2 What Are Bulk Fill (BF) Composites and How Do They Differ from Non-BF Composites?

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2.1 What Are Bulk Fill Composites?

Since resin composites were introduced over 50 years ago they have been increasingly used for the restoration of anterior and posterior teeth [1]. Two factors have promoted this increase in use; the perceived risk of toxicity caused by amalgam restorations and the patient demand for aesthetic restorations [2]. Despite the improvements made to the materials, polymerization shrinkage remains their main shortcoming, affecting their long-term stability [3]. In general, resin composites have volumetric shrinkage values that range from less than 1% up to 6%, depending on their formulation and curing settings [4]. Various clinical approaches have been proposed to overcome this problem and to obtain an adequate degree of conversion, such as the use of "incremental layering technique." This method involves the application of resin composite in layers of 2 mm for anterior and posterior restorations [5]. The layering technique or stratification using different opacities is used for aesthetic purposes, and has been the state of the art for the last decade. Despite its aesthetic outcomes and reduction in polymerization shrinkage, it is time consuming. Completing a posterior composite restoration, can take up to 2.5 more time as compared to placing an amalgam, as it involves several steps including the application of the adhesive system [6]. As well as polymerization shrinkage the dentist can face other clinical difficulties including the establishment of an adequate contact point and occasionally post-operative sensitivity.

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Today more than 200 brands of resin composites from different manufacturers are available on the market. In the last decade, many types of resin-based materials have been launched, but not all of them have been successful including Compomer, packable composites, siloranes, and self-adhesive composites. On the other hand, flowable composites, nanocomposites, and more recently, bulk fill resin composites have been shown to be clinically suitable.

Many bulk fill materials for posterior restorations are available from different manufacturers as given in Table 2.1. The different classifications of bulk fill materials will be detailed later in this chapter.

Table 2.1 List of available bulk fill resin composite from different manufacturers

	Composite BF	Manufacturer	Shades available
Bulk Fill RBC			
1	Filtek Bulk Fill	3M ESPE	A1, A2, A3, B1, C2
2	Filtek one bulk fill	3M ESPE	A1, A2, A3, B1, C2
3	Tetric Evo Ceram Bulk Fill	Ivoclar-Vivadent	IVA (Universal A shade) IVB (Universal B shade) IVW (white for light coloured or deciduous teeth)
4	Tetric N-Ceram Bulk Fill	Ivoclar-Vivadent	IVA, IVB, IVW
5	X-tra fil	VOCO	Universal shade
6	Aura Bulk Fill	SDI dental	BKF
7	Beautifil bulk restorative GIOMER	SHOFU	Universal, A
8	EverX Posterior	GC	Universal shade (transparent)
9	Dexta Fill Bulk	Dexter	A, U
10	Ecosite Bulk Fill	DMG	Light, universal, contrast for core build ups
11	Opus Bulk fill APS	FGM	A1, A2, A3
12	Reveal HD Bulk Fill	BISCO	A1, A2, A3, B1
13	Alert Condensable composite	Pentron	A2, A3, A3.5, B1, C2
Bulk Fill Base RBC			
14	Surefil SDR flow	Dentsply Sirona	Universal, A1, A2, A3
15	Filtek Bulk Fill Flowable	3M ESPE	Universal, A1, A2, A3
16	Venus Bulk Fill	Heraeus Kulzer	Universal
17	Tetric EvoFlow Bulk-Fill	Ivoclar-Vivadent	Universal shades IVA, IVB, IVW
18	X-tra base	VOCO	Universal, A2
19	QuiXX Posterior	Dentsply Sirona	Universal
20	Beautifil Bulk Flow GIOMER	SHOFU	Dentin, universal
21	Bulk Base Hard	MORITA	
22	Capo bulk fill plus	Schütz dental	Universal dentin colour natural appearance
23	Dexta fill bulk	Dexter	D, U
24	Estelite Bulk Fill Flow	Tokuyama Dental	U, B1, A1, A2, A3
25	EverX Flow	GC	Bulk shade, dentin shade
26	Geanial Bulk Injectable	GC	A1, A2
27	LC Base	Parkell	Universal
28	Palfique Bulk Flow	Tokuyama Dental	A1, A2, A3, B1, U
29	Opus Bulk Fill Flow	FGM	A1, A2, A3
Sonic activated bulk fill			

Table 2.1 (continued)

