

# Bulk-Fill Composites: A Review of the Current Literature

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**Purpose:** The aim of this article was to provide an overview of the literature on the currently available bulk-fill composites, and to describe the common trends as well as the wide variations. The findings may help the clinician to select the proper material with regard to its applicability in various clinical situations.

**Methods:** The literature up to October 2016 was reviewed based on a PubMed search (keywords: “bulk-fill OR bulkfill OR bulk fill” AND “composite OR composites”).

**Results:** This review revealed that bulk-fill composites differ most from conventional composites in their increased depth of cure, which could mainly be attributed to an increase in translucency. However, the literature is inconsistent regarding the determination of the depth of cure. Flowable “base” bulk-fill composites seem most suitable for narrow cavities deeper than 4 mm, in particular when a higher adaptation potential thanks to better flowability in less accessible cavity configurations is desirable. In more extensive cavities, “full-body” bulk-fill composites with a high filler load are preferable. Then, resistance against wear and fracture becomes increasingly important, while a thicker consistency might also help in obtaining a good contact point. Tests related to shrinkage stress induced by bulk-filling seem inconsistent and their clinical relevance is unclear.

**Conclusion:** More clinical studies that specifically focus on bulk-filling deep and large restorations are definitely required to fully explore the clinical benefits of bulk-fill composites.

**Keywords:** bulk fill, composite, review, depth of cure, polymerization shrinkage.

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Today, dentists most often make use of light-curable direct composite to restore teeth. Classically, a restoration is placed in increments that are cured separately.<sup>120,136</sup> The limited depth of cure of most conventional

composites has precluded the use of thicker layers in many clinical cases.<sup>104</sup> Another reason for using the incremental technique is to reduce polymerization shrinkage,<sup>87,89,114</sup> even though this theory has also been contradicted.<sup>20,131</sup> Low-shrinkage composites were developed to tackle the issue of polymerization shrinkage but their success was limited, mainly because the clinical benefit was not always clear; no apparent differences in outcome were found<sup>94,128</sup> and layering was still required due to the limited depth of cure.<sup>60</sup> In addition, composites based on new low-shrinkage monomer technology<sup>146</sup> were often less practical to use due to the requirement of a specific bonding system.<sup>16,63</sup>

Meanwhile, the demand for a true amalgam alternative kept on increasing, due in part to the more comprehensive ban on products containing mercury and the global amalgam “phase-down” program instituted by the WHO.<sup>32,42,103,115</sup> Ideally, such an amalgam alternative would be an easy-to-use, forgiving material. In this respect, the possibility of filling a cavity in bulk has some attractive benefits; above all, the procedure takes less time and the “window of opportunity” for technical errors, such as void

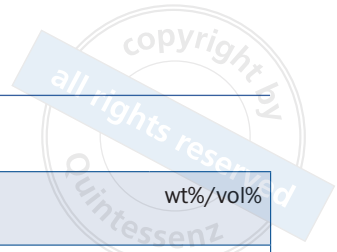
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**Table 1 Overview of the currently available bulk-fill composites**

	Name Manufacturer	Maximum layer thickness <sup>1</sup>	Capping layer	Available shades	Composition <sup>2</sup>	wt%/vol%
Flowable 'BASE' bulk-fill composites	Filtek Bulk Fill Flowable 3M ESPE; Seefeld, Germany	4 mm	2 mm required	Universal A1 A2 A3	Bis-GMA, UDMA, bis-EMA, Procrylat resin, ytterbium trifluoride, zirconia filler, silica	65/43
	Surefil SDR Flow Dentsply; Konstanz, Germany	4 mm	Required	Universal A1 A2 A3	Modified UDMA, ethoxylated bisphenol A dimethacrylate (EBPADMA), TEG-DMA, Ba-Al-F-B silicate glass, Sr-Al-F silicate glass, camphorquinone, photo-accelerator, BHT, UV stabilizer, titanium dioxide, iron oxide pigments, fluorescent agent	68/45
	Venus Bulk Fill Heraeus Kulzer; Wehrheim, Germany	4 mm	Required	Universal	Multifunctional methacrylate monomers (UDMA, EBPADMA), Ba-Al-F silicate glass, YbF <sub>3</sub> , SiO <sub>2</sub>	65/38
	X-tra base Voco; Cuxhaven, Germany	4 mm	Required	Universal A2	Inorganic filler in a methacrylate matrix aliphatic dimethacrylate, bis-EMA	75/61
Paste-like 'FULL-BODY' bulk-fill composites	Filtek Bulk Fill Posterior <sup>2</sup> 3M ESPE	5 mm	No	A1 A2 A3 B1 C2	AUDMA, UDMA, 1,12-dodecane-DMA non-agglomerated/non-aggregated 20-nm silica filler, non-agglomerated/non-aggregated 4- to 11-nm zirconia filler, aggregated zirconia/silica cluster filler (comprised of 20-nm silica and 4- to 11-nm zirconia particles), ytterbium trifluoride filler consisting of agglomerate 100-nm particles	77/59
	QuiXfil, Quixx Posterior Dentsply	4 mm	No	Universal	UDMA, TEG-DMA, dimethacrylate and trimethacrylate resins, carboxylic acid, modified dimethacrylate resin, butylated hydroxy toluene (BHT), UV stabilizer, camphorquinone, ethyl-4-dimethylaminobenzoate, silanated strontium aluminum sodium fluoride phosphate silicate glass	77/58
	SonicFill Kerr; Orange, CA, USA	5 mm	No	A1 A2 A3 B1	Bis-GMA, TEG-DMA, bis-EMA, barium glass, silicon dioxide	86/66
	SonicFill 2 <sup>3</sup> Kerr	5 mm	No	A1 A2 A3 B1	Bis-GMA, TEG-DMA, bis-EMA, zirconium oxide	-
	Tetric EvoCeram Bulk Fill, Tetric N-Ceram Bulk Fill Ivoclar Vivadent; Schaan, Liechtenstein	4 mm	No	IVA IVB IVW	Dimethacrylates (bis-GMA, bis-EMA, UDMA), barium glass, ytterbium trifluoride, mixed oxide and prepolymer, additives, catalysts, stabilizers, pigments	81/61
	X-tra fil Voco	4 mm	No	Universal	Inorganic filler in a methacrylate matrix (bis-GMA, UDMA, TEG-DMA)	86/70

<sup>1</sup>As recommended by the manufacturer; <sup>2</sup>according to technical information provided by the respective manufacturer; <sup>3</sup>no studies available.

incorporation and contamination between layers, can be decreased. Concerning this quality, reinforced glass-ionomers cements (GICs; eg, Equia Forte, GC [Tokyo, Japan]; ChemFil Rock, Dentsply [Konstanz, Germany]) have been marketed as well.<sup>58,61</sup> Just like amalgam, these GICs can be placed in bulk and the use of a separate adhesive is obviated. However, like chemically curing composites,<sup>23</sup> they lack the great advantage of light curing,<sup>124</sup> which in-

creases the working time and thus facilitates controlled restoration placement to a great extent. A dual-curing UDMA-based material categorized as "alkasite" (Cention N, Ivoclar Vivadent; Schaan, Liechtenstein), which claims to contain alkaline glass fillers capable of releasing substantial levels of fluoride, has also been recently proposed for bulk placement in retentive preparations without the application of an adhesive. Ideally, the material would be self-adhering, to

avoid the use of an adhesive or an invasive retentive cavity design. Today, experimental versions of self-adhering bulk-fill composites are being developed in an attempt to meet these demands.

