Influence of Composite Inlay/Onlay Thickness on Hardening of Dual-cured Resin Cements

• Omar M. El-Mowafy, BDS, PhD, FADM •
• Marcia H. Rubo, DDS, M.Sc. •

Abstract

This investigation evaluated the effect of resin composite inlay/onlay thickness on the hardness of a group of eight dual-cure resin-based cements. Fourteen disc specimens measuring 6 mm in diameter and 2.5 mm thick were prepared from each of eight dual-cure cements: Adherence, Choice, Duolink, Enforce, Lute-It, Nexus, Resinomer and Variolink. Two specimens from each material were directly light-cured while the remainder of the specimens were light-cured through resin composite spacers varying in thickness from 1 mm to 6 mm. Curing through the spacers always resulted in a decrease in the Knoop hardness number. For some cements, hardness values were reduced by 50% or more when the resin composite spacer thickness was 4 mm or greater even when measurements were made one week after dual-curing. Low hardness values indicate the presence of a weak chemical-curing mechanism that may compromise cement quality in areas of the cavity not readily accessible to the curing light.

MeSH Key Words: *dental bonding; inlays; resin cements/chemistry*

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It is important for dual-cured resin cements to be formulated in such a way that they are capable of achieving a sufficient degree of hardening with and without light-curing to ensure adequate polymerization of the cement in areas that are not readily accessible to the curing light. This investigation was conducted as a continuation of previously published work on this subject.[1] The reader is referred to the introduction of this published work for background information about the subject as well as for a comprehensive list of references. This current study evaluated the influence of resin composite inlay/onlay thickness on the hardening of a group of eight dual-cure resin-based cements.

Methods and Materials

Eight dual-cured resin-based cements were examined in this study (Table 1): Adherence, Choice, Duolink, Enforce, Lute-It, Nexus, Resinomer and Variolink. Resinomer is a resin/ionomer cement. Following manufacturers' instructions for proportioning and mixing, two disc specimens measuring 2.5 mm in thickness and 6 mm in diameter were prepared from each cement using metal rings. If a selection of cement shades was available, middle range shades were selected. Each ring was placed on a glass plate lined with a Mylar strip, filled with the mixed cement and covered with another Mylar-strip–lined glass plate. The two glass plates were pressed together with two clamps and were subjected to light from a light-curing unit for 60 seconds from one surface only. Prepared specimens were stored at 37°C until testing.

Using 8-mm diameter Teflon moulds, six resin composite inlay spacers, each 1 mm thick, were prepared from a resin composite inlay material (Herculite XRV, Laboratory Inlay Kit, Kerr Co., Romulus, MI). To simulate clinical conditions, the resin composite spacers were prepared and used in a manner such that the first 2 mm of spacers were made from enamel shade A2 and the remaining 4 spacers from dentin shade A2. Another set of 12 cement specimens was prepared from each cement material in the same manner as above; however, these specimens were subjected to light-curing through the six resin composite spacers. Two specimens were cured through one spacer at a time. Following storage and using a Tukon 300 microhardness tester (Acco Industries Inc., Wilson Instrument Division, Bridgeport, CT) with a Knoop indenter and a 30-g weight, the surface microhardness of each specimen was determined at one hour, one day and one week. Five read-

Table 1 Manufacturers and shades for the eight dual-cure resin-based cements

Material	Manufacturer	Shades used
Adherence M5	Confi-Dental Products Co. Louisville, CO 80027	Light yellow Light grey
Choice	Bisco Inc. Itasca, IL 60143	A1 B1
Duolink	Bisco Inc. Itasca, IL 60143	One shade provided
Enforce	Dentsply/Caulk Milford, DE 19963-0359	A2 C2
Lute-It	Jeneric/Pentron Inc. Wallingford, CT 06492	Light Dark
Nexus	Kerr USA, Orange, CA 92667	Neutral Dark
Resinomer	Bisco Inc. Itasca, IL 60143	One shade provided
Variolink	Vivadent, FL-9494 Schaan, Liechtenstein	Yellow Brown

