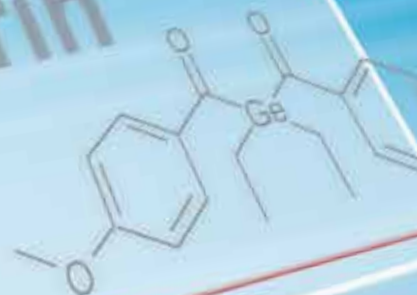


# REPORT

Research and Development Ivoclar Vivadent AG, 9494 Schaan / Liechtenstein

Aessencio  
technology

Ivocerin



**Tetric EvoCeram® Bulk Fill**  
sculptable

**Tetric EvoFlow® Bulk Fill**  
flowable

**Dr Andreas Facher**

Head of Department  
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Nearly four years ago, in 2011, Ivoclar Vivadent launched the composite Tetric EvoCeram® Bulk Fill. Tetric EvoCeram Bulk Fill is a further development of Tetric EvoCeram®, a universal composite that has proven its worth in ten years of clinical use [1]. Tetric EvoCeram Bulk Fill, a sculptable composite for the posterior region, can be cured in large increments of up to four millimetres, and requires minimal light exposure time. The patented, highly reactive photo-initiator Ivocerin® [2] is responsible here. In addition, Tetric EvoCeram Bulk Fill offers outstanding handling. The composite comes in three enamel-like universal shades: <sup>IV</sup>A, <sup>IV</sup>B and <sup>IV</sup>W, which blend naturally with the adjacent tooth structure providing appealing esthetic results.



Marking the next step in Tetric evolution, the sculptable Tetric EvoCeram Bulk Fill has now been complemented with the flowable Tetric EvoFlow® Bulk Fill. In essence, Tetric EvoFlow Bulk Fill is based on the chemistry of Tetric EvoCeram Bulk Fill. Like its sculptable counterpart, it can be applied in large increments of up to four millimetres in thickness and requires only a short curing time. This material is aimed at users who, in an initial step, prefer to use a flowable composite for volume replacement in cavity Classes I and II or for the restoration of deciduous teeth. The product's excellent affinity to cavity walls represents a further advantage in these applications.

In Class I and II restorations, the flowable composite is covered with a layer of load-bearing composite. For optimum combined use, the shades <sup>IV</sup>A, <sup>IV</sup>B and <sup>IV</sup>W are matched to those of Tetric

EvoCeram Bulk Fill. A new technology – Aessencio technology – has been developed by Ivoclar Vivadent in order to ensure a particularly natural-looking, esthetic result. Due to this technology, Tetric EvoFlow Bulk Fill features a low, dentin-like translucency. In combination with the light initiator Ivocerin, this technology enables composite increments of up to four millimetres to be cured. At the same time, a low, dentin-like translucency can be maintained which, among other things, allows tooth discolouration to be effectively masked. The development of the Aessencio technology represents a further step in enhancing the lifelike appearance of bulk-filled composite resin restorations. The apparent technological contradiction between high curing depth and simultaneous low translucency has finally been overcome.

In summary, Tetric EvoFlow Bulk Fill is the perfect complement to the time-tested Tetric EvoCeram Bulk Fill. The two products are ideally coordinated in terms of handling, bulk placement and shading. They feature translucencies adjusted to their application as volume replacement or as a capping layer and are based on proven Tetric EvoCeram chemistry. The articles in this Ivoclar Vivadent Report, allow readers to gain a deeper insight into the material properties of Tetric EvoFlow Bulk Fill and they present a variety of interesting clinical aspects.

**Literature**

- [1] Ivoclar Vivadent AG, Scientific Report 10 years of Tetric Evolution, Vol. 01, 2014
- [2] Ivoclar Vivadent AG, Report No. 19 Research and Development of Ivoclar Vivadent AG, Ivocerin® – a milestone in composite technology, 2013



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Restoratives and Prosthetics, Research & Development*

## Tetric EvoFlow® Bulk Fill, the flowable complement to Tetric EvoCeram® Bulk Fill – The next step in Tetric evolution

Today, flowable composites are frequently placed as a first layer when restoring teeth with direct adhesive techniques. This creates an even cavity floor and facilitates adaptation of the subsequently applied filling material. In addition, flowable, low viscosity bulk-fill materials enable a large part of the cavity “volume” to be filled up and thus serve as volume replacement materials. In view of this, Tetric EvoFlow® Bulk Fill was developed as the complementary flowable product to the sculptable bulk fill material Tetric EvoCeram Bulk Fill. In order to be suitable as a volume replacement material, flowable composites need to demonstrate excellent affinity to cavity walls. The flowability and consistency of Tetric EvoFlow Bulk Fill has been specifically adjusted to meet this need with the help of clinicians.

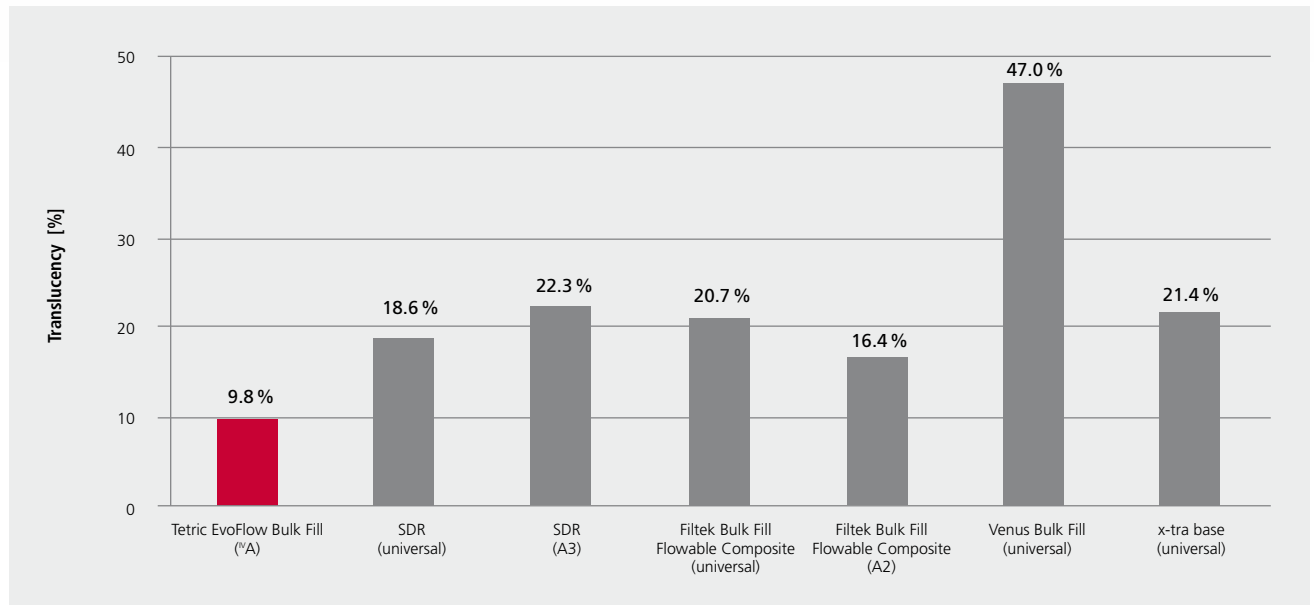
Just like Tetric EvoCeram Bulk Fill, Tetric EvoFlow Bulk Fill is a posterior composite suitable for the bulk-filling technique. Similarly to Tetric EvoCeram Bulk Fill, it can be applied and cured in large increments of up to four millimetre thickness, and requires minimal light exposure time. When a state-of-the-art curing light with a light intensity of at least 1,000 mW/cm<sup>2</sup> such as Bluephase® Style (1,100 mW/cm<sup>2</sup>) is used, a four millimetre increment of Tetric EvoFlow Bulk Fill can be cured in just ten seconds. Due to its higher monomer content and the resulting lower surface hardness compared with sculptable composites, Tetric EvoFlow Bulk Fill needs to be covered with a high-viscosity composite just like other flowable composites. Ideally, Tetric EvoCeram Bulk Fill in the matching shades <sup>®</sup>A, <sup>®</sup>B and <sup>®</sup>W is used for this purpose. While Tetric EvoCeram Bulk Fill features an enamel-like translucency of 15 per cent, Tetric EvoFlow Bulk Fill's translucency is <10 per cent and thus similar to that of natural dentin. As a result, the composite is ideally suitable for use as a volume replacement material or for discoloured teeth. Even dentin discolouration

can be effectively masked (see article by Dr S. Heintze “Bulk-fill materials differ quite considerably”, page 22 and onwards). The low, dentin-like translucency of the flowable composite ensures improved esthetic results.

In contrast to Tetric EvoFlow Bulk Fill, many flowable bulk-fill composites feature a translucency that is unnaturally high when used as a dentin replacement material (Figure 1). The major challenge in the development of Tetric EvoFlow Bulk Fill was to successfully deal with the apparent contradiction between low, dentin-like translucency and curing the shades <sup>®</sup>A, <sup>®</sup>B and <sup>®</sup>W in four millimetre increments. One key element in achieving this goal was Ivocerin® [1,2,3,4], the proven, highly reactive light initiator that had already been employed in Tetric EvoCeram Bulk Fill. The second important element was the Aessencio technology, a new proprietary development by Ivoclar Vivadent.

Before it is cured, Tetric EvoFlow Bulk Fill features a high translucency of 28 per cent. This enables light in the blue spectrum to penetrate the composite and initiate the polymerization reaction – ensuring thorough depth of cure, even in deeper layers. As polymerization progresses, translucency decreases to <10 per cent. This is caused by a change in the refractive index that occurs when uncured monomer is converted into a polymer matrix.

Apart from this advancement in bulk-fill technology, Tetric EvoFlow Bulk Fill and Tetric EvoCeram Bulk Fill feature the same technologies as Tetric EvoCeram, which has proven its worth in ten years of clinical use. Special composite fillers (shrinkage stress relievers) have been incorporated to minimize shrinkage stress. A light sensitivity filter ensures extended working times under operatory light conditions.



**Fig. 1** Results of translucency measurements in the flowable bulk-fill composites Tetric EvoFlow Bulk Fill ("A) (Ivoclar Vivadent), SDR (universal) (Dentsply), SDR (A3) (Dentsply), Filtek Bulk Fill Flowable Composite (universal) (3M Espe), Filtek F Bulk Fill Flowable Composite (A2) (3M Espe), Venus Bulk Fill (universal) (Heraeus Kulzer), x-tra base (Universal) (Voco); Measurements: R&D, Ivoclar Vivadent AG, December 2014

Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill are posterior composites in a sculptable and a flowable consistency that are perfectly coordinated with each other. Proven and new technologies have been combined in Tetric EvoFlow Bulk Fill. By incorporating the highly reactive light initiator Ivocerin and the new Aessencio technology, a bulk-fill composite has been created that allows even more natural-looking results to be achieved. Moreover, the apparent technological contradiction between high curing depth and simultaneous dentin-like translucency has finally been overcome. Tetric EvoFlow Bulk Fill represents the next step in the evolution of bulk-fill composite materials.