However, several criteria must be met before a composite is truly suitable for bulk filling. Besides the increased depth of cure and effective handling of polymerization shrinkage issues, the composite should have sufficient wear and fracture resistance to avoid early failures and should possess acceptable dimensional stability.

It seems unlikely that all required properties can be optimized in one ideal material, since improvements in one property will often be made at the expense of another; several key properties are influenced by the same variable, so that compromises are nearly inevitable. This most likely explains the large differences in properties seen with existing bulk-fill composites. Moreover, due to large compositional variations, which are generally not completely disclosed by the manufacturer, a proper classification of composition-related properties based on the commercially available materials is impractical, if not impossible.

The purpose of this literature review was to provide an overview of the existing bulk-fill composite technology, disclose existing trends in their properties and behavior, and identify the most important lacunae.

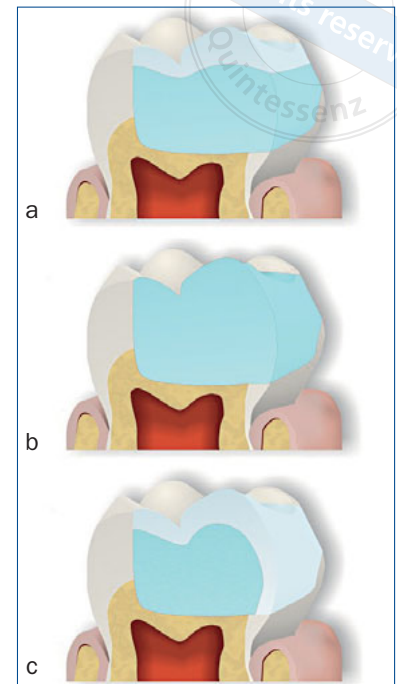
## METHODS

A PubMed search was conducted up to October 2016, using the keywords “bulk-fill OR bulkfill OR bulk fill” AND “composite OR composites”. An additional search was conducted with each of the commercial names of the bulk-fill products being investigated in the literature. Reference lists were further checked for relevant articles. Only articles investigating bulk-fill composites that can cure up to a depth of at least 4 mm according to the manufacturer’s instructions were included.

## BULK-FILL STRATEGIES

Based on the different strategies, the bulk-fill composites can be categorized into two groups (Table 1): base and full-body bulk-fill composites. The base bulk-fill composites (Fig 1a) usually have low viscosity (ie, they are flowable), enabling placement through a small nozzle from a syringe, which facilitates placement and adaptation in less accessible cavities. Generally, these composites have a lower filler content, which renders the surface less wear resistant; hence, capping with a conventional composite is required. Commonly, these base materials are also referred to as flowable bulk-fill composites.

The full-body bulk-fill composites (Fig 1b) can be regarded as the only true bulk filling type, since the whole restoration can be placed at once without requiring any coverage. These materials generally have higher filler loads, which make them highly viscous; for this reason, these ma-



**Fig 1** Types of bulk-fill strategies, with a flowable base bulk-fill technique presented in (a), and a paste-like full-body bulk-fill technique in (b). Some fiber-reinforced or large-particle core composites are intended to replace dentin in bulk, but require a conventional composite at the outer restoration surface (c).

terials are often referred to as paste-like bulk-fill composites. The higher filler load renders the surface more wear resistant and due to the associated viscous consistency, the surface is sculptable. An exception in this group is SonicFill (Kerr), which involves the use of an air-driven handpiece that dispenses the composite while applying sonic vibration.<sup>3</sup> The manufacturer claims that this vibration reduces the viscosity of the material by 84%, similar to a flowable consistency, which facilitates adaptation. Recently, SonicFill 2 (Kerr; Orange, CA, USA), which comprises a new filler system, has been introduced to replace its predecessor. It should be mentioned that other high-viscosity types of composites exist that can be placed in bulk (Table 2); they contain material-reinforcing filler particles intended to strengthen the restored tooth complex. For instance, Alert Condensable Composite (Pentron; Orange, CA, USA) and everX Posterior (GC) contain glass fibers as filler, which provide specific properties to these composites. Fiber-reinforced composites have been designed to be used as dentin replacement<sup>55,56,138</sup> in conjunction with a conventional composite used as enamel replacement. Fibers are known to prevent and stop crack propagation.<sup>138</sup> Fractures are considered to be one of the main causes of composite restoration failure.<sup>97,110,143</sup> As such, a fiber-reinforced composite is recommended to be applied in bulk as a reinforced base of large composite restorations in particular. For Alert (Pentron), the manufacturer only recommends the use of a protective sealant.

So-called core buildup composites (Fig 1c) usually contain larger glass filler particles than that commonly contained in conventional composites. These composites are basically intended to fabricate core buildups as crown support, and therefore do not need to be polishable to a high

**Table 2 Overview of other resin-based materials with a DOC  $\geq$  4 mm (not included in this review)**

Name Manufacturer	Maximum layer thickness <sup>1</sup>	Capping layer	Reason for exclusion
Activa Bioactive Restorative Pulpdent; Watertown, MA, USA	4 mm	No	Ionic composite resin <sup>2</sup> ; dual curing
Admira Fusion x-tra Voco; Cuxhaven, Germany	4 mm	No	Ormocer
Alert Condensable Composite Pentron; Orange, CA, USA	5 mm	Sealant	Fiber-reinforced composite
Beautifil-Bulk Flowable Shofu; Kyoto, Japan	4 mm	Required	Giomer
Beautifil-Bulk Restorative Shofu	4 mm	No	Giomer
Bis-core Bisco; Schaumburg, IL, USA	-	Complete coverage required	Core material; dual curing
Bisfil 2B Bisco	-	Required	Chemically curing
Bisfil II Bisco	-	Required	Chemically curing
Cention N Ivoclar Vivadent; Schaan, Liechtenstein	-	No	Alkasite restorative <sup>2</sup> ; dual curing
Clearfil Core Kuraray Noritake, Tokyo, Japan	-	Complete coverage required	Core material; chemically curing
Clearfil DC Core Plus Kuraray Noritake	-	Complete coverage required	Core material; dual curing
Clearfil PhotoCore Kuraray Noritake	7 mm	Complete coverage required	Core material
Core-Flo Bisco	-	Complete coverage required	Core material; chemically curing
Core-Flo DC Bisco	-	Complete coverage required	Core material; dual curing
Core-Flo DC Lite Bisco	-	Complete coverage required	Core material; dual curing
Core Restore 2 Kerr; Orange, CA, USA	-	Complete coverage required	Core material; dual curing
HardCore Pulpdent	-	Complete coverage required	Core material; dual curing
everX Posterior GC	4 mm	Complete coverage required	Fiber-reinforced composite; core material
Fill up! Coltene; Altstätten, Switzerland	-	No	Dual curing
Light-core Bisco	5 mm	Complete coverage required	Core material
N'Durance Dimer Core Septodont; Saint-Maur-des-Fossés, France	-	Complete coverage required	Core material; dual curing
ParaCore Coltene	-	Complete coverage required	Core material; dual curing
Spee-Dee Build Up Pulpdent	-	Complete coverage required	Core material; dual curing

<sup>1</sup>As recommended by the manufacturer; <sup>2</sup>term used by manufacturer.

gloss. Although most composites in this category are chemically or dual-curing composites, Clearfil Photo Core (Kuraray Noritake) is a solely light-curing material that can be applied in bulk up to a layer of 7 mm according to the manufacturer (Table 2). Although such fiber-reinforced and core buildup composites have an increased depth of cure (DOC), similar to that of bulk-fill composites, they are quite different in terms of composition and indication; hence, they are not included in this review.