	Composite BF	Manufacturer	Shades available
30	SonicFill	Kerr	A1, A2, A3, B1
31	SonicFill 2	Kerr	A1, A2, A3, B1
32	Sonic fill 3	Kerr	A1, A2, A3
Thermo viscous technology			
33	VisCalor bulk	VOCO	U, A1, A2, A3
Dual cured bulk fill			
34	Fill Up!	Coltene-Whaledent	A2, A3
35	HyperFil	Parkell	A1, A2, B1, B2
36	Bulk EZ	Danville	A1, A2, A3
37	Bulk EZ PLUS	Zest dental solutions	A1, A2, A3, A3.5, B1, B2, B3, C2, C3, BL, OP, CORE WHITE
38	Profil Bulk Fill	Silmet	U, enamel
39	Light-core (fiber reinforced)	BISCO	Translucent and blue shades
40	N'Durance dimer Core	Septodont	Bleach white
41	ParaCore	Coltene/Whaledent	Dentin, white, translucent
42	Spee-Dee build up	Pulpdent	Yellow, white
43	Activa bioactive	Pulpdent	A1, A2, A3, A3.5
44	Admira fusion x-tra	VOCO	Omni-chromatic shade covers classic shade range
45	Bis-core (DC)	BISCO	Natural and opaque
46	Bisfil 2B (CC) Self-cure	BISCO	Universal, A3 and A3.5 shade
47	Bisfil II Self-cured	BISCO	Universal
48	Clearfil Core (CC)	Kuraray Noritake	Neutral colour shade
49	Clearfil DC Core Plus (DC)	Kuraray Noritake	White
50	Clearfil PhotoCore	Kuraray Noritake	Translucent
51	Core-Flo DC	BISCO	Natural/A1 and opaque white
52	Core-Flo DC Lite	BISCO	Natural/A1 and opaque white shades
53	Core Restore 2 (DC)	Kerr	Universal, white, blue, untinted
54	HardCore (DC)	Pulpdent	Off-white coloúr

2.2 Composition and Microstructure

A resin composite is mainly composed of an organic (resin matrix) and inorganic part (fillers) linked by a coupling agent (silane) [1, 7]. Bulk fill materials have similar chemical composition to the conventional RBCs with some variations, related to the filler particles and resin matrix that will be discussed later in this chapter. In general, the main monomers which form the resin matrix of most composites are present, such as the Bis-GMA, UDMA, TEGDMA, and EBPDMA with a moderate molecular weight. Yet, other monomers with lower viscosities have been added. These changes contribute to the "bulk" characteristic of bulk fill composites [8].

2.2.1 Organic Phase (Resin Matrix)

2.2.1.1 Conventional Composite Monomer

Composite formulations are described in details in the literature [9–11]. The organic phase includes different monomers, additives, and a curing system. Commercial dental composites are based on Bis-GMA (2.2-bis[4-(2-hydroxy-3-methacryloyloxy-propoxy) phenyl propane) monomer, commonly called Bis-glycidyl methacrylate. This resin has an aromatic structure in the central part of the molecule, causing much larger barriers to rotate around the bonds, and thus increasing its stiffness [9]. Their high molecular weight (512 g/mol) explains their lower polymerization shrinkage and less water sorption compared to other monomers [12]. However, high molecular monomers are very viscous and the use of a diluent or a viscosity controller is mandatory to achieve filler loading and a workable consistency [10].

2.2.1.2 Bulk Fill Monomer Modifications

The common characteristic to all bulk fill composites is their application and polymerization in layers of 4 mm and even 5 mm for some products. Several modifications have been made to the bulk fill formulations, in particular concerning the translucency, the use of a polymerization modulator and a specific photo initiator.

There is no generalized composition for all bulk fill as each product is manufacturer dependent. For instance, *Surefil SDR* flow (DENTSPLY/Caulk) contains a specific monomer; *UDMA* (dimethacrylate urethane). The manufacturers claim that it has a stress decreasing resin (SDR) technology from which it obtained its name. This provides superior molecule flexibility, therefore eluding polymerization stress during curing. *Filtek bulk fill* flowable (3 M ESPE) is based on a combination of four different monomers: *Bis-GMA*, *UDMA*, *Procrylat*, and *Bis-EMA*. The UDMA-based monomer has a high molecular weight of 849 g/mol, thus decreasing polymerization shrinkage [8]. This monomer is modified to include a photoactive group which the manufacturer refers to it as the *"polymerization modulator."* Polymerization shrinkage is reduced when the material is exposed to light, and the photoactive groups are cleaved. Simultaneously the oligomer chain breaks, which contains the stress while generating radicals that can promote more conversion and crosslinking of the material maintaining the polymerization rate or degree of conversion [13]. Additionally, the Procrylat monomer is responsible for more fluidity hence reducing polymerization stress.

2.2.2 Inorganic Phase (Fillers)

2.2.2.1 Conventional Composite Fillers

Filler particles are used to fill and reinforce the resin matrix. They also improve the mechanical properties, provide radiopacity, minimize the coefficient of thermal expansion and are thought to reduce the polymerization shrinkage. The particle size will influence other properties such as surface roughness, polishability, and fluidity [11, 14].