## Literature

- [1] Ivoclar Vivadent AG, Report No. 19 Research and Development of Ivoclar Vivadent AG, Ivocerin® – a milestone in composite technology, 2013
- [2] Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Invest published online: 11. January 2014
- [3] Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mat 30 (2014):149-154.
- [4] Special Edition Tetric EvoCeram Bulk Fill, State-of-the-art fillings for posterior teeth, Prof. Dr Jürgen Manhart / Prof. Dr Dipl.-Ing. Nicoleta Ilie, 2015

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## From Tetric EvoCeram® to Tetric EvoCeram® Bulk Fill and on to Tetric EvoFlow® Bulk Fill

### The key technologies of Ivoclar Vivadent

Tetric EvoCeram® has been on the market for over ten years and has been in successful use ever since [1]. The material successfully meets the requirements for a durable and esthetic restorative material. Tetric EvoCeram was developed with a view to providing a material that offers enhanced shrinkage and shrinkage stress properties whilst at the same time delivering favourable surface characteristics (polishability and wear). Tetric EvoCeram Bulk Fill also meets these criteria. In addition to its favourable esthetic and functional properties, the material allows increments of up to four millimetres to be applied in bulk and polymerized in ten seconds.

Tetric EvoCeram Bulk Fill has been successfully used in clinical applications for almost four years. The highly reactive photoinitiator Ivocerin [2, 3, 4, 5] contained in Tetric EvoCeram Bulk Fill substantiated the confidence in the effectiveness of bulk-fill composites (see article by Dr S. Heintze "Bulk-fill materials differ quite considerably", page 22 and onwards). The time was ripe to take this technology a step further. The key technologies incorporated into Tetric EvoCeram Bulk Fill formed the cornerstones for the new development.

- Highly reactive initiator system (= Ivocerin and camphorquinone)
- Shrinkage stress control via incorporation of a composite filler (= shrinkage stress reliever)
- Long working time (= light sensitivity filter)

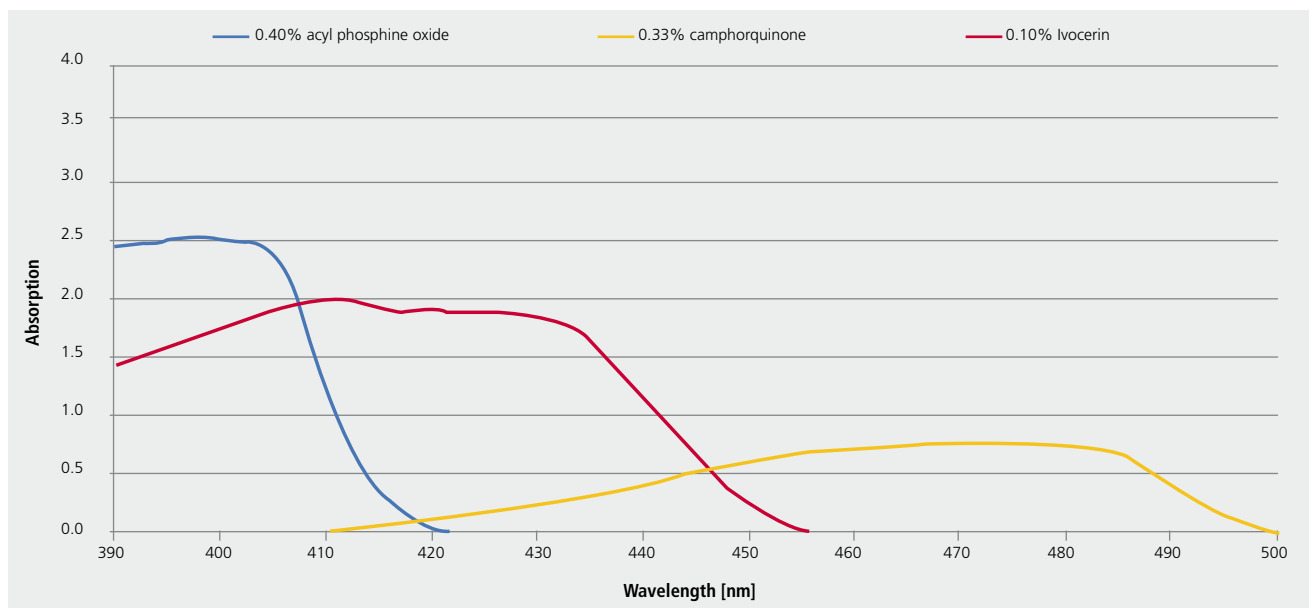
All three components are protected by patents.

#### What are the hallmarks of these components?

##### Ivocerin®

Not much has happened in the field of initiators since camphorquinone was first introduced in composite technology in 1976 [6]. The fillers advanced from macro-fillers to microfillers and then to micro-hybrid fillers. The output performance of curing lights consistently improved so that polymerization times of ten seconds and shorter became possible. Little changed however, in the field of initiator technology. Camphorquinone, combined with amine, is still used. Ultraviolet initiators absorbing light in both the ultraviolet and visible light wavelength spectrum were added to the range. An example is the acyl phosphine oxide group (e.g. Lucirin TPO). Given their low absorption of visible light, these initiators feature a very light yellowish colour and are therefore often used in composite bleach shades. Advantageously, acyl phosphine oxide need not be paired with another initiator and can react directly with monomers. It is also noticeably more reactive than camphorquinone.





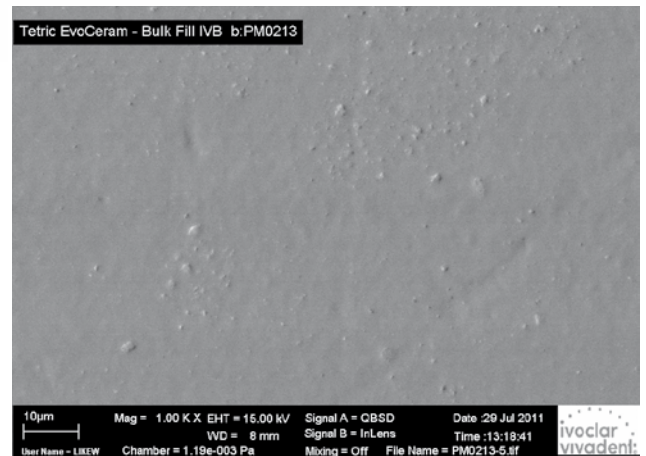
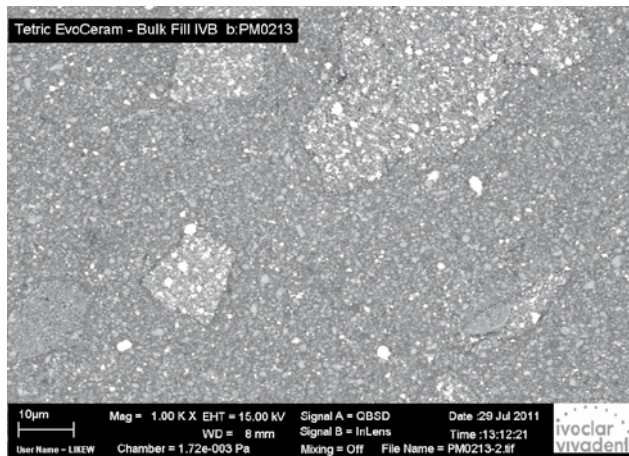
**Fig. 1** Absorption spectra of acyl phosphine oxide (e.g. Lucirin TPO), camphorquinone and Ivocerin (R&D Ivoclar Vivadent, 2012).

Like others, Ivoclar Vivadent searched for alternative photoinitiators and succeeded in developing tailor-made visible light initiators based on germanium compounds in cooperation with Prof. R. Liska of the Vienna University of Technology. Apart from demonstrating a more rapid polymerization process, composites containing Ivocerin exhibit excellent bleaching behaviour and require a considerably lower photoinitiator concentration to achieve comparable mechanical properties (Figure 1) [2].

### Shrinkage stress reliever

At first sight, the shrinkage stress reliever is simply a standard filler, however at a second glance, it reveals a multitude of advantageous properties. Why is a filler capable of reducing shrinkage stress? Shrinkage stress occurs as the composite polymerizes in the cavity and at the same time begins to shrink but cannot pull away from the cavity wall because it is bonded to it with an adhesive. The filler system can have a favourable





**Figs 2a and b** Polished Tetric EvoCeram Bulk Fill surface. The composite fillers are fully integrated into the matrix; the transition to the matrix is smooth. (scanning electron microscope; 1000x magnification) (R&D, Ivoclar Vivadent AG, 2011)

effect on the material's ability to adapt to the new shape smoothly even if the matrix shrinks. Conventional glass fillers demonstrate a modulus of elasticity in the region of 70 GPa, which means that the material is brittle, hard and barely capable of yielding to tensile stress. The composite fillers contained in Tetric EvoCeram and in all subsequent Ivoclar Vivadent composites feature a modulus of elasticity of ten GPa. As a result, these fillers are capable of accommodating the tensile stresses occurring during polymerization. Due to its relatively large particle size ( $\varnothing = 28 \mu\text{m}$ ), the composite filler has a low overall surface area – meaning the proportion of matrix in the composite can be kept as low as possible and volumetric shrinkage reduced. The composite filler consists of a monomer matrix and a mixture of fine particulate fillers. As the filler is completely integrated into the composite, the transitions between composite filler and monomer matrix merge. The result is a material with low wear and high polishability (Figs 2a and 2b).

### Light sensitivity filter

The user requirement for a long working time under well lit conditions followed by rapid polymerization appears to be irreconcilable at first, because the light (wavelength range) required for polymerization lies in the visible blue light domain

and corresponds with part of the wavelength spectrum of ambient light. Hence, it is difficult to reconcile an optimum working time (sensitivity to light in the visible range) with a short curing time.

Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill contain Ivocerin as an additional initiator. Without a light sensitivity filter, the light sensitivity behaviour would deteriorate with increasing concentration due to the high reactivity of Ivocerin. In addition to coordinating the proportions of camphorquinone and Ivocerin, using a light sensitivity filter provides the solution to this challenge, enabling both a conveniently long working time and rapid polymerization. IPS Empress® Direct, Tetric EvoCeram, Tetric EvoFlow, Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill are all equipped with a light sensitivity filter that prevents premature polymerization and provides a working time of more than three minutes under defined light conditions of 8000 lux (ISO 4049:2009). Conventional phenolic stabilizers (MeHQ, BHT) require a concentration of at least 1000 ppm relative to the monomer in order to delay a reaction to ambient light. Just 1/10 of this amount is necessary in the case of the light sensitivity inhibitor. This is advantageous, as the small amount of stabilizer/inhibitor delays the polymerization process at low-level blue light, without impairing the depth of cure or any of the other polymerization properties.



### Viscosity controller in Tetric EvoCeram® Bulk Fill

Users place particular importance on the handling characteristics when applying a composite material. Sculptable composites should be of a consistency that enables them to adapt the material easily to cavity walls, create contact areas and contour occlusal structures. The viscosity of the material should be perfectly matched to these tasks. Layered silicates are used as a viscosity controller; they are complex organic-inorganic compounds that form a three-dimensional network.

The monomer matrix of the composite is embedded in the network of the layered silicate using an elaborate procedure. The monomer forms hydrogen bridge linkages with the layered silicate, creating a stable gel structure. This gel structure is one of the most important properties resulting from the incorporation of the layered silicate into the composite. It ensures consistent and controlled handling characteristics and easy sculpting properties. The consistency is neither too viscous nor too sticky, irrespective of the shearing forces that may occur during application of the composite.

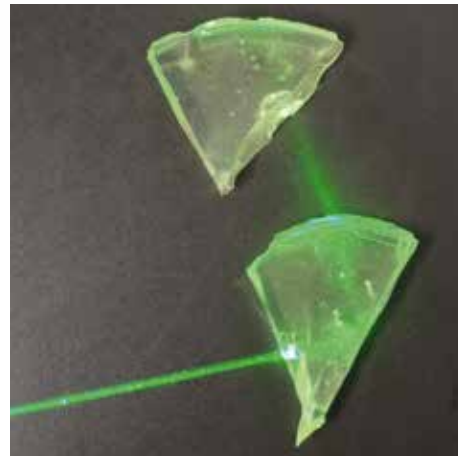
### **NEW** Aessencio technology in Tetric EvoFlow® Bulk Fill

To explain the new technology, we must start by describing a number of physical processes that occur when a material polymerizes.

