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Effect of Composite or Ceramic Thickness on the Polymerization Hardness of 5 Different Dual-Cured Resin Luting Cements

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Research Article

History

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ABSTRACT

Objectives: The aim of the present study was to evaluate the influence of ceramic and composite thickness on polymerization hardness of five different dual-cure resin cements.
***Materials and Methods**:* A total of 100 disc-shaped spacer, 10-mm in diameter and five varying thicknesses (1.0mm, 2.0mm, 3.0mm, 4.0mm, 5.0mm) were fabricated from ceramic and composite materials. Dual-cure resin cement specimens with 8-mm diameter were prepared using metal brass mold and activated by light beneath the composite and ceramic disc shaped spacers. A total of 100 specimens of five different dual-cure resins (RelyX, Variolink DC, NX3, Calibra Universal, Panavia F2.0) were prepared. Knoop hardness of each dual-cure resin cement was measured at five different point using a microhardness device with a 500 gm load, after 1 hr, 1 day, and 1 week polymerization. All data were statistically evaluated using one-way ANOVA.
Results: Multivariate analysis of variance revealed significant differences in hardness of specimens dual-cured under composite resin or ceramic spacers and different time intervals. Specimens cured through composite resin spacers showed less hardness values than ceramic spacers, with increasing thickness of the spacer. Also increasing the thickness of the composite or ceramic spacers produced a statistically significant decrease in microhardness of the dual-cure cements. Hardness values significantly reduced when composite spacers were thicker than 2 mm and ceramic spacers thicker than 3 mm.
***Conclusions**:.* Dual-cured resin cements are needed to be improved to achieve sufficient degree of hardening under composite and ceramic restorations. Different commercially available brands have different polymerization properties.
Key words: Composite Inlay, Ceramic Inlay, Dual-Cure Resin Luting Cement, Microhardness.

Kompozit veya Seramik Kalınlığının 5 Farklı Dual-Cure Resin Yapıştırıcı Simanın Polimerizasyon Sertliği Üzerine Etkisi

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ÖZ

Amaç: Bu çalışmanın amacı, seramik ve kompozit kalınlığının beş farklı dual-cure rezin simanının polimerizasyon sertliği üzerindeki etkisini değerlendirmektir.
***Gereç ve Yöntemler**:* Seramik ve kompozit malzemelerden, 10 mm çapında ve beş farklı kalınlıkta (1.0 mm, 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm) toplam 100 adet disk şeklinde örnek hazırlanmıştır. 8 mm çapında dual-cure rezin siman numuneleri metal pirinç kalıp kullanılarak hazırlanmış ve kompozit ve seramik disk şeklindeki örnekler altında ışıkla polimerize edilmiştir. Beş farklı dual-cure rezin simandan (RelyX Universal, Variolink DC, NX3, Calibra Universal, Panavia F2.0) toplam 100 numune hazırlanmıştır. Her bir dual-cure rezin simanın Knoop sertlik değerleri, polimerizasyondan 1 saat, 1 gün ve 1 hafta sonra, 500 gr kuvvet uygulayan mikrosertlik ölçüm cihazı ile 5 farklı noktadan ölçülerek elde edilmiştir. Tüm veriler tek yönlü ANOVA kullanılarak istatistiksel olarak değerlendirilmiştir.
Bulgular: Çok değişkenli varyans analizi, kompozit veya porselen örnekler altında polimerize edilen dual-cure rezin simanların sertliklerinde, farklı zaman aralıklarında ölçüldüklerinde önemli farklılıklar olduğunu ortaya çıkarmıştır. Kompozit örnekler altındaki dual-cure rezin simanların, kalınlık arttıkça seramik örnekler altındaki dual cure rezin simanlara göre sertlik değerinin daha düşük olduğu gözlenmiştir. Ayrıca, kompozit veya seramik örneklerin kalınlığı arttıkça dual-cure rezin simanların mikrosertlik değerlerinde istatistiksel olarak anlamlı bir azalma olmuştur. Kompozit örnekler 2 mm'den kalın olduğunda ve porselen örnekler 3 mm'den kalın olduğunda sertlik değerleri önemli ölçüde azalmıştır.
***Sonuçlar**:* Kompozit ve seramik restorasyonlar altında yeterli derecede sertleşme elde etmek için dual-cure rezin simanların iyileştirilmesi gerekmektedir. Piyasada bulunan markaların polimerizasyon özellikleri birbirinden farklıdır.
Anahtar Kelimeler: Kompozit İnley, Seramik İnley, Dual-Cure Rezin Yapıştırma Simanı, Mikrosertlik.

