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Effect of light exposure time on the depth of curing in various composite resin systems

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Abstract

Hardness of both the top and bottom surfaces were determined for five different composite resins varying the thickness and exposure time to light. Specimens of the five different composite resins (Durafill®, Visio-Dispers®, Prisma-Fil®, Estilux®, and Visio-Fil®) were prepared in brass rings with thicknesses of 1.5, 2.0, and 2.5 mm. A Barcol Hardness Number (BHN) of the top or bottom surfaces of the specimens was obtained immediately after exposure to light (20, 40, 60 sec). The mean and standard deviations of the individual readings were calculated. For each thickness, the hardness of the top surface increased with time. Although this was also true for the bottom surface, the difference in the hardness of the top and bottom was increased with the increase of thickness. The maximum difference always occurred with the shortest time intervals for light exposure. Thus, as the thickness of composite restoration increases, longer exposure time is required. For all the materials, the hardness number of composite resin after 20- and 40-sec exposure to light were always significantly lower than the 60-sec exposure. At BHN 50, it was difficult to mar the surface of composite resin. Thus, BHN 55 was selected as a conservative baseline for the minimal hardness of the surface.

Visible light-curing composite resins are being used in dentistry for a variety of restorative and preventive procedures. These materials have the following advantages over the self-curing composite resins: (1) the single paste formulation requires no mixing — resulting in less porosity, (2) they have adequate working time, (3) they cure faster, and (4) they have better color stability since there is no amine accelerator present. Visible light-curing composite resins also have certain advantages that the ultraviolet light-curing composite resins do not possess: deeper curing depth, and effective light penetration through tooth structure. There are only a few disadvantages found in the visible light-curing composite resins that chemical-curing composite resins do not have: (1) the technique is sensitive [polymerization can begin under an operating light], (2) additional equipment is necessary, and (3) there is limited cure depth.

The advantages listed for these systems are dependent on inherent properties in the composite resins. In composite resins with chemically induced polymerization, the reaction takes place almost uniformly throughout the bulk of material. However, it has been found that the degree of polymerization of visible light-curing composite resin is generally dependent on the thickness of the restoration.[1,2]

Incomplete polymerization in the inner part of the restoration may lead to retention failures and adversely affect the pulp tissue.[3,4]

To determine the cure depth, the following variables were studied: (1) time of light exposure, (2) resin shade, (3) distance of the light from the resin surface, and (4) postexposure time. Ruyter and Oysaed[5] showed that there is an increase in maximal curing depth with increasing time.

Leung et al.[6] investigated the polymerization of visible light-curing composite resins after a short exposure to light (10-60 sec). They measured hardness immediately following cessation of exposure to the light source, and at a later time. They found that the extent of polymerization at the top and bottom surfaces increased with postirradiation time. The general trend for the hardness of the surface after a specific exposure time followed the typical saturation curve; there was a slow increase in hardness values for the first 20 min after exposure, followed by gentle leveling off up to 60 min, and then slightly higher hardness values at one and seven days.

The size and amount of the inorganic particles are also important variables. Ruyter and Oysaed[5] also concluded from their study that greater curing depths were attained with materials containing larger inorganic fillers than those containing smaller inorganic fillers.

In clinical situations, it would be an advantage to know the hardness of composite restorations immediately after insertion since patients may begin mastication immediately following their dental appointments.

The purpose of this study was to determine the hardness of top and bottom surfaces among five different composite resins of various thicknesses immediately after being cured by the same visible light device as a function of the light exposure time.

Method and Materials

Method

Specimens of the five composite resins were prepared in 5 mm brass rings with thicknesses of 1.5, 2.0, and 2.5 mm. The molds were placed on a dark blue plastic plate with a smooth surface and were filled to the top with resin.