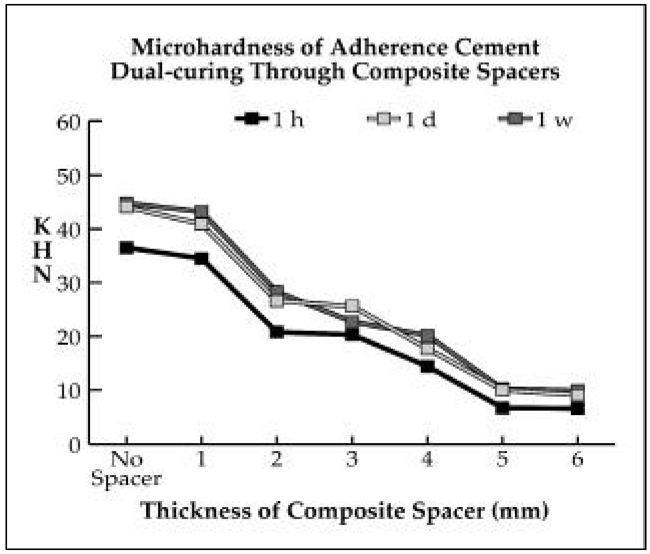

Figure 1: *Mean KHNs for Adherence obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

ings were obtained from each specimen at each test interval. Mean Knoop hardness numbers (KHNs) were calculated for each material at the three test intervals. Data were analyzed statistically using analysis of variance (ANOVA) and Duncan's tests.

A light radiometer (Cure Rite, model # 8000, EFOS Inc., Williamsville, NY) was used to measure the curing light intensity directly and through the six resin composite spacers to determine the degree of light attenuation as it passed through the different spacers.

Results

When specimens were cured through resin composite spacers, there was a tendency for hardness to decrease gradually with increasing thickness of the spacer. The degree of decrease varied among the eight cements (Figs. 1 to 8). ANOVA revealed significant differences in KHNs among the materials ($p < 0.0001$) and between different spacer thicknesses ($p < 0.0001$).

For Adherence, a decrease in the KHN from 47.9 to 9.9 (79.4%) occurred when the spacer thickness was 6 mm compared to curing without a spacer at the one-week test interval (Fig. 1). The mean KHN for Adherence was significantly decreased when spacer thickness was increased to more than 1 mm at the one-week test interval. For Choice, decreases in KHNs ranged from only 17% to 30% when spacer thickness increased from 1 to 6 mm at the three test intervals (Fig. 2). Significant decreases in KHNs of Choice occurred when the spacer thickness was more than 2 mm at the three test intervals. For Duolink, the KHN decreased from 57.1 to 23.5 (58.9%) when spacer thickness was 6 mm compared to curing without a spacer at the one-week test interval (Fig. 3). Significant decreases in KHNs of Duolink occurred when the spacer thickness was 3 mm or more at the three test intervals. In

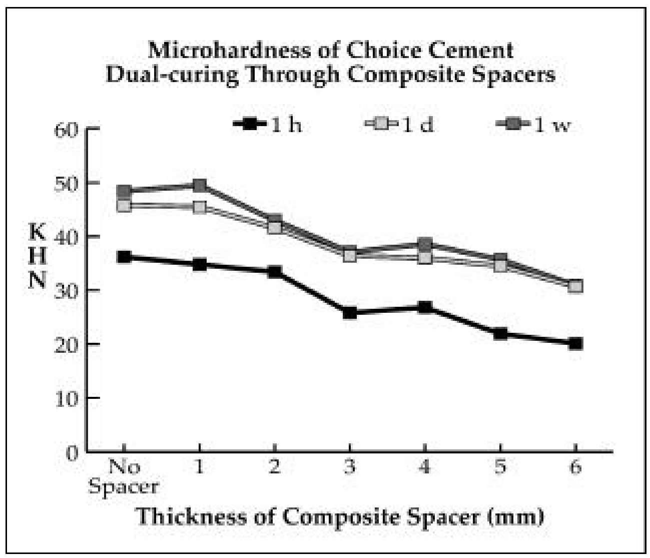

Figure 2: *Mean KHNs for Choice obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

contrast, the KHN of Enforce decreased from 52 to 42.1 (19.1%) when the spacer thickness was 6 mm compared to curing without a spacer at the one-week test interval (Fig. 4). Enforce's KHNs decreased significantly when the spacer thickness was 3 mm or more at the one-week test interval. For Lute-It, decreases in KHNs ranged from 87.5% to 91.4% when spacer thickness was 6 mm compared to curing without a spacer at the three test intervals (Fig. 5). All KHNs obtained for this cement were significantly different at the three test intervals except for the one-day test interval between the 1-mm and 2-mm spacers, where there was no significant difference. In contrast, the KHN of Nexus decreased from 52.1 to 40.8 (21.7%) when spacer thickness was 6 mm compared to curing without spacer at the one-week test interval (Fig. 6).

