Special Edition

State-of-the-art restorations for posterior teeth

Tetric EvoCeram® Bulk Fill

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Summary

» Ever since composite-based restorative materials gained acceptance as a standard means of restoring load bearing posterior teeth, efforts have been underway to improve and further develop these materials and the associated adhesive systems and polymerization equipment. At the same time, the indication range of composite materials has gradually increased as a result of extensive clinical research studies. The results of these investigations have led to the introduction of effective modifications in clinical applications and in treatment protocols.

The introduction of bulk-fill composites, which offer improved depth of cure, represents a further milestone in the development of adhesive dentistry. These materials are already proving to be very popular among dental practitioners. With these new light-curing composites, large cavities can be restored using only a few increments, adding a new dimension to the direct adhesive technique in posterior teeth. In short, they offer an efficient, state-of-the-art, economical solution for restoring posterior teeth.

Ivoclar Vivadent introduced a material of this kind in 2011: Tetric EvoCeram Bulk Fill. In terms of its formulation, the product is closely related to the hybrid composite Tetric EvoCeram, which has firmly established itself in dental practices over the past decade. As a result of the favourable clinical performance of Tetric EvoCeram in posterior dentition, similar results can be expected for the bulk-fill version. «

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1. Long-term performance of composites in posterior teeth

Ongoing scientific dental research together with the introduction of completely new restorative materials and the continuous further development of existing materials is bringing about many changes to dental treatment approaches. These advances are also significantly influencing the life span of dental restorations [90]. Within the past three decades major changes have taken place in the way in which restorative materials are handled [50, 53, 91]. In addition, the esthetic standards of posterior tooth restorations have risen considerably [13].

Composite resin restorations have shown to be a viable and esthetic alternative to metal-based restorations over the past thirty years [67]. These materials have evolved quite substantially over the past decade. The initial clinical data on posterior composite restoratives in the 1980s were rather discouraging due to inadequate mechanical properties in particular. Low wear resistance led to the loss of restoration contours in quite a short time. Fractures, marginal cracking and leakage and the associated staining, secondary caries and hypersensitivity due to polymerization shrinkage additionally limited the life span of restorations [42, 70, 73, 77, 109]. However, these shortcomings have been greatly reduced as a result of advances made in the development of composite resins and adhesive systems in the past years [35, 80].

In the meantime, direct composite restorations have become an integral component of the treatment spectrum of modern conservative dentistry. They are very popular due to their wide range of application and their tooth preserving nature (defect-oriented cavity design) and the support of the tooth structure provided by adhesive bonding. [29,86]. Moreover, these restorations are much more affordable compared with indirect alternatives (inlays, partial crowns, full crowns) and they require less time to place [54]. Composite resin restorations are also quite easy to repair within the oral cavity, if the need should arise [52].

Type of restoration	Range	Mean value (standard deviation)
Amalgam	0-7,0	3,0 (1,9) [C]
Composite inlays	0-10,0	2,9 (2,6) [BC]
Direct composites	0-9,0	2,2 (2,0) [ABC]
Ceramic inlays	0-7,5	1,9 (1,8) [AB]
CEREC inlays	0-5,6	1,7 (1,6) [A]
Gold inlays	0-5,9	1,4 (1,4) [A]

Table 1: *Annual failure rate (AFR in %) of different types of restorations. Superscripts identify statistically different groups [83].*

The results of a comprehensive review of clinical studies involving various types of posterior tooth restorations in adult patients has shown that the annual failure rate (AFR) of composite resin (AFR = 2.2%) today is not statistically significant compared with that of amalgam (AFR = 3%), which currently sets the standard for clinical longevity [83]. The results of the survey of the annual failure rate of various restorative materials and restoration types are listed in Table 1[83]. A comparison of the data shows that composite restorations can actually compete with indirect restorations, provided they are placed accurately and within the range of correct indications.

Furthermore, in a long-term clinical study involving 1,202 amalgam and 747 composite restorations in large Class II cavities, OPDAM reported that composite restorations showed significantly better performance than amalgam restorations after 12 years *in situ*, with an annual failure rate of 1.68% (amalgam AFR = 2.41% [99]. After a very long observation period of 22 years, DA ROSA RODOLPHO determined an excellent AFR of 1.5% and 2.2% for two differently filled hybrid composites (77 vs 57 vol%). Nevertheless, in the second half of the study period, the annual failure rate of the lower filled material increased from 1.5% to 2.2%, while that of the higher filled composite remained constant [26].

Due to the decline in popularity of amalgam throughout the world, direct composite resins stand a good chance of replacing amalgam as the most widely used restorative materials in the near future [29]. Correctly placed adhesive composite restorations show outstanding clinical survival rates [29]. Consequently, they have firmly established themselves in the field of restorative dentistry.