The refractive index plays a significant role in this. It is defined as follows:

$$\text{Refraction} = n = \frac{c_O}{c_M} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the medium}}$$

The refractive index characterizes an optical property of a material. This property can be made visible at the boundary between two media (chemical substances) where light of a specific wavelength travels through from one medium to the other. Each substance has its own characteristic refractive index (Figure 3).



**Fig. 3**  
In this sample, the laser beam is bent on entering and leaving the material.

### Composite:

The refractive index can be determined for each constituent material of a composite. For the sake of simplicity, a single refractive index is assigned to the monomer mixture, which is composed of the refractive indices of the individual constituents. Each individual filler has its own characteristic refractive index.

### What happens during polymerization?

When activated, the initiators form radicals. These radicals react with the monomers, which in turn react with other monomers and form a network. The refractive index of this newly formed network is higher than the refractive index of the unpolymerized monomer mixture. As a result, the light is refracted differently in the composite after polymerization and the material's optical properties have altered. Only the refractive index of the matrix has changed; the refractive indices of the fillers have remained unaltered.

This process of refractive index change following polymerization can be ideally utilized for the curing of bulk fill materials. The goal here is to achieve good depth of cure in large increments. To achieve this, the refractive index of the unpolymerized monomer mixture is matched to the refractive indices of the fillers. This results in a highly translucent paste. When the composite polymerizes, the light can travel through the translucent filling without impediment. Due to the highly reactive initiator Ivocerin, the material polymerizes rapidly and reliably, even in deep areas at the interface to the tooth.

structure. With progressive polymerization, translucency decreases and the composite becomes more opaque. This reduced translucency lends Tetric EvoFlow Bulk Fill a dentin-like opacity and the ability to mask discolouration.

### What about translucency change in other bulk-fill composites on the market?

The translucency of the paste in its unpolymerized state was never a point of discussion in the development of composites. The objective was always to obtain an esthetic restoration after the polymerization process. The change in translucency resulting from an increase in the refractive index of the matrix was not given any attention. This is understandable because

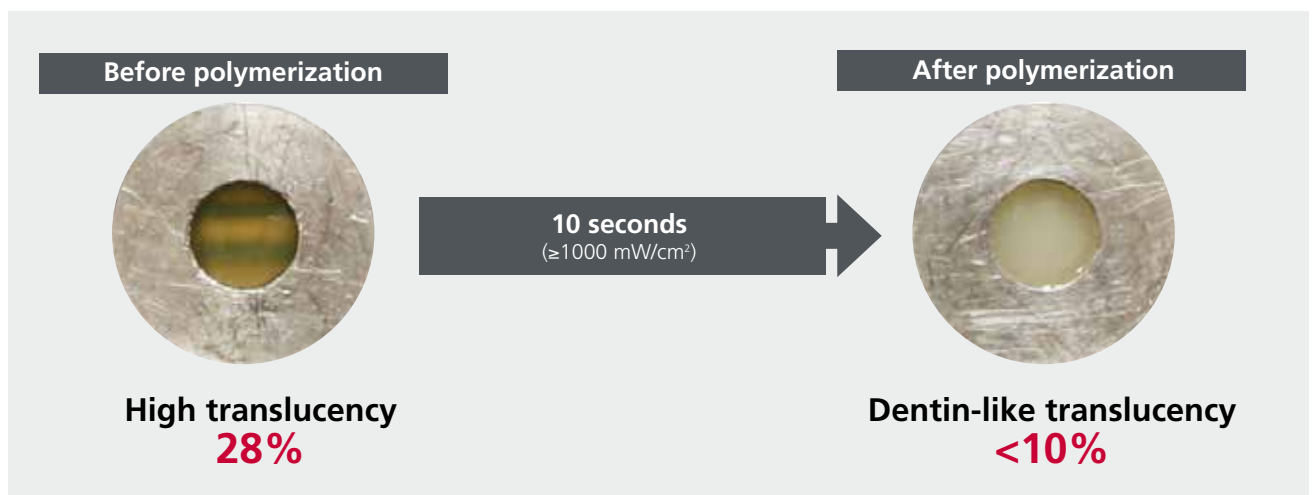


Fig. 4 Aessencio technology



Fig. 5 Test setup with integrating sphere

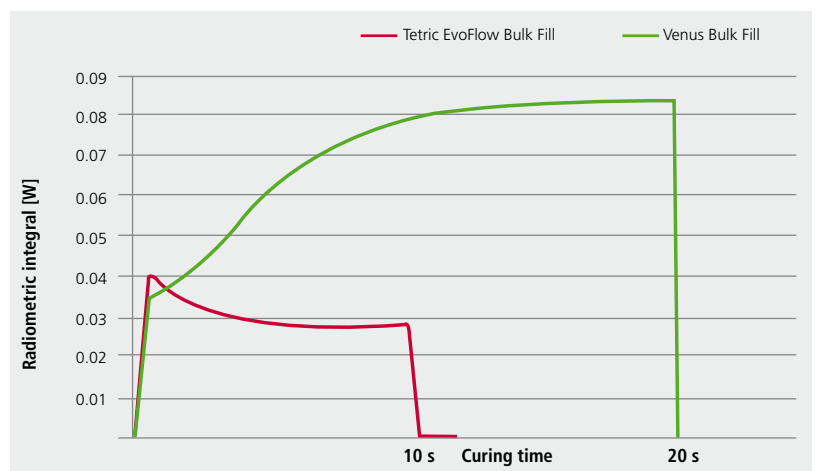


Fig. 6 Light intensity recording in a four-millimetre thick composite increment during irradiation of Tetric EvoFlow Bulk Fill (Ivoclar Vivadent) and Venus Bulk Fill (Heraeus Kulzer) (R&D Ivoclar Vivadent AG, 2014)

the paste undergoes a bleaching process as the initiators react during polymerization - a concurrent process that is much more noticeable than the change in translucency. In addition, the aim was to design bulk-fill materials capable of providing a high depth of cure. Without using Ivocerin or Aessencio technology, this can only be achieved with composites that demonstrate a high level of translucency when polymerized.

### Translucency during polymerization

Translucency change is only the most obvious effect. The goal of the new technology is to enable large amounts of light to pass through to the deeper layers of the filling for a reliable bulk cure without risking a loss in esthetics or an insufficient cure. Proof that the light transmission has been optimized can be obtained with the help of an integrating sphere (Figure 5). The method used in this test determines the decrease in light transmission by measuring the light emitted by a curing light when polymerizing a four-millimetre thick sample. To conduct the measurement, the integrating sphere is mounted in such a way that a metal aperture of a six-millimetre diameter is positioned over the entrance window of the measuring device. A cylinder-shaped white resin mould measuring four millimetres in height and six millimetres in diameter is placed over the aperture. The composite-filled mould is then light-cured while the integrating sphere measures the light emitted by the curing light (Figure 6).

In the case of Venus Bulk Fill (Heraeus Kulzer), more light was measured as the curing process progressed. This means that more light passes through the composite as it polymerizes and becomes more translucent. The opposite is true for Tetric EvoFlow Bulk Fill. Here, the light transmission decreased with progressing polymerization, as evidenced by the reduction in translucency.

### Conclusion

With the help of Ivocerin and Aessencio technology, we succeeded in developing Tetric EvoFlow Bulk Fill – a composite that features a dentin-like translucency, polymerizes in ten seconds in four-millimetre increments and compares favourably with any modern direct restorative composite in terms of optical properties.

### Literature

- [1] Ivoclar Vivadent AG, Scientific Report 10 years of Tetric Evolution, Vol. 01, 2014
- [2] Ivoclar Vivadent AG, Report No. 19 Research and Development of Ivoclar Vivadent AG, Ivocerin® – a milestone in composite technology, 2013
- [3] Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Invest published online: 11. January 2014
- [4] Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mat 30 (2014):149-154.
- [5] Special Edition State-of-the-art fillings for posterior teeth, Prof. Dr Jürgen Manhart / Prof. Dr Dipl.-Ing. Nicoleta Ilie, 2015
- [6] Frederick A. Rueggeberg, State-of-the-art: Dental photocuring – A review, dental materials 27 (2011) 39-52

## *In vitro* investigations

### Depth of cure determined by Vickers hardness measurement at the top and at a depth of four millimetres using various curing settings

#### Material:

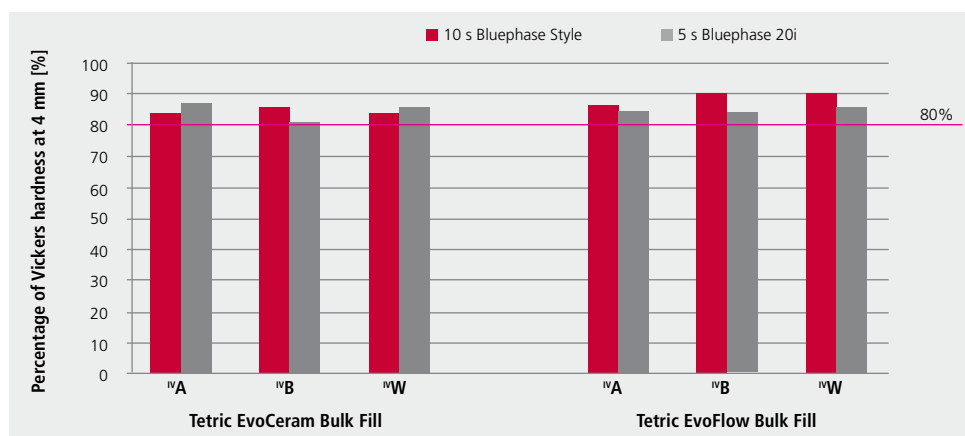
Tetric EvoCeram Bulk Fill <sup>iv</sup>A, <sup>iv</sup>B, <sup>iv</sup>W

Tetric EvoFlow Bulk Fill <sup>iv</sup>A, <sup>iv</sup>B, <sup>iv</sup>W

#### Method:

Samples of both materials and in each of the three shades were light-cured using the defined light-curing program. After 24-hour storage at 37°C, the Vickers hardness was measured at the top and at a depth of four millimetres. The values measured at the top are set to 100 per cent. The values measured at four millimetres are expressed as a percentage of this value. Various light intensities and curing times were employed to conduct the measurements.

#### Results:



R&D Ivoclar Vivadent AG, Schaan, December 2014

#### Summary:

Professor David Watts of the University of Manchester, UK, defined an acceptable curing depth as when the bottom hardness corresponds to at least 80 per cent of the surface hardness [1]. Both materials achieved a minimum of 80 per cent of the surface hardness at a depth of four millimetres and this was true for all three shades.

#### Conclusion:

Both materials and all shades achieved the required 80 per cent hardness ratio under both curing settings. Layer thicknesses of up to four millimetres are recommended for Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill.