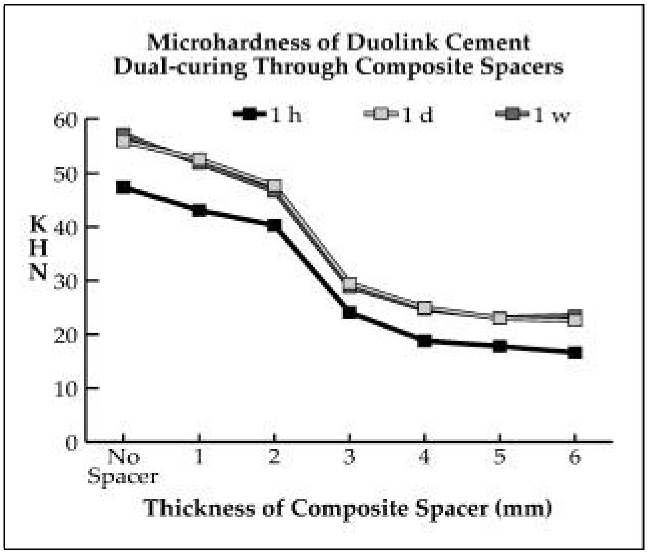

Figure 3: *Mean KHNs for Duolink obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

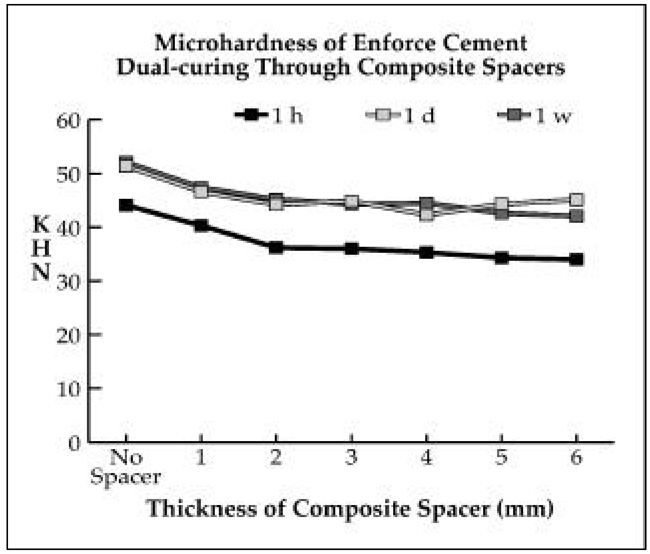

Figure 4: *Mean KHNs for Enforce obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

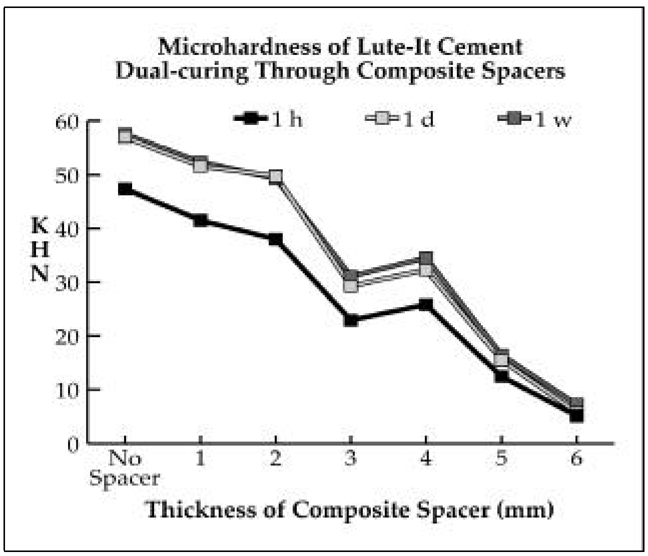

Figure 5: *Mean KHNs for Lute-It obtained with six resin composite spacers at the three test intervals. Mean KHNs obtained without spacer were included for comparison.*

