have been used to light cure sealants.[13] Recently, a variety of light-curing units (**LCUs**) with much greater power output—such as high intensity QTH, plasma arc units (**PAC**), and light emitting diode devices (**LEDs**)—have been introduced. LED units generate energy within a very narrow spectral range, more closely matching the absorption requirements of camphorquinone than do the more broadly generating units, QTH and PAC.[15] Despite marketing claims of adequate polymerization in as fast as 3 to 5 seconds, PAC units require exposure times similar to conventional QTH units to provide adequate polymerization and marginal adaptation of fissure sealants.[13,16] By contrast, some high-intensity QTH and LED units have demonstrated a significant reduction in clinical exposure duration without impairing the polymerization rate (conversion values) of fissure sealants.[13] These time-saving approaches could have significant clinical implications, provided that there is no adverse effect on the fissure sealant's marginal integrity.

While one study has been conducted on the effectiveness of LEDs to polymerize sealant materials, there is a scarcity of published data regarding their effects on the marginal integrity of fissure sealants. The aim of the present study was, therefore, to assess the microleakage of a light-cured, ormocer-based fissure sealant when photopolymerized with 2 different LED units and a conventional QTH unit. The null hypothesis was that the tested photopolymerization units had no significant effect on the microleakage of the tested fissure sealant.

METHODS

Caries-free, extracted human maxillary and mandibular third molars were collected from 9 adolescent in oral and maxillofacial surgery clinic in Baskent University Faculty of Dentistry, Ankara, Turkey. The extracted teeth were extracted from healthy children ages 20-25 who were undergoing orthodontic treatment and living in a nonfluoridated area. Organic remnants were removed off of teeth, and the occlusal surfaces were cleaned with a slow speed bristle brush with a continuous irrigation of water coolant. The teeth were then examined under a dissecting microscope to discard those with caries, any visible hypoplasia, extraction damage, or microcracks. Teeth with irregular occlusal morphology were also excluded. Accordingly, 30 teeth were selected and assigned randomly into 1 of 3 experimental groups (N=10):

In group 1 (QTH), pits and fissures were etched with 37% phosphoric acid (Vococid, Voco, Cuxhaven, Germany) for 30 seconds, rinsed with air-water spray for 15 seconds, and air-dried for 10 seconds. An unfilled bonding resin (Admira Bond, Voco, Cuxhaven, Germany) was applied on the fissures according to the manufacturer's instructions and light cured for 20 seconds with a conventional QTH curing unit (Hilux, Benlioglu, Istanbul, Turkey). A radiometer was utilized for detecting the curing unit's performance. Thereafter, an ormocer-based fissure sealant (Admira Seal, Voco, Cuxhaven, Germany) was applied to the fissures and left undisturbed for 20 seconds. Light curing was performed for 30 seconds with the same QTH curing unit.

In group 2 (LED1), the acid-etch and bonding procedures were performed as with group 1, with the exception of 10 seconds of light curing using a SmartLite LED curing unit (Dentsply, Germany). The ormocer-based sealant was applied as with group 1 and light cured with Smartlite for 10 seconds.

In group 3 (LED2), acid-etch and bonding procedures were performed as in groups 1 and 2, with the adhesive resin being light cured for 10 seconds with another LED curing unit (Elipar Free Light 2, 3M ESPE). The ormocer-based sealant was applied as with groups 1 and 2 and light cured with the Elipar curing unit for 10 seconds.

Specimens were stored in deionized water at 37°C for 24 hours, after which thermal cycling in deionized water was performed at 5±2°C to 55±2°C for 500 cycles with a dwell time of 30 seconds and a transfer time of 10 seconds. Thereafter, the teeth were kept in distilled water at 37°C for 4 weeks before dye-penetration procedures. The water (pH :7) was changed every week.[17]

Prior to dye penetration, the apices were sealed with sticky wax and the samples were coated with 2 consecutive layers of nail varnish up to 1 mm from the sealant margins. Samples were then immersed in 0.5% basic fuchsin solution (Wako Pure Chemical Industry, Osaka, Japan) for 24 hours. After thoroughly rinsing with distilled water, the samples were air-dried and embedded in epoxy resin (Struers, Copenhagen, Denmark). Five parallel longitudinal sections were made through the occlusal surfaces using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, Ill) in the buc-

Table 1. Distribution of Dye Penetration Scores in the Experimental Groups

Light curing unit	Dye penetration score			
	0	1	2	3
QTH (Hilux)	42	5	0	3
LED1 (SmartLite)	28	15	3	4
LED2 (Elipar Freelight 2)	39	8	2	1

colingual direction. One calibrated researcher examined all sections under a stereomicroscope at X16 magnification (Wild Type 308700, Heerbruug, Switzerland). He was blind to the groups.