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Introduction

Using dual-cure resin cements for indirect restorations such as ceramic and composite inlays are used widely during clinical practice. Dual-cured composite resin cements are ideal for bonding these restorations. The major advantage of these photo-activated materials is their ease of use. The working time is not a limitation, therefore excess luting material can be removed prior to curing.

Adequate cure of the resin-based cement is an important prerequisite for the stability and bio-compatibility of the restoration. Composite resin or ceramic inlays reduce the amount of the light reaching the bottom of the cavity and therefore compromise photo-activation of the luting material.[1-5] Dual-cure luting cements have been developed in order to combine the advantages of chemically and photo-activated materials. The chemical curing component is expected to ensure complete polymerization at the bottom of deep cavities, whereas photo-activation allows immediate finishing after exposure to the curing light. Many studies have revealed that the chemical curing mechanism alone is less effective than dual-curing and may be almost ineffective for some materials.[1,2,6-10]

The polymerization of dual-cured resin composite luting agents depends, on exposure time and the intensity of the light source [1-4,10-19] The shade of the restoration can also influence the polymerization[4,14,15]. Also, it has been reported that dual-cured resin composite luting agents are not sufficiently polymerized under thick and/or opaque ceramic or resin composite restorations.[3,4,10,11,13-24] It is therefore questionable where there is sufficient hardening of the dual-cured resin luting agents of different brands in those parts of a tooth reached by insufficient light intensity.[25,26]

The aim of the present study therefore was to evaluate the thickness of ceramic and composite resin inlays on the hardening of five commercially available dual-cure resin cements after 1 hour, 1 day and 1 week.

Materials and Methods

Composite Resin and Ceramic Disc Specimen Preparation

A total of 50 ceramic (Ceramco Finesse-Dentsply, York, USA) discs (diameter, 10 mm) were fabricated using leucite reinforced pressable glass ceramic, with lost wax injection moulding fabrication method. Ceramic disc thicknesses were 1.0 mm, 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm. Fifty composite resin (Tetric Ceram, Ivoclar Vivadent Shaan, Liechtenstein) discs were also fabricated at the same dimensions. Composite resin and ceramic disks 1.0-5.0 mm were used as spacers to simulate composite and ceramic inlays with different thicknesses and were constructed in A2 colors.

Preparation of Dual-Cure Resin Samples

A brass mold was used to polymerize the dual-cure luting cements under ceramic and composite spacers. Five dual-cure resin-based cements were selected for the study (Table 1). Dual-cure resin cement was placed in the hole 8 mm diameter and 1 mm depth, in a brass mold and covered with transparent filmstrip. Composite resin and ceramic spacers with different thicknesses were placed over the strip and dual-cure cements were polymerized through the disc using a visible light-polymerizing unit (Translux EC Heraeus Kulzer GmbH D-61273 Wehrheim-Germany) at a power density of 450 mW/cm^2 for 60 seconds.

Two specimens for each composite thickness were prepared, and they were separated to three groups for each time interval. In this way, 10 specimens were prepared for each dual-cure cement. The same procedure was repeated for ceramic spacers and a total of 100 samples were obtained. Specimens were stored at 37^{0}C until testing was done.

Surface Hardness Measurements of Dual-Cure Resin Samples

A Tukon microhardness tester (Acco Industries Inc, Wilson Instrument Division, Bridgeport, Conn.) with a Knoop indenter and 500 gm weight was used to determine the surface microhardness of each specimen after 1 hour, 1 day and 1 week. Five readings were obtained for each specimen, at each test interval with a total of 1500 readings. Mean Knoop Hardness numbers (KHNs) were calculated for each dual-cure luting cement. The results were analyzed statistically with multivariate analysis of variance (MANOVA) and Tukey tests were performed at the 95 % level of confidence.