Composites contain a variety of fillers such as fused silica (SiO_2), quartz, and radiopaque particles based on oxides of barium, strontium, zirconium, and other metals [12, 14]. Composite classifications are often based on their filler size, shape, and distribution. Size varies between 0.01 μm and 85 μm. Filler morphologies depends on the development process. Filler loading is expressed in percentages by weight or volume. In general, filler load ranges between 35 and 70 vol% or 50 and 85 wt% [15, 16].

Hybrid resin composites contain a heterogeneous aggregate of filler particles. They have a filler load of 70–80% by weight, with their size ranging from 0.04 μm and 1–5 μm. The average particle size of hybrid composites is usually >1 μm. This mixture of fillers gives them their excellent physical properties and high polishability, however, they are unable to maintain their gloss. Further refinements in the particle size resulted in composites with particles averaging about 0.4–1.0 μm which are referred to as "microhybrids." They may contain up to 60–70% of fillers by volume. These materials are generally considered to be universal composites as they can be used in both anterior and posterior cavities. Nowadays, the hybrid category represents the most used resin composite. A decade ago, nanofilled composites or nanohybrids were introduced onto the dental market. Those composites use nanoparticles ranging from 0.005 to 1 μm or 5–100 nm. They are linked together into what is called a ″nanocluster″ and are assumed to produce a composite restoration that has strength similar to hybrid composites yet smoother surfaces with high lustre resulting in optimal aesthetics. Nano fill describes filler particle sizes that have been used in microfill composites. The nanofilled composites present similar mechanical and physical properties to microhybrid composites, but polishability and gloss retention similar to micro filled composites [17].

2.2.2.2 Bulk Fill Filler Modifications

The percentage of fillers in bulk fill composite is 66–70% by volume and is lower than conventional microhybrid and nanohybrid composites. However, it has comparable percentage by volume to conventional flowable RBCs but higher percentage by weight. This can be explained by the large filler size (20 μm). The lower percentage of fillers with a bigger size, decreased the refractive index between the matrix and filler system, consequently permitting more light penetration, hence an increased depth of cure [8]. Manufacturers have identified many of the bulk fill components that improved the depth of cure, yet, some information remains undisclosed such as the ratio of each monomer, the filler content or their proprietary formulations.

For example, Tetric N-Ceram Bulk fill (TBF; Ivoclar Vivadent, Schaan, Liechtenstein) and SDR (Caulk DENTSPLY, York, PA, USA) were launched with the manufacturer claiming that they contain a *shrinkage stress reliever* that minimizes polymerization shrinkage [18].

2.2.3 Microstructure

A study that evaluated the polymerization performance and depth of cure of highly filled conventional flowable and bulk fill resin composites it has been shown that the composition affected the linear polymerization shrinkage and polymerization shrinkage stress measurement [18]. Rafaela A. Melo et al. evaluated the chemical composition and other parameters of a regular high viscosity bulk fill and a traditional composite resin. They prepared 80 samples of (Aura/SDI, FiltekZ250 XT/3 M, Aura Bulk Fill/SDI, and Filtek Bulk Fill/3 M). Scanning electron microscopy (SEM) and energy dispersity spectroscopy (EDS) were used to assess the morphology of the filler particles present and the chemical characteristics of the composites. They found that the elements carbon, oxygen, silicon, and aluminium were present in all composites studied. In addition to those elements barium and zirconia were found in Aura bulk fill. Zirconia was also found in large amounts in Filtek bulk fill and fluoride. Two other studies of bulk fill composition found similar inorganic elements in various amounts including silicon, aluminium, fluoride, barium, and zirconia. The purpose of adding those specific elements was to improve optical density properties of the composite including other properties [19].

Differences in filler content and the SEM are given in Table 2.2.

Table 2.2 Comparison between some conventional composites and bulk fill resin composites from the same manufacturer