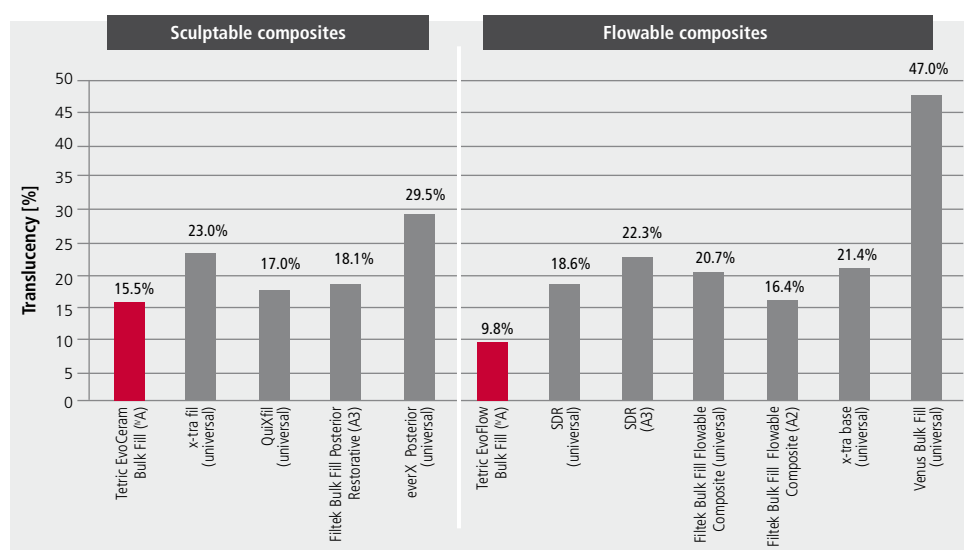
[1] D. Watts, O. Amer, E. Combe. Characteristics of visible light-activated composite systems. Br Dent J 156 (1984) 209-215

## Translucency comparison of various materials

### Method:

The translucency of the composites in the diagram below was measured after polymerization. A Minolta CM-5 spectrophotometer was used for the measurements. This method measures the light that passes through a one-millimetre thick, polymerized composite disc.

### Results:



Measurement: R&D Ivoclar Vivadent AG, December 2014

### Summary:

Tetric EvoCeram Bulk Fill features a translucency of 15 per cent. Similar levels of translucency are also employed in conventional direct composites. All the other composites are more translucent. Only Tetric EvoFlow Bulk Fill demonstrates a translucency of ten per cent and is the only bulk-fill composite that offers a dentin-like translucency that allows dentin discolourations to be masked reliably.

### Conclusion:

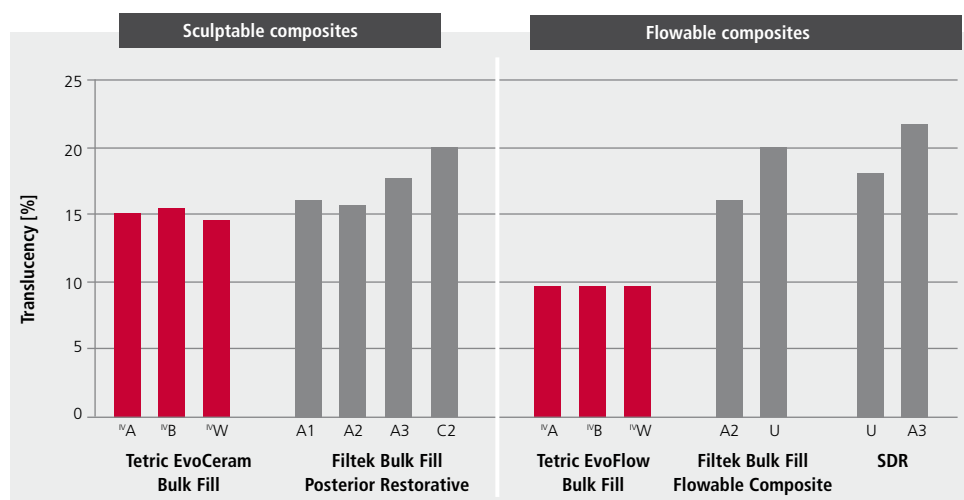
The same range of shades is offered for Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill. All three shades within each respective material, demonstrate the same translucency and this translucency is matched to the respective field of application (Tetric EvoFlow Bulk Fill = dentin-like translucency, Tetric EvoCeram Bulk Fill = dentin- and enamel-like translucency).

## Translucency comparison of various shades

### Method:

The translucency of the cured material was measured for the following composites: Tetric EvoCeram Bulk Fill, Tetric EvoFlow Bulk Fill in shades <sup>IV</sup>A, <sup>IV</sup>B and <sup>IV</sup>W, Filtek Bulk Fill Posterior Restorative (3M Espe) in shades A1, A2, A3, C2, Filtek Bulk Fill Flowable Composite (3M Espe) in shades A2 and U and SDR (Dentsply) in shades U and A3. A Minolta CM-5 spectrophotometer was used for the measurements. This method measures the amount of light that passes through a one-millimetre thick, polymerized composite disc.

### Results:



Measurement: R&D Ivoclar Vivadent AG, December 2014

### Summary:

Tetric EvoCeram Bulk Fill demonstrates a translucency of approx. 15 per cent while the translucency of Tetric EvoFlow Bulk Fill is < 10 per cent i.e. the translucencies of these materials are coordinated with natural enamel and dentin respectively. The three shades of each material feature the same level of translucency. The translucency of both Filtek Bulk Fill Flowable Composite and SDR is significantly higher than that of Tetric EvoFlow Bulk Fill. Furthermore, the translucency of Filtek Bulk Fill Posterior Restorative, Filtek Bulk Fill Flowable Composite and SDR varies from shade to shade. Darker shades demonstrate a higher translucency than lighter shades.

### Conclusion:

The same range of shades is offered for Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill. All three shades within each respective material feature the same translucency and this translucency is matched to the respective field of application (Tetric EvoFlow Bulk Fill = dentin-like translucency, Tetric EvoCeram Bulk Fill = dentin- and enamel-like translucency).

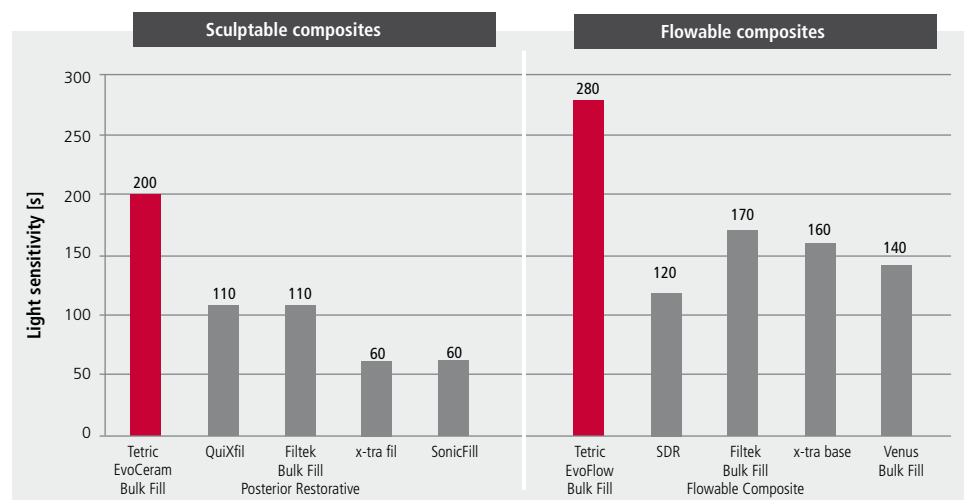


## Sensitivity to ambient light (= working time)

### Method:

The sensitivity to ambient light was measured for the following composites: Tetric EvoCeram Bulk Fill, Tetric EvoFlow Bulk Fill, SDR (Dentsply), QuiXfil (Dentsply), Venus Bulk Fill (Heraeus Kulzer), Filtek Bulk Fill Flowable Composite (3M Espe), Filtek Bulk Fill Posterior Restorative (3M Espe), x-tra fil (Voco), x-tra base (Voco) and SonicFill (Kerr). The test was carried out according to ISO standard 4049. Light sensitivity is measured by illuminating a small amount of composite with a high-pressure xenon light at a light intensity of 8000 lux. The time available during which the composite does not polymerize, is recorded.

### Results:



Measurement ISO 4049 (8000 lux), R&D Ivoclar Vivadent AG, December 2014

### Summary:

A working time of 200 seconds was recorded for Tetric EvoCeram Bulk Fill and 280 seconds for Tetric EvoFlow Bulk Fill. Therefore, both materials stayed unhardened for a significantly longer time than any of the other materials tested in the investigation. All composites tested met the requirements of the ISO standard (> 55 s).

### Conclusion:

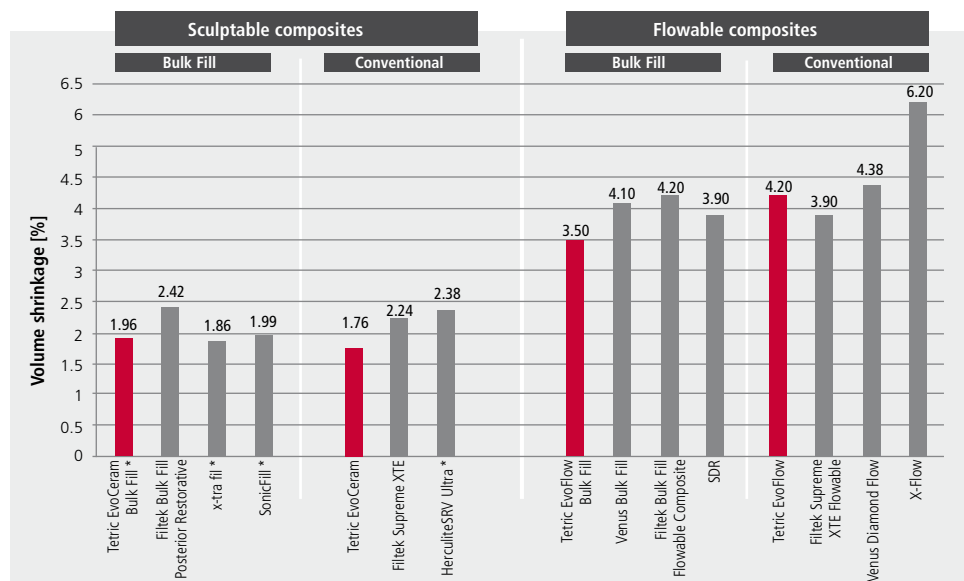
Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill are distinctly different from competitive products. Sensitivity to ambient light is indicative of the working time in visible light. Both materials contain a light sensitivity filter and are therefore less sensitive to the effects of ambient light.

## Shrinkage comparison of various composites

### Method:

The polymerization shrinkage was measured for the following ranges of materials: four packable bulk-fill composites comprising Tetric EvoCeram Bulk Fill, Filtek Bulk Fill Posterior Restorative (3M Espe), x-tra fil (Voco), SonicFill (Kerr), three conventional packable composites comprising Tetric EvoCeram, Filtek Supreme XTE (3M Espe), Herculite XRV Ultra (Kerr), four flowable bulk-fill composites comprising Tetric EvoFlow Bulk Fill, Venus Bulk Fill (Heraeus Kulzer), Filtek Bulk Fill Flowable Composite (3M Espe), SDR (Dentsply) and four conventional flowable composites comprising Tetric EvoFlow, Filtek Supreme XTE Flowable (3M Espe), Venus Diamond Flow (Kerr) and X-Flow (Dentsply). The shrinkage of the sculptable composites was measured over a period of sixty minutes using a mercury dilatometer. The shrinkage of the flowable composites was determined after 24 hours according to ISO 17304 (Archimedes principle).

### Results:



Measurement: R&D Ivoclar Vivadent AG, December 2014 / \*AADR 2012 Abstract 858

### Summary:

Because of their lower monomer content, packable composites shrink less than flowable ones. The ISO method determines the shrinkage only after 24 hours – the value measured may therefore be slightly affected by post-polymerization shrinkage compared with the mercury dilatometry values. The shrinkage values measured for the conventional and bulk-fill composites are essentially the same.

