The Hardness Differences between Packable Composite and Bulk Fill Composite

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Abstract

Composite resin is dental restorative material with fast development such as packable composite that offers handling easiness because it is less sticky when applied to the cavity. Meanwhile, bulk fill composite offers easiness in terms of 4 mm depth of cure to simplify application. Increasing the thickness of the depth of cure is positively related to the increase in the degree of conversion. This study aimed to analyze the hardness difference between packable and bulk fill composite.

Both composites were restored in acrylic plate molds. The samples were cured for 20 seconds and tested with Vickers Microhardness Tester with 100 grams loads for 20 seconds. Data analyzed using one-way ANOVA, followed by Tukey's test.

The difference between packable and bulk fill composite with the average hardness value of packable composite on the upper surface is (81,3 ± 3,4 VHN); on the bottom surface is (80,1 ± 3,5 VHN); bulk fill composite on the upper surface is (65,3 ± 0,6 VHN); and on the bottom surface is (63,4 ± 2,1 VHN).

There was a significant hardness difference between packable composite and bulk fill composite. Packable composite had a higher hardness value than bulk fill composite.

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Introduction

Composite resin is the primary choice of restoration in many countries. Increased demand for composite due to its possibility of a minimally invasive dental treatment and increased patients seeking aesthetic and tooth-colored restoration, which make composite as a primary choice, reaching a high level of restorations due to its physical, mechanical and aesthetic properties.[1,2] Dental resin composites are structures that are composed of several major components, such as resin matrix, filler, coupling agent and initiator-accelerator. Resin-based composite becomes the most popular and widely used because it mimics the appearance of natural teeth. Another advantage of resin composites is they can be made in various consistencies, from highly fluid to rigid paste, which allows them to be manipulated and molded easily, and then converted through a polymerization process to hard and durable materials.[3,4]

As one of the most common choices of dental restoration, the composites have been developed for years. The development is being done by altering the chemical composition, filler reinforcement, and adhesive techniques.[5] One of the drawbacks of conventional composites is the difficulties in placement. During condensation, the composite may stick to the applicator and be pulled out from the cavity walls. In order to overcome the difficulties in placement, packable composites were introduced with the expectation that they could be manipulated and condensed like amalgam.[3,6] The heavier consistency and less stickiness of packable composites are produced by modifying the filler and matrix components.[3] Packable composite is composed of monomers like Bis-GMA, TEGDMA, UDMA and Bis-EMA with aluminum oxide, zirconium oxide and silica as its filler.[7] Modification of its filler and monomers provide a consistency and handling characteristics similar to amalgam.[3]

The placement of packable resin composites, however, still has limitations. Packable composites should be placed in the incremental layer technique, in which the

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restorative material is placed in subsequent increments of about 2 mm of thickness or less. The purpose of the incremental technique is to achieve an optimal degree of conversion by curing composite resin in thin layers.[8] The incremental technique improves light penetration thus allowing adequate polymerization, reducing the amount of shrinkage stress, reducing the cavity configuration factor and cuspal deflection.[9–11] However, incremental placement can be time-consuming and can potentially introduce unwanted restoration voids, leading to a reduction in strength, preventing appropriate sealing or causing post-operative sensitivity.[9,12–16]

Recent developments in composite resins have produced a new class of composite. Manufacturers have introduced bulk fill composites that can be placed into the cavity in thickness of 4 mm in a single increment. This new class of composite contains modified monomers and fillers that allow high light-transmission.[17–22] Bulk technique simplifies the restorative procedure and minimizes the time required for composite placement of large posterior cavities.[9,16,23–27] The possibility of applying up to a maximum of 4 mm thickness in a single increment is due to its higher translucency, thus allowing the light to reach deeper.[28] This new class of composite can be subdivided into two groups based on its consistency: such as low viscosity/flowable bulk-fill which should be used as a base/liner; and high viscosity bulk-fill which are sole cavity filling materials and can be exposed to the oral environment.[20,29]

The differences in filler and matrix components between packable and bulk fill composite affect the hardness. Hardness is an indicator used to predict the wear resistance of a material against permanent indentation or penetration on the surface of restoration and its ability to abrade opposing tooth structures.[3,30]

The hardness value is determined by the degree of conversion. Degree of conversion (DC) is a measure of the percentage of double carbon bonds (C=C) that have been converted to single bonds (C-C) to form the polymer chains during the polymerization process. There are several contributing factors that can influence the degree of conversion such as the composition of composite and the transmission of light.[3] A lower conversion rate can lead to a reduction in strength, post-operative sensitivity and early failure of the restoration.[9] Several studies have confirmed the linear relationship between hardness and degree of conversion. The degree of conversion is considered acceptable if the hardness ratio between the top and bottom surface is more than 80%.[30] Hence, this article aims to review the hardness difference between packable composite and bulk fill composite.

