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Curing Composite Resin Through a Clear Polyvinyl Siloxane Matrix and its Effect on Microhardness

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ABSTRACT

Objectives: To evaluate the effect of curing composite resin through a clear polyvinyl siloxane (PVS) matrix system with a microhardness test.

Methods: 7 groups with 10 samples in each group and cured at different distances: 0mm, 4mm no PVS, 4 mm PVS, 6mm no PVS, 6mm PVS, 8mm no PVS, 8mm PVS. Knoop Microhardness Test performed at 4 sites on the top and bottom surfaces of each sample.

Results: All groups had a bottom/top ratio over 0.80; however, the top side was significantly harder than the bottom (all $P<0.05$). The highest KHN Hardness values were found for the 0mm group (44.0, SD = 6.5) and the 4mm no PVS group (42.2, SD=4.5). Groups without PVS are harder than groups with PVS. The top surface is harder than the bottom surface in each group, but the bottom to top ratio does not appear to be affected by PVS.

Significance: Clear PVS matrices cause a significant reduction in microhardness of the composite resin, especially when the curing light is 6mm from the restoration. If clear PVS matrix systems are used the restoration should be cured again after removing the matrix.

Introduction

Free handed composite resin restorations lack exact reproduction of occlusal anatomy in posterior teeth and are difficult to create positive esthetic results in the anterior teeth. A less common technique involves using a clear matrix to achieve exact replication of previous anatomy or anatomy created in a wax up with a smooth surface finish. However, using a curing light to achieve polymerization through a clear matrix may or may not be adequate. Inadequate polymerization can lead to early failure of the composite resin restoration.

History

Two case studies used composite resins with a clear matrix technique to treat patients with amelogenesis imperfecta. Bogosavljevic, 2016, used a transparent splint plate. The composite was inserted into the matrix and pressed onto the tooth slowly to allow excess material to be expressed out the sides. Excess was removed, and the restoration was light cured through the matrix for 20 sec according to manufacturer recommendations. There was a final light cure for 20 more sec. without the matrix.[1] Ozer, 2010, created an essix retainer based on a wax up with vent holes to allow the excess composite to escape. The restorations were light cured with the matrix on and then again after it was removed. They used an essix retainer "because of unsatisfactory polymerization related to" silicone impressions. They did not discuss studies that have shown this, nor mention clear silicone matrices. Again, this technique cures through the clear matrix, then removes the matrix and cures a second time.[2]

Conte et al, 2008, performed a technique with a clear polyvinyl siloxane matrix for posterior direct composites. The technique consisted of applying the last layer of composite, seating a clear matrix (coated in alcohol) with pressure to squeeze out the excess. The matrix was then removed so the margins could be cleaned. The matrix was replaced and the restoration light cured for 60 seconds followed by an additional 60 seconds to each surface once the matrix was removed "to obtain the highest degree of polymerization conversion in the deepest layers of the composite resin material." They did not, however, have any references to show that polymerization is decreased when curing through a clear matrix nor how much time to light cure after the matrix is removed.[3]

Wada, 2015, performed a study using a clear vinyl polysiloxane matrix for direct full-crown composite restorations in primary teeth. This technique was similar to Conte et al; the composite was place within the clear PVS matrix held in a clear impression tray and pressed onto the tooth. Pressure was applied as the restoration was cured through the matrix for 60 seconds and it was cured for an additional 60 seconds after the matrix was removed.[4]

Purpose

There are studies showing different techniques and uses for a clear matrix while using direct composite resins.[5, 6, 7, 8] While it is common to use silicone impressions there is no evidence to support whether polymerization is adequate through the matrix. One study (Proto, 1998) did not have a second light cure after removing the clear matrix, but this study used clear straws cut to the size of a class V restoration to ensure a thin matrix.[9] There are no studies on adequacy of polymerization through a clear matrix.

If the light cure of a composite resin through a clear matrix is inadequate then this study would support the need to cure restorations again after removing the matrix. It is possible that the cure is adequate through a clear matrix as long as the distance of the light to the composite is not too great. If that is the case this study would also help clinicians know what types or thickness of matrices they could use in the clear matrix technique.

Hypotheses

Light curing of a composite resin through a clear PVS matrix will decrease microhardness.

Light curing a composite resin from a farther distance will decrease hardness.