## DEPTH OF CURE (DOC)

Improved DOC is the key parameter in this new class of bulk-fill composites. Several strategies are followed to obtain an improved DOC. Light-curing resin-based composites contain photo-initiators, which decompose upon radiation via visible blue light into reactive species that activate polymerization. This implies that a sufficient amount of light with a wavelength within the absorption spectrum of the photo-initiator is necessary to initiate the polymerization reaction. Most bulk-fill composites still contain camphorquinone (CQ) as the primary photo-initiator and a tertiary amine as co-initiator. Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) contains a dibenzoyl germanium derivative, referred to as Ivocerin, as an additional photo-initiator besides the CQ/amine photo-initiator.<sup>106</sup> Ivocerin features a high absorption coefficient, with its maximum in the wavelength range of 370 to 460 nm.

DOC is chiefly limited by the attenuation of the curing light, which is inversely correlated to the material's translucency. All bulk-fill composites, except for SonicFill (Kerr), exhibit an increased translucency.<sup>27,88</sup> This entails a compromise at the expense of esthetic properties, which cannot be avoided. Matching between refractive indices of matrix and filler,<sup>130</sup> changes in filler size, shape and coating can all influence the light transmittance through a composite. The strategies employed by the manufacturers differ for the different bulk-fill composites.<sup>27</sup> SDR (Dentsply), X-tra base, and X-tra fil (both from Voco) contain larger filler particles.<sup>27</sup> Regarding their shape, a rounded, regular shape, such as in Tetric EvoCeram Bulk Fill (Ivoclar Vivadent), improves the translucency.<sup>11</sup> On the other hand, nanofillers with a diameter less than the wavelength of the light passing through are unable to scatter light, thus possibly improving translucency as well.<sup>68,71</sup>

Currently, there are many techniques to determine DOC.<sup>33,48,60,91,113,134</sup> In general, they can be divided in two groups. First, DOC can be measured indirectly by surface hardness; eg, ISO 4049 standard prescribes a scraping method to remove insufficiently cured material, after which the specimen height is simply measured and divided by two,<sup>68</sup> or it can be described in terms of the actual microhardness value. In the latter case, the data are usually expressed in percent, such as the bottom-to-top hardness ratio or as percentage of the maximum hardness measured. An arbitrary cut-off score of 80% is usually chosen.<sup>24,104</sup> Second, DOC can be measured based on the

degree of conversion (DC), which in turn can be measured directly with either (micro-)Raman or Fourier transform infrared (FTIR) spectroscopy. Usually, a percentage of the maximum DC or the DC at the top surface is chosen as a cut-off score, analogous to the above-mentioned hardness-based methods.<sup>93</sup> A lack of consensus and standardization in the methodology and a paucity of clinical evidence in the determination of DOC complicate the interpretation of the outcomes and might provide seemingly contradictory results in different studies. Moreover, differences in irradiation regarding spectrum, time and intensity, in molds that differ for size and material, and in post-cure time intervals are also responsible for variations in the data reported and so may further confuse its interpretation.

The ISO 4049 standard – also known as the scraping test – was a first attempt to standardize DOC.<sup>75</sup> Flury et al<sup>48</sup> concluded that all the tested materials met the ISO standard, except for Tetric EvoCeram Bulk Fill (Ivoclar Vivadent). Garcia et al<sup>54</sup> and Ibarra et al<sup>67</sup> also used the ISO 4049 standard and concluded that SonicFill (Kerr) had a DOC below 4 mm after curing for 20 s. In two other studies, the DOC of both Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) and SonicFill (Kerr) was below 4 mm, when measured in accordance with the ISO 4049 standard.<sup>19,56</sup> Miletic et al<sup>102</sup> used a modification of the ISO 4049 standard, termed the acetone-shaking test,<sup>85</sup> and reported that, as opposed to Tetric EvoCeram Bulk Fill (Ivoclar Vivadent), SonicFill (Kerr) reached a DOC lower than 4 mm. Yap et al<sup>147</sup> also found DOC below 4 mm for Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) and SDR (Dentsply). Tsujimoto et al<sup>135</sup> found adequate DOC at a depth of 4 mm for both SDR (Dentsply) and Tetric EvoCeram Bulk Fill (Ivoclar Vivadent); however, the light-curing time was extended to 30 s. Using a slightly different mold than the one described in ISO 4049, Menees et al<sup>101</sup> reported adequate DOC at 4 mm for Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) but only as far as 3.5 mm for Filtek Bulk Fill Posterior (3M ESPE). Although there were differences in outcome between all the studies that applied ISO 4049, the general conclusions seemed to be consistent.

In some studies, it has been suggested that the estimated DOC determined by ISO 4049 is lower than the depth corresponding to 80% of the top or maximal microhardness.<sup>48,55</sup> What might be even more important is that the relation between 80% microhardness and ISO 4049 was highly material-dependent, as the ranking of materials for DOC changed considerably. Logically, it is possible to reason that scraping off unset material would be more related to the absolute hardness, while a calculated percentage is inherently relative.

Using the Vickers hardness test, Flury et al<sup>48</sup> found that only Venus Bulk Fill (Heraeus Kulzer) could maintain a DOC of 4 mm after 20 s of irradiation. However, it must be pointed out that in contrast to ISO 4049 measurements, a hemi-circular mold was used for the Vickers hardness tests, and thus the specimens' irradiated surface was halved, which may have decreased DOC.<sup>43</sup> In the studies by Garcia et al<sup>54</sup> and Yap et al,<sup>147</sup> none of the tested bulk-fill composites could maintain an 80% bottom-to-top Knoop hard-

ness ratio at a depth of 4 mm. AlQahtani et al<sup>6</sup> reported that the 80% bottom-to-top hardness threshold could only be obtained when Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) was overexposed to light for 40 s, while Garoushi et al<sup>57</sup> reported the opposite outcome. Son et al<sup>132</sup> also reported that 40 s of irradiation was not sufficient to maintain the DOC at a 4-mm depth above 80% for any of the tested bulk-fill composites.