Results

Specimens cured through composite resin spacers showed less hardness values than ceramic spacers (*P*<0.001). Also, hardness values decreased gradually with increasing thickness of the spacer. The mean microhardness values of five dual-resin cements are shown in figures 1-5. MANOVA revealed significant differences in KHNs among composite and ceramic spacers (P<0.001), different time intervals (P<.001) and between different spacer thickness (P<0.05).

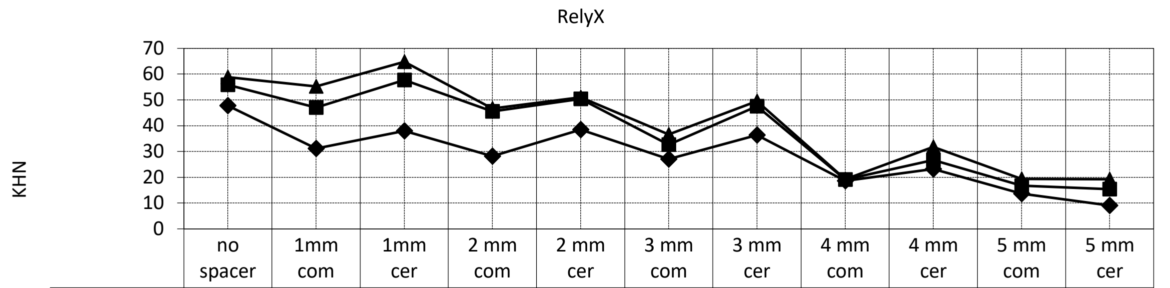
For RelyX a decrease in the KHN from 58,83 to 19,32 (67%) occurred when the composite spacer thickness was 5 mm compared to curing without a spacer at the 1-week test interval. The value was 19,24 (67%) for the ceramic spacer. Significant decreases in KHNs of RelyX Universal occurred when the spacer thickness was more than 3 mm (Figure 1).

For Calibra, mean KHNs decreased from 48.89 to 40.94 (16 %) for composite and 31.71 (35 %) for ceramic, when the spacer thickness was 5 mm compared to the value obtained without a spacer at the 1 week test interval (Figure 2).

For NX3, mean KHNs decreased from 56.83 to 7.80 (86 %) for composite and 25.86 (56 %) for ceramic spacers with 5 mm thickness at the 1 week test interval (Figure 3)

Table 1. The five resin based dual-cure cements that were examined

Material	Manufacturer	Shades used	Filler Type	Filler Percentage
RelyX Universal	3M ESPE Dental Products, St. Paul, Minn. U.S.A	A1	Hibrit	82
Calibra Universal	Dentisply Caulk, Milford, Del. USA	Dark	Hibrit	65
NX3	Kerr Corporation, Orange, Calif. USA	Yellow	Mikrohibrit	68
Variolink DC	Ivoclar-Vivadent, Schaan, Liechtenstein	Warm	Mikrohibrit	71
Panavia F2.0	Kuraray America, Inc. NY. USA	Light	Hibrit	78



	no spacer	1mm com	1mm cer	2 mm com	2 mm cer	3 mm com	3 mm cer	4 mm com	4 mm cer	5 mm com	5 mm cer
1 hour	47,72	31,1	37,92	28,17	38,5	26,99	36,34	18,58	23,16	13,62	9,05
1 day	55,87	46,99	57,7	45,58	50,35	32,6	47,51	19,05	26,68	16,69	15,41
1 week	58,83	55,22	64,76	46,68	50,97	36,61	49,5	19,25	31,69	19,32	19,24

Figure 1a. Mean KHNs of RelyX dual cured through resin composite and ceramic spacers and without a spacer at three test intervals.

