Effect of Different Light Curing Distances on Surface Hardness of Two Different Bulk-Fill Flowable Resin-Based Composite Materials

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Abstract

Objectives: To evaluate the effect of different light curing distances(0,2,4&6mm)on surface hardness and degree of conversion for two bulk-fill flowable resin-based composite materials(Filtek&X-tra base).

Method: 20 disk shaped samples(4x4mm) of each composite type for each test were prepared.Light curing was performed with LED unit for 20s.Vickers hardness&degree of conversion tests were performed on both top&bottom surfaces of each specimen.

Results: Statistical analysis revealed that irradiation distance had significant effect on both VHN&DC.

Conclusion: Irradiance distance is important factor to consider to obtain adequate polymerization of flowable BF-RBCs.

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Introduction

The increasing demand for aesthetic,tooth-colored and mercury-free restorations has made RBCs to largely replace dental amalgam as the direct material of choice for restoring posterior teeth.In addition to being esthetic& repairable,the cavity preparations for composite restorations are more conservative when compared to amalgam due to the use of micro-mechanical and chemical retention, and are adhesively bonded to the tooth with a compatible bonding system.[1,2] In spite of advances in RBC technologies, limited depth of cure and stresses that occurs as a result of polymerization shrinkage are among its major disadvantages,which might prevent total polymerization of greater increments,thus decrease in the physical/ mechanical and biological properties of composites.[3,4,5]To overcome these issues,incremental layering technique has been "The gold standard technique" for composite application,especially in large cavity preparations >2 mm,by virtue of the sufficient exposure of the entire increment to the curing light,as well as the reduction of the volume of the contracting material.If not carried out effectively, areas of uncured or partially cured composite resin may remain at the base or between layers at the bottom of each increment.This can lead to reduction in strength, prevent adequate sealing of the restoration or cause post-operative sensitivity and early failure of the restoration.Hence, highly complex,technical challenging for the operator and time consuming for both the operator and the patient. In addition to increase possibility of air bubble inclusion or moisture contamination between individual increments of resin composite restoration.[1,2,3,4]Recently,a new class of RBC, known as "bulk-fill"(BF)composites had been introduced into the dental market.The unique advantage of this new material class is stated that it can be placed in 4mm thick increments and cured in one step using a monoblock or single-layer technique, without adverse effect on polymerization shrinkage,cavity adaptation,or degree of conversion. Through the use of special modulators,unique fillers and filler control, manufacturers claim these materials have lower polymerization shrinkage and depths of cure of (DOC) up to 4mm.[2,3,4]Two

groups of BF composites can be distinguished(a) low-viscosity materials which are used as base materials and require an additional capping layer (b) high-viscosity materials which are sole cavity filling materials[6] Unfortunately, studies investigating the clinical performance of BF resin composites are still limited.

MATRIALS AND METHODS

Two flowable BF-RBCs were investigated by assessing microhardness (HV) and DC as function of distances away from the light tip(0,2,4& 6 mm). Filtek[TM] Bulk Fill Flowable Restorative{**Matrix:**Bis-GMA-Bis-EMA-UDMA-Procrylat resin, **Filler:** Zirconia/silica (0.01_3.5 microns)-Ytterbium tri-fluoride filler (0.1_5 microns) (64.5% by wt., 42.5% by vol.)} X-tra Base[®]{ **Matrix:**UDMA-Bis-EMA,**Filler**:Inorganic filler (based on barium aluminium silicate glass-fumed silica) 975% by wt.,58% by vol.)} The Teflon mold was positioned on top of Mylar strip and rested over glass slide,to obtain a smooth surface area on resin composite for the microhardness evaluation..The tip was kept in contact with the Mylar strip at the bottom of the mold,until the mold became slightly overfilled.This technique was used to minimize air bubbles entrapment as the mold was filled.After application, the top of composite was covered by another Mylar strip to avoid oxygen inhibition layer formation[7,8].Then glass slide was applied over the strip and gently pressed under the load of finger pressure to extrude any excess&forcefully adapt composite to all mold confines[3,9,10,11,12,13]The slide was removed&specimen was light irradiated using a LED curing unit[14,15]at intensity output 1000 mW/cm^{2}.For 0 mm distance light-curing tip was positioned directly against the second strip (zero contact), kept perpendicular for full light penetration&standardization[3,7,10,11,13] For 2,4&6 mm distance, the specimen was irradiated through hollow cylindrical molds with heights 2,4&6 mm,corresponding to the curing distances assessed.The output intensity of the LED curing unit was firstly checked prior&post curing each group.The curing time was fixed for all specimens to be 20s.After curing,the strips were discarded,the samples were removed from the mold,the excess material was removed.The top surface of the specimens were marked to distinguish them