For each section, the following criteria was used to rate dye penetration scores[18,19]: score 0=no dye penetration; 1=dye penetration restricted to the outer half of the sealant; 2=dye penetration into the inner half of the sealant; and 3=dye penetration into the underlying fissure. The microleakage score of each tooth was obtained by calculating the mean score of 5 slices each.[19] Statistical evaluation of microleakage scores between the test groups was performed using the Kruskal-Wallis test with significance set at P=.05.

RESULTS

A total of 150 sections were evaluated for dye penetration scores. Microleakage was observed in all groups. The extent of dye penetration for each experimental group is presented in Table 1. Overall, light curing with the Smartlite LED unit and the Hilux QTH unit displayed the highest and lowest microleakage scores, respectively. The Kruskal-Wallis test, however, revealed no significant differences between the experimental groups (P=.07). Representative micrographs of each group are presented in Figures 1, 2, and 3.

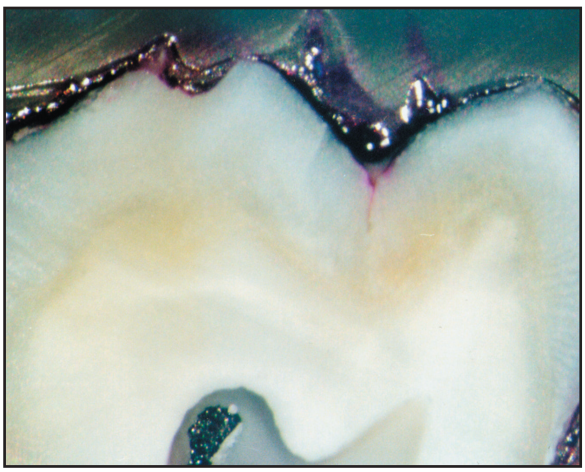

Figure 1. Microleakage (score=3) represented by section 2 in group 1 (QTH curing, 16X magnification).

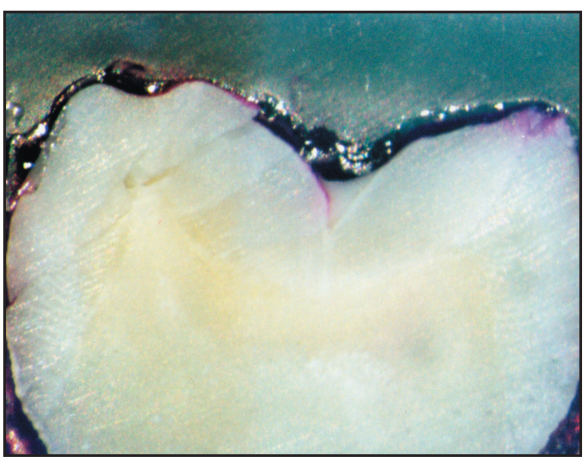

Figure 2. Microleakage (score=3) associated with LED–cured sealant (Smartlite, group 2, 16X magnification).

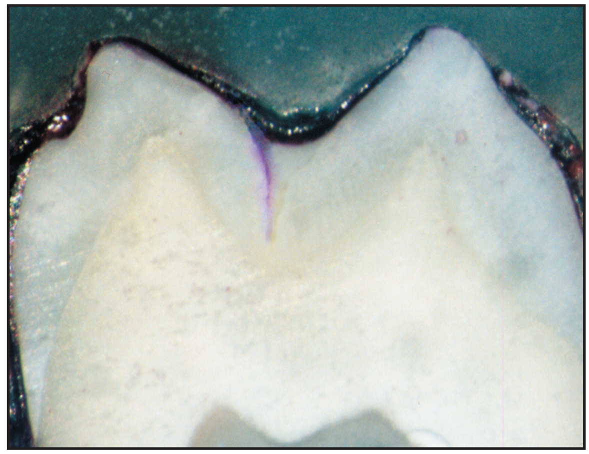

Figure 3. Micrograph depicting severe microleakage (score=3) in group 3 (Elipar Freelight 2, 16X magnification).