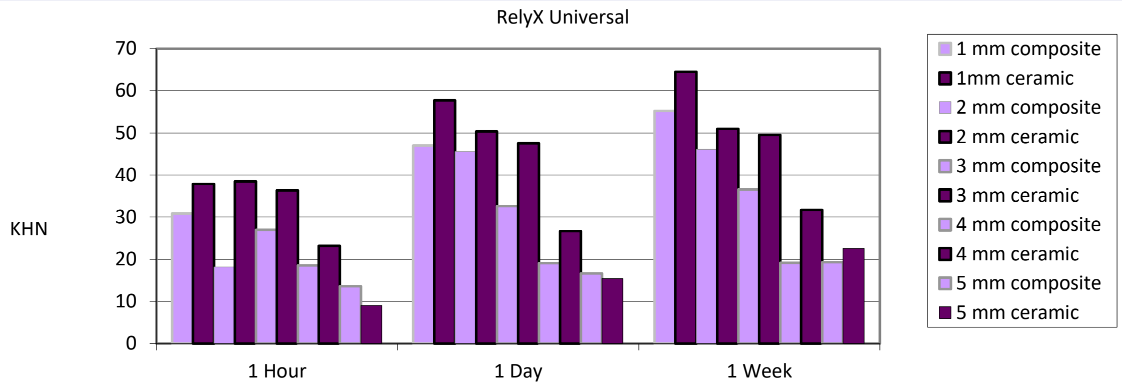
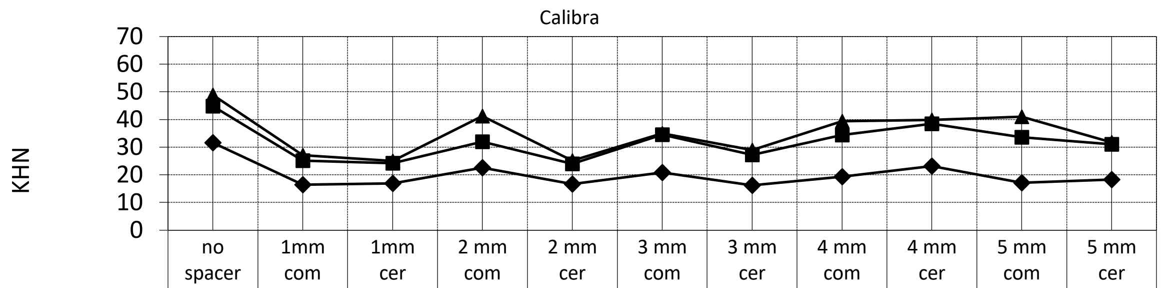


Figure 1b. Comparison of Knoop hardness values of dual-cure polymerized RelyX Universal resin cement under composite and ceramic spacers of different thicknesses.



	no spacer	1mm com	1mm cer	2 mm com	2 mm cer	3 mm com	3 mm cer	4 mm com	4 mm cer	5 mm com	5 mm cer
1 hour	31,56	16,36	16,82	22,6	16,61	20,82	16,14	19,35	23,15	17,13	18,31
1 day	44,85	25,09	24,17	31,91	23,89	34,51	27,22	34,36	38,48	33,55	31,01
1 week	48,89	27,03	25,03	41,19	25,13	34,95	28,91	39,33	39,84	40,94	31,71

Figure 2a. Mean KHNs of Calibra dual cured through resin composite and ceramicspacers and without a spacer at three test intervals.