### Conclusion:

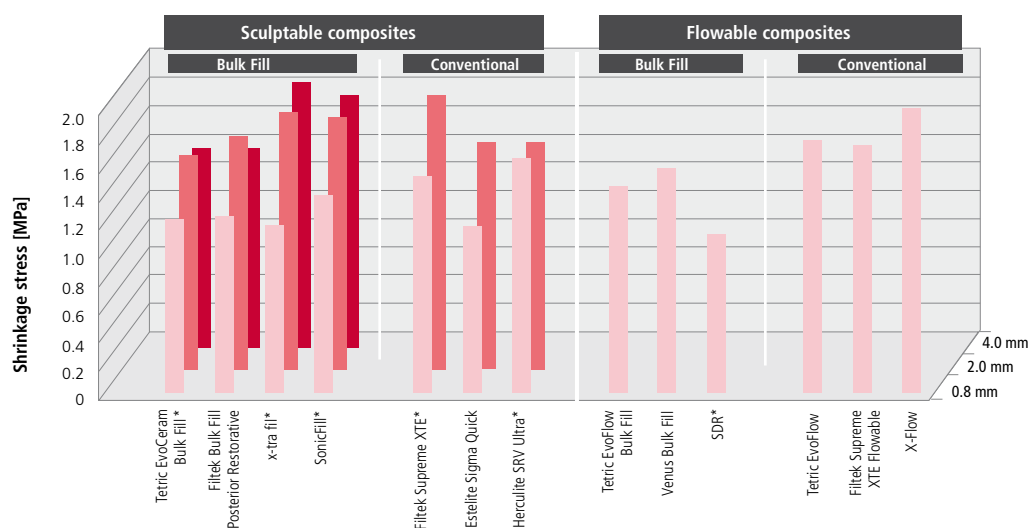
Tetric EvoCeram, Tetric EvoCeram Bulk Fill and x-tra-fil show the lowest polymerization shrinkage of all the packable composites tested. Tetric EvoFlow Bulk Fill demonstrates the lowest value of all the flowable bulk-fill composites.

## Shrinkage stress comparison of various composites

### Method:

The polymerization shrinkage was measured for the following ranges of composites: four packable bulk-fill composites comprising Tetric EvoCeram Bulk Fill, Filtek Bulk Fill Posterior Restorative (3M Espe), x-tra fil (Voco), SonicFill (Kerr), three conventional packable composites comprising Filtek Supreme XTE (3M Espe), Estelite Sigma Quick (Tokuyama), Herculite SRV Ultra (Kerr), three flowable bulk-fill composites comprising Tetric EvoFlow Bulk Fill, Venus Bulk Fill (Heraeus Kulzer), SDR (Dentsply) and three conventional flowable composites comprising Tetric EvoFlow, Filtek Supreme XTE Flowable (3M Espe), Venus Diamond Flow (Kerr). The shrinkage stress was measured with a Bioman shrinkage-stress instrument (D. Watts, Manchester, UK). To conduct the measurement, the packable bulk-fill composites were applied in thicknesses of 0.8 millimetre, two millimetres and four millimetres between a sandblasted metal rod (attached to the stress measuring device) and a silanized glass plate. The conventional composites were only measured in thicknesses of 0.8 millimetre and two millimetres due to their indication. The composites were irradiated through the glass plate according to the manufacturer's instructions. The flowable composites could only be measured in a thickness of 0.8 millimetre because of their low viscosity. The progression of the shrinkage force was measured over a period of 30 minutes.

### Results:



Measurement: R&D Ivoclar Vivadent AG, December 2014 / \*AADR 2012 Abstract 858

**Summary:**

The shrinkage stress rises if the thickness is increased from 0.8 millimetre to two millimetres. An additional increase from two to four millimetres did not result in a concomitant rise in shrinkage stress. When applied in a layer thickness of 0.8 mm, the bulk-fill materials demonstrate lower shrinkage stress than conventional composites. Moreover, even if applied in a layer thickness of four millimetres, sculptable bulk-fill materials show a similar or lower level of shrinkage stress than conventional sculptable materials applied in a thickness of two millimetres. Conventional flowable composites exhibit the highest shrinkage stress.

**Conclusion:**

Tetric EvoCeram Bulk Fill belongs to the group of composites with the lowest shrinkage stress at 0.8 millimetre, two millimetres and four millimetres. At a 4-mm thickness the sculptable bulk-fill composites show similar or lower shrinkage stress than conventional composites at a 2-mm thickness. The flowable bulk-fill composites demonstrate lower shrinkage stress than conventional sculptable composites.

**Dr Siegwand Heintze***Head of Department  
Preclinic*

## Bulk-fill materials – beyond all doubt?

Bulk filling seems to be in many minds and mouths these days. All the large dental manufacturers now offer bulk-fill materials, and they are promoting these products quite intensively. Studies on the subject of bulk-fill materials have started to appear fairly frequently in professional dental journals and these products are growing in popularity among dentists. As a result, more and more patients are finding themselves with bulk fillings in their mouths.

In Europe and in the United States a dentist will typically place 20 to 30 composite fillings per week. Sixty per cent of these fillings are located in the posterior dentition, which is the main area in which bulk-fill materials are used [1]. Over the past ten years, the use of composite resins in posterior teeth has increased quite dramatically. In fact, these materials are now used even more widely than amalgam [2].

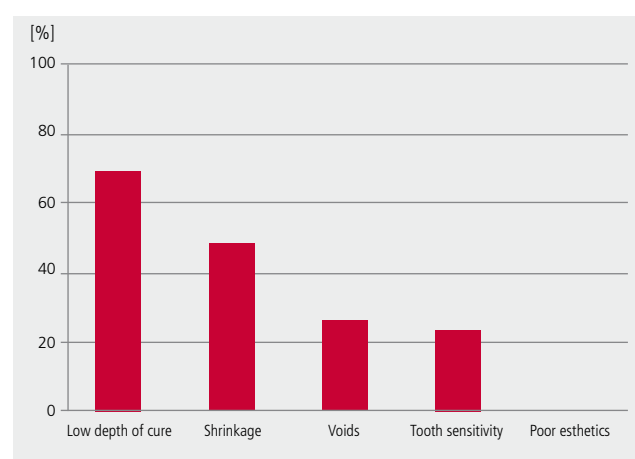
Nevertheless, some dentists still have their doubts about bulk-fill materials in general. They lack confidence in the performance of these products, for example, in terms of their depth of cure. They are also concerned that large composite increments could damage tooth substance (enamel cracks) due to shrinkage and shrinkage forces, or cause postoperative sensitivity to cold or chewing pressure.

But are these concerns justified? Before we address these issues, we should establish the features and benefits of bulk-fill materials.

But first an aside:

### How do dentists perceive bulk-fill materials?

The Gordon J. Christensen Clinicians Report (a popular dental publication in the US) [3] recently conducted a survey among US dentists on the topic of bulk-fill materials. Sixty-nine percent of the people surveyed were concerned about inadequate depth of cure and 48 percent about shrinkage (Figure 1). Twenty-three per cent of the respondents had the opinion that increased cases of postoperative sensitivity would occur with these materials and 26 per cent feared that the fillings would contain voids. The issue of esthetics was not mentioned by this group of dental practitioners.



**Fig. 1** Results of a survey conducted among American dentists about their concerns related to using bulk-fill materials [3].

## Benefits of bulk-fill materials

Bulk filling of dental cavities involves the placement of large composite increments (four to five millimetres), which are subsequently light cured. The word "bulk" refers to a large quantity. It is derived from the late Middle English "bolke" meaning "a pile/heap". Similar words exist in Danish (bulk = lump) or Old Swedish ("bolk", "blkast" = mass). The concept of bulk filling is not new. The first composites introduced in the 1970s and 1980s were self-curing paste-paste materials, which were applied in bulk and then cured. Many dentists will remember products such as Adaptic and Concise. Strictly speaking, the dental composites that are promoted as bulk-fill materials today are not really bulk-fill products if the definition of bulk filling means to fill all of a cavity at one time. The light-curing bulk-fill composites on the market today cannot be placed in layers that are more than four to five millimetres thick. Nevertheless, this is their main advantage: Dentists no longer have to place several small increments of 1.5 to 2 mm in the cavity and cure each layer separately – as is the case with conventional composite resins. With these new materials cavities can be filled with larger increments. However, the layers must not exceed a thickness of four to five millimetres. This technique saves time and heightens the reliability of the treatment for both the benefit of the patient and the practitioner. It can generally be assumed that in many practical situations conventional composites have been applied in increments that were thicker than the maximum permissible 1.5 to 2 millimetres. As a result, it is questionable that these restorations were properly polymerized. Insufficiently cured composite filling material is more easily dissolved, which can accelerate the formation of marginal caries. In addition, the release of monomers can cause allergic reactions [4,5]. Scientific studies have shown that the proximal part of up to 90 per cent of the cavities in posterior teeth (for example, when replacing amalgam fillings) is between two and five millimetres deep [6]. Only about ten per cent of the cavities are deeper than five millimetres. Consequently in daily practice dentists can fill most of the cavities in posterior dentition, with layers of four to five millimetres. It is expected that dentists can most probably treat 100 per cent of the cavities in deciduous teeth with bulk-fill materials. However, systematic studies on the depth of cavities in deciduous teeth are not available. These materials are exceptionally suitable for filling deciduous

teeth, since they speed up the treatment procedure, which is highly desirable when dealing with children who are uncooperative or difficult to treat. In these cases, bulk-fill materials improve clinical reliability.

## Do bulk-fill materials really cure to a depth of four to five millimetres?

Do the materials really attain the depth of cure promised by the manufacturers? This aspect needs to be examined in a laboratory. ISO provides a standardized testing method for this purpose [7]. In this test, composite material is polymerized in a metal mould. Subsequently, any unset composite is scraped off the sample with a plastic spatula. The remaining thickness of the composite is measured and this number is divided by two. The depth reading is halved in order to make sure that the value measured reflects a sufficient hardness. Another method for determining the depth of cure involves measuring the surface hardness at the top and the bottom of specimens of different thicknesses, 24 hours after they have been polymerized. A material is considered to be sufficiently cured when the bottom of a specimen exhibits 80 per cent of the hardness measured at the top [8]. This 80 per cent rule, however, is rather arbitrary and has not been systematically evaluated. In addition, composite resins also show differences in terms of their hardness, and therefore absolute values cannot be compared.

The results of the two test methods do not correlate particularly well. This has been established in-house at Ivoclar Vivadent and in investigations conducted by other test institutes [9]. Bulk-fill materials in particular did not achieve the four millimetre depth of cure required by the ISO standard, even though the surface hardness at the bottom of the sample was 80 per cent of that measured at the top. The fact that the ISO test is performed with a metal mould, which does not correspond to the conditions within the tooth, is most certainly responsible for the discrepancy. The translucent properties of dentin and enamel allow the dental tissue to transmit the light of a polymerization device into deep areas of the filling. If a translucent acrylic resin is used instead of metal, the depth of cure measured according to the ISO standard is considerably higher [10].



Whether or not a composite material cures sufficiently is also dependent on other factors: for example, the colour and translucency of the composite, the light intensity of the curing device, the light exposure time and the distance between the light guide and the composite resin [11]. Apart from an irregular and poor bond between the adhesive system and the substrate, inadequate curing of the composite material may be responsible for the frequent formation of marginal caries in the gingival part of Class II restorations. Clinical studies have shown that up to 80 per cent of marginal caries forms in the cervical-gingival part of Class II fillings and only 20 per cent in the occlusal margin [12]. Marginal staining also tends to occur more often in this area [13].