Two studies found that DOC, expressed in microhardness, of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) was not significantly different from the DOC of conventional composites.<sup>37,76</sup> Tarle et al<sup>134</sup> also found a microhardness below 80% at a 4-mm depth for Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) and SonicFill (Kerr). In contrast, Alrahlah et al<sup>7</sup> found that SonicFill (Kerr) and Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) had the greatest DOC of all the tested bulk-fill materials. Nagi et al<sup>107</sup> also reported that two full-body bulk-fill composites (Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; X-tra fil, Voco) could be properly cured in bulks of 4 mm. Marigo et al<sup>99</sup> reported that SDR (Dentsply) reached a significantly higher DOC at a 4-mm depth (82% bottom-to-top hardness) in comparison to conventional composites. Miletic et al<sup>102</sup> found that the DOC at a depth of 4 mm expressed as microhardness is dependent on light-curing time, since bottom-to-top ratios were above or below 80% when full-body bulk-fill composites were cured for 20 or 10 s, respectively. After testing several bulk-fill composites, Alshali et al<sup>8</sup> and Fronza et al<sup>52</sup> reported a bottom-to-top microhardness ratio higher than 90% for all materials. Bucuta and Ilie<sup>27</sup> found that all bulk-fill composites could maintain a bottom-to-top microhardness above 80%, in contrast to the conventional composites tested. This was confirmed in other studies from the same research group, provided that sufficient irradiance was applied.<sup>69,73,74</sup> While all bulk-fill composites behaved differently under the analyzed curing conditions, an increase in DOC with increased energy density was observed with all materials. With prolonged curing times at the same energy density, the mechanical properties in depth could be improved, thereby confirming that the energy reciprocity law is not absolute.<sup>73,74</sup>

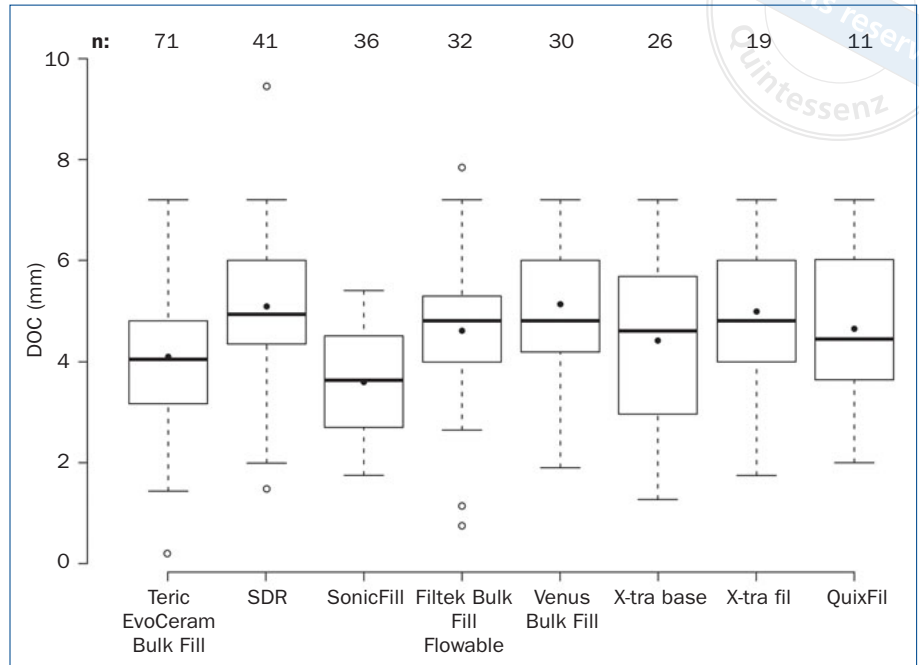
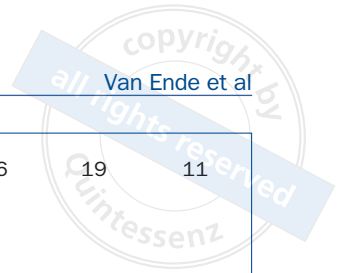
A DC of at least 90% of the maximum value has been proposed to estimate DOC.<sup>93</sup> Most bulk-fill composites show ratios equal to or higher than 90% at a depth of 4 mm.<sup>52,57,99,102,112,113,134</sup> DC was found to be more sensitive to change in parameters than microhardness.<sup>69</sup> Other authors found that DOC may be overestimated when determined on the basis of DC.<sup>134</sup>

Two studies found different DC ratios at a 4-mm depth for Filtek Bulk Fill Flowable (3M ESPE) by means of micro-Raman spectroscopy. Pongprueksa et al<sup>117</sup> reported an adequate DOC of 92%, while Lempel et al<sup>90</sup> found only 62%. The latter study also reported 73% and 80% as DOC for X-tra base (Voco) and SDR (Dentsply), respectively. It seems that setup differences related to the mold (diameter and transparency), measurement (time and position) and light-curing source (light irradiance, spectral emission, tip diameter and curing time) may have a considerable impact on the results.

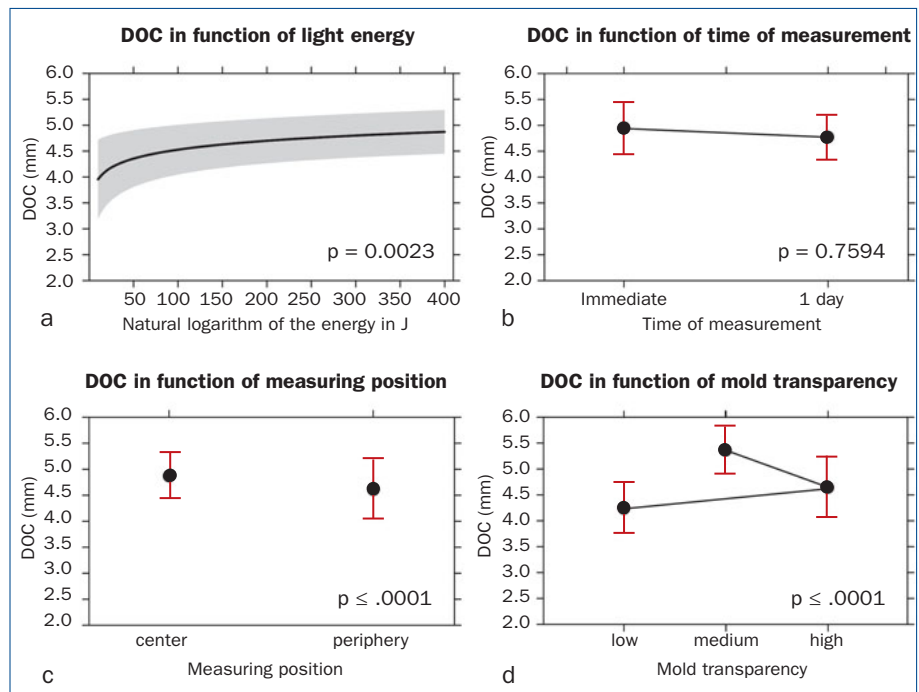
Although there is definitely a strong correlation between hardness and DC,<sup>24,91</sup> it must be borne in mind that these remain different material properties, which also depend on other factors. Moreover, the correlation between hardness and DC was indeed found to be material dependent.<sup>71</sup> Both parameters independently have an important impact on the restorative's behavior in the mouth and thus both should be taken into consideration when evaluating DOC.<sup>47,69,71,134,149</sup>

Despite a wide variation in the estimated DOC, mostly due to differences in the estimated parameters and the study setups, some trends could be identified. In general, the base bulk-fill composites seem to reach a higher DOC than the full-body bulk-fill composites.<sup>48,52,54,57,76,93,102,112,132,149</sup> Although the increased DOC of bulk-fill composites was generally confirmed when proper curing times and irradiances were employed, the full-body bulk-fill composites SonicFill (Kerr)<sup>19,54,55,57,60,73,102,112,134</sup> and Tetric EvoCeram Bulk Fill (Ivoclar Vivadent)<sup>19,48,55,57,107,134,135,147</sup> often performed just at the limit or below the DOC suggested by the manufacturer.