from bottom surface.They were stored dry in lightproof container for 24 hours at room temperature[3,16] to allow for the majority of post – irradiation (dark polymerization) to occur.After storage,the surface to be assessed was scrapped by lancet to get composite powder,to be ground finely with pestle& mortar& mixed with dry potassium bromide (KBr) powder salt for 1 minute [3,17,18] The mixture was placed into evacuable KBr die&pressed under vacuum in manual hydraulic press with load of 25 tons for 30 s to obtain transparent KBr pellet of 13mm diameter.The uncured paste was assessed as baseline record during calculation of the DC of the cured specimens.The KBr pellet was loaded into holder attachment in optical compartment of FTIR to be exposed to the IR radiation [3,17,18]. For FTIR quantitative analysis,the standard baseline technique with aid of spectral analysis computer program, provided with the spectrometer,was performed.The DC%was obtained by assessing the peak height ratio of the absorbance intensity of the aliphatic (C = C) bond at 1638 cm^{-1} against the absorbance intensity of the internal standard aromatic (C = C) bond at 1608 cm^{-1},obtained from both the cured and uncured specimens.Since the aromatic ring was not affected by the polymerization process,thus the aromatic peak intensities can be used as internal standard. The aliphatic peak intensities are reduced after polymerization due to breakdown of these chemical bonds during the polymerization process[19,20]The DC was calculated by the following equation [17,18,21]

$$DC\% = 1 - \left[\frac{R \text{ polymerized}}{R \text{unpolymerized}} \right] \times 100$$

Where

$$R = \left[\frac{\text{peak height at aliphatic C = C } [1638\,cm^{-1}]}{\text{peak height at aromatic C = C } [1608\,cm^{-1}]} \right]$$

The Vickers hardness(VH)test consists of indenting the test material with a diamond indenter (Tukon 1102, Buehler's Wilson, USA)in the form of a right pyramid with square base&angle of 136degrees between opposite faces subjected to 100g load for 10 s[22]The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope& their average calculated.The area of the sloping surface of the indentation was calculated.The VH is the quotient obtained by dividing the Kg load by the square mm area of indentation. In the present study,five hardness measurements were taken across the top&bottom surfaces&mean VH was obtained.

Statistical analysis: It was performed with IBM® SPSS® Statistics Version 20 for Windows.Data was presented as mean and standard deviation.Three-way ANOVA was conducted to evaluate the effect of assessed variables and their interactions on DC&VH.One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related samples.Independent Student test was used to compare between two independent groups.

RESULTS

The results showed that the variable "restorative material" had no statistically significant effect on DC at P=0.121.While the variables "curing distance"& "surface" had a significant effect on DC at P<0.001 and P=0.002,respectively.

Table (1): Means and standard deviations (SD) for the effect of different assessed surfaces on DC (%)

Variables	Degree of conversion															
	Filtek Bulk Fill (R₁)								X-tra base (R₂)							
	0mm(D₁)		2mm(D₂)		4mm(D₃)		6mm(D₄)		0mm(D₁)		2mm(D₂)		4mm(D₃)		6mm(D₄)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Top surface (S₁)	67.9	2.6	62.3	6.2	54.3	6.1	51.4	4.0	69.1	10.2	64.4	8.6	59.2	7.5	56.5	5.2
Bottom surface (S₂)	60.1	9.1	58.7	8.1	49.0	5.4	47.5	8.8	62.7	12.0	61.0	7.8	51.3	12.2	49.4	7.1
p-value	0.103NS		0.466NS		0.185NS		0.404NS		0.396NS		0.537NS		0.260NS		0.114NS	

Table (2): Means and standard deviations (SD) for the effect of different curing distances on DC (%).