DISCUSSION

As documented by numerous clinical studies, the use of pit and fissure sealants is among the primary prevention strategies of the American Academy of Pediatric Dentistry due to their significant benefit in the reduction of caries risk.[20,21] Nevertheless, it is disappointing that, despite their proven benefits, pit and fissure sealants are being underused and offered only to a small percentage of at-risk populations due to concerns of cost-effectiveness.[22,23] While this fact might imply that there may be little hope for improving sealant adhesion further, other considerations such as minimizing the time for sealant application may help reduce the real cost of fissure sealants.[24] To achieve this goal without adversely affecting retention, studies have been conducted to evaluate the effect of reduced etching time on sealant quality.[24-26] Another method is the reduction in overall application time, which can be achieved by shorter polymerization periods. Additional advantages of shorter yet effective exposure time would be the reduced risk of contamination and the time saved when treating children with behavior or compliance problems.[27]

In the present study, the light-curing units failed to demonstrate any significant effect on the microleakage of the tested ormocer-based sealant; necessitating acceptance of the null hypothesis. Although not significant, the number of specimens with a score of 0 was less in the SmartLite group when compared with the QTH and Elipar FreeLight 2 groups. The samples cured with Elipar Free Light 2 and QTH unit were quite similar regarding the number of specimens with score of 0. This difference may be explained by their different wavelengths and power output and differences in the efficiency of the optical delivery systems (ie, light guiding tips).[28] Information provided by the manufacturers, the light intensity produced by the Elipar FreeLight 2 unit is 1,000 mW/cm^2,[29] whereas the maximum output of the SmartLite Unit is 950 mW/cm2.[30] Since double-bond conversion correlates with the product of the irradiation period and intensity (ie, total energy applied),[31,32] a lower-intensity LED unit may only be expected to perform better with longer periods of exposure.

The different tip designs of the tested LED units may be considered another factor contributing to the microleakage scores achieved.[33] It has been stated that irradiance of light-curing units is affected by the angular aperture of the light guide.[33] Accordingly, the 2 LED units may have performed differently, although both units have the same tip diameter. Distance, another well-documented factor on the performance of all light-curing units[34] was ruled out as a contributory factor, since irradiation distance was kept standard and minimized during specimen preparation.

The applicability of flowable restorative systems in dentistry has increased mainly due to their beneficial properties such as low modulus of elasticity[35,36] and ease of handling.[37] This allows such materials to be successfully placed in ultraconservative preparations and as fissure sealants. It has been reported that their higher amount of filler particles provides lesser porosity[38] and better wear resistance.[39,40] Filled sealant materials have yielded good shear-bond strength *in vitro*,[41] confirming their clinical retention rates which were found to be similar to that of conventional sealants.[38,42] On the other hand, concern has been raised regarding the penetration of filled sealants into etched enamel to reach the depth of acid etching.[43] For the ormocer-based sealant tested, it is presumable that the manufacturer stipulates application of the adhesive resin prior to the sealant due to the sealant's relatively high viscosity. This may prevent complete penetration into the etched enamel surfaces, rather than providing better adhesion and resistance against microleakage. The same material could, therefore, not be used without adhesive resin to serve as a control group. Further studies utilizing unbonded fissure sealant materials are required to enable cross-comparisons.

Studies conducted on resin-based composite materials have shown that LED units are compliant with the ISO standard 4049 in terms of curing depth.[28,44] This has been claimed, however, to be product-dependent with special regard to older-generation LED units.[45,46] Today, most light-cured dental composites contain camphorquinone as the photoinitiator. The maximum emission spectrum of a LED curing unit is 465 nm, being very close to the absorption of camphorquinone which is maximum at 468 nm.[47] Resin-based composites that contain other photoinitiators (so-called "co-initiators") that absorb light at shorter wavelengths cannot be polymerized with LED curing units.[48] The ormocer-based material tested contains only camphorquinone as a photoinitiator, ruling out the possibility of inadequate polymerization due to the photoinitiator. With only one published study on the polymerization kinetics of a commercially available sealant material,[13] the need for further studies evaluating a wider range of sealant materials cured with LED units is evident.