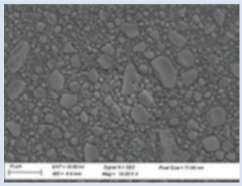
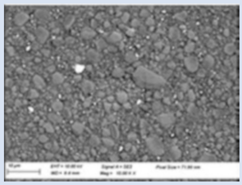
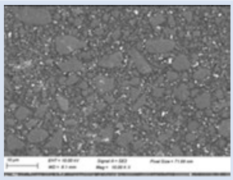
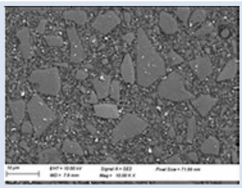
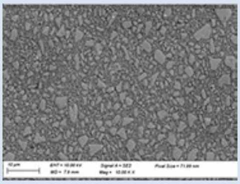
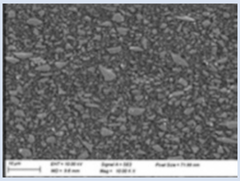
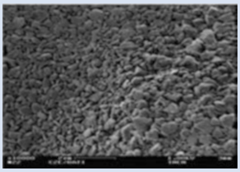
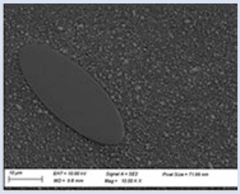
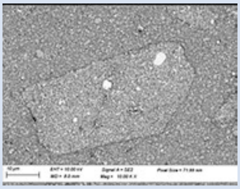
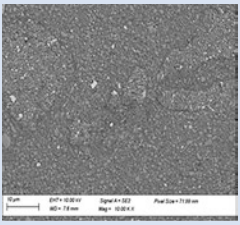
Manufacturer	Material	Composition	Filler loading	Filler's morphology (SEM) 10.00 K×
3MESPE	Filtek Z350 XT	UDMA, Bis-GMA, TEGDMA	55.6 vol% 72.5 wt%	
	Filtek One Bulk Fill	AUDMA), UDMA, addition fragmentation 1, 12-dodecane-DMA	76.5 wt% 58.4 vol%	
Kavo Kerr	Harmonize	Bis-GMA UDMA TEGDMA Bis-EMA6	78.5 wt% 63.3 vol%	
	Sonic fill	Bis-GMA TEGDMA Bis-EMA	83.5 wt%	

Table 2.2 (continued)

Manufacturer	Material	Composition	Filler loading	Filler's morphology (SEM) 10.00 K×
Voco	GrandioSO	Bis-GMA, Bis-EMA, TEGDMA	89 wt%	
	Grandioso Flow	Bis-EMA MMA	80% wt	
GC	Geanial Universal Flow	UDMA, TEGDMA, Bis-MEPP, silicon dioxide, strontium glass	50 vol% 69 wt%	
	EverX posterior	Bis-GMA TEGDMA PMMA	53.6 vol%	
Ivoclar	Tetric Evoceram Bulk fill	Bis-GMA UDMA Bis-EMA	80 wt% 61 vol% Barium glass filler	
	Tetric Power fill	Bis-GMA, Bis-EMA, UDMA, Bis-PMA, DCP, D3MA	(79 wt%, 53–54 vol%) Barium glass, ytterbium, Trifluoride, copolymer, mixed oxide (SiO_2/ZrO_2)	

SEM photomicrographs of the fillers at 10,000× magnification are shown in Fig. 2.1a–f. Filler size included both small or large fillers, while their shapes included angular, rounded or spherical, depending on the product. Different shapes of fillers were observed for the materials of the same category.