Variables	Degree of conversion							
	Filtek Bulk Fill (R$_1$)				X-tra base (R$_2$)			
	Top surface (S$_1$)		Bottom surface (S$_2$)		Top surface (S$_1$)		Bottom surface (S$_2$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0mm (D$_1$)	67.9^a	2.6	60.1^a	9.1	69.1	10.2	62.7	12.0
2mm (D$_2$)	62.3^{ab}	6.2	58.7^a	8.1	64.4	8.6	61.0	7.8
4mm (D$_3$)	54.3^{bc}	6.1	49.0^{ab}	5.4	59.2	7.5	51.3	12.2
6mm (D$_4$)	51.4^c	4.0	47.5^b	8.8	56.5	5.2	49.4	7.1
p-value	<0.001*		0.048*		0.111NS		0.125NS	

Table (4): Means and standard deviations(SD)for the effect of different assessed surfaces on HV.

Variables	Microhardness															
	Filtek Bulk Fill (R$_1$)								X-tra base (R$_2$)							
	0mm (D$_1$)		2mm (D$_2$)		4mm (D$_3$)		6mm (D$_4$)		0mm (D$_1$)		2mm (D$_2$)		4mm (D$_3$)		6mm (D$_4$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Top surface (S$_1$)	46.6	5.0	45.7	3.8	44.1	3.7	41.7	1.6	60.6	3.3	60.9	3.2	62.8	1.1	60.0	1.5
Bottom surface (S$_2$)	45.3	1.8	46.4	4.3	43.5	4.7	40.9	1.7	61.3	1.7	60.8	3.0	59.7	2.1	57.5	2.2
p-value	0.578 NS		0.446 Ns		0.832 NS		0.366 NS		0.561 NS		0.967NS		0.053 NS		0.176 NS	

Table (3): Means and standard deviations (SD) for the effect of different restorative materials on DC (%)

Variables	Degree of conversion															
	Top surface (S$_1$)								Bottom surface (S$_2$)							
	0mm (D$_1$)		2mm (D$_2$)		4mm (D$_3$)		6mm (D$_4$)		0mm (D$_1$)		2mm (D$_2$)		4mm (D$_3$)		6mm (D$_4$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Filtek Bulk Fill (R$_1$)	67.9	2.6	62.3	6.2	54.3	6.1	51.4	4.0	60.1	9.1	58.7	8.1	49.0	5.4	47.5	8.8
X-tra base (R$_2$)	69.1	10.2	64.4	8.6	59.2	7.5	56.5	5.2	62.7	12.0	61.0	7.8	51.3	12.2	49.4	7.1
p-value	0.808NS		0.672NS		0.291NS		0.129NS		0.705NS		0.664NS		0.712NS		0.714NS	

Table (5): Means and standard deviations (SD) for the effect of different curing distances on HV.

Variables	Microardness							
	Filtek Bulk Fill (R$_1$)				X-tra base (R$_2$)			
	Top surface (S$_1$)		Bottom surface (S$_2$)		Top surface (S$_1$)		Bottom surface (S$_2$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0mm (D$_1$)	46.6^a	5.0	45.3^a	1.8	60.6^a	3.3	61.3^a	1.7
2mm (D$_2$)	45.7^a	3.8	46.4^a	4.3	60.9^a	3.2	60.8^a	3.0
4mm (D$_3$)	44.1^a	3.7	43.5^a	4.7	62.8^a	1.1	59.7^a	2.1
6mm (D$_4$)	41.7^a	1.6	40.9^a	1.7	60.0^a	1.5	57.5^a	2.2
p-value	0.213ns		0.102ns		0.361ns		0.086ns	

Microhardness: The results showed that the variables "restorative material" and "curing distance: had a statistically significant effect on microhardness at P<0.001 and P=0.002, respectively.While, the variable "surface" had no statistically significant effect at P=0.211.