Materials and methods

For this study, two composite resins were evaluated: Filtek™ P60 Posterior Restorative and Filtek™ Bulk fill Posterior Restorative. The tested materials along with their composition and characteristic are displayed in Table 1.

Materials	Type	Shade	Increment thickness (mm)	Matrix	Filler size	Filler % (wt)	Manufacturer
Filtek™ P60	Packable	A3	2 mm	Bis-GMA, TEGDMA, UDMA, Bis-EMA	Microhybrid	83%	3M ESPE GmbH, Seefeld, Germany
Filtek™ Bulk fill	Bulk fill	A3	4 mm	AUDMA, AFM, DDDM, UDMA	Nanofiller	76,5	3M ESPE GmbH, Seefeld

Table 1. Tested materials.

Twenty specimens of each resin composite were prepared (n=20) for hardness measurements in acrylic molds. These contained two dimensions of acrylic molds (2 mm deep x 8 mm in diameter) that were held together using bolts in Figure 1.

Figure 1. Acrylic molds.

Packable composites were inserted into the 4 mm deep molds using the horizontal incremental technique with a thickness of 2 mm per increment, while bulk fill composites were inserted into the cavities in a single increment. A Mylar strip was positioned on top of the material. A glass plate was gently pressed on the material surface to obtain a flat and smooth surface, followed by the scraping of the excess material. Each specimen was cured for 20 seconds using

a visible light-curing unit with a tip diameter of 8 mm (EliparTM S10, 3M ESPE, USA) with 1200 mW/cm^2 output and wavelength range 430–480 nm. The irradiance at each use of the light cure unit was calibrated.

All specimens were examined using a Vickers microhardness testing machine (Zwick Roell Indentec ZHμ.HD). For each specimen, a total of ten indentations were accomplished with five indentations on each surface. A fixed load of 100 g was applied for 20 seconds. Data were calculated as hardness numbers, then analyzed using one-way ANOVA, followed by Tukey's test at a 0.05 significance level.

Results

The means and standard deviations of each resin composite on the upper and bottom surfaces were presented in Table 2 and shown graphically in Figure 2.

	Filtek™ P60	Filtek™ Bulk fill
Upper surface	81.3 ± 3.4 VHN	65,3 ± 0.6 VHN
Bottom surface	80,1 ± 3.5 VHN	63,4 ± 2.1 VHN

Table 2 Means and standard deviations of each resin composite.

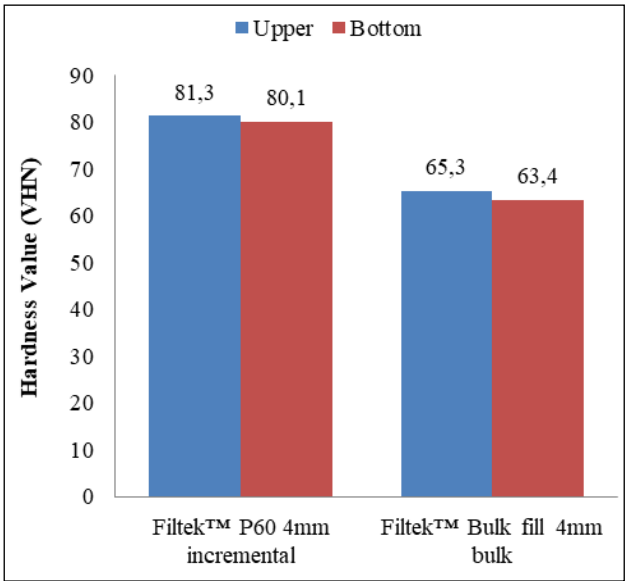

Figure 2. Means hardness value of each resin composite.