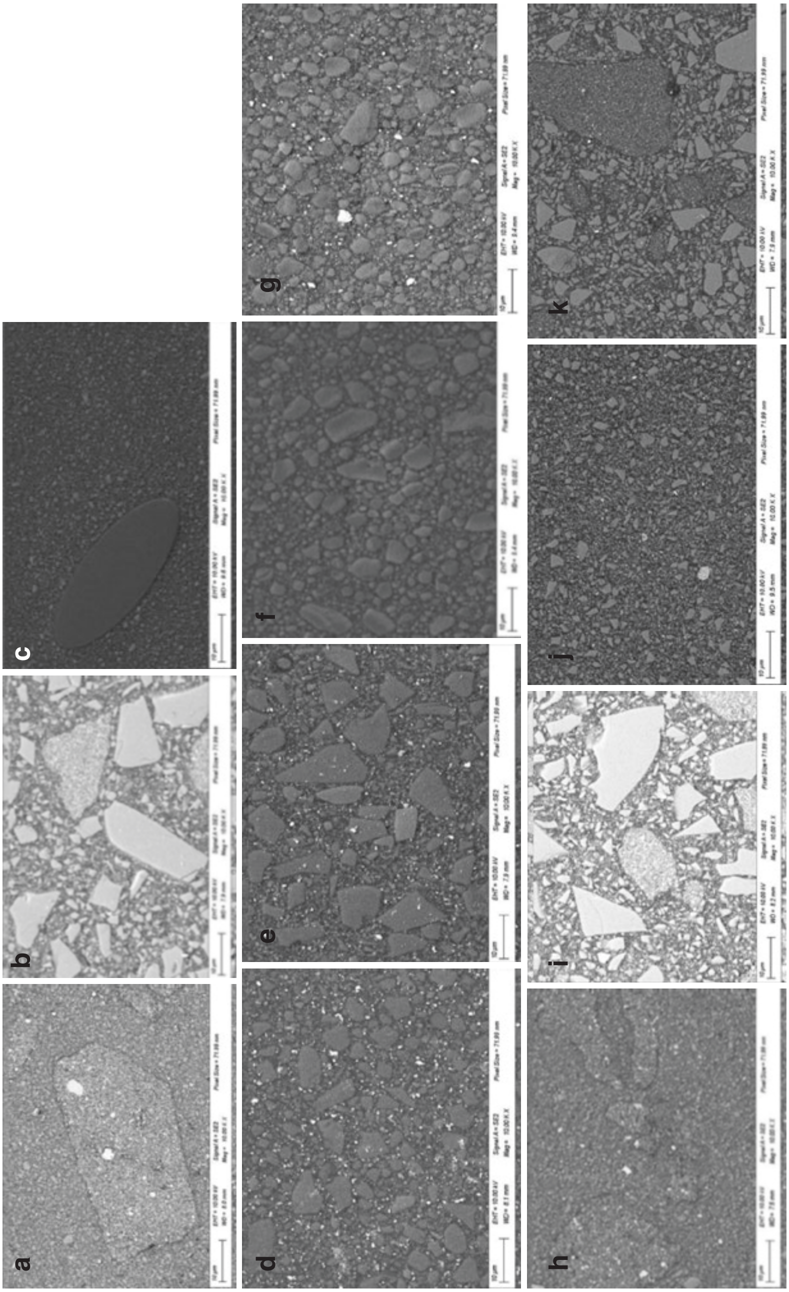


Fig. 2.1 The SEM photomicrographs above (**a**–**f**) are of the fillers at 10,000× magnification show filler morphology of some pairs of resin composites (conventional versus bulk fill resin composites), (**a**) Tetric EvoCeram Bulk fill (**b**)Tetric EvoFlow Bulk fill (**c**) EverX posterior (**d**) Harmonize (**e**) SonicFill 3 (**f**) Filtek Supreme XTE (**g**) one Bulk Fill (**h**) Tetric PowerFill (**i**) Tetric Power Flow (**j**) Venus Bulk fill (**k**) Beautifil

Some pairs of resin composites issued from the same manufacturer (universal versus a flowable of highly filled bulk) were compared (a) Tetric EvoCeram Bulk fill (b)Tetric EvoFlow Bulk (d) Harmonize and (e) Sonicfill 3, (f) Filtek Supreme XTE (g) one Bulk Fill, (h) Tetric PowerFill, (i) Tetric Power Flow.

For each pair of composites, at least one feature, the shape or the percentage of fillers or the composition of the organic matrix was modified. Some bulk fill resin composites showed bigger fillers size like Sonicfill 3 (e), Tetric Power Flow (i), and Beautiful (k), while others showed similar size to their corresponding conventional from the same manufacturer, Harmonize (d) and Sonicfill (e) and Filtek Supreme XTE (g) one Bulk Fill.

2.2.4 Coupling Agent (Silanes)

As the two major constituents of resin composites are chemically different, the bond between the inorganic fillers and resin matrix is provided for by the coupling agent or silane. Coupling agents work better with silica particles. Therefore, most of dental composites are based on silica-containing fillers [14]. The most common used coupling agent is the MPMA (γ-methacryloxypropyl-trimethoxy silane) followed by APM (γ-acryloxypropyl-trimethoxysilane). It has been shown that the presence of silane enhances the mechanical properties of resin composites and protects the filler surfaces [20]. The presence of silane allows greater filler loading, thus reducing the polymerization shrinkage. Nevertheless, the interfaces between filler particles and the matrix are the weakest link and may be destroyed by hydrolytic degradation [21]. A bond failure can occur at the silane–filler interface, resulting in a filler debonding with leaching of the monomers [22, 23]. In order to improve filler-matrix coupling and to enhance wear and fatigue-resistance of resin composites, chemical decontamination methods are employed as pre-treatment of the silanization process [24]. Various cleaning processes are reported in the literature, including the use of acids, bases, and organic solvents at several temperatures.

2.2.4.1 Polymerization Initiation System of Bulk Fill

Some manufacturers have added novel photo initiator such as Ivocerin, by Ivoclar vivadent in Tetric Evoceram bulk fill. This photo initiator acts as a polymerization promoter that is based on the chemical element Ge (germanium), which makes Ivocerin more reactive due to greater absorption of 400–450 nm when compared to the traditional photo initiator camphorquinone. It has been claimed that it also can filter light pollution, giving a more suitable clinical working time [8].

2.3 Classification of Bulk Fill Composite

The exact composition of many of the currently available bulk fill materials is not made available by the manufacturers making it impossible to develop an accurate classification of the materials [25]. They can be categorized according to their viscosity and mode of application (Fig. 2.2).