The resin then was covered with a mylar matrix strip and a glass plate was placed over the strip. Finger pressure was exerted on the plate to extrude any excess resin. Prior to light activation, the top glass plate was removed, the tip of the Elipar light was then placed in direct contact with the matrix strip, and the light was activated for 20, 40, or 60 sec. Immediately after exposure by the light, the matrix strip and the plastic plate on the bottom of the mold were removed. A Barcol Hardness Number (BHN) of the top or bottom surfaces of the specimens was obtained with a Barber-Colman hardness tester.[d]

Only one hardness reading on each specimen was obtained immediately after curing to minimize time variance in curing rates. This reading was taken at the center area of the top or the bottom of each composite resin specimen.

Four-hundred-fifty specimens were prepared with five different composite resins, and three different brass ring thicknesses (1.5, 2.0, and 2.5 mm). This enabled the testing of 10 specimens for each of the variables. The variables tested were three exposure times (20, 40, 60 sec), and thicknesses of various composite resins. Each hardness test then was recorded.

Materials

Five different composite resins (Durafill[a], Estilux[a], Visio-Dispers,[b] Visio-Fil[b] and Prisma-Fil[c]) were tested. Durafill and Visio-Dispers were selected as representatives of microfilled composite resins (Durafill as an example of microfilled composite resin with splintered prepolymerized heterogeneous particles and Visio-Dispers as an example of heterogeneous microfilled composite resin with agglomerated microfiller

[a] Kulzer and Co., Laguna Hills, CA.
[b] Espe-Premier Sales Corp., Morristown, PA.
[c] L.D. Caulk Co., Milford, DE.
[d] Model GYZJ 934-1 — Barber-Colman Co., Loves Park, IL.

Table 1. Barcol Hardness

mm	Sec	20″ mean	20″ SD	Δ	40″ mean	40″ SD	Δ	60″ mean	60″ SD	Δ
A	*Durafill*									
1.5	Top	40	1.9	8	45	1.5	5	45	1.5	2
	Bottom	32	1.1		40	2.5		43	1.5	
2.0	Top	40	1.1	30	45	0.7	14	45	1.5	6
	Bottom	10	1.8		31	1.9		39	1.1	
2.5	Top	37	0.9	37	43	1.1	24	45	1.3	16
	Bottom	0	0		19	2.8		29	2.9	
B	*Visio-Dispers*									
1.5	Top	52	0.9	22	60	0.4	11	61	1.1	7
	Bottom	30	3.0		49	1.6		54	1.5	
2.0	Top	51	1.1	36	60	1.1	19	62	1.3	12
	Bottom	15	2.1		41	1.1		50	1.8	
2.5	Top	52	1.0	52	61	1.1	37	61	1.5	33
	Bottom	0	0		24	30		28	1.4	
C	*Prisma-Fil*									
1.5	Top	59	1.9	7	60	0.7	5	61	1.1	2
	Bottom	52	1.6		55	1.9		59	0.7	
2.0	Top	59	1.0	18	60	0.7	8	61	1.1	5
	Bottom	41	1.2		52	1.1		57	1.2	
2.5	Top	57	0.7	39	60	1.1	20	61	0.7	12
	Bottom	18	2.4		40	2.3		49	0.7	
D	*Estilux*									
1.5	Top	49	1.8	8	56	1.8	4	57	0.7	1
	Bottom	41	2.3		52	1.1		56	1.1	
2.0	Top	49	19	25	54	0.8	6	54	1.1	4
	Bottom	24	2.6		48	1.6		50	0.7	
2.5	Top	42	1.1	42	53	1.3	15	57	0.9	9
	Bottom	0	0		38	32		48	1.1	
E	*Visio-Fil*									
1.5	Top	63	0.7	10	70	0.8	3	70	0.7	0
	Bottom	53	1.5		67	1.6		70	0.7	
2.0	Top	63	1.5	18	69	2.1	7	70	1.6	2
	Bottom	45	2.9		62	1.9		68	0.9	
2.5	Top	63	0.7	33	69	1.1	13	70	1.1	4
	Bottom	30	3.8		56	2.8		66	0.4	

Δ = Hardness of top minus hardness of bottom.