2. Clinical aspects of the bulk-fill technique

2.1 Conventional incremental layering technique

To date, incremental layering is considered to be the gold standard for placing light-curing composite materials [102]. Generally, conventional composites are placed in individual layers of maximum 2 mm thickness due to their particular polymerization properties and limited depth of cure. The increments are individually light polymerized for 10 to 40 s, depending on the light intensity of the curing light used and the colour and translucency level of the corresponding composite paste [64]. Thicker layers of these regular composites, however, do not polymerize properly and therefore produce poor mechanical and biological properties [18, 37, 118]. The incremental technique allows the individual composite layers to be favourably oriented within the cavity, which lowers the C-factor (configuration factor = number of bonded to unbonded composite surfaces). This minimizes the material's intrinsic polymerization induced shrinkage and the related negative effects on the restoration [34, 118]: e.g. debonding of the composite from the cavity walls, marginal leakage and staining, secondary caries, enamel fractures, cusp deflection, crack formation in the cusps and hypersensitivity.

2.2 Demand for alternative composite resin application protocols

The conventional increment technique can be very time-consuming and complicated when it is used to fill large and voluminous cavities in posterior teeth. As a result, many dentists eagerly anticipated the arrival of an alternative to this highly technique sensitive multiple layering technique. The main aim of the development efforts was to a find a way of placing composites efficiently and with enhanced reliability. The bulk-fill composites have been developed in response to this growing demand for more efficiency. These materials can be placed in increments of 4 to5 mm thickness [25, 39, 81, 82]. The following factors can help to speed up the placement of light-curing composite restorations in posterior teeth and therefore make this procedure more economical:

- Universal shade of the restorative material ➔ Elimination of complicated and time-consuming shade selection
- Enhanced translucency of the composite ➔ Increased depth of cure per layer, therefore, fewer increments
- Optimization of the photo-initiator system of the light-curing composite ➔ Shorter curing times and increased depth of cure
- Low-shrinkage composite resisns with minimal stress build-up ➔ Thicker layers, therefore, fewer increments
- High-performance polymerization lights ➔ Shorter and more intensive light polymerization
- Efficient creation of functional occlusal surfaces ➔ Faster finishing and polishing

2.3 General information about bulk-fill composites

Special composite resins are now available for the bulk-fill technique. They can be placed more easily and efficiently due to the fact that they require less time to polymerize than other composites at correspondingly higher light intensities (usually ≥ 800 – 1,000 mW/cm²) and have a high depth of cure (4 – 5 mm increment thickness) (e.g. Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; QuiXfil, Dentsply; x-tra fil, Voco; SonicFill, Kerr). The first bulk-fill composites to be supplied to the market were delivered in a high-viscosity, sculptable consistency (QuiXfil, Dentsply;

x-tra fil, Voco). These materials have been available for more than a decade (market launch of QuiXfil in 2003). However, despite their enhanced depth of cure, they were unable to establish themselves successfully on the market [118]. It took another few years and the launch of the first flowable bulk-fill composite (SDR, Dentsply) in 2009 before the demand for these materials would grow dramatically. This paved the way for the introduction of additional products (in high-viscosity and flowable form). The characteristics required of a bulk-fill composite are summarized below:

- Extensive and reliable depth of cure
- Low polymerization shrinkage (volumetric shrinkage in %) and low shrinkage stress (polymerization contraction stress in MPa) [31, 127].
- Excellent adaptation of the material to the cavity margins and walls/floor
- Appropriate physical and mechanical properties (flexural strength, fracture toughness K_{IC}, modulus of elasticity, Vickers hardness, etc.) also in deep cavities/thick increments
- Sufficient wear resistance
- Sufficient working time for clinical application and occlusal moulding (of highly viscous materials)
- Sufficient radiopacity

The bulk-fill composites are specially engineered to meet the above requirements. Both polymerization shrinkage and shrinkage stress have a major influence on the quality of the margins of composite-based restorations [110]. To this end, special monomers or fillers have been added to the bulk-fill composites, which reduce the shrinkage stress during polymization: The modulus of elasticity rises slowly during the curing phase, without detrimentally affecting the polymerization rate and the final degree of polymerization (an adequately high conversion rate is important for achieving good mechanical and biological material properties) [15, 31, 46, 59, 119, 126]. Apart from the traditional glass fillers, Tetric EvoCeram Bulk fill contains a shrinkage stress reliever in the form of a patented, special filler (prepolymer), whose modulus of elasticity is relatively low at 10 GPa (by comparison: the modulus of elasticity of glass fillers is approx. 71 GPa). This filler acts like a microscopic spring and absorbs the stresses generated during light activation [120].