For a more in-depth analysis of DOC, a further numerical assessment was conducted on the 34 manuscripts<sup>6-8,19,27,33,47,48,52,54,56,57,60,67,71,73,74,76,90,93,99-102,107,112,113,117,118,123,132,134,147,149</sup> which assessed DOC of bulk-fill composites, in order to identify the parameters that affect DOC. All literature data were extracted along with relevant parameters, such as the measurement method used, the specification of the curing light and time, and the mold employed to prepare specimens to measure DOC. A linear mixed-effects statistical model was constructed from the respective linear mixed-effects models to analyze DOC in function of the parameters, with a likelihood ratio test at a significance level of  $\alpha = 0.05$  (anova.lme function in nlme package, R, R Foundation for Statistical Computing; Vienna, Austria). The DOC reported in the literature for bulk-fill composites ranges from 0.2 to 9.45 mm (Fig 2). Parameters that affected DOC, as measured in the literature, are presented in Fig 3. The total energy principle promotes the common assumption that varying combinations of curing irradiance and exposure time provide similar material properties at constant radiant exposure. This principle is commonly known as the exposure reciprocity law. The total energy (J) is dependent on the irradiance of the curing light (mW/cm<sup>2</sup>), curing time (s) and irradiated surface (cm<sup>2</sup>). From the statistical analysis, the data in the literature revealed that DOC is significantly ( $p < 0.05$ ) influenced by the total light energy, with an increase in conversion following a higher energy dose (Fig 3a). However, it must be kept in mind that even though this indicates that the general trend confirms the exposure reciprocity law, the outcome might vary depending on individual conditions, as it is known that reciprocity does not hold in all circumstances.<sup>62</sup> The time point at which DOC is measured does not significantly influence DOC (Fig 3b); DOC measured immediately or 24 h after specimen preparation was found to be statistically similar ( $p > 0.05$ ). DOC was about 0.25 mm lower at the specimen periphery than at the specimen center (Fig 3c), and the measurement position was also found to signifi-



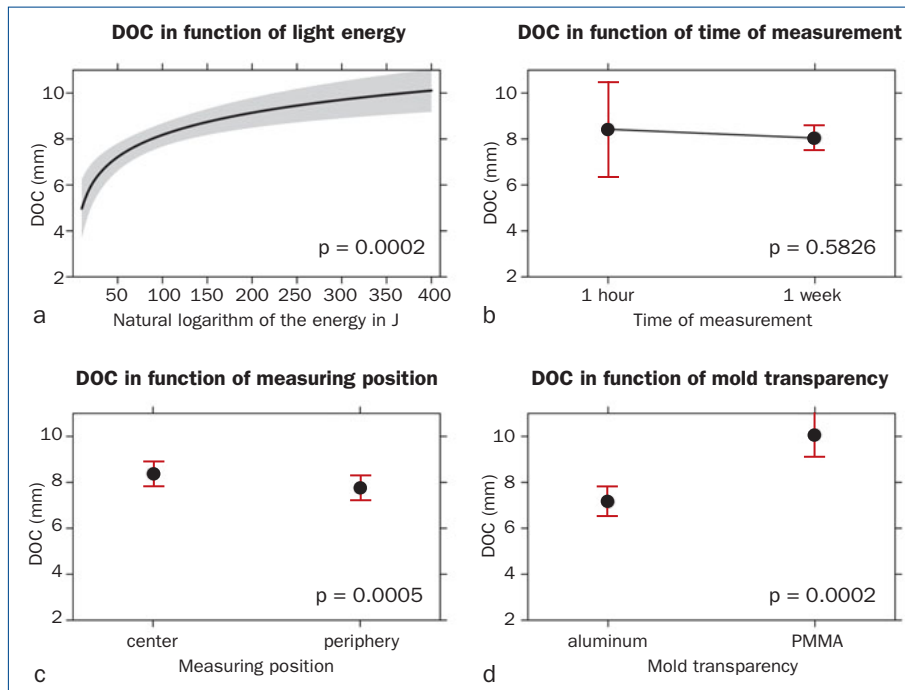
**Fig 2** DOC (in mm) of bulk-fill composites reported in the literature. n refers to the number of specimens tested in the literature for the respective bulk-fill composite. The thick horizontal line and the black dots represent median and the mean, resp; the boxes represent the first to the third quartile; the whiskers represent the lower and the upper quartile with the exception of outliers, which are represented by open dots.



**Fig 3** Parameters influencing DOC, based on data measured in the literature (34 publications). p-values from ANOVA, representation of linear mixed-effects model. Means (black dots) connected by lines were not significantly different.

cantly ( $p < 0.05$ ) influence DOC. Finally, the transparency of the mold material was decisive: molds with intermediate transparency (teflon or tooth) significantly ( $p < 0.05$ ) increased DOC with about 1.1 mm in comparison to non-transparent metal and silicone molds. However, the use of highly translucent molds (PMMA or no mold) did not result in significant differences in comparison with both low- and intermediate-translucency molds (Fig 3d).

Since the amount of data in the literature per parameter was too limited to draw reliable conclusions about the impact the parameters have on DOC, an additional laboratory investigation was conducted to analyze this trend in a more standardized way. Composite blocks (10 mm thick) of one of the most tested bulk-fill composite (SDR, Dentsply) mentioned in the literature were made using two different mold materials (aluminum and PMMA) with diameters ranging



**Fig 4** Parameters influencing DOC, based on data measured using micro-Raman spectroscopy in a laboratory study involving the base bulk-fill composite SDR (Dentsply).  $p$ -values from ANOVA, representation of linear mixed-effects model. Means (black dots) connected by lines were not significantly different.

from 2 to 8 mm and curing conditions at different radiant exposures (0.85 to 22.4 J/cm<sup>2</sup>, as measured by MARC, BlueLight Analytics; Halifax, Canada). After cross sectioning the specimens at the specimen center, DOC was measured centrally as well as peripherally using micro-Raman spectroscopy ( $\mu$ Raman, Senterra, Bruker; Billerica, MA, USA) 1 h after specimen preparation and after 1 week. A significant ( $p < 0.05$ ) increase in DOC was found with increasing light energy (from 2.4 to 8.75 mm for 0.85 and 22.4 J/cm<sup>2</sup>, respectively) (Fig 4a), thus confirming the conclusion mentioned above drawn from the literature. No significant ( $p > 0.05$ ) difference in DOC was measured at 1 h versus 1 week after specimen preparation (Fig 4b), which confirms the outcome of the literature, although the studies measured DOC after only 24 h. DOC at the specimen center was significantly ( $p < 0.05$ ) higher than at the specimen periphery (Fig 4c), again confirming the data from the literature. Finally, DOC was significantly ( $p < 0.05$ ) higher for specimens prepared with a PMMA than with an aluminum mold (Fig 4d), which also partially corresponded to the findings from the literature. While a DOC of at least the full depth of 10 mm was measured with all transparent molds, irrespective of their diameter, DOC was reduced with the metal molds; this depended on the specimen diameter (DOC of 6.1, 7.0, 8.1, 9.1, 9.6, 9.9 mm for the 2-, 3-, 4-, 5-, 6- and 8-mm aluminum mold diameters, respectively).