The highest hardness value was exhibited by P60 on the upper surface, while the lowest hardness value was exhibited by the Bulk fill on the lower surface. The statistical analysis of both composites was shown in Table 3 and Table 4. P60 showed statistically significant differences with bulk fill ($p < 0.05$). Furthermore, P60 on the upper and bottom surface showed no significant differences ($p > 0.05$), while bulk fill showed statistically significant differences on the upper and bottom surface ($p < 0.05$).

Source	SS	df	MS	F cal	F Tab	P
Treatment	5392,7	3	1797,6	747,8	2,72	$2,67 \times 10^{-56}$
Error	182,7	76	2,4			
Total	5575,4	79				

Table 3. Statistical analysis using One-Way ANOVA.

	Mean	P60 Upper	P60 Bottom	Bulk fill Upper	Bulk fill Bottom
		81,3	80,1	65,3	63,4
P60 Upper	81,3				
P60 Bottom	80,1	0,0616			
Bulk fill Upper	65,3	$7,58 \times 10^{-31}$	$2,26 \times 10^{-29}$		
Bulk fill Bottom	63,4	$3,95 \times 10^{-30}$	$7,21 \times 10^{-29}$	$6,26 \times 10^{-6}$	

Table 4. Statistical analysis using post hoc t-test .

Discussion

Hardness is one of the important mechanical properties which frequently used to compare restorative materials, to evaluate the surface resistance of a material to indentation or penetration. Hardness should always be taken into account, especially in large areas of the masticatory force.[31,32] Hardness is highly correlated with the degree of conversion of resin composites. Factors affecting the hardness of a material restoration can affect its durability.[33] In this study, the hardness of packable and bulk fill composite materials was determined and compared with each other.

The hardness of dental material is usually measured using Vickers methods. This technique was using a diamond tip to provide an indentation, with a specified load applied for a certain time. Hardness is examined through the microscope and obtained by dividing the applied load by the measured length of each diagonal indentation. The Vickers Hardness Test is easy to use and offers several advantages.[32] For these reasons, the hardness of resin composite was evaluated by Vickers testing with a fixed load of 100 g for 20 seconds.

In this study, there was a difference in hardness between packable and bulk fill composite. The difference in hardness is affected by the degree of conversion and the composition of the composite including the size, type and volume of filler.[34] Increased degree of conversion

provides higher mechanical properties, such as hardness.[35] The degree of conversion depends on several factors: these include intrinsic factors such as chemical structure and resin composition, and extrinsic factors such as the thickness of each increment, the light source used, irradiation time, light transmission through the material, power density, light-tip size, light-curing duration, light wavelength, distribution of filler particle size, type of fillers and shade of the composite resins.[3,8,36,37]

The degree of conversion is also affected by the composite viscosity and reactivity of the monomer system. The degree of monomer systems increases in the following order: BisGMA < BisEMA < UDMA < TEGDMA. BisGMA is considered as the most viscous monomer due to the strong intramolecular hydrogen bonding, which decreases the mobility and reactivity of the monomer during the polymerization process. This might be one of the factors that contributed to limited cure depth on packable composite.[38] However, no significant difference in hardness was found between the top and bottom surfaces of packable composite. This is due to the 2 mm thickness of the horizontal incremental technique that was used in the placement of packable composite. The incremental technique could optimize the conversion rates, thus increasing the mechanical properties such as hardness.[8]

The packable composite consists of UDMA (urethane dimethacrylate) and Bis-EMA(6) (Bisphenol A polyethylene glycol diether dimethacrylate) as the monomer matrix. Both of these resins are higher molecular weight and therefore have fewer double bonds per unit of weight. The possibility of amalgam-like handling characteristic is due to the higher molecular weight of UDMA, hence impacting the measurable viscosity.[39]

Packable composite has a higher amount of filler compared to bulk fill composite. Increased filler loading increases mechanical properties.[3] The total inorganic filler loading of packable composite is approximately 61% by volume (83% by weight) with particle size distribution ranging from 0.01µm to 3.5µm with an average particle size of 0.6µm. The varied filler particle size allows smaller filler particles to fill the space produced by larger filler particles, thus increasing the number of fillers.[3] Meanwhile, the bulk fill composite is approximately 58,4% by volume (76,5% by weight), containing a combination of a non-agglomerated/non-aggregated 20 nm silica filler, a non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, an aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles), with an important addition of agglomerate 100 nm Ytterbium trifluoride (YbF3) particles to increase the radiopacity.[39,40] The packable composites tested showed a higher hardness value than bulk fill composites at all measured depths, this is due to the higher filler loading of packable composites.