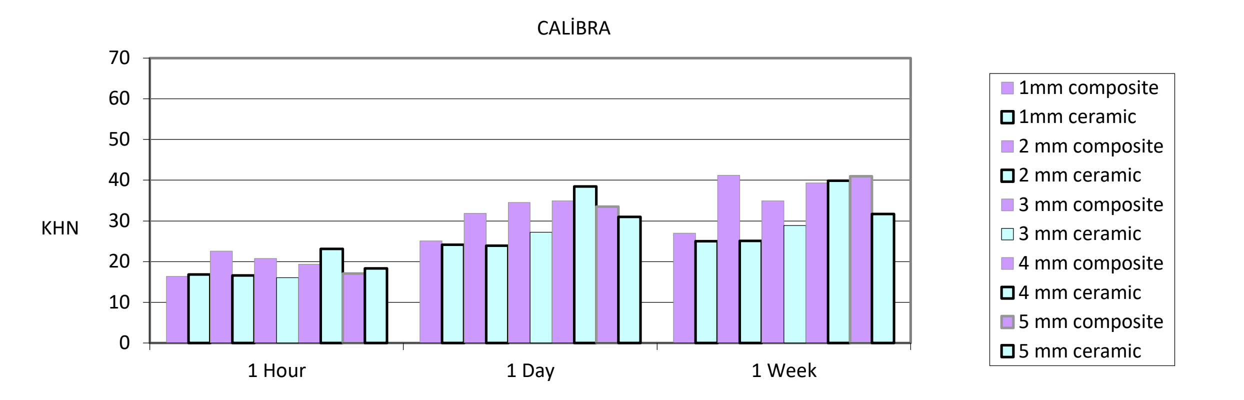
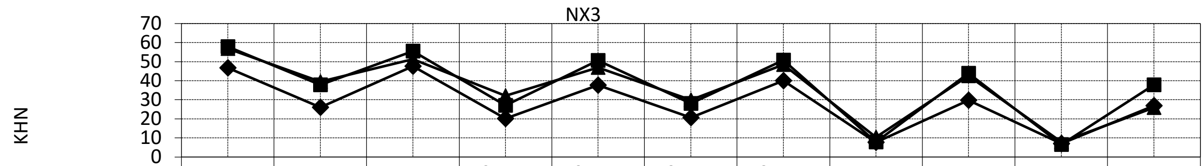


Figure 2b. Comparison of Knoop hardness values of dual-cure polymerized Calibra resin cement under composite and ceramic spacers of different thicknesses.



	no spacer	1mm com	1mm cer	2 mm com	2 mm cer	3 mm com	3 mm cer	4 mm com	4 mm cer	5 mm com	5 mm cer
1 hour	46,72	26	47,63	20,2	37,57	20,57	39,93	7,73	29,7	7,05	26,9
1 day	57,87	37,79	55,48	27,1	50,52	28,04	50,78	7,77	43,85	6,47	37,88
1 week	56,83	39,5	51,3	32,01	46,96	29,88	48,44	10,35	42,5	7,8	25,86

Figure 3a. Mean KHNs of NX3 dual cured through resin composite and ceramic spacers and without a spacer at three test intervals.

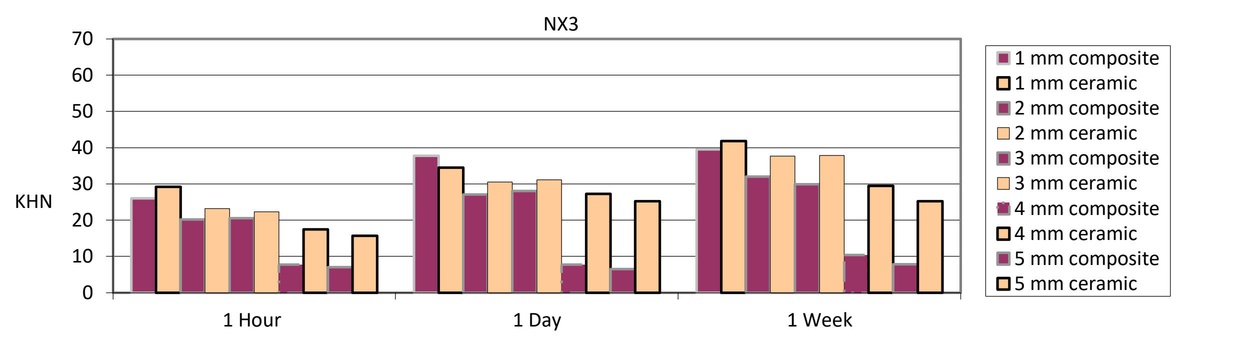
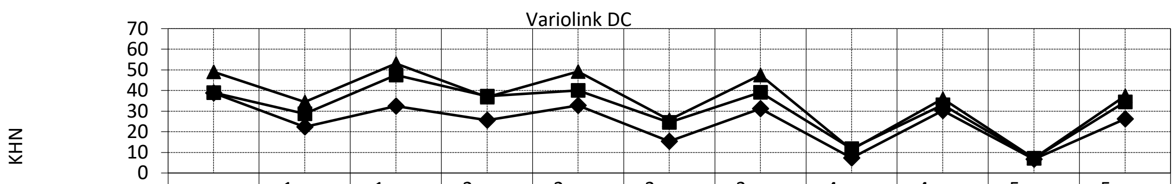