Table 2. Rank of Barcol Hardness Number at 60 Sec

A *1.5 mm Thickness*

Rank	*Product*	*Hardness* Top (x ± 2SEM)	Bottom (x ± 2SEM)	t-test
1	Visio-Fil	70 ± 0.7	70 ± 0.7	0 N.S.
2	Prisma-Fil	61 ± 1.1	59 ± 0.7	1.54 N.S.
3	Visio-Dispers	61 ± 1.1	54 ± 1.5	3.76 $p < 0.01$
4	Estilux	57 ± 0.7	56 ± 1.1	0.77 N.S.
5	Durafill	45 ± 1.5	43 ± 1.6	0.91 N.S.

B *2.0 mm Thickness*

Rank	*Product*	*Hardness* Top (x ± 2SEM)	Bottom (x ± 2SEM)	*t-test*
1	Visio-Fil	70 ± 1.6	68 ± 0.4	1.21 N.S.
2	Prisma-Fil	62 ± 0.7	57 ± 1.2	3.60 $p < 0.01$
3	Visio-Dispers	62 ± 1.3	50 ± 1.8	5.41 $p < 0.001$
4	Estilux	54 ± 1.1	50 ± 0.7	3.08 $p < 0.05$
5	Durafill	45 ± 1.5	39 ± 1.1	3.23 $p < 0.05$

C *2.5 mm Thickness*

Rank	*Product*	*Hardness* Top (x ± 2SEM)	Bottom (x ± 2SEM)	t-test
1	Visio-Fil	70 ± 1.1	66 ± 0.4	3.42 $p < 0.01$
2	Prisma-Fil	61 ± 0.7	49 ± 0.7	12.12 $p < 0.001$
3	Visio-Dispers	61 ± 1.5	28 ± 1.4	16.10 $p < 0.001$
4	Estilux	57 ± 0.9	48 ± 1.1	6.34 $p < 0.001$
5	Durafill	45 ± 1.3	29 ± 2.4	5.86 $p < 0.001$

complexes). Prisma-Fil, Estilux, and Visio-Fil were selected as representatives of traditional composite resins as defined by Lutz and Phillips[7] (large inorganic fillers).

The most widely used shades of composite resins for permanent tooth restoration were tested in this study.

The visible light source, Elipar light,[b] was used to cure the five different composite resins.

Results

The mean and standard deviations of the individual readings were calculated and are presented in Table 1. The delta (δ) value in the table represents the mean difference between the hardness of the top and bottom surfaces.

For each thickness, the hardness of the top and bottom surface increased with time. This is also true for the bottom surface. The difference in the hardness of the top and bottom increased with the increase in thickness. The maximum difference always occurred with the shortest time interval for light exposure. Thus, with increased thickness and shorter time exposure to light, the hardness of the bottom surface decreased.

Discussion

Restoration hardness is one of the most important features to determine the ultimate prognosis of the dental treatment.[5,8] Hardness of composite resins cured by visible light are found to be influenced by light exposure time.[1,2,5,6,9] If composite resin does not cure well, it might encourage leakage of irritants into the pulp,[8] retention failures due to weakness of material,[5] inability to obtain a smooth surface after polishing, or poor resistance to degradation in the oral environment (abrasive wear, mastication forces, oral fluids, or food).

During the course of the preliminary investigation to evaluate the usefulness of the brass rings as a container for the composite resins, it was found that when the BHN was greater than 50, it was difficult to penetrate or scratch the surface of composite resins. Because this was observed for all the cured resins at a BHN of 50 or greater, BHN 55 was selected as a conservative baseline for the minimal hardness acceptable in test specimens.

Table 1 shows that as the thickness of composite restoration increases, longer exposure times are required.

In all of the materials presented in Table 1, the BHN of composite resin after 20- and 40-sec exposure to light was always significantly lower ($p < 0.05$) than the 60-sec exposure. Because the 60-sec exposures gave the best overall results, this time interval was further analyzed (Table 2).

Table 2 ranks the composite resins by BHN after a 60-sec exposure to light.

In Table 2 (A), the cured resins are ranked by hardness at a 1.5 mm thickness. In this series Visio-Fil, Prisma-Fil, and Estilux had acceptable hardness for restoration. On the other hand, Durafill and Visio-Dispers had a softer bottom surface (BHN < 55). There was a significant difference between top and bottom hardness for Visio-Dispers. Thus, at a thickness of 1.5 mm and a 60-sec light exposure, Visio-Fil, Prisma-Fil, and Estilux showed the greatest hardness at the top and bottom surfaces.