Both the literature and additional laboratory data indicate that differences in the study setup may produce considerable differences in DOC. Especially the use of small-diameter opaque molds could significantly decrease DOC, and this should be taken into consideration when data are interpreted and compared.

## MECHANICAL PROPERTIES

Since bulk filling is mostly desirable in the posterior, stress-bearing region, a bulk-fill composite should have adequate mechanical properties.<sup>92</sup> In the past, flowable composites were regarded as not suitable for restoring these areas. Thus, concerns have been raised, especially in terms of the flowable base bulk-fill composites.<sup>38,92</sup> Although there is little correlation between composite properties and their clinical performance,<sup>45</sup> strength, toughness, and wear resistance are desired qualities in the posterior region.

In general, the filler volume seems to be positively correlated with material properties, such as elastic modulus,<sup>92</sup> strength<sup>1,68</sup> and hardness.<sup>9,41,48</sup> As a consequence, the flowable base bulk-fill composites generally have lower mechanical properties. SonicFill (Kerr) and X-tra fil (Voco) revealed the best mechanical properties, while Venus Bulk Fill (Heraeus Kulzer) and Filtek Bulk Fill Flowable (3M ESPE) were presented with the lowest properties; this is in line with their filler load.<sup>1,21,33,55,60,68,92,122,134</sup> The lower flexural strength of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) found in several studies is notable, even lower than that of most flowable base bulk-fill composites.<sup>37,55,68,92,135</sup> On the other hand, according to Ilie et al,<sup>68,71</sup> the mechanical properties of X-tra base (Voco) are sufficiently good to render a capping layer redundant, despite the fact that the manufacturer recommends it. Engelhardt et al<sup>41</sup> also reported significantly higher wear resistance and hardness for X-tra base (Voco), which has the highest filler ratio among the flowable base bulk-fill composites (61 vol%) and equals the filler ratio of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) (Table 1). The variability in viscosity for the same filler con-



tent may be explained by differences in the resin matrix, as well as the viscosities and relative concentrations of the different monomers included.<sup>59</sup> Despite demonstrating better mechanical properties, SonicFill (Kerr) showed increased wear as compared to conventional composites, while the performance of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) was similar to conventional composites.<sup>15</sup>

Interestingly, Al Sunbul et al<sup>9</sup> reported a significant decrease in surface microhardness of two flowable base bulk-fill composites (SDR, Dentsply; Venus Bulk Fill, Heraeus Kulzer) after storage in food-simulating solvents, which supports the recommendations of the manufacturers to veneer these materials. The tested full-body bulk-fill composite (Tetric EvoCeram Bulk Fill, Ivoclar Vivadent) showed results comparable to other conventional microhybrid composites.

El-Safty et al<sup>39,40</sup> examined the creep of four bulk-fill composites and found that the mean maximum creep strain of bulk-fill composites significantly decreased with increasing filler load. The bulk-fill composites exhibited creep deformations within acceptable limits. Papadogiannis et al<sup>112</sup> confirmed that the use of a layer of conventional composite on top of flowable base bulk-fill composites is mandatory to achieve higher creep resistance. The *in vitro* study conducted by Rauber et al<sup>119</sup> reported that bulk-filling Class II MOD cavities with full-body composite (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent) resulted in fatigue resistance similar to that of a nanohybrid composite (Tetric N-Ceram, Ivoclar Vivadent) applied in 2-mm increments. These findings are corroborated by dynamic fatigue tests and Weibull analysis that showed comparable reliability and decline of strength over time between bulk-fill and conventional composites.<sup>144</sup>

Among the *in vitro* studies that investigated fracture resistance of teeth with large Class II MOD restorations, Rosato et al<sup>122</sup> found significantly lower values for molars incrementally restored with conventional composite in comparison to bulk-fill composites. In contrast, Yasa et al<sup>148</sup> reported no difference between nanohybrid composite and flowable base bulk-fill composite. Other studies that investigated premolars also revealed no significant effect of the filling technique on the fracture strength.<sup>13,14,82</sup>

## SHRINKAGE STRESS AND MARGINAL INTEGRITY

Shrinkage stress is not a material property; it is influenced by several tooth-related variables, such as the configuration and size of the cavity as well as its compliance. The most important properties influencing shrinkage stress are the volumetric shrinkage and the elastic modulus of the composites. However, these properties are often inversely related to each other and depend to a great extent on the filler load. Indeed, due to their higher filler load, the full-body bulk-fill composites exhibit less volumetric shrinkage than do the base composites<sup>19,54,84</sup> but higher elastic modulus.<sup>27,92</sup> The relative influence of these factors is difficult to estimate, not only because it is also dependent on tooth cavity-related factors, but also because shrinkage

stress already starts to develop during the early phase of curing, while the elastic modulus increases considerably. Hence, besides purely mechanical properties, stress is also influenced by temporospatial, dynamic characteristics. The composition of bulk-fill composites varies considerably and the manufacturers usually do not release detailed information about this. Causal relationships with regard to composition can hardly be defined in this miscellaneous group of bulk-fill composites. By varying relative amounts of selected monomers, specific properties can be optimized.<sup>12</sup> Many bulk-fill composites, for instance, contain UDMA, which is less viscous and more flexible in comparison with bis-GMA. It was found that the NH groups in UDMA may cause chain transfer reactions, which increase the mobility of radical sites through the network.<sup>130</sup> In terms of shrinkage stress, the base bulk-fill composite SDR is the most investigated product. A modified UDMA-monomer with incorporated photo-active groups is claimed to function as a polymerization modulator;<sup>70</sup> it allows the monomers to link more flexibly during the formation of the polymer network,<sup>125</sup> thereby reaching a high degree of conversion and network density.