Figure 3b. Comparison of Knoop hardness values of dual-cure polymerized NX3 resin cement under composite and ceramic spacers of different thicknesses.



	no spacer	1mm com	1mm cer	2 mm com	2 mm cer	3 mm com	3 mm cer	4 mm com	4 mm cer	5 mm com	5 mm cer
1 hour	38,75	22,31	32,43	25,56	32,68	15,42	31,15	7,33	30,22	6,74	26,15
1 day	38,92	28,73	47,5	37,25	40,01	24,51	39,05	11,85	33	7,07	34,38
1 week	49,02	34,41	53,13	36,8	49,15	25,73	47,44	11,26	36,04	7,09	37,46

Figure 4a. Mean KHNs of Variolink DC dual cured through resin composite and ceramic spacers and without a spacer at three test intervals.

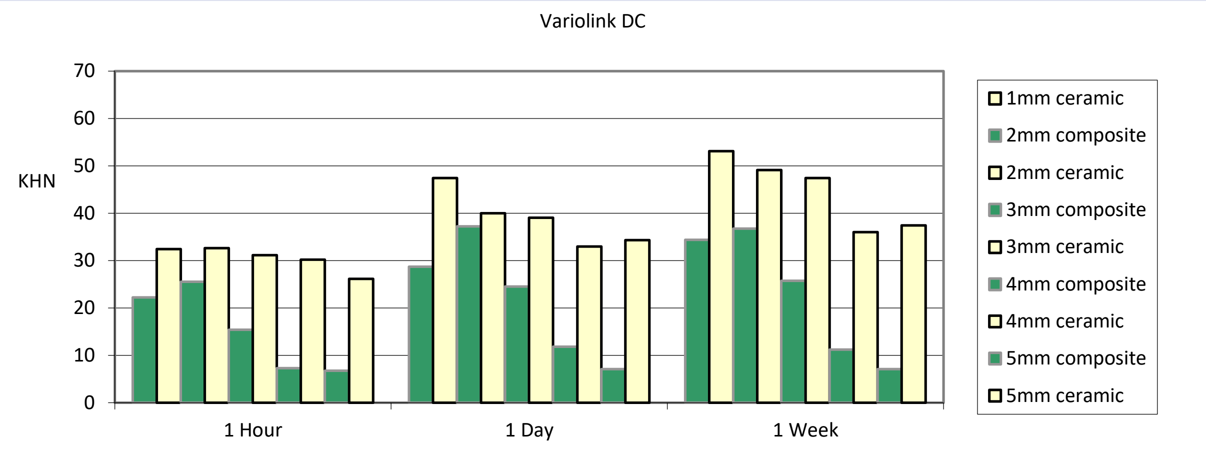
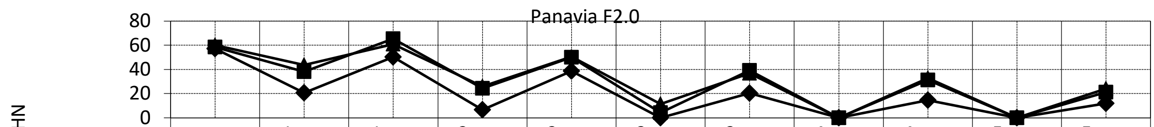


Figure 4b. Comparison of Knoop hardness values of dual-cure polymerized Variolink DC resin cement under composite and ceramic spacers of different thicknesses.