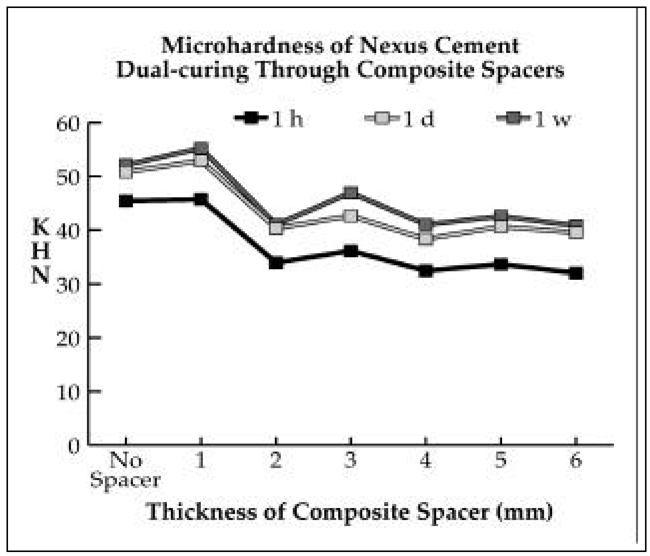

Figure 6: *Mean KHNs for Nexus obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

For Resinomer, mean KHNs decreased from 44.6 to 32.5 (27.2%) when the spacer thickness was 6 mm compared to the value obtained without a spacer (Fig. 7). KHNs for Resinomer decreased significantly when the spacer thickness was more than 1 mm for the one-hour and one-day test intervals. For Variolink, mean KHNs decreased from 53.8 to 14 (74%) when the spacer thickness was 6 mm compared to curing without spacer (Fig. 8). Significant decreases in KHNs of Variolink occurred between all spacer values at the one-day and one-week test intervals.

Figure 9 shows radiometer readings of the light intensity of the light-curing unit when measured with and without spacers. Through only a 1-mm resin composite spacer there was an abrupt decrease in light intensity of about 70%. Beyond 1 mm, light intensity continued to decrease gradually with increasing thickness of the resin composite spacer; the light was totally obstructed at 4 mm.

Discussion

The findings of this investigation agree in general terms with findings reported in other studies.[1-5] However, there was some variability among the cements tested in the amount of hardening achieved through thicker resin composite spacers. For Choice, Enforce, Nexus and Resinomer, sufficient degrees of hardening (67% to 80% of maximum hardness with the lowest KHN not less than 30) were achieved one day after dual-curing through the 6-mm resin composite spacer. These values were slightly further enhanced for some of these

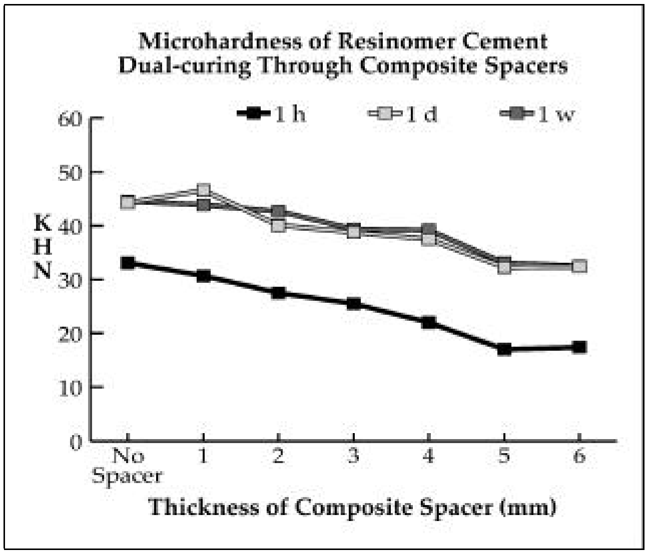

Figure 7: *Mean KHNs for Resinomer obtained with the six resin composite as well as without a spacer at the three test intervals.*

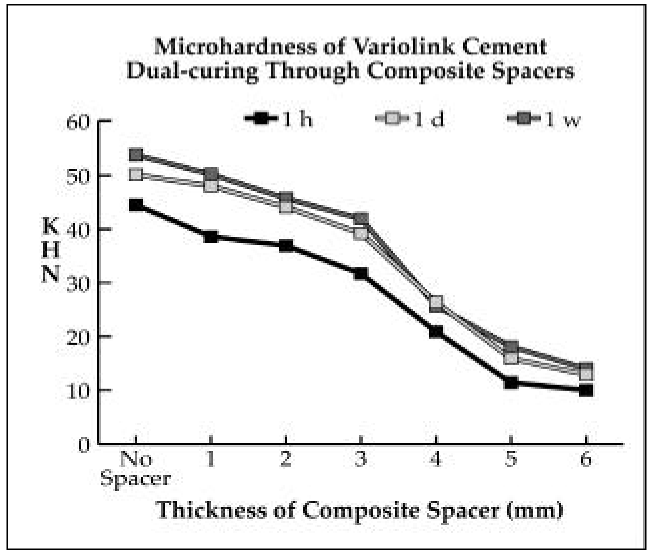

Figure 8: *Mean KHNs for Variolink obtained with the six resin composite spacers as well as without a spacer at the three test intervals.*