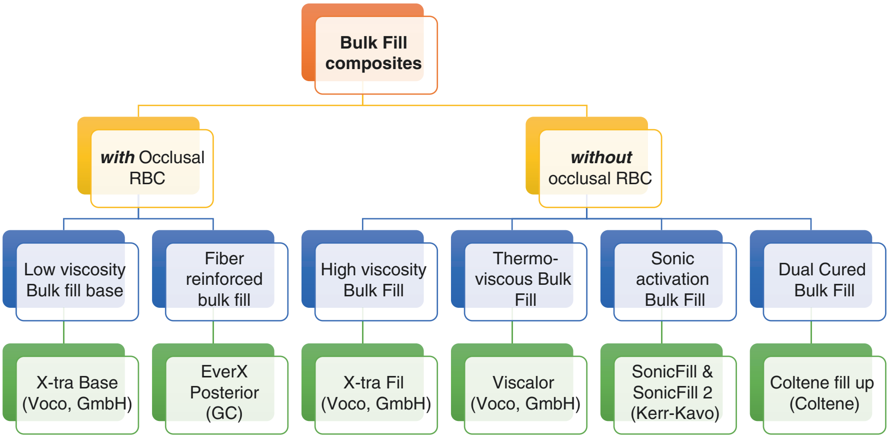


Fig. 2.2 Bulk fill composite classification

2.3.1 According to Viscosity

2.3.1.1 Low Viscosity Bulk Fill

A base bulk fill is a low viscosity flowable material facilitating placement through a small nozzle of a syringe. This helps in their adaptation in deeper and less accessible cavities. They display inferior mechanical properties; the surface is less wear resistance due to the lower amount of fillers present compared to conventional/microhybrid or nanohybrid resin composites. Thus, overlaying with a conventional composite is necessary, representing a two-step bulk fill technique. These base bulk fills are also named flowable bulk fill composites [25–28].

2.3.1.2 High Viscosity Bulk Fill

The full body bulk fill composites have a higher inorganic filler content when compared to the low viscosity base bulk fills, causing them to be more wear resistant and better at handling masticatory load. Hence, they can be used to fill all of the cavity and sculpt its occlusal surface as a final layer without the need to be covered with a conventional composite. This group of bulk fills are a true representation of the bulk fill category allowing the reconstruction of the lost tooth structures [25, 28, 29].

2.3.2 Modified High Viscosity Bulk Fill

2.3.2.1 Sonically Activated Bulk Fill

The high viscosity bulk fills have better mechanical properties when compared to the low viscosity bulk fills, whereas, the low viscosity base bulk fills are easier to apply into deeper cavities. Sonic activated bulk fill material (SonicFill and SonicFill 2, and more recently SonicFill 3 Kerr; Orange, CA, USA) have been introduced. These are high viscosity bulk fill which are dispensed via an air-driven hand piece using sonic vibration resulting in a reduction in the materials viscosity by almost 84%. As a result it can be applied easily into the cavity as a flowable composite, before resuming to its more viscous state which can then be sculped in the required anatomy [25, 28, 30].

2.3.2.2 Thermo-Viscous Bulk Fill

VisCalor bulk fill is the first material on the market that uses thermo-viscous-technology. The filler surface is treated and synchronized with the resin matrix which aids in prolongation of its reduced viscosity during the increase in temperature. The effect of this technology is a material that is applied in a flowable consistency at a temperature of 68 °C via a composite warmer or the new VisCalor dispenser, yet it is sculpatable like packable composites at normal temperature.

2.3.2.3 Fibre-Reinforced Bulk Fill

There are other high viscosity composites, which can be placed in bulk; they contain glass fibre fillers that reinforce the tooth/composite complex when restored. These include EverX Posterior (GC). These fibre-reinforced composites are used as a dentine substitute when restoring large cavities. The fibre fillers tend to prevent and inhibit crack propagation, avoiding fracture which is one of the most common reasons for composite failure [25].

2.3.3 Dual Cured Bulk Fill Composite Resin

Bulk fill composites can be also categorized according to their photo polymerization mode; light or dual-cure bulk fill composites [31, 32]. The dual cured BFC such as fill-up have a low filler load (65% Wt.), yet manufacturers state that this material can be used without a conventional RBC as a final layer. Due to the lack of clinical studies to support this information, authors alert clinicians, that low filler content in composite would be expected to make it less wear resistant [28].