	no spacer	1mm com	1mm cer	2 mm com	2 mm cer	3 mm com	3 mm cer	4 mm com	4 mm cer	5 mm com	5 mm cer
1 hour	57,17	20,53	50,2	6,65	38,51	0	20,43	0	14,61	0	11,73
1 day	58,57	38,1	65,43	24,27	49,93	4,2	39,09	0	31,12	0	21,22
1 week	60,03	43,61	60,89	25,82	50,47	11,32	36,68	0	32,69	0	23,93

Figure 5a. Mean KHNs of Panavia F2.0 dual cured through resin composite and ceramic spacers and without a spacer at three test intervals.

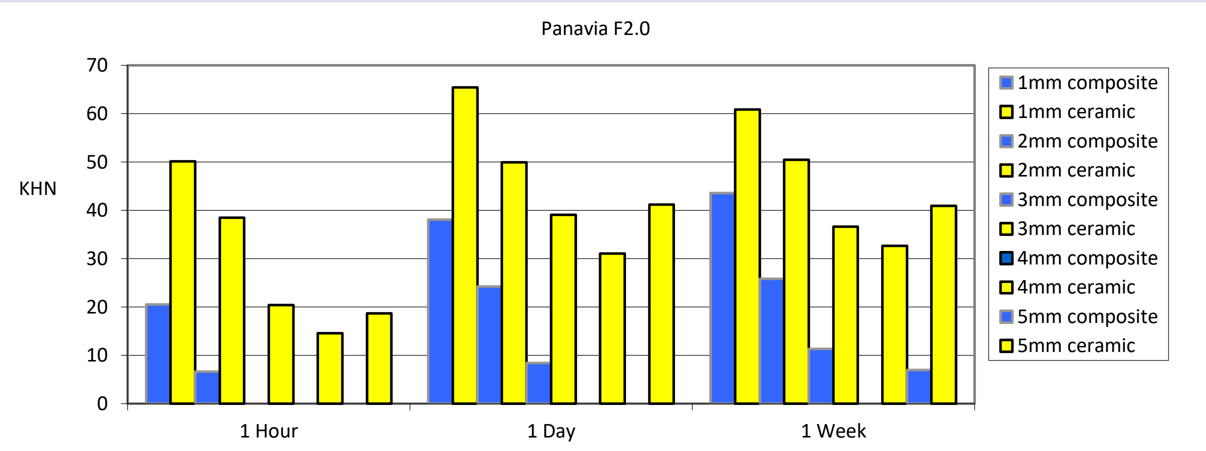


Figure 5b. Comparison of Knoop hardness values of dual-cure polymerized Panavia F2.0 resin cement under composite and ceramic spacers of different thicknesses.

For Variolink, these values decreased from 49.02 to 7.09 (86 %) for composite and 37.46 (24 %) for ceramic spacers with 5 mm thickness at the 1-week test interval (Figure 4).

Significant decreases in KHNs of NX3 and Variolink occurred under composite and porcelain spacers more than 3 mm thickness.

For Panavia F2.0, surface hardness was not measurable under composite resin spacers more than 3 mm thickness. Mean KHNs decreased from 60.03 to 23,93 (60%) for ceramic spacers with 5 mm thickness at the one-week test interval (Figure 5). Panavia F2.0 showed highest KHNs under porcelain spacers compared to the other dual-cure cements.

Discussion

This study revealed that the thickness of ceramic and composite resin restorations effect hardening of the dual-cure resin cement. There are several factors that can influence the degree of polymerization of a dual-cure resin cement, such as shade, light unit and curing time. These factors were kept constant in our study to determine the influence of thickness and time only. Also the thickness of the spacers was between 1 and 5 mm, since the thickness of deep cavity restorations may be 5 mm or more. Statistically significant differences were found in the hardness of the specimens dual-cured through composite spacers versus ceramic spacers. The reason for these differences is most likely because of the way ceramic was more translucent than composite. Significant differences were also found in the hardness of specimens dual-cured through ceramic or resin composite spacers 2 to 3 mm in thickness or more the gradual reduction that occurred in KHNs with increasing spacer thicknesses could be attributed to attenuation of the light caused by the increasing opacity with the increasing spacer thickness. This attenuation may be caused by the light-absorbing characteristics of the restorative material (ceramic or composite resin). It is likely that the hardness achieved at 5 mm resulted mainly from the chemical-curing component of the cement instead of the light-curing component.