Table (6): Means and standard deviations (SD) for the effect of different materials on HV

Variables	Microhardness															
	Top surface (S_1)								Bottom surface (S_2)							
	0mm(D_1)		2mm(D_2)		4mm(D_3)		6mm(D_4)		0mm(D_1)		2mm(D_2)		4mm(D_3)		6mm(D_4)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Filtek Bulk Fill (R_1)	46.6	5.0	45.3	1.8	45.7	3.8	46.4	4.3	44.1	3.7	43.5	4.7	41.7	1.6	40.9	1.7
X-tra base (R_2)	60.6	3.3	61.3	1.7	60.9	3.2	60.8	3.0	62.8	1.1	59.7	2.1	60.0	1.5	57.5	2.2
p-value	<0.001*		<0.001*		<0.001*		<0.001*		<0.001*		<0.001*		<0.001*		<0.001*	

For all tables*: Significant (p<0.05); NS: non-significant (p>0.05). Means with different superscript letters in the same column indicate statistically significant difference.

DISCUSSION

A-Materials: The universal shade was chosen to for all the tested materials for standardization.The composite shade is related to translucency of material,hence has strong effect on irradiance reaching the bottom of composite and on depth of polymerization.[23]

B-Methodology:Selection of mold: Split Teflon molds 4x4mm were used for sample preparation to investigate the 4mm DOC,claimed by manufacturers[24]It has been confirmed by a study,where black mold produced lower DOC than white mold[25,26]that the mold size can influence the DOC& its color can affect amount of curing light absorption& reflection.Study found that ISO 4049 method overestimated DOC compared to Vickers hardness[27]where stainless steel opaque metal molds did not represent what occurs in the tooth accurately[28]**The curing unit:**Light produced by light-curing devices initiates polymerization of the composite resin only when the light intensity& wavelength (470nm) are sufficient to activate the photo initiator Camphorquinone. LED are characterized by relatively narrow emission spectrum,higher light intensity,more efficient bulbs&lower heat generation compared to QTH[8]Thus, in this study a LED-LCUwas used[14,15]

C-The results:Effect of material: The results showed that the variable restorative material had no statistically significant effect on DC. Higher mean DC % values were obtained by X-tra base® compared to Filtek™ .The DC is influenced by composite formulation,through the type of resin-matrix, filler type, size&loading.Both tested materials were methacrylate-based containing Bis-GMA&UDMA mnomers. This was in agreement with study [15]showed that no significant difference in DC% at the top surface,while at the bottom surface, all of the other investigated materials had statistically significant differences in DC% when compared to each other,except between X-tra base® and Filtek™.But it detected tendency for higher DC value in Filtek™ compared to X-tra base®.This finding might be explained by the higher filler content of XB,which increases light scattering,causing decrease of translucency for blue light.Regarding higher mean DC % values obtained by X-tra base® compared to Filtek™ in recent study, this might be attributed to variation in translucency,which is linked to light transmission[29] Filtek differs from X-tra base by containing zirconia filler,which was shown to decrease translucency due to resin/filler refractive index mismatch.This was in agreement with study[30]found that DC values at 4mm depth 24hours post cure were decreasing in the X-tra base more than Filtek.Hence, they conducted that DC of flowable BF composites at maximal recommended depth of 4mm,appears to be dependent on the material's translucency. Moreover, a study[31] found that mean DC values measured,both immediately&24 h post-cure were in X-tra base® > Filtek™. This was supported by a study[29]conducted that selection of the components of the monomer matrix has an influence on the DC % of resin composites.Regarding microhardness results,the variable "restorative material" was found to have a statistically significant effect. X-tra base® showed higher statistically significant mean DC % value compared to Filtek™. HV is a measurement of the whole filler matrix system, being the filler