Polymerization stress is considered one of the major drawbacks of direct composite restorations.<sup>22,25,26,44</sup> Hence, several methods have been developed to measure the effects of shrinkage stress.<sup>127</sup> Eight studies were identified that measured shrinkage stress in bulk-fill composites by means of force transducers.<sup>9,37,70,76,78,83,84,100</sup> Ilie and HICKEL<sup>70</sup> found that the shrinkage stress of the base bulk-fill composite SDR was lowest, not only when compared to some flowable composites, but also when compared to some conventional paste-like composites, even including a silorane-based material. Marovic et al<sup>100</sup> confirmed the low shrinkage stress of SDR and found it to be significantly lower than that of two flowable bulk-fill and one conventional flowable composite. In the study by Kim et al,<sup>84</sup> the measured shrinkage stress positively correlated with the product of shrinkage and the complex shear modulus. They reported that only SDR induced significantly less shrinkage stress than all other tested composites; for full-body bulk-fill composites, no advantage could be found in terms of shrinkage stress as compared to conventional composites. Shrinkage stress measurements were also found to correlate strongly with the number of acoustic events, which arise at the moment of damage or fracture; this confirmed the likelihood of debonding due to increasing shrinkage stress.<sup>84</sup> However, El-Damanhoury and Platt<sup>37</sup> found that all bulk-fill composites induced less shrinkage stress than the conventional composite they used as control. They also recorded less shrinkage stress for flowable than paste-like bulk-fill composites. Three more studies confirmed that bulk-fill composites provided better results with regard to shrinkage stress than conventional composites when comparing similar consistencies.<sup>52,76,83</sup> However, in the latter studies, lower shrinkage stress was found for the paste-like bulk-fill composites, which is in contrast to previous findings.<sup>52,76,83</sup> After investigating eighteen composites, Al Sunbul et al<sup>9</sup> reported that one full-body and three flowable

base bulk-fill composites presented significantly lower shrinkage stress than flowable composites, but differences were product dependent when compared to conventional composites. Photo-elastic determination was used in one study,<sup>125</sup> in which SDR exerted less shrinkage stress than conventional composites, but similar shrinkage stress to other types of low-shrinking composites. Rossato et al<sup>122</sup> combined cuspal strain measurement using gauges and finite element analysis to demonstrate that bulk-fill composites are associated with lower post-gel shrinkage stresses than are conventional composites.

Cuspal deflection is widely accepted as an indirect measure of shrinkage stress.<sup>20,34</sup> Vinagre et al<sup>145</sup> confirmed that bulk-filling cavities with conventional composite induces significantly more cuspal deflection. In several studies, a lower cuspal deflection was found with bulk-fill composites as compared to an incremental filling procedure using conventional composites,<sup>50,105,122,137</sup> while others found no significant difference.<sup>35</sup> Tomaszewska et al<sup>137</sup> found less cuspal deflection with a full-body than with a base bulk-filling technique, although this was product-dependent. Francis et al<sup>50</sup> and Campodonico et al<sup>28</sup> found no significant difference in the cuspal flexure of a flowable bulk-fill composite whether it was placed in bulk or increments. Behery et al<sup>18</sup> reported differences in cuspal deflection for cavities restored with three full-body bulk-fill composites. The authors suggested that the significantly lower mean value of Tetric EvoCeram Bulk Fill (Ivoclar Vivadent) might be attributed to its lower elastic modulus in comparison to X-tra fil (Voco) and Quixx Posterior (Dentsply).

Another undesirable effect of shrinkage stress manifests when tensile forces are transferred to the bonded interface.<sup>46,127</sup> When the bond strength is not sufficient to withstand these forces, the marginal seal of the bonded restoration can be damaged, resulting in loss of retention or marginal gap formation. Most studies did not show any significant effect on marginal adaptation when using bulk-fill composites,<sup>4,13,19,29,53,65,121,129</sup> while others found particularly flowable bulk-fill composites to improve marginal integrity.<sup>66,80,108,109</sup> However, other studies found it to be product dependent. Agarwal et al<sup>2</sup> reported that the viscosity of the bulk-fill composite influenced the proportion of gap-free margins; internal adaptation to dentin was again described to be better with flowable than with paste-like bulk-fill composites. This was, however, not attributed to polymerization shrinkage per se, but rather to the restricted flow of the high-viscosity bulk-fill composites. In contrast, Poggio et al<sup>116</sup> found better marginal adaptation in Class II restorations when they were placed with conventional paste-like composite, albeit using the incremental technique. Increased gaps at the cervical floor were found for some flowable bulk-fill composites as well, in particular for Venus Bulk Fill (Heraeus Kulzer) despite an adequate DOC.<sup>19,29</sup> In four studies, different bulk-fill composites were bonded into the cavity, each using the adhesive produced by the respective manufacturer; hence, conclusions were limited to the adhesive/composite combination.<sup>52,53,77,111</sup>

Furness et al<sup>53</sup> revealed clearly different dye-penetration patterns at the bonded interface for some bulk-fill composites. The discrepancy found in this study between a notable pulpal floor gap and absent dye penetration (in some groups) might be due to gap formation between adhesive and composite, while the interface between adhesive and dentin remained tight. Fronza et al<sup>52</sup> found a positive correlation between higher shrinkage stress of some bulk-fill composites and higher percentage of interfacial gap formation at the bottom of 4-mm Class I cavities. Tomaszewska et al<sup>137</sup> found less microleakage with an incremental filling technique, even though cuspal strain increased as previously mentioned. This may suggest that a decrease in cuspal strain might be a consequence of loss of marginal integrity, which partially released stress. Kalmowicz et al<sup>79</sup> found no difference in terms of marginal microleakage in dentin margins when using a full-body bulk-fill composite (SonicFill, Kerr) or 2-mm increments of conventional composite to restore Class II cavities. However, Class I cavities with enamel margins revealed significantly less dye penetration, which suggests that the bonding substrate is the primary limiting factor.

In three studies, gaps and voids in bulk-fill composite restorations were evaluated using microcomputed tomography; they revealed less shrinkage at the cavity bottom and fewer voids for bulk-fill composites.<sup>66,108,109</sup> Optical coherence was used in one study, in which a paste-like bulk-fill composite (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent) showed internal adaptation results comparable to those of some microhybrid composites placed in increments; however, the use of a flowable base bulk-fill composite (Venus Bulk Fill, Heraeus Kulzer) did not result in low shrinkage stress in large, high C-factor cavities.<sup>64</sup>

Eight studies evaluated the bond strength of different bulk-fill composites to dentin. Overall, a sufficient bond strength was obtained for bulk-fill composites when applied in bulk up to a thickness of 4 mm, while under the same conditions, the bond strength decreased for conventional composites.<sup>49,126</sup> Even in 5-mm deep proximal boxes, the use of flowable base bulk-fill composite (SDR) resulted in higher bond strengths than a conventional composite for both bulk and incremental techniques.<sup>86</sup> The same trend was observed by Al-Harbi et al<sup>4</sup> when bulk filling Class II cavities up to 4 mm with SDR or SonicFill (Kerr); however, no differences in bond strength were found between two full-body bulk-fill composites (Tetric N-Ceram Bulk Fill; Tetric EvoCeram Bulk Fill) and an incrementally placed microhybrid composite. Another study involving extended Class II MOD restorations in premolars revealed that the use of SDR did not jeopardize the resin-dentin bond strength to the bottom of the cavities.<sup>13</sup> In other studies, bond strength of bulk-fill composites was found to be product dependent;<sup>72,142</sup> this was attributed rather to differences in mechanical properties and consistency than to differences in induced shrinkage stress. However, as mentioned above, following a study by Ilie et al<sup>72</sup> and Juloski et al,<sup>77</sup> the actual adhesive employed to bond the bulk-fill composite remains the most influential factor.