Dual-cured cements contain the peroxide/amin components found in chemical-cure systems in addition to the photosensitizer, camphoroquinone, used in light-cure materials. A slow–acting peroxide/amin system is used to achieve an extended working time and to adequately harden surfaces of the resin insufficiently exposed to light. The light –activated component provides rapid, initial hardening of the resin for stabilization of the restoration. Dual-cure initiator systems have been found to improve curing, solvent resistance and tensile strength of composites [14,15,24]

Knoop hardness measurements of the examined cements were recorded at varied times (1 hour, 1 day, and 1 week). From these findings, a relatively high degree of hardness was seen for specimens at 1 week test interval versus at other times test intervals. Even after 1 hour, dual-cured resin cements did not achieve adequate hardness. For this reason, it can be recommended not to stress bonding after cementation because the hardness at that time may be much lower than the maximum.

The KHNs of the examined cements can be sequenced in descending order as; RelyX, Variolink, NX3, Calibra, Panavia F2.0. Panavia F2.0 showed distinctly different pattern from other cements (Fig. 5). Its hardness values with no spacer were the highest values, but when composite spacer thickness was more than 2 mm, Knoop hardness measurements cannot be recorded, because the specimens were very soft. It may be attributed to its lower chemical curing component and greater dependence on light-activation. These findings conflict with the concept that the chemical-activated component will provide complete hardening of the cements in parts of the tooth not reached by the curing light. The attenuation of light by the tooth and restoration resulted in lower hardness and the chemical-cure component did not produce complete hardening. It can be recommended that Panavia F2.0 resin cement should be used under 1- or 2-mm thickness of ceramic restoration.

Calibra showed different pattern from other cements (Figure 2). In this study, the dark color of Calibra cement was used. As the spacer thickness increased, the KHN values also increased. It even reached higher hardness values under composite spacers compared to ceramic spacers. It may be attributed to its chemical curing components more than the light curing component. Also it can be said that it is not affected by the translucency of the ceramic spacer since the light activation component is low. Therefore, the polymerization hardness increased chemically over time, regardless of the thickness. Calibra is the cement with the lowest filling ratio among the cements we used (Table I). It may be possible to evaluate this cement as a chemically polymerized cement.

El-Badrawy and El-Mowafy[4] studied Knoop hardness values of seven different dual-cure resin cements through composite resin and ceramic spacers, under 1-6 mm. thickness. Also, in another study[22,23,24] they evaluated the effect of resin composite thickness on the hardness of eight different dual-cure resin composites. The results of these studies agree in general terms with our results, but the dual-cure cement brands were different, so there are some variabilities among the cements tested. The reason for these differences may be attributed to the formulations of the cements.

Complete polymerization of luting resin cement is essential for stability, and clinical success and longevity of the restoration. Decreased curing of resin cements caused by light attenuation significantly decreases the bond strength. The results of this study show that, currently available dual-cure resin cements cannot reach maximum hardness under 2 mm composite spacers and under 3 mm and more ceramic spacer thickness. From these findings it can be recommended that more work should be undertaken to improve the hardening of the currently available dual-cure resin cements so that maximum hardness can be achieved through the chemical curing component alone as efficiently as with the dual-curing component.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

- 1.The polymerization potential of five commercially available dual-cure cements was found to vary greatly with brand.
- 2.Composite resin spacer obstructed light significantly more than ceramic resin spacer.
- 3.For most dual-cure resin systems tested, the hardness observed 1-hour postmix was significantly lower comparing 1-week values.

It can be recommended not to stress bonding after cementation because the hardness at that time is much lower than the maximum.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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