component the dominating factor over the softer matrix.Polymerization of RBCs is affected by the amount of light transmitted through the material,which is affected by the chemical composition of the filler and matrix&the differences in the refractive index of both components.As RBCs consist of heterogeneous substances, resin&fillers,the passing light is scattered at the resin-filler interface due to differences in the refractive indices of the individual compounds.Light transmittance was shown to decrease with increased filler content and for irregular filler shape due to the increase of specific surface between fillers and resin. Similar refractive indices of the components of a RBC, as demonstrated for Bis-GMA&silica filler particles,were shown to improve translucency in dental materials[32]Accordingly, positive correlation between the HV&the filler volume content of the materials was suggested[5] In this respect, HV measurements could be more sensitive than %DC,as HV indirectly considers the matrix network crosslinking,whilst %DC only reveals the amount of remaining carbon double bonds[29] The presence of filler larger than 20 μm in X-tra base decreases,at a similar filler amount,the total filler surface,hence, results in lowering the total filler–matrix interface, thus reducing light scattering,allowing for more blue light penetration in depth&better cure the RBCs in depth[32,33,16]This was in agreement with a study[34]found that X-tra base® have the highest VH among tested materials,including Filtek[TM]. Another study[16] ranked the tested BF materials in terms of strength characteristics where X-tra base® exhibited reasonable mechanical properties&Filtek[TM] had the lowest values.For Filtek[TM],the use of plastifying monomers to reduce shrinkage stress might have caused variations of polymer network density. Thus, they conducted differences in mechanical properties influenced by filler mass fraction&specificities of the organic matrix,such as variations of polymer network density.A Study[33] proved that the effect of the parameter material significant on HV.The results ranked the tested materials in descending sequence; X-tra base, Filtek™.A Study[35] showed that the mechanical properties (HV)were significantly influenced in

descending order by material, incremental thickness,filler volume,filler weight& maximum transmitted irradiance.A study[5]measured the depth of cure of different bulk fill resin composites by the determination of their VHN/depth profiles.They found statistically significant differences in max.VHN and depth of cure, corresponding to 80% of max.VHN,between different BF materials.The results showed higher max.VHN value for X-tra base compared to Filtek™.A Study[32] showed that the strongest influence on HV was performed by the filler volume,followed by the filler weight,followed by material. The resulted values for hardness,for all tested materials including Filtek[TM] but except for X-tra base®, clearly confirm manufacturer indications for adding capping layer of regular RBC.The composition and filler loading of the BFCs seem to be the most important factors affecting the polymerization efficiency of BF composites.The variability on the conclusion of the authors was mainly dependent on the BF composite evaluated&in general,the low-viscosity BFCs performed better regarding polymerization efficiency compared to the high-viscosity BFCs[36]Among previous studies,DC was found to be significantly linked with the HV. More extensive polymerization means more cross-linking occurs,better degree of conversion& increased depth of cure,resulting in higher hardness[5,35,37]While others conducted poor correlation between degree of conversion and the mechanical properties.This was expected because all materials are based on different monomer contents,thus present their own specific relationship between DC&HV.Second, all materials in this study were cured more than the manufacturers' recommendations (40 s), thus very likely that each material was optimally cured.Only with suboptimal cure can differences in DC result in differences in mechanical properties.[16]

Effect of distance: The results showed the variable "curing distance" had a significant effect on both DC at P<0.001&on HVat P=0.002,where 0mm showed the significantly highest DC % &HV values. Depth of polymerization is directly related to the amount of photons being transmitted through

the material and reaching its deeper portions to activate the polymerization reaction. It depends not only on the irradiance of the curing light and irradiation time but also on the distance of the light tip from the tooth-restorative material. The light intensity diminishes as the tip of the source light moves away from the resin composite's surface[9,37] Because light disperses in open spaces, therefore, more evenly distributed light throughout the restoration is found at short distances between the tip of the LED-LCU&the surface of the restoration.While,longer curing distance causes light to disperse rather than focus on a certain area, thus decreasing the degree of polymerization[38]Thus,polymerization in depth can be expected to be hampered in more opaque materials where light transmission is jeopardized.DC depends on the emission spectra of LCU matching the absorption spectra of photo-initiators used in these materials&on the light actually reaching all portions of the restoration.Hence,reduction on conversion toward deeper areas was expected,with the more marked reduction being observed for the most opaque shade[23] The HV has been measured to evaluate the extent of polymerization,by comparing the hardness of the top surface to the bottom surface[8]This was in agreement with study[39]found significant differences in curing depth of pits and fissure sealants when the light source was placed directly upon the pit and fissure sealant in comparison to 5&10mm distances.Study[8]demonstrated that there was a significant difference in the Knoop hardness between 9 investigated distances($P < 0.001$)in all LCU used in study.They conducted an inverse relationship exists between the light-curing distance&the microhardness on the top&bottom of the composite.A Study[14] conducted the best results for DC % when there was maximum contact with a light source&exposure time was increased as long as it did not lead to adverse effects like increasing in tooth temperature.Study [40]did not measure light intensity but found that depth of cure was greatly affected by light source-specimen distance.It showed that although DOC did not follow Inverse Square law,but was reduced in linear manner with increasing light