## CLINICAL STUDIES

Only a few clinical studies involving bulk-fill composites are available. Quixfil (Dentsply) has been studied most, which is not surprising because according to the authors' knowledge, it was the first bulk-fill composite launched on the market.<sup>51</sup>

In a randomized controlled trial with recalls at 1 year,<sup>30</sup> 2 years,<sup>10</sup> and 3 years,<sup>31</sup> 41 restoration pairs were placed in 31 patients, of which 23 patients (31 restorations pairs) were recalled after 3 years. Quixfil restorations obtained predominantly alpha scores at 1, 2 and 3 years. Mahmoud et al<sup>94</sup> found similar results for Quixfil and a silorane composite in 78 patients after 3 years. In these studies,<sup>30,31,94</sup> an incremental technique was used to place restorations in vital teeth, this without any cusp involvement. In another randomized controlled trial by Manhart et al with recalls at 3, 6 and 12 months,<sup>98</sup> and at 3<sup>96</sup> and 4 years,<sup>95</sup> 46 Quixfil restorations were placed and compared with 50 Tetric Ceram (Ivoclar Vivadent) restorations as control. At the last recall period, 37 Quixfil and 46 Tetric Ceram restorations were assessed. Quixfil showed good clinical results after 18 months, 3 and 4 years, which were not significantly different from the clinical data recorded for the control. In the studies by Manhart et al,<sup>95,96,98</sup> only vital teeth in patients with good oral hygiene were included, thereby excluding confounding patient factors. Interestingly, it was mentioned that Quixfil was applied incrementally in this study, with the first layer being 4 mm only when the cavity exceeded this depth.<sup>95</sup> More detailed information with regard to the cavity depth would be interesting in order to determine its bulk-fill eligibility. Another study by Doğan et al<sup>36</sup> conducted on 62 patients demonstrated good results with Quixfil after one year, but again only small and medium-sized cavities were included.

In a randomized controlled clinical trial conducted by van Dijken et al with recalls at 3<sup>139</sup> and 5 years,<sup>140</sup> 91 restoration pairs (68 Class I and 115 Class II) placed in molars (62%) and premolars (38%) were assessed after 5 years. Restorations with a bulk-fill base (SDR) up to 4 mm and veneered with a 2-mm occlusal layer of nanohybrid composite showed an acceptable annual failure rate (AFR) of 1.1%, which was not significantly different from the AFR of conventional composite restorations placed in 2-mm layers (1.3%). The AFR of Class I restorations was 0%. When only Class II restorations were considered, an AFR of 1.4% with the bulk-fill base was found versus an AFR of 2.1% in the conventional composite restorations. In that study, no patients were excluded because of high caries risk, periodontal problems or parafunctional habits in order to reflect the entire patient population. The main reason for failure was cusp fracture in bruxing participants. Regarding the size of the cavities, it was mentioned that the majority of the cavities were deep and large, although this was not further specified. Also, no inclusion criteria regarding tooth vitality were mentioned.

In the randomized clinical trial conducted by Bayraktar et al,<sup>17</sup> 172 Class II restorations placed in 43 patients were

assessed over the course of 1 year. Only vital teeth in patients with good oral hygiene and without bruxism were included. Each patient received four restorations: one with a bulk-fill base (Filtek Bulk Fill Flowable, 3M ESPE) veneered with a 2-mm occlusal layer of microhybrid composite (Filtek P60, 3M ESPE), two with full-body bulk-fill composites (Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; SonicFill, Kerr), and the last one with a conventional nanohybrid composite (Clearfil Photo Posterior, Kuraray Noritake) placed in 2-mm layers. After one-year follow-up, all restorations were classified as acceptable according to modified USPHS criteria and no significant differences were observed between the conventional and bulk-fill composites. Although only medium-size cavities with an isthmus of no more than 2/3 of the intercuspal distance and with a gingival margin above the cemento-enamel junction were included, no details regarding the extension (mesial and/or distal) or depth of the cavities were reported. It should be also taken into consideration that after removal of the matrix band, the proximal regions of the restorations were additionally polymerized buccally and lingually for 10 s, which might have influenced the depth of cure (DOC).

In the randomized clinical trial published by Karaman et al,<sup>81</sup> 33 of 47 restoration pairs placed in endodontically-treated teeth were recalled after 3 years. Patients with poor oral hygiene and history of bruxism were excluded. Class II cavities (mesio-occlusal or disto-occlusal) were restored by an expert operator either with a bulk-fill composite base (X-tra base, Voco) up to 4 mm and veneered with a 2-mm layer of hybrid composite (GrandioSO, Voco), or with a 2-mm layer of conventional flowable composite (Aelito Flo, Bisco) veneered with the same hybrid composite placed in 2-mm layers. Restorations with a bulk-fill base showed a clinically acceptable performance, which was not significantly different from the incrementally placed composite restorations. It was reported that the average buccolingual width of each cavity was greater than 1/3 of the distance between the cusp tips, but again the depth of the cavities was not described.

These first findings on clinical effectiveness are promising for bulk-fill composites in posterior cavities in the short and middle term. Unfortunately, it is not always explicitly mentioned whether the bulk-fill composites were actually applied in only one increment. A consistent bulk-fill placement procedure is much more difficult to control in a clinical setting. Moreover, since bulk filling seems convenient especially in deep cavities, more detailed information regarding the cavity depth would be desirable.

## CONCLUSION

Bulk-fill composites differ from conventional composites in their increased depth of cure (DOC), which can mainly be attributed to an increase in translucency. The literature is inconsistent regarding the determination of DOC and some results are contradictory. Inherent to light attenuation, properties within the composite will decrease with increasing

depth after a certain threshold, resulting in an inhomogeneous material. This can render the outcome less predictable, especially when the volume is considerable. However, how this depth should be determined or what range in variation is considered acceptable, is still a matter of debate. Nevertheless, the vast majority of studies found a relevant increase in DOC for bulk-fill composites when compared to conventional composites, regardless of the measured parameter and experimental setup. Thus, when clinically relevant thicknesses are considered, bulk-fill composites can be considered more forgiving.

An increased DOC is only relevant when the mechanical and physical properties of the composite meet all criteria for a restoration in a stress-bearing area. Since material properties vary considerably, the cavity size, type, and location must guide the choice for the material in a clinical situation. Flowable base bulk-fill composites seem suitable for narrow, deep cavities and Class I cavities deeper than 4 mm, such as a post-endodontic restoration. The lower viscosity facilitates adaptation in less accessible spaces due to plastic flow. In larger cavities, on the other hand, resistance against wear and fracture becomes increasingly important. The thicker consistency might also help obtain a good contact point. Materials with high filler load should be preferred in that case. Tests related to shrinkage stress seem inconsistent due to variations in the test setup. However, its clinical relevance is unclear and the influence exerted on the interface is also strongly dependent on the adhesive used. Regarding suitability for bulk filling, the ultimate proof can only be established through randomized controlled clinical trials. However, only relatively short- to middle-term data are available to date. Moreover, in the few clinical trials that have been conducted, depth and size of the cavities are largely unknown, so the proportion of restorations which actually require bulk-fill properties remains unknown. More clinical studies that specifically focus on deep, large restorations are required to fully explore their benefits.

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**Clinical relevance:** Flowable base bulk-fill composites seem most suitable for narrow cavities that exceed a 4-mm depth due to their better flow capacity and higher adaptation potential. Paste-like full-body bulk-fill composites with a higher filler load are preferred in more extensive cavities that require better resistance against wear and a good contact point.