Materials and Methods

Material	Composition	Fillerload (wt%/vol%)	Manufacturer	Batch Number
Filtek™ Supreme Ultra, Body, A2	*Bisphenol-A-glycidyl methacrylate* (Bis-GMA), *Urethane dimethacrylate* (UDMA), *Triethyleneglycol dimethacrylate* (TEGDMA), *Ethoxylated bisphenol-A dimethacrylate* (Bis-EMA (6)) resins. The fillers are a combination of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles). The Dentin, Enamel and Body (DEB) shades have an average cluster particle size of 0.6 to 10 microns.	78.5/63.3	3M, ESPE, St. Paul, MN, USA	N894460

The Knoop Microhardness test was performed on 70 samples of a nanofill composite resin, Filtek Supreme Ultra.[10, 11] The 70 samples were divided into 7 groups with 10 samples in each. The groups were based on the distance of the curing source to the composite material as well as whether or not there was clear PVS material placed between the light source and the composite. The following groups were made: 0mm, 4mm without PVS, 4mm with PVS, 6mm without PVS, 6mm with PVS, 8mm without PVS, and 8mm with PVS. Shade A2 was selected for all 70 samples. The height of the molds were measured using calipers to ensure each sample was 2mm tall and the diameter was 5mm in each. The top surface of each mold was marked as such. Composite was loaded into each well and a clear mylar strip was used to ensure a smooth surface. Spacers of 4mm, 6mm, and 8mm in height were used to ensure the samples in each group were cured at the proper distance, repeatedly. The spacers are the same diameter as the composite molds. The same spacer was used for every sample in a given group. Clear PVS was then placed within the spacers to repeat the test at the same distances, 4, 6, and 8mm. Samples were cured with the light at the top surface for 20 seconds according to manufacturer's guidelines. A Demi Plus LED dental curing light was used.[12] The light source is 8mm in diameter to ensure complete coverage of the 5mm diameter sample while curing. Curing light was calibrated before use according to manufacturer's guidelines.

All samples were then tested in a Knoop hardness tester (Leco, LM300 At, St. Joseph, MI) under a load of 500 grams for a dwell time of 5 seconds. For each sample, a Knoop hardness number (KHN) was obtained by dividing the applied load (kg) by the projected area of the impression (mm^2). Knoop hardness numbers (KHNs) were collected from four sites on both the top and bottom surfaces. Thus for each sample a total of eight measurements were taken. Knoop hardness tester was calibrated before use according to manufacturer's guidelines.

Statistical Methods

Normality of the KHN sampling distribution was confirmed with the Shapiro-Wilk test and the homogeneity of variance was assessed using Levene's test. Sample hardness measures are reported as means with associated standard deviations. Knoop hardness ratios were obtained by dividing the bottom side hardness of each sample by its respective top side hardness. Adequate curing was defined as a hardness ratio of at least 80% as other studies have done.[13, 14] Statistical analysis was performed using a one-way analysis of variance (ANOVA) with Tukey HSD post-test. Data were analyzed using SPSS version 25 (IBM, Armonk, NY, USA). Statistical significance for all statistical tests was declared at $P < 0.05$.

Results

Examination of the KHNs of the groups revealed a significant effect of depth ($P<0.001$, $\eta^2 =0.36$). The highest KHN Hardness values were found for the 0mm group (44.0, SD = 6.5) and the 4mm no PVS group (42.2, SD=4.5). The 4mm PVS group had a significantly lower

KHN (39.5, SD=4.8) than both its no PVS counterpart as well as the 0mm group (both P<0.01). With a mean KHN of 40.3 (SD=5.4), the 6mm no PVS group was not meaningfully different than either the 4mm groups but was weaker than the 0mm group (P<0.001). In contrast, the 6mm PVS group had a lower KHN (36.1, SD=4.7) than all but the 8mm PVS group (all P<0.001). The 8mm PVS group's mean KHN of 32.3 (SD=3.2) was the lowest among all the groups (all P<0.001). The 8mm no PVS group on the other hand did not significantly differ in hardness compared to either the 4mm PVS or the 6mm PVS groups (both P>0.05). Table 1 and Figure 1 show both the mean KHN for the overall sample as well as by location.

In all groups, the top side was significantly harder than the bottom (all P<0.05). A significant PVS effect was also noted, with an η^2 effect size of .13, P<0.001 (see Figure 1). This indicates that approximately 13% of the variation in hardness is attributable to PVS. Excluding the 0mm control group, the overall KHN for non PVS samples was 40.0 (SD=5.1). In contrast, the PVS samples were significantly weaker with an overall KHN of only 36.0 (SD=5.2).

Despite the overall KHN difference between the groups, no difference was observed with respect to Knoop hardness ratios based on sample depth, P=0.53. All groups regardless of depth or PVS achieved a ratio of at least 90%. Mean hardness ratios for each group are shown in Table 2.