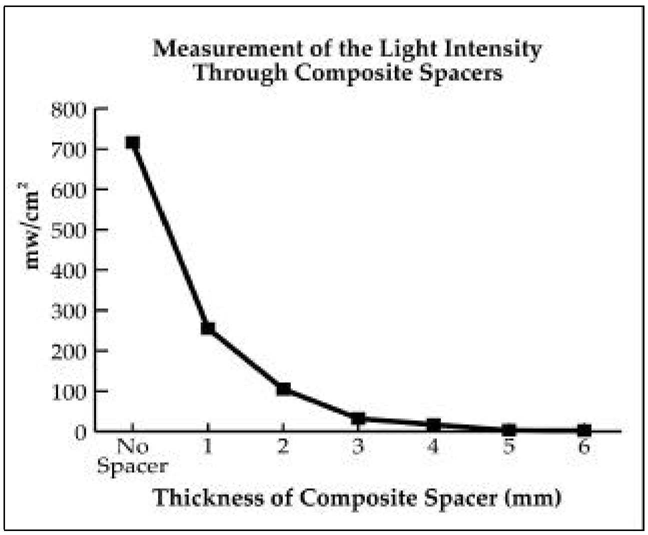

Figure 9: *Curing-light intensity measurements made with and without resin composite spacers. Note the significant drop in light intensity with only 1 mm of resin composite spacer.*

cements one week after dual-curing. In contrast, Adherence, Lute-It and Variolink had a relatively weak chemical-curing component and were able to achieve only 30% or less of maximum hardness when the resin composite spacer thickness was 5 mm, even when measurements were made one week after dual-curing; the highest hardness values remained well below the 20-KHN mark.

Insufficient hardening of cement may lead to post-operative sensitivity due to washout of the unset cement material with subsequent microleakage and recurrent caries. When manufacturing dual-cure resin cements, proportioning of the ingredients should be made such that the materials are capable of achieving a degree of hardening through self-curing similar to or not significantly lower than the one achieved through dual-curing. This measure would ensure adequate polymerization of the cement in areas underneath the inlay/onlay restorations that do not get exposed to the full intensity of the curing light.

For most of the cements examined, there was little difference in KHNs obtained with the 5-mm and 6-mm spacers. This finding is easily explained by the fact that there was total light obstruction beyond 4-mm thickness of the resin composite spacer (Fig. 9). In a clinical situation where an inlay/onlay restoration with a deep gingival seat is being cemented, the operator should apply the curing light from the buccal and lingual aspects of the restoration as well as from the occlusal aspect to maximize light penetration through the inlay material. In the meantime, manufacturers should modify their dual-cured resin cement formulations to optimize the efficiency of the self-curing component. This modification must be done with great care to avoid incorporation of an excessive amount of the chemical-curing component, which can lead to significant shortening of the working time of the cement and subsequent problems in inserting the restoration.

Conclusions

For cements Adherence, Duolink, Lute-It and Variolink, hardness values were reduced by 50% or more when the resin composite inlay/onlay thickness was 4 mm or more, even when measurements were made one week after dual-curing. Enforce exhibited the highest values of hardness, which were best sustained through up to 6-mm of resin composite inlay/onlay material. The Enforce hardness values ranged from 52 KHN without spacer to 46 KHN at 6 mm at the one-day test interval. ◆

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Dr. El-Mowafy is associate professor in the department of restorative dentistry of the faculty of dentistry, University of Toronto.

Dr. Rubo is a former M.Sc. student in the department of restorative dentistry of the faculty of dentistry, University of Toronto.

Correspondence to: Dr. Omar El-Mowafy, Department of Restorative Dentistry, Faculty of Dentistry, University of Toronto, 124 Edward St., Toronto ON M5G 1G6

The authors have no declared financial interest in any company manufacturing the types of products mentioned in this article.

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