CONCLUSION

Within the experimental conditions of the present study, photopolymerization of the tested ormocer-based sealant using different light sources did not significantly affect post-cure microleakage values.

REFERENCES

1. Kalsbeek H, Verrips GH. Dental caries prevalence and the use of fluorides in different European countries. J Dent Res 1990;69:728-32.
2. Hicks MJ, Flaitz CM. Epidemiology of dental caries in the pediatric and adolescent population: A review of past and current trends. J Clin Pediatr Dent 1993;18:43-9.
3. Brunelle JA, Carlos JP. Changes in the prevalence of dental caries in US schoolchildren, 1961-1980. J Dent Res 1982;61:21346-51.
4. Ripa LW. The current status of pit and fissure sealants: A review. J Can Dent Assoc 1985;51:367-75, 377-80.
5. Ripa LW. Sealants revisited: An update of the effectiveness of pit and fissure sealants. Caries Res 1993;27:77-82.
6. Simonsen RJ. Retention and effectiveness of a single application of white sealant after 10 years. J Am Dent Assoc 1987;115:31-6.
7. Bohanan HM, Bader JD. Future impact of public health and preventive methods on the incidence of dental decay. J Can Dent Assoc 1984;50:229-33.
8. Brown LJ, Kaste L, Seltwitz RH, Furman L. Dental caries and sealant usage in US children, 1988-1991: Selected findings from the Third National Health and Nutrition Examination Survey. J Am Dent Assoc 1996;127:335-43.
9. Rethman J. Trends in preventive care: Caries risk assessment and indications for sealants. J Am Dent Assoc 2000;131:85-115.
10. Disney JA, Bohannan HM. The role of occlusal sealants in preventive dentistry. Dent Clin North Am 1984;28:21-35.
11. Weintraub J. Pit and fissure sealants in high caries-risk individuals. J Dent Educ 2001;65:1080-94.
12. Simonsen RJ. Retention and effectiveness of dental sealants after 15 years. J Am Dent Assoc 1993;122:34-42.
13. Warnock RD, Rueggerberg FA. Curing kinetics of a photopolymerized dental sealant. Am J Dent 2004;17:457-61.
14. Blankenau RJ, Kelsey WP, Cavel WT, Blankenau P. Wavelength and intensity of seven systems for visible light-curing composite resins: A comparison study. J Am Dental Assoc 1983;106:471-4.
15. Hammesfahr PD, O'Connor MT, Wang X. Light-curing technology: Past, present, future. Compendium 2002;23(suppl 1):18-24.
16. Stavridakis MM, Favez V, Campos EA, Krejci I. Marginal integrity of pit and fissure sealants: Qualitative and quantitative evaluation of the marginal adaptation before and after in vitro thermal and mechanical stressing. Oper Dent 2003;28:403-14.
17. Kitasako Y, Burrow MF, Nikaido T, Tagami J. The influence of storage solution on dentin bond durability of resin cement. J Dent 2000;16:1-6.