### **Sufficient polymerization of the composite is important**

Many dentists choose to reduce the recommended polymerization time for composites. In order to attain the desired depth of cure of bulk-fill materials however, it may be important to increase the light exposure time in some cases [14,15]. Ten seconds of light polymerization per layer is adequate for Tetric EvoCeram® Bulk Fill and Tetric EvoFlow® Bulk Fill, provided a polymerization device is used which demonstrates a light intensity of  $\geq 1,000 \text{ mW/cm}^2$ , for example Bluephase Style ( $1,100 \text{ mW/cm}^2$ ).

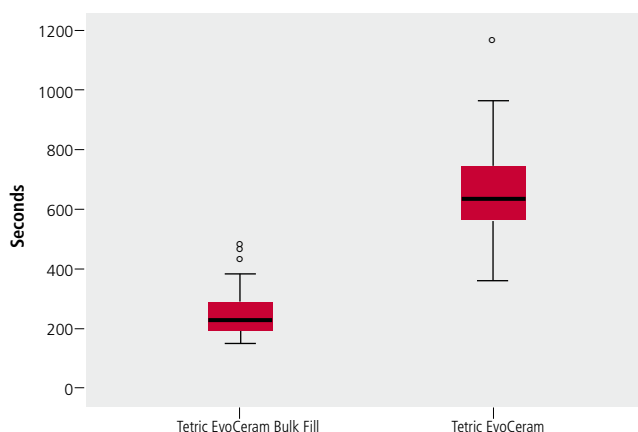
Apart from short curing times, poor maintenance of the polymerization light and inadequate verification of its performance may represent additional sources of error. A field test involving 301 dental practices, which was conducted in Germany in 2006, established that the light intensity of 26 per cent of the devices examined was below the minimally acceptable  $400 \text{ mW/cm}^2$  [16]. Moreover, 48 per cent of the light guides were either damaged or contaminated with composite residue. According to a recent investigation by the same examiner, only very few of the new LED polymerization devices did not fulfill the current light intensity requirements. The direct relevance of the curing depth test for clinical practice remains unclear. Not least due to the fact that it is difficult to reach certain areas in the mouth with the polymerization device and the light guide cannot be placed directly on the filling surface. What is more, the light curing

task is often delegated to dental auxiliaries who may lack polymerization experience. To date, these variables have not been systematically studied. In an effort to establish some clarity on these issues, Ivoclar Vivadent has investigated certain scenarios: for example, holding the light probe at an angle ( $40^\circ$ ) or at a distance to the filling or using a light guide contaminated with composite resin [17]. For this purpose, two cavities with a depth of four millimetres were prepared in a lower molar. Both cavities were filled with a layer of Tetric EvoCeram Bulk Fill and then cured. During the polymerization process, the light guide was held in suboptimal positions in relation to the composite surface. The composite layer was polymerized for ten seconds with Bluephase Style. The relatively short light guide of Bluephase Style allows the practitioner to get very close to the unpolymerized filling material. Subsequently, the fillings (four per group) were removed, embedded and then cut into two halves after one day. The surface hardness (Vickers hardness) of the two halves was measured at intervals of 0.5 mm. The hardness value in the cervical region of the composite resins did not fall below 80 per cent of that of the surface in any of the test groups. Seventy-one per cent of the coronal value was measured only in the cervical area of the group that was irradiated with the contaminated light guide. Therefore, one can conclude that Tetric EvoCeram Bulk Fill cures sufficiently even if the light guide cannot be optimally positioned on the filling. It goes without saying that the dental practitioner should use a polymerization light that exhibits an adequately high light intensity. Furthermore, the light should be regularly checked with a suitable testing device.

### **Efficiency in the use of bulk-fill materials**

How much time do dentists save when they use bulk-fill materials to place fillings? Ivoclar Vivadent has tried to answer this question. Thirty-two experienced dentists from 21 countries were asked to fill two-surface cavities in acrylic teeth with one layer of Tetric EvoCeram Bulk Fill or with several layers of Tetric EvoCeram. On average, these dentists placed a filling in four minutes with the bulk-fill method and in 10.5 minutes with the conventional technique. In other words, bulk-filling required 60 per cent less time than regular filling (Figure 2). Nevertheless, these time savings are related only to the actual

filling of the cavity. The overall time saved, based on the entire treatment process, is about ten per cent.



**Fig. 2** Box plot diagram of the time needed to place a filling with Tetric EvoCeram Bulk Fill (one layer, n=32) and Tetric EvoCeram (several layers, n=32) in one acrylic tooth. Thirty-two dentists took part in the trial conducted by Ivoclar Vivadent.

Box plot explanation: Fifty per cent of the values are found within the box; the black line is the median, which indicates that 50 per cent of the values are above and 50 per cent below this value. The vertical lines represent the extreme values, and the circles the outliers.

As mentioned, many dentists are still quite wary of these materials. They believe that these composites will not live up to their promises. Moreover, they are of the opinion that the advantages of placing fillings in large increments will be negated by certain disadvantages. Before we address these issues, however, we will briefly look at how dental manufacturers have managed to develop composites that demonstrate a high depth of cure.

### Bulk-fill materials differ quite considerably

It is important to note that the bulk-fill materials of different manufacturers differ quite substantially. Today, bulk-fill materials are available in low-viscosity (flowable), and high-viscosity (packable) form. If dental practitioners choose to use a flowable bulk-fill material, they cannot produce the entire restoration with it. Rather, they have to place a final occlusal capping layer made of a high-viscosity composite to cover the filling. On the one hand, this is required due to purely practical reasons: Flowable composites are difficult to sculpt. On the other hand, technical reasons are involved: Because of their

high monomer content, flowable composites are quite soft [18], and they wear and degrade quite easily [18,19]. By contrast, high-viscosity bulk-fill materials do not need to be covered by a capping layer. In order to achieve a high depth of cure, the bulk-fill materials of most manufacturers are highly translucent. Therefore, the light of polymerization devices can penetrate and polymerize deep areas of the composite materials. Furthermore, most of the manufacturers incorporate coarse fillers into their materials, which provide fewer surfaces from which light can refract, compared with smaller particles. Nevertheless, this approach has a number of drawbacks: poor esthetics, inadequate masking of dentin areas and insufficient polishing properties.

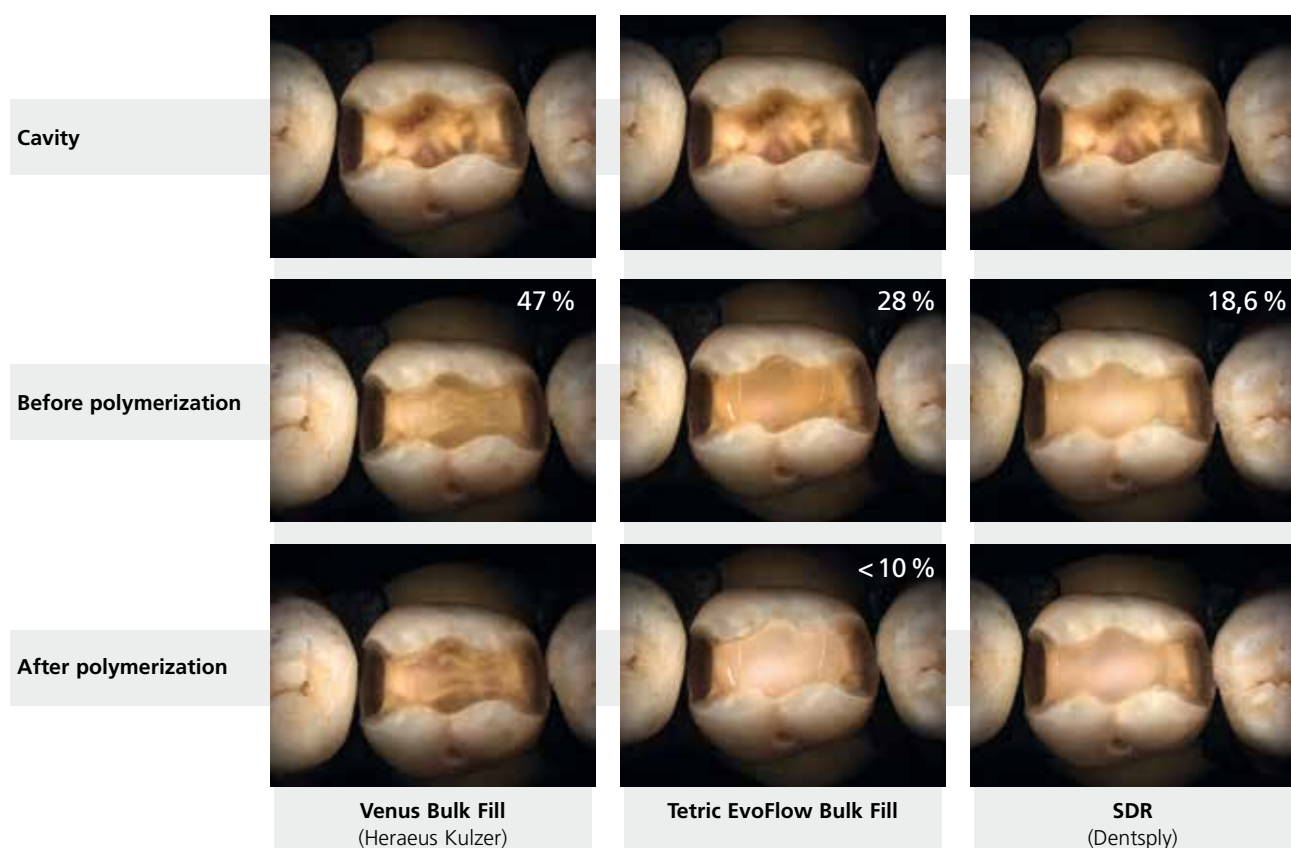
Ivoclar Vivadent decided to pursue another strategy. Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill contain a special patented photo-initiator: a dibenzoyl-germanium compound, named Ivocerin [20]. This absorbs visible light over a relatively wide wavelength-range from 370–460 nm [8]. In the appropriate formulation, it increases the light reactivity to ensure a high depth of cure. Therefore, this new photo-initiator allows the fabrication of composite materials that demonstrate a tooth-like translucency [21] – in contrast to the bulk-fill materials of other manufacturers, which owe their high depth of cure to a high level of translucency. The sufficient depth of cure of 4-mm layers of Tetric EvoCeram Bulk Fill has been established in a large number of studies [8,21–25]. The flowable Tetric EvoFlow Bulk Fill additionally features what is known as Aessencio technology, which ensures exceptional curing results. Before the material is polymerized, it is highly translucent. Once the monomer has been polymerized, the translucency level drops from 28 per cent to below ten per cent. This is achieved due to the sophisticated monomer-filler composition, which takes into account the refractive index change of the monomer matrix as a result of curing.

The high-viscosity Tetric EvoCeram Bulk Fill contains small fillers. Therefore, it is easy to polish to a high-gloss finish. The low-viscosity material features larger fillers and is somewhat more difficult to polish. Since flowable composites are not generally used to restore occlusal surfaces and they are usually covered with a high-viscosity composite, the issue of polishability is not regarded as critical in these cases. If this type of material is used in the proximal-cervical margin of two or three-surface fillings, a proximal metal matrix will help to produce a relatively smooth composite surface, which does

not have to be polished. In the placement of proximal fillings, it is neither expedient nor practicable to create a contact with flowable composite. Practitioners who have worked with SDR, the first flowable bulk-fill material on the market, will have experienced the difficulties of producing proximal contacts with this type of material first hand: 41 percent of the professionals surveyed reported that they found it hard to create proximal contacts with SDR [26].