2.3.4 Clinical Relevance

The mechanical characteristics of bulk fill composites vary based on the quantity of inorganic fillers present. Hence, low viscosity materials which exhibit low wear resistance require an additional cap layer of conventional composite. In addition to the occlusal surfaces, authors advice that proximal contact points be restored with conventional composite when using low viscosity base bulk fills due to the risk of wear alongside the adjacent tooth leading to an open contact [28, 33]. Furthermore, another reason for covering the bulk fill composite with acceptable wear resistance is aesthetic as many BFs are translucent. Some base bulk fills have a similar filler content to high viscosity materials, whereas some high viscosity bulk fills have mechanical characteristics comparable to the low viscosity BF, making the decision to use a specific material more difficult [34]. In general, all of the bulk fill composites could be covered with a conventional resin composite, to enhance both aesthetics and their physical properties [28]. For example, SDR which is a flowable BF requires a conventional composite resin layer on top of it.

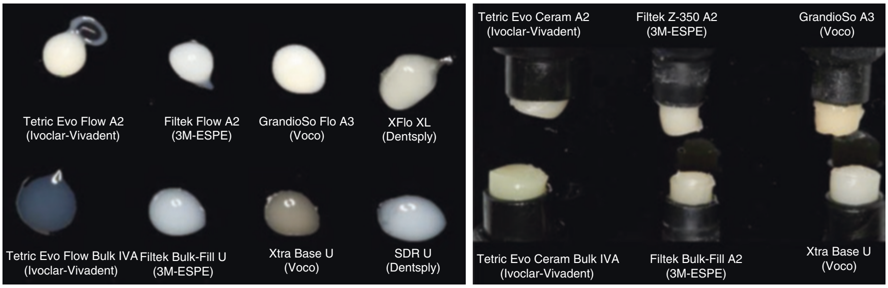


Fig. 2.3 Comparison of bulk fill shades to conventional composite

2.4 Bulk Fill Shades and Depth of Cure

Every manufacturing company provide their own shades for bulk fill composites. However, the shades tend to be more translucent than similar shades of conventional universal composites as displayed in Fig. 2.3.

Translucency is an optical characteristic that is highly distinct in bulk fill composites, when compared to conventional composites. This property is affected by several parameters such as the size and percentage of fillers, translucency of fillers, opacifiers, organic resin, and refractive index of the resin. When the refractive index of the resin and organic fillers is almost the same the material is more translucent.

The high translucency facilitates the penetration of light through the resin during polymerization increasing the degree of conversion and depth of cure. This explains the ability of bulk fill to be placed in an increment of more than 4 mm. Low viscosity bulk fill composites have a low filler load making the composite more translucent, hence a greater depth of cure. Despite their better DOC, other properties are compromised to obtain this translucency, such as aesthetics. If aesthetics is a priority for patient in posterior region, a capping layer of conventional composite can be placed as it is compatible with most bulk fill materials. Some manufacturers have tried to eliminate this limitation, such as Ivoclar by introducing "*asencio*" the chameleon effect bulk fill which increases in opacity post polymerization. Also the SonicFill (Kerr) which can be applied in a single layer technique [7, 13, 28].

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References

1. Ferracane JL. Resin composite—state of the art. Dent Mater. 2011;27(1):29–38.
2. Rasines Alcaraz MG, Veitz-Keenan A, Sahrmann P, Schmidlin PR, Davis D, Iheozor-Ejiofor Z. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth. Cochrane Database Syst Rev. 2014;31(3):CD005620.