In Table 2 (B), the cured resins were ranked by hardness at a 2.0 mm thickness. In this series, Visio-Fil and Prisma-Fil had acceptable hardness for a restoration. Visio-Dispers, Estilux, and Durafill had soft bottom surfaces (BHN < 55), and there were significant differences between top and bottom hardness for all three. Thus, at a thickness of 2.0 mm and 60-sec light exposure, Visio-Fil and Prisma-Fil showed the greatest hardness at the top and bottom surfaces.

In Table 2 (C), the cured resins were ranked by hardness at a 2.5 mm thickness. In this series, Visio-Fil had acceptable hardness for a restoration. Prisma-Fil, Visio-Dispers, Estilux, and Durafill had soft bottom surfaces (BHN < 55) and there were significant differences between top and bottom hardnesses. Thus, at a thickness of 2.5 mm and 60-sec light exposure, Visio-Fil showed the greatest hardness at the top and bottom surfaces. The results from this model system can be extended to certain clinical situations. For example, these findings might affect treatment of patients who clench, gnash and/or brux their teeth.

Conclusions

1. As the thickness of a composite restoration increases, longer light exposure times will be required.
2. Light exposures of 20 or 40 sec are too short to attain acceptable hardness of composite resin for restorations of varying thicknesses.
3. A 60-sec light exposure gave the following results.
   a. At a 1.5 mm thickness Visio-Fil, Prisma-Fil, and Estilux had an acceptable hardness.
   b. At a 2.0 mm thickness Visio-Fil and Prisma-Fil had an acceptable hardness.
   c. At a 2.5 mm thickness only Visio-Fil had an acceptable hardness.

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1. Cook WD: Factors affecting the depth of cure of UV-polymerized composites. J Dent Res 59:800–808, 1980.
2. Salako NO, Cruickshanks-Boyd DW: Curing depths of materials polymerized by ultraviolet light. Br Dent J 146:375–79, 1979.
3. Buonocore MG, Davila J: Restoration of fractured anterior teeth with ultraviolet-light polymerized bonding materials: a new technique. JADA 86:1349–54, 1973.
4. Lee HL, Orlowski JA, Rogers BJ: A comparison of ultraviolet-curing and self-curing polymers in preventive, restorative, and orthodontic dentistry. Int Dent J 26:134–51, 1976.
5. Ruyter IE, Oysaed H: Conversion in different depths of ultraviolet- and visible light-activated composite materials. Acta Odontol Scand 40:179–92, 1982.
6. Leung RL, Fan PL, Johnston WM: Postirradiation polymerization of visible light-activated composite resin. J Dent Res 62:363–65, 1983.
7. Lutz F, Phillips RW: A classification and evaluation of composite resin systems. J Prosthet Dent 50:480–88, 1983.
8. Heys RJ: Biologic considerations of composite resins. Dent Clin North Am 25:257–70, 1981.
9. Swartz MJ, Phillips RW, Rhodes B: Visible light-activated resins: depth of cure. JADA 106:634–37, 1983.

Quotable quote: microwave ovens, infants and wrists

The safety of microwave ovens is operator dependent. Heating a bottle of infant formula in the microwave oven is popular and should be simple, but it is potentially treacherous when undertaken by the uninformed. Although several variables contribute to the overheating of infant formula in the microwave oven, the two most important appear to be the extreme rapidity of heating small volumes of formula and the temperature differential between the surface of the bottle and the inner liquid. The heating characteristics of the microwave oven are very much what would be predicted, but the rapidity with which liquids in infant bottles is heated is far greater than might be expected. The best "cure" for accidental injury is prevention. The axiom that infant formula should be pretested on one's wrist before feeding to the baby is ancient and is especially sound advice for the microwave generation.

Sando W, Gallaher K, Rodgers B: Risk factors for microwave scald injuries in infants. J Pediatr December, 1984.