18. Ovrebo RC, Radaal M. Microleakage in fissures sealed with resin or glass ionomer cement. Scand J Dent Res 1990;98:66-9.
19. Güngör HC, Turgut MD, Attar N, Altay N. Microleakage evaluation of a flowable polyacid-modified resin composite used as a fissures sealant on air-abraded permanent teeth. Oper Dent 2003;28:269-75.
20. American Academy of Pediatric Dentistry. Guideline on pediatric restorative dentistry. Pediatr Dent 2005; (suppl):106-14.
21. Feigal RJ. The use of fissure sealants. Pediatr Dent 2002; 24:374.
22. Cherry-Peppers G, Gift HC, Brunelle JA, Snowden JB. Sealant use and dental utilization in US children. J Dent Child 1995;62:250-5.
23. Gonzalez CD, Fraizer PJ, LeMay W, Stenger JP, Pruhs RJ. Sealant status and factors associated with sealant presence among children in Milwaukee, Wis. J Dent Child 1995;62:335-41.
24. Main C, Thomson JL, Cummings A, Field D, Staphan KW, Gillespie D. Surface treatment studies aimed at streamlining fissure sealant application. J Oral Rehabil 1983;10:307-17.
25. Cuba CJ, Cochran MA, Swartz ML. The effect of varied etching time and etching solution viscosity on bond strength and enamel morphology. Oper Dent 1994;19:146-53.
26. Tandon ST, Kumari R, Udupa S. The effect of etch-time on the bond strength of a sealant and on the etch pattern in primary and permanent enamel: An evaluation. J Dent Child 1989;56:186-90.
27. Kim JW, Jang KT, Lee SH, Kim CC, Hahn SH, Garcia-Godoy F. Effect of curing time on the microhardness and wear of pit and fissure sealants. Dent Mater 2002;18:120-7.
28. Tsai PCL, Meyers IA, Walsh LJ. Depth of cure and surface microhardness of composite resin cured with blue LED curing lights. Dent Mater 2004;20:364-9.
29. Elipar FreeLight 2 [technical product profile]. St. Paul, Minn.,USA 3M ESPE; 2004:30.
30. SmartLite PS Curing Light [product catalog]. New York, USA. Dentsply; 2004:1.
31. Miyazaki M, Oshida Y, Moore BK. Onose H. Effect of light exposure on fracture toughness and flexural strength of light cured composites. Dent Mater 1996; 12:328-32.
32. Abate PF, Zahra VN, Macchi RL. Effect of photopolymerization variables on composite hardness. J Prosthet Dent 2001;86:632-5.
33. Nomoto R, McCabe JF, Hirano S. Effect of aperture size on irradiance of LED curing units. Dent Mater 2004;20:687-92.
34. De Creane GP, Martens LC, Dermaut LR, Surmont PA. A clinical evaluation of a light cured tissue sealant (Helioseal). J Dent Child 1989;56:97-102.
35. Prager MC. Using flowable composites in direct posterior restorations. Dent Today 1997;16:62-9.
36. Labella R, Lambrechts P, Van Meerbeek B, Vanherle G. Polymerization shrinkage and elasticity of flowable composites and filled adhesives. Dent Mater 1999;15:128-37.
37. Murchison DF, Cahrlton DG, Moore WS. Comparative radioopacity of flowable resin composites. Quintessence Int 1999;30:179-84.
38. Garcia-Godoy F, Carranza F. Clinical evaluation of flowable resin used as a fissure sealant. J Dent Res 2001;80:200 (abstract 1319).
39. Ciamponi AL. *Assessment "In Vitro" of the Microleakage in Enamel/Sealant Interface: Influence of Contamination, Using the Primer, and Different Sealants* [thesis]. Sao Paulo, Brazil: School of Dentistry, University of Sao Paulo; 1995.
40. Czerner A, Weller M, Lohbauer U, Ebert J, Frankenberger R, Kramer N. Wear resistance of flowable resin composites as pit and fissure sealants. J Dent Res 2000;79:279 (abstract 1087).
41. Eminkahyagil N, Gokalp S, Baseren M, Korkmaz Y, Karabulut E. Sealant and composite bond strength to enamel with antibacterial/self-etching adhesives. Int J Pediatr Dent 2005;15:274-81.
42. Autido-Gold JT. Clinical evaluation of a medium-filled flowable restorative material as a pit and fissure sealant. Oper Dent 2002;27:325-9.
43. Irinoda Y, Matsumura Y, Kito H, et al. Effect of sealant viscosity on the penetration of resin into etched human enamel. Oper Dent 2000;25:274-82.
44. Jandt KD, Mills RW, Blackwell GB, Ashworth SH. Department of cure and compressive strength of dental composites cured with blue light emitting diodes (LEDs). Dent Mater 2000;16:41-7.
45. PriceRBT, Ehrnford L, Andreou P, Felix CA. Comparison of Quartz-tungsten-halogen, light-emitting diode, and plasma arc curing lights. J Adhes Dent 2003;5: 193-207.
46. Besnault C, Paradelle N, Picard B, Colon P. Plasse effect of a LED versus halogen light cure polymerization on the curing characteristics of three composite resins. J Dent Med 2003;16:323-8.
47. Neumann MG, Miranda WG Jr, Schmitt CC, Rueggeberg FA, Correa IC. Molar extinction coefficients and the photon absorption efficiency of dental photoinitiators and light-curing units. J Dent Res 2005; 33:525-32.
48. Uhl A, Sigusch BW, Jandt KD. Second generation LEDs for the polymerization of oral biomaterials. Dent Mater 2004;20:80-7.