3. Schricker SR. Composite resin polymerization and relevant parameters. In: Eliades T, Brantley WA, editors. Orthodontic applications of biomaterials. Cambridge: Woodhead Publishing; 2017. p. 153–70.
4. Weinmann W, Thalacker C, Fau-Guggenberger R, Guggenberger R. Siloranes in dental composites. Dent Mater. 2005;21:68–74.
5. Mantri SP, Mantri SS. Management of shrinkage stresses in direct restorative light-cured composites: a review. J Esthet Restor Dent. 2013;25(5):305–13.
6. Leinfelder KF. Posterior composite resins. J Am Dent Assoc. 1988;117(4):21E–6E.
7. Sabbagh J, Hajj M, Feghali M, Mansour H. Les composites en monocouche ou bulk-fill partie I-composition, particularités et classification. Biomatériaux Cliniques. 2016;2:12–8.
8. Corral-Núnez C, Vildósola-Grez P, Bersezio-Miranda C, Alves-Dos Campos E, Fernández GE. State of the art of bulk-fill resin-based composites: a review. Rev Fac Odontol Univ Antioq. 2015;27(1):177–96.
9. Peutzfeldt A. Resin composites in dentistry: the monomer systems. Eur J Oral Sci. 1997;105(2):97–116.
10. Moszner N, Salz U. New developments of polymeric dental composites. Prog Polym Sci. 2001;26(4):535–76.
11. Braden M, Clarke RL, Parker S, Nicholson J. Polymeric dental materials. Berlin: Springer Science & Business Media; 1997.
12. Albers HF. Tooth-colored restoratives: principles and techniques. Toronto, ON: BC Decker; 2002.
13. Fugolin APP, Pfeifer CS. New resins for dental composites. J Dent Res. 2017;96(10):1085–91.
14. Ritter AV, Boushell LW, Walter R. Sturdevant's art and science of operative dentistry. 7th ed. St. Louis: Elsevier; 2019.
15. Anusavice KJ, Shen C, Rawls HR. Phillips science of dental materials. 12th ed. Philadelphia: Saunders; 2003.
16. Sabbagh J, Bachérius L, Biebuyck JJ, Vreven J, Lambrechts P, Leloup G. Characterization of the inorganic fraction of resin composites. J Oral Rehabil. 2004;31(11):1090–101.
17. Tuncer S, Demirci M, Öztaş E, Tekçe N, Uysal Ö. Microhybrid versus nanofill composite in combination with a three step etch and rinse adhesive in occlusal cavities: five year results. Restor Dent Endod. 2017;42(4):253–63.
18. Jang JH, Park SH, Hwang IN. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flsowable resin. Oper Dent. 2015;40(2):172–80.
19. Melo RA, Bispo ASL, Barbosa GAS, Galvão MR, de Assunção IV, Souza ROA, et al. Morphochemical characterization, microhardness, water sorption, and solubility of regular viscosity bulk fill and traditional composite resins. Microsc Res Tech. 2019;82(9):1500–6.
20. Mohsen NM, Craig RG. Hydrolytic stability of silanated zirconia-silica-urethane dimethacrylate composites. J Oral Rehabil. 1995;22(3):213–20.
21. Santerre JP, Shajii L, Leung BW. Relation of dental composite formulations to their degradation and the release of hydrolyzed polymeric-resin-derived products. Crit Rev Oral Biol Med. 2001;12(2):136–51.
22. Calais JG, Soderholm KJM. Influence of filler type and water exposure on flexural strength of experimental composite resins. J Dent Res. 1988;67(5):836–40.
23. Spahl W, Budzikiewicz H, Geurtsen W. Determination of leachable components from four commercial dental composites by gas and liquid chromatography/mass spectrometry. J Dent. 1998;26(2):137–45.
24. Shirai K, Yoshida Y, Nakayama Y, Fujitani M, Shintani H, Wakasa K, et al. Assessment of decontamination methods as pretreatment of silanization of composite glass fillers. J Biomed Mater Res. 2000;53(3):204–10.
25. Van Ende A, De Munck J, Lise DP, Van Meerbeek B, Ermis B. Bulk-fill composites: a review of the current literature. J Adhes Dent. 2017;19(2):95–109.
26. Al-Nabulsi M, Daud A, Yiu C, Omar H, Sauro S, Fawzy A, et al. Co-blend application mode of bulk fill composite resin. Materials (Basel). 2019;12:122504.

27. Kaptan A. Bulk fill composites. J Dent Oral Health. 2019; 1.
28. Chesterman J, Jowett A, Gallacher A, Nixon P. Bulk-fill resin-based composite restorative materials: a review. Br Dent J. 2017;222(5):337–44.
29. Veloso SRM, Lemos CAA, de Moraes SLD, do Egito Vasconcelos BC, Pellizzer EP, de Melo Monteiro GQ. Clinical performance of bulk-fill and conventional resin composite restorations in posterior teeth: a systematic review and meta-analysis. Clin Oral Investig. 2019;23(1):221–33.
30. Reis AF, Vestphal M, Amaral RC, Rodrigues JA, Roulet J-F, Roscoe MG. Efficiency of polymerization of bulk-fill composite resins: a systematic review. Braz Oral Res. 2017;31:e59.
31. Aggarwal N, Jain A, Gupta H, Abrol A, Singh C, Rapgay T. The comparative evaluation of depth of cure of bulk-fill composites invitro study. J Conserv Dent. 2019;22(4):371–5.
32. Lima RBW, Troconis CCM, Moreno MBP, Murillo-Gómez F, De Goes MF. Depth of cure of bulk fill resin composites: a systematic review. J Esthet Restor Dent. 2018;30(6):492–501.
33. Al-Nahedh HN, Alawami Z. Fracture resistance and marginal adaptation of capped and uncapped bulk-fill resin-based materials. Oper Dent. 2020;45(2):E43–56.
34. Haugen HJ, Marovic D, Par M, Khai Le Thieu M, Reseland JE, Johnsen GF. Bulk fill composites have similar performance to conventional dental composites. Int J Mol Sci. 2020;21(14):5136.