Their low translucency compared with other bulk-fill materials makes Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill stand out among their competitors. Due to this property, these materials produce enhanced esthetic results. In some cases, they are even capable of masking discoloured dentin. The high-viscosity material exhibits 15 per cent translucency, while the translucency of the low-viscosity material is below ten per

cent. That is, one millimetre thick samples of the high-viscosity composite will allow 15 per cent light to penetrate and the other material will allow ten per cent light to pass through it. According to a Korean publication, dentin demonstrates a translucency of 16 per cent and enamel of 19 per cent [27]. However, these values may vary somewhat due to the thickness of the tooth structure, the age of the teeth and the measuring method used. In addition, differences can occur between patients, as has been shown by *in vivo* investigations of upper anterior teeth [28]. Nevertheless, despite the different measuring techniques and the variability of the biological substrate, the translucency of Tetric EvoCeram Bulk Fill comes very close to that of natural tooth structure. The very low translucency of the flowable version allows the material to be used for masking certain stains in dentin, for example, those produced by amalgam fillings (Figure 3).



**Fig. 3** In one three-surface cavity showing stained occlusal dentin, three different flowable bulk-fill materials were applied for the purpose of studying the masking effect: on the left Venus Bulk Fill, in the middle Tetric EvoFlow Bulk Fill and on the right SDR. The composites are shown before and after polymerization. The adjustment of the translucency in Tetric EvoFlow Bulk Fill is clearly visible.  
(R&D Ivoclar Vivadent AG, 2014)

How do the fillings perform in clinical situations? In the section on clinical studies, this will be shown on the basis of three clinical cases, one involving Tetric EvoFlow Bulk Fill, one with Tetric EvoCeram Bulk Fill and one utilising both composites.

Incidentally, deciduous molars can be filled using just the flowable bulk-fill material, without having to place a capping layer. Why is this possible? Fillings in deciduous teeth are much smaller compared to those in permanent teeth. As a result, a smaller surface is exposed to wear. Furthermore, the chewing force of children is significantly lower than that of adults [29,30], and primary teeth are not as firmly attached to the alveolar bone as permanent teeth, because of root resorption. All these factors are responsible for reducing the wear of fillings in deciduous teeth. Since these fillings have a relatively short life span in the child's mouth due to dentition change, wear is not a critical issue, if it should occur.

The esthetic appearance of posterior teeth, particularly that of the occlusal surface, should not be overestimated. At a speaking distance, small discrepancies in the colour and translucency of a filling in comparison with that of the tooth are not visible. In most cases, patients are not even aware of them. Consequently, bulk-fill materials are available in a limited selection of shades. Some manufacturers offer only one "universal" shade. The streamlined shade range additionally speeds up the placement procedure, because the dentist does not have to select the most appropriate shade from a wide selection, or apply several layers of different shades to achieve an acceptable result. The bulk-fill materials from Ivoclar Vivadent are available in three shades: A, B and Bleach (W = white) shades. The shades of the packable and the flowable version are matched and can therefore be combined easily. Some dentists may regard the small shade range as a drawback. These practitioners are encouraged to try the bulk-fill materials in clinical situations, as practical experience is likely to change their minds. The well-known US test institute Dental Advisor asked 31 dentists to test Tetric EvoCeram Bulk Fill. This group placed a total of 746 posterior fillings with this material. Ninety-seven per cent of the dentists reported that they were generally very satisfied with the product, including its esthetic properties.

## Why and in which situations do dentists use flowable composites?

A survey among 700 dentists in Germany revealed that the majority of dental professionals (78 per cent) use flowable composites as a liner under posterior composite resin fillings [26]. About 70 per cent also use this type of material to fill small occlusal cavities (Figure 4). In most cases (70 per cent) dentists use composite liners because they hope to improve the quality of the margin and prevent or reduce the formation of voids under the filling or within the material (Figure 5). Only

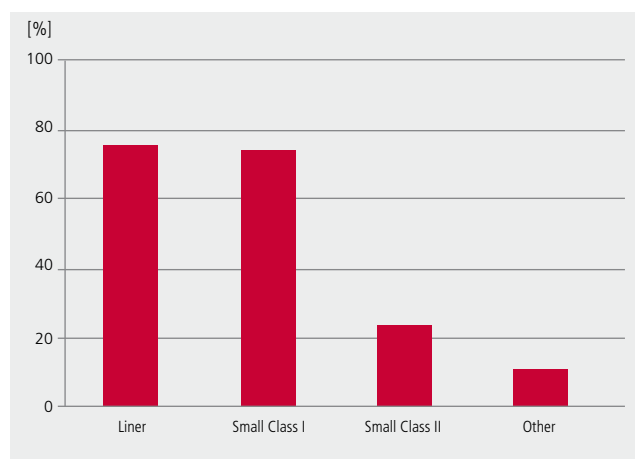


Fig. 4 Results of a survey conducted among German dentists about the indications for flowable composites [26]

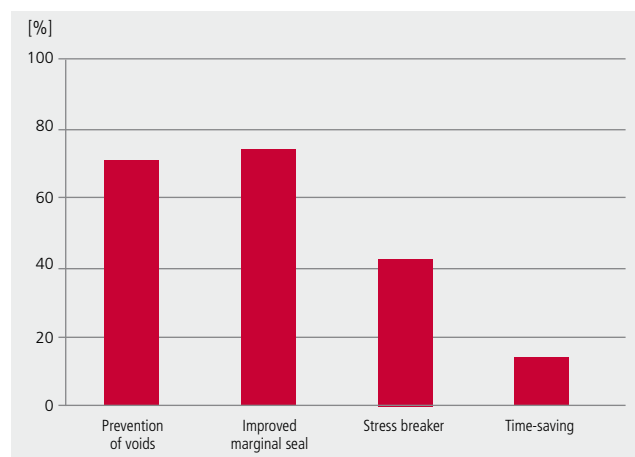


Fig. 5 Results of a survey conducted among German dentists regarding their reasons for using flowable composites [26]

about 40 per cent of the practitioners believe that flowable composites will function as a "stress breaker", which will counteract the potentially negative effects of shrinkage or shrinkage stress in the composite. A mere 15 per cent of the dentists think that fillings can be placed more efficiently by first using a flowable composite as a liner. Are the assumptions of these dentists correct? Some of the effects can be established in laboratory tests. However, it is essential to determine these effects in clinical situations. In these cases, the evidence is clear. All the clinical studies, even those that extended over a period of five to eight years, showed that fillings which had been placed together with a composite liner were not better or worse than fillings without a composite liner. This applied to all the relevant evaluation parameters, such as sensitivity after filling placement (postoperative sensitivity), marginal discolouration, marginal seal, marginal caries or replacement of the filling [31–34]. When they were examined in detail under a microscope, the margins of fillings that were extracted one month after their placement were not found to differ, irrespective of whether or not a liner had been used [35]. Therefore, the decision to place a composite resin as a liner or to fill the entire cavity with a high-viscosity composite depends entirely on the preference of the dental practitioner. Bulk-fill composites offer dentists who like to use a liner, the convenience of not having to worry about placing the material in very thin layers of 1.5 to two millimetres. Dentists can layer the composite in thicker increments – however not more than four millimetres – which increases their efficiency.

### What about voids within the material?

Voids in the composite material may form during the product manufacturing process, or they are incorporated by the dentist during application [36–38]. Additionally, polymerization kinetics may cause flowable materials that are applied in thick layers to pull away from the margins and form large pores (Figure 6). Voids that form during polymerization can be large and may promote the formation of marginal caries in caries-active patients. The flowable Tetric EvoFlow Bulk Fill was optimized and specially designed to minimize air entrapment (Figure 7). Voids and pores should also not form in the high-viscosity Tetric EvoCeram Bulk Fill, provided the material is



**Fig. 6** Proximal filling placed with a flowable bulk-fill material in an extracted tooth. Note the voids that formed at the proximal cervical margin during the polymerization process.



**Fig. 7** Proximal fillings placed with Tetric EvoFlow Bulk Fill in an extracted tooth. No voids or pores are visible at the margin.

carefully placed. If the dentist uses the material as directed, no voids should be visible with the unaided eye or with loupes. Keeping the syringe tip embedded in the composite resin while placing the flowable will also help to minimize air entrapment. The tip is raised slowly as the cavity is filled.

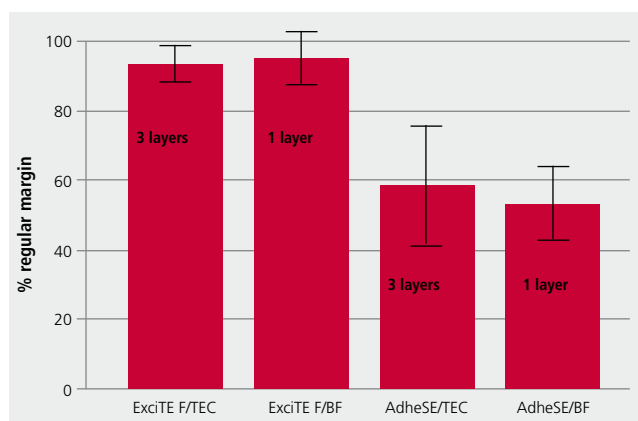
### Fillings composed of large increments show good marginal seal

What about the shrinkage and shrinkage force of bulk-fill composites? Can the mechanical properties of these materials stand up to chewing forces? From a materials engineering perspective, bulk-fill materials do not differ significantly from conventional composites. They are very similar in terms of their flexural strength (> 100 MPa) [39], their elastic modulus (above four GPa in most cases) [39] and their shrinkage and shrinkage stress. The shrinkage of "packable" composites, however, is considerably lower than that of flowable materials (shrinkage of 2 to 2.5 % compared to 3 to 4 %). The shrinkage force is similar (80 to 120 N) [40–42]. Due to a special shrinkage stress reliever, the shrinkage and shrinkage force of Tetric EvoCeram Bulk Fill are relatively low. However, dentists tend to be more concerned about bulk fillings increasing the stress on the cavity walls and floor. As a consequence, postoperative sensitivity could occur, and cracks in the tooth enamel and marginal gaps could form. All these possible effects have been studied in depth in the laboratory by various test institutes.

The findings can be summarized as follows:

1. The marginal seal of fillings in extracted teeth, which were placed with one composite increment (four to five millimetres) is comparable to that of fillings placed with conventional composites in several increments [43–48]. This was established for both low-viscosity and high-viscosity composites and also for Tetric EvoCeram Bulk Fill (Figure 8). The quality of the marginal seal is mainly determined by the effectiveness of the adhesive system used and not the characteristics of the composite. Adhesive systems that require the dental enamel to be separately etched with phosphoric acid produce a better marginal seal in enamel than self-etching systems.
2. Cusp deflection due to polymerization shrinkage of the composite can occur irrespective of the number of layers applied and is very slight (approx. 20 µm) [49]. It is greater in three-surface fillings than in fillings with two surfaces [50]. Therefore, an increased risk of enamel cracking is not to be expected. In any case, water absorption during the first month after the placement of the filling compensates for the shrinkage within the composite resin [51]. Studies

that investigated the movement of restorations before and after polymerization using micro-computer tomography (micro CT imaging) revealed that composite fillings containing radiopaque fillers, which were placed in extracted teeth using the adhesive bonding technique, tended to move from the cavity bottom towards the occlusal surface rather than away from the filling margin [52,53]. This was also established in experiments involving cavities in extracted teeth [54]. The so-called C-Factor or configuration factor (relationship between the number of bonded tooth surfaces to the number of un-bonded surfaces [55]) does not seem to have a relevant influence on the quality of the filling. To date, it is accepted that a high C-factor is unfavourable for the restoration. The highest C-factor is recorded in occlusal fillings. As a result, these fillings are expected to show the most marginal caries and staining. However, systematic studies on posterior composite fillings in which the results have been statistically evaluated have shown that this is not the case [56,57]. Marginal caries is mainly located in the cervical areas of multi-surface fillings and not necessarily in the occlusal margin [12]. In most cases, marginal caries is not caused by marginal gaps. Rather, its formation correlates with the caries activity of the patient [58,59].