curingdistance.Study[41]conducted that Vickers hardness VHN values of all resin composites decreased with the increased irradiation distance.Study[42] confirmed a relation between the depth of cure at increasing distance to log10 of the mean light intensity.Their results showed that depth of cure decreased modestly and in a linear manner with increasing distance, however, intensity did not obey the inverse square law over distances 0-10 mm& the reduction in DOC at the extreme 15 mm separation distance was less than expected.Study[9]showed that regarding microhardness ratio,there were statistically significant differences for all analyzed factors; shade, distance and composite resin type,where there was decrease in values as the curing distance increased.The highest values were recorded at 0 mm& the lowest values at 12 mm.Study[37]analyzed the results of the LED at distances of 6&9 mm,found that there was decrease in DC at the 3&4mm thicknesses.They confirmed increase in curing distance promotes decrease in HV&DC for all LCUs studied.Study [38]concluded that curing distance&time both significantly affect the surface hardness of nano-filled composite resin.Light intensity is maximized if the curing distance is 0mm&the LCU is perpendicular to the composite surface, hence, polymerization of the composite resin is maximized.They found when the curing distance was longer than 5mm,longer curing times increased the surface hardness.This was in partial agreement with study[23]showed that increasing the curing distance had limited effect on irradiance loss & DC % &significant effects were only observed beyond 2&4mm of depth.Despite study[43]conducted that the distance influenced both HV and DC,but they found that distance effect was stronger on HV but lowest on DC.The drop in DC values between the most favourable conditions (sample surface, 0 mm distance + 40 s irradiation) and least favourable conditions (6 mm depth, 7 mm distance + 10 s) irradiation) was larger in the high viscosity BF Tetric EvoCeram than in low viscosity BF X-tra base® .The reason for that is the higher translucency of X-tra base®,which allows a better penetration of light in deeper layers&the dimension of fillers was increased in X-tra base® to a size of 20 mm which decreases the total filler surface at

a similar filler amount&decreases the filler–matrix interface.Thus, light scattering at the filler–matrix interface is reduced, allowing more light to penetrate the material&to better cure the RBCs in depth. They concluded that variation in irradiance is highly material dependent.That study used FTIR-ATR for assessment of DC, hence,different methodology.On contrary, study[33]found that the influence of distance was strong on DOC but low on HV of X-tra base[®]&not significant for HV of all other materials including Filtek[TM] .This was in contradiction to study[44] found that the curing distance did not significantly influence either the cytotoxicity or the DC of the tested dental adhesives.A possible explanation may be attributed to differences in filler proportion thickness&viscosity between composites &adhesives.The less filled, thinner&low viscous adhesives could enable a similar light-polymerization independently from the curing distances used.

Effect of the surface: The results of the current study showed that the variable "surface" had a significant effect on degree of conversion.The light intensity of LCUdecreases as the curing distance increases, as well as during passage through the layers of resin composite. This could be attributed to the scattering and absorption and reflection of light that occurred while passing through organic matrix&filler particles of the bulk of the material where the light intensity reaching the bottom surface was greatly reduced. Consequently,the effectiveness of the light for resin polymerization was reduced as the depth increased.As the thickness of composite increases, the number of photons available to raise CQ to the activated state is limited by absorption and scattering,thus decreasing the monomer conversion.This was in agreement with study[45]found that the DC values of bottom surfaces of all tested materials were lower compared to top surfaces in all situations.Their results showed that increase of the distance to the LCUs tip did not affect the DC of the top surface,except for nanofilled composite cured with LED 2.They found same radiant exposure for all light curing devices demonstrating a significant influence on the curing distance on the DC,