Increased filler loading imparting radiopacity. As light transmission is strongly dependent on material opacity, the incremental technique has been recommended for packable composite to enhance the degree of conversion.[38]

Bulk fill composite is a nanofiller composite with Bis-EMA, DDDMA, AUDMA, AFM and UDMA as monomer matrix.[38,40] UDMA is less viscous than Bis-GMA which affects the migration of free radicals, thus increasing the degree of conversion. As shown in Figure 3, AFM contains a third reactive site that can fragment to relieve stress during polymerization. The fragments, however, still retain the capability to re-polymerize at a lower stress rate. AUDMA has a larger monomer than found in traditional dimethacrylates, as shown in Figure 4. Limiting the number of shrinkage zones helps reduce the amount of shrinkage and stress that occurs during polymerization.[40,41] Beside monomer system, the size of nanomeric particles is smaller than visible light (400-800 nm) thus producing a highly translucent material, which improves light penetration along with the degree of conversion, allowing a greater depth of cure.[4]

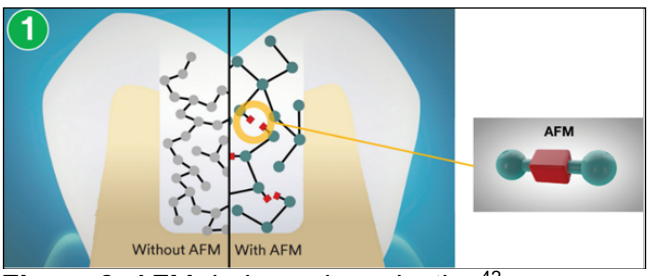

Figure 3. AFM during polymerization[42].

Nanofiller composite, however, produces light scattering, which adversely affects the physical properties. Turssi et al. believe that the scattering effect occurs in composites whose

filler particle size is closer to the wavelength of the activating light, which decreases the degree of conversion. Massoti et al. also reported that fillers with sizes approaching half of the light irradiation wavelength showed increased scattering. The lower filler size increases the total filler surface and the filler matrix interface. Thus, light scattering at the filler matrix interface is increased, reducing more light to penetrate through the material.[20]

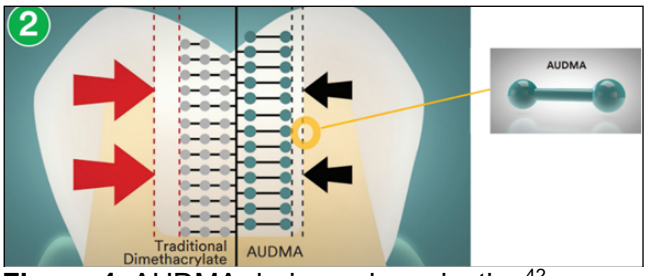

Figure 4. AUDMA during polymerization[42].

On the top surface, the power density is usually sufficient for adequate polymerization; this is because the photo-irradiation tip of the light cure unit focuses directly on the top surface. However, on the bottom surface, the power density is greatly reduced due to the scattering of light by filler particles and resin matrix, hence decreasing the degree of conversion and reducing hardness.[43] Reduced hardness on the bottom surface was also affected by reduced curing time which is only 20 seconds for the bulk filling technique, compared to the 2 x 20 seconds incremental technique.[37] This explains the statistical differences between the top and bottom surfaces of bulk fill composite.

However, according to several authors, the hardness ratio of 80% or greater between the bottom and the top surface is considered as adequate polymerization.[30] This statement is consistent with our findings that showed a ratio of 98.5% and 97% between the top and the bottom surfaces of packable and bulk fill composites which show adequate polymerization.

Conclusions

There was a significant difference in hardness between packable composite and bulk fill composite. Packable composite had a higher hardness value than bulk fill composite.

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Declaration of Interest

The authors report no conflict of interest.

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