**Fig. 8** Proximal marginal quality in enamel of fillings placed with Tetric EvoCeram Bulk Fill "BF" (one layer) and Tetric EvoCeram "TEC" (three layers) in extracted teeth in relation to the adhesive system used (etch-and-rinse system Excite® F and self-etching system AdheSE®). The average percentage of regular margin is shown (evaluation with a light microscope, x10). The quality of the margin is apparently related to the adhesive system, rather than the number of layers used. [46]

What about postoperative sensitivity once the filling has been placed? This factor cannot be simulated in the laboratory. Indicators such as colour penetration at the filling margin or shrinkage stress have not been shown to have a relationship with postoperative sensitivity [60]. The performance of bulk-fill materials in this respect will be discussed in the next section.



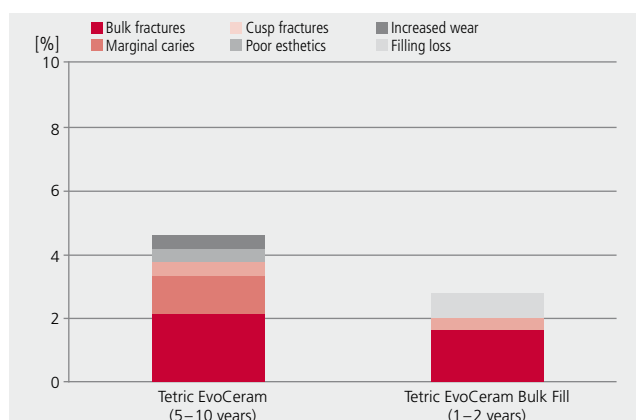
### Do clinical studies on bulk-fill materials exist?

To date, only very little clinical data is available on bulk-fill materials, at least with regard to long term evaluation (see below). Since laboratory examinations on mechanical data, shrinkage and marginal behaviour of fillings in extracted teeth (see above) usually do not show any significant differences compared with the results of conventional, clinically proven composites, dental manufacturers do not see the need to clinically test new materials many years before their introduction in an effort to have long-term clinical evidence available at the market launch. On the basis of laboratory data, therefore, a high probability was established that posterior restorations produced with Tetric EvoCeram Bulk Fill would have a quality similar to that of Tetric EvoCeram fillings. This assumption could be made due to the fact that the composition of Tetric EvoCeram Bulk Fill is largely based on that of Tetric EvoCeram. Clinical results from 840 posterior fillings examined over a period of up to ten years (USA, Sweden, Turkey, Belgium, Italy, Liechtenstein) – which were placed with various adhesive systems – are available for the latter material [61–66]. Thirty-eight of the 840 fillings had to be replaced during the five to eight year study period. This corresponds to a rate of 4.5 per cent (2.2 % bulk fractures, 1.2 % marginal caries and 0.4 %

each for cusp fractures, poor esthetics and high rate of wear) (Figure 9). In one per cent of the cases, patients initially complained of sensitivity. These results are significantly better than those of investigations involving other composite filling materials in posterior dentition [56,57,67].

In the meantime, a number of studies have been published on bulk-fill materials, for example, a clinical investigation of the bulk-fill material SDR, which was introduced in 2011. This material has to be covered with a viscous capping material. In this study, it was compared with a conventionally layered composite [68]. At the beginning of the study, sensitivity which lasted three weeks was reported in a tooth filled with the conventional composite. In the group treated with the bulk-fill material, none of the patients complained about postoperative sensitivity. During the three-year study period, two incidents (one bulk fracture and one cusp fracture) were reported for the conventional composite (n=53), while no special incidents were recorded in the group of patients treated with the bulk-fill material (n=53).

What about investigations on Tetric EvoCeram Bulk Fill? About two to three years ago, clinical studies on this product were started in various countries (Spain, Sweden, France, Turkey, Liechtenstein, USA). To date, however, no data has been published in dental journals, with the exception of the results from the in-house Ivoclar Vivadent study [69]. In addition, The Dental Advisor in the US published the results of its examiners [70]. If the results of these studies are pooled, a total of 399 posterior fillings were placed with Tetric EvoCeram Bulk Fill. In most cases, the material was compared with conventional composites placed using the layering technique. A variety of adhesive systems was used. The current observation period spans one to two years. To date, 360 fillings have been re-examined. So far, only one patient has complained of postoperative sensitivity. After two years, ten fillings (=2.8 %) had to be replaced (1.7 % filling fracture, 0.3 % cusp fracture, 0.8 % filling loss). Marginal caries was not detected in any of the cases (Figure 9). These results are comparable to or even better than those of other studies performed with conventional composites [56,57,67].



**Fig. 9** Summary of the clinical studies on posterior fillings placed with Tetric EvoCeram (observation period of five to ten years). The diagram shows the frequency in per cent of clinical events, which led to the replacement of the fillings. (Ivoclar Vivadent Scientific Report 10 Years Tetric EvoCeram, Vol. 01, 2014)



**Fig. 10** Two-surface filling placed with Tetric EvoCeram Bulk Fill in an upper molar: (top left) defective amalgam filling, (top right) cavity, (bottom left), filling after its placement, (bottom right) filling after two years  
Clinical pictures courtesy of Dr Arnd Peschke, Director of R&D Clinic Schaan

Figures 10, 11 and 12 show three clinical cases: a permanent molar restored with Tetric EvoCeram Bulk Fill alone; a deciduous molar restored with Tetric EvoFlow Bulk Fill alone and a permanent molar restored with both Tetric EvoFlow Bulk Fill and Tetric EvoCeram Bulk Fill. The composites mask discolouration considerably better than competitor products. Nevertheless, in the case of very tough stains, the dentist should use an additional opaque liner, for example, IPS Empress Direct Opaque.

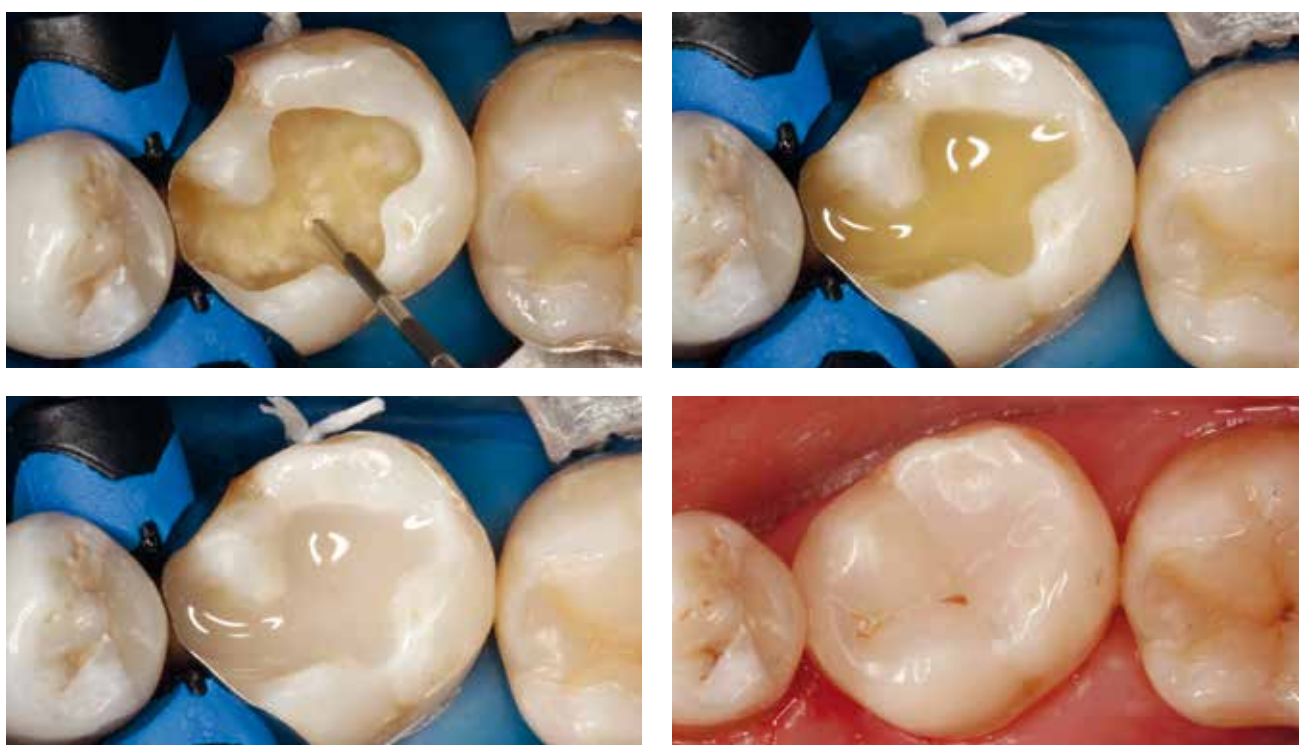
### Summary and outlook

Bulk-fill materials, Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill in particular, offer outstanding clinical reliability. Due to the special germanium-based photo-initiator Ivocerin, the two materials cure sufficiently when placed in increments of up to four millimetres. This gives dentists the possibility of applying the composites in thicker layers, which saves time and increases quality, as practitioners need not focus on the application of thin layers. This also applies to situations where a flowable composite liner has to be applied before the packable and sculptable composite is placed. The liner is available in bulk fill quality (Tetric EvoFlow Bulk Fill – up to four millimetres). No compromises have to be made with regard to

esthetics. The translucency of Tetric EvoCeram Bulk Fill is similar to that of natural enamel and the translucency of Tetric EvoFlow Bulk Fill is similar to that of dentin. Stains in dentin can be masked to a certain extent. The dentin-like translucency of Tetric EvoFlow Bulk Fill is achieved via what is known as Aessencio technology. Furthermore, dentists no longer have to make any compromises with regard to the marginal seal of fillings as a result of placing the composite in thick layers. The shrinkage of the materials is no greater than that of the comparable composites Tetric EvoCeram and Tetric EvoFlow. Moreover, the use of bulk-fill composites does not increase the risk of cracks in teeth. The risk of air voids is minimal in both materials, even if dentists apply them in increments of four millimetres. Clinical studies involving more than 300 fillings show that postoperative sensitivity does not occur more frequently than with conventional composites. Are there still any doubts about the clinical reliability of bulk-fill materials? A critical appraisal of all the data gathered from clinical studies and laboratory trials allows the following conclusion to be drawn: The clinical reliability of Tetric EvoCeram Bulk Fill and Tetric EvoFlow Bulk Fill is beyond all doubt – at least based on the information available today. All the concerns raised in the survey conducted by CR (see Introduction) can be dispelled for Tetric EvoCeram Bulk Fill und Tetric EvoFlow Bulk Fill.



**Fig. 11** Two-surface filling in a lower deciduous molar placed with Tetric EvoFlow Bulk Fill: (left) cavity, (middle) first layer before polymerization (two layers were necessary for sculpting the proximal contact), (right) filling after polymerization.  
Clinical pictures courtesy of Dr Lukas Enggist, R&D Clinic Schaan



**Fig. 12** Two-surface filling placed with Tetric EvoFlow Bulk Fill/Tetric EvoCeram Bulk Fill in a lower molar: (top left) cavity (depth of 4 mm), (top right) Tetric EvoFlow Bulk Fill before polymerization, (bottom left) Tetric EvoFlow Bulk Fill after polymerization, (bottom right) the finished filling coated with a layer of Tetric EvoCeram Bulk Fill  
Clinical pictures courtesy of Dr Ronny Watzke, Director of R&D Clinic Schaan

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