Discussion

Hypothesis accepted since there is a decrease in hardness when composite resin is cured through a clear PVS matrix system. The data suggests that the 0mm and 4mm no PVS groups are both adequately cured based on KHN. Hardness decreases as the curing light distance increases. No PVS groups are harder than their PVS counterparts. The bottom to top ratio remains similar whether or not there is PVS.

A microhardness test inherently has a limitation that it does not have a direct correlation to clinical performance. Another limitation is that the hardness ratio for each group is above the 80% value to show the cure is adequate; although the depth of cure is similar in the top versus the bottom surface it could be completely uncured, simply uniform. Non-digital calipers were used in measuring the well height, so the reduced accuracy could introduce errors in the data, especially with such a small sample size. However, the main trend has been set so the sample size appears to be clinically relevant. A larger sample size would simply fine tune the trends found; a 225 sample size would be needed to achieve $P<0.05$ significance.

Conclusion

The light source should remain as close to the composite resin as possible. Microhardness tests do not have a direct correlation to clinical performance, but it is recommended that a clear matrix only be used for the most superficial 2 mm of the composite resin and that the composite resin should be cured again after removing the matrix.

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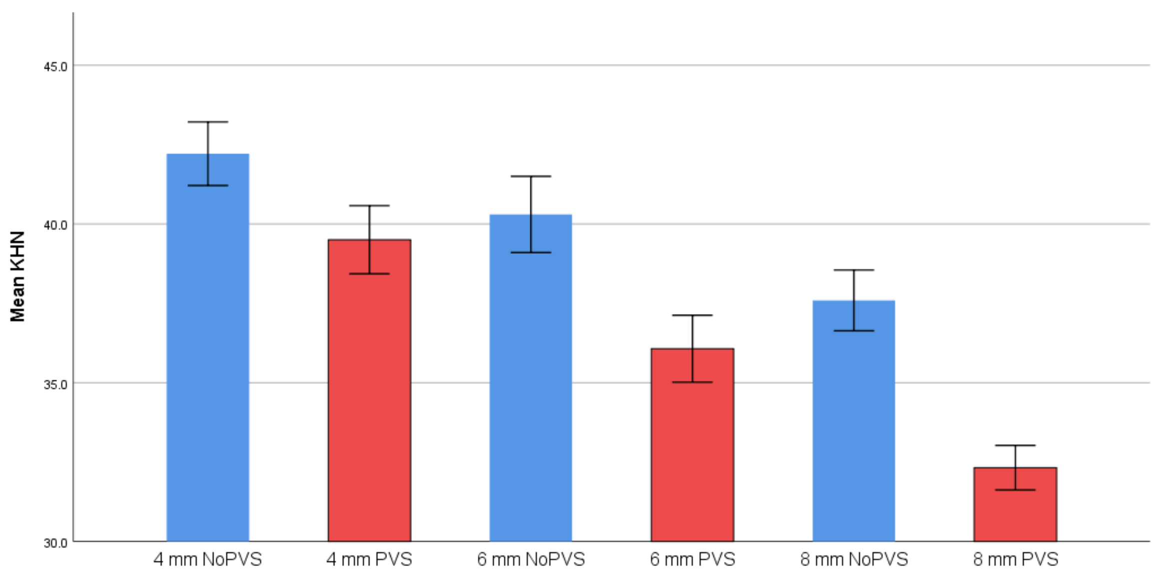
Appendix

Table 1. Knoop Hardness Number by Group and Sample Location

Group	Total		Top		Bottom		P	η^2
	Mean	SD	Mean	SD	Mean	SD		
0mm	44.0	6.5	46.3	6.6	41.8	5.6	<0.01	0.12
4mm no PVS	42.2	4.5	43.5	4.9	41.0	3.8	0.01	0.08
4mm PVS	39.5	4.8	40.9	4.7	38.1	4.6	0.01	0.08
6mm no PVS	40.3	5.4	41.8	5.4	38.8	5.0	0.02	0.07
6mm PVS	36.1	4.7	37.7	4.6	34.4	4.3	<0.01	0.12
8mm no PVS	37.6	4.3	39.2	4.7	36.0	3.1	<0.001	0.15
8mm PVS	32.3	3.2	34.0	2.4	30.7	3.0	<0.001	0.28

Figure 1. Mean Hardness by PVS and Depth*



*error bars represent 95% Confidence Interval

Table 2. Bottom to Top Hardness Ratios by Group

Group	Mean KHN Ratio	SD
0mm	0.91	0.10
4mm no PVS	0.95	0.13
4mm PVS	0.94	0.13
6mm no PVS	0.94	0.13
6mm PVS	0.92	0.14
8mm no PVS	0.92	0.10
8mm PVS	0.90	0.09