principally for the bottom surface.This was in contradiction with study[12]observed that the DC of Filtek BF was similar at the top and bottom,except for the extreme 6mm thickness.With a safety margin of 1 mm,the manufacturer's instructions of most BF composites limiting the single layer increment to a thickness of 4 mm had been justified. This might be explained by the translucency of the flowable bulk-fill composites appeared sufficient for light to reach the specimen bottom to properly cure at the 4 mm depth. Moreover,the initial flowable nature of these composites& the imino groups (NH) in UDMA monomer had been considered responsible for continued polymerization through chain transfer reactions and increased mobility of radical sites.Study[29]investigated bulk-fills showed no significant decrease in %DC at 2 or 4mm when compared to top, for both light curing times On the other hand, the investigated conventional composite cured as indicated by the manufacturer,showed significant inferior %DC at 4mm specimen thickness in comparison to top. When being light cured for 30s conventional had no significant differences in %DC at 2 or 4mm compared to top.This was explained by higher translucency of BF than conventional composites. As light transmission is linked to material opacity, the observed %DC at 4mm thickness might be result of their reduced opacity.As disclosed by the manufacturers, all tested BF,except TBF show slightly lower filler volume fraction compared to the conventional composite.It has been demonstrated that increasing the filler-to-matrix ratio decreases DC of composites. Interestingly, all investigated bulk-fills showed inferior %DC at top when compared to 2&4mm when being light cured for 30s.This might be due to heterogeneity of temperature increase with material thickness during polymerization,variation of the degree of crosslinking with depth,oxygen inhibition.However,a mylar strip was placed on top&bottom of the mold to prevent oxygen inhibition.Studies with unfilled systems showed inferior %DC on top surface when irradiance was increased,which thought to be due to diffusion-limitation at early stage caused by the increased irradiance.However this explanation cannot be transferred directly

to filled resin composite systems making further studies necessary to explain this phenomenon.On the other hand, the results of the current study showed that the variable "surface" had no statistically significant effect on HV.This was expected result for BF material as their manufacturers claimed that they can be placed in single layer of 4mm.That was obtained by changes in their fillers contents either by increasing their size or decreasing filler loading,thus increasing their translucency,enhanced light transmission,resulting in betterDOC.This is in agreement with study[12]found no difference in VH between the specimen top&bottom surface for flowable BF composites SDR&Filtek,represented by bottom-to-top VH ratios approximated 1,thus achieving their best VH in case of all filling procedures, except the extreme 6mm thickness. Study[29,46]found that no signifcant differences between HV of top&bottom surface for both SDR& X-tra base.On contrary,all tested BFs&conventional resins presented significant decrease in HV at 4mm irrespective of the curing time.When the 80% HV bottom-top-ratio criterion was applied as a minimum acceptable threshold, all tested materials,except TBF &FSF,showed adequate hardness at 4mm.This was in contradiction with study[8] stated that the light intensity of LCU decreases as the curing distance increases&during passage through the composite layers.The decrease in light intensity was significantly related to the decrease in microhardness.They conducted that this relation was more significant on the bottom surface.That study investigated conventional nano composites.

CONCLUSIONS

Within study limitations1-Both DC and DOC in terms of HVof BF resin composites are adversely affected by increasing the light curing distance2-DC is affected by the surface,but not material dependant3-The tested materials showed different VHN values depending on their composition&filler contents5-The tested materials can be adequately cured to 4mm as their manufacturers calim.

RECOMMENDATIONS

The clinical recommended distance between the tip of the light source and the resin surface is 1 mm.When this proximity is not possible,dentists can use longer curing time or LCU of higher irradiance. Further investigations studying the effect of increasing light intensity and prolonging curing time on the tooth pulp. Dentists should periodically evaluate the condition of their LCU to ensure that they produce maximal light intensity. Development of narrower LCU tips,which could be used within the cavity, may help overcome the limitations of curing from distance and ensure that the deepest parts of the restoration receive adequate irradiation.

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