Bulk-fill composites are generally more translucent than conventional composites (shade and translucency level influence the depth of cure of composites) in order to ensure sufficient light polymerization of thick restoration layers. Nevertheless, individual products can differ quite considerably in this respect [12, 33, 57]. This provides a partial explanation for why thick increments of some bulk-fill composites cure just as effectively as thin two-millimetre layers of conventional composites. The elevated level of translucency of these materials may compromise the esthetic appearance of the restoration to a certain extent. However, the issue of esthetics is usually not important in posterior teeth [71]. On the one hand, high translucency of a composite may cause a restoration to look slighly greyish [15]. On the other hand, if the tooth structure has dark stains, the material may not provide adequate masking properties. This effect has to be taken into consideration, e.g. on the mesial surfaces of premolars [33, 51].

When 4-mm thick composite layers are light polymerized, considerably fewer photons penetrate to the cavity floor or the bottom of the increment than originally reached the restoration surface, since the light rays are scattered by the filler particles and absorbed by the colour pigments. Advanced, highly sensitive and reactive light initiator systems (e.g. Ivocerin in Tetric EvoCeram Bulk Fill, Ivoclar Vivadent), therefore, provide the second part of the explanation for the enhanced curing depth of bulk-fill composites. In addition to the popular initiators such as camphorquinone and acyl phosphine oxide, Tetric EvoCeram Bulk Fill also contains a new highly sensitive light initiator system (Ivocerin). This innovative polymerization booster, which is based on dibenzoyl germanium derivatives, features an absorption spectrum similar to that of the widely used camphorquinone. However, it shows improved quantum efficiency due to its higher light absorption rate in the visible wavelength range and therefore higher light-reactivity [94]. As a result, even very little light (photons) can trigger polymerization and achieve a high depth of cure [15, 94].

High-performance lights with an intensity of at least 1,000 mW/cm^2 should be used to polymerize bulk-fill composites (e.g. Bluephase Style from Ivoclar Vivadent). This will ensure a high conversion rate throughout the entire increment. Moreover, the final restoration will exhibit good mechanical and biological properties (tissue compatibility) – even if the light guide could not be optimally focused on the composite: for example, if the tooth is difficult to reach or the distance between the light guide and the composite surface is very large, or if a divergent radiation angle is involved. Generally, bulk-fill composites take 10 s to cure per 4-mm increment. In contrast to some of the considerably translucent bulk-fill composites, Tetric EvoCeram Bulk Fill is slightly more opaque with an enamel-like translucency. This appearance is achieved as a result of the high quantum efficiency of the photo-initiator Ivocerin, which in combination with the coordinated light refraction index of the fillers (mixed oxides, glass fillers, radiopaque agents) and the polymer matrix produces excellent light-optical properties, which match those of dental hard tissue (enamel in particular) [93, 120]. The three shades (IVA, IVB, IVW) in which Tetric EvoCeram Bulk Fill is supplied are more than adequate for creating virtually invisible restorations in posterior teeth with normally coloured dentin.

"Bulk Fill" means that a cavity can be filled completely in a single step according to state-of-the-art restorative techniques, without having to place multiple layers [51]. To date, the only direct filling materials available for this type of application have been cements and chemically or dual-curing core build-up composites. Nevertheless: Cements are not suitable for placing clinically durable restorations in load-bearing posterior teeth, since their mechanical properties are inadequate for this indication. Therefore, cements should only be used for temporary fillings/long-term temporaries [45].
Moreover, core build-up composites are not approved for use as restorative materials and they are not suitable for this purpose due to their specific handling properties (e.g. lack of sculptability for the design of the occlusal surface anatomy). Even amalgam has to be placed in the cavity in increments, which then have to be condensed individually. Technically, the present bulk-fill composites that are available for the simplified restoration of posterior teeth are not really bulk-fill materials, because many proximal cavities extend into areas that are deeper than the maximum curing depth of these materials (4 – 5 mm) [44, 46]. Nonetheless, if a suitable composite is used, cavities with a depth of up to 8 mm – which includes most of the cavities seen on a daily basis in dental clinics – can be restored with two increments.

Case 1:
Large two-surface restoration in an upper molar

In this first case, a large restoration was placed with Tetric EvoCeram Bulk Fill. When it was finished, the restoration was virtually indistinguishable from the natural tooth structure.

Initial situation

Figure 1
First upper molar with a provisional seal after endodontic treatment

Figure 2
The old filling was removed and the root canal openings were covered with glass ionomer cement.

Figure 3
A dry working field was created with a rubber dam, and the cavity was separated using a sectional matrix. Then, the tooth structure was conditioned with Adhese® Universal according to the self-etch technique (reaction time 20 s).

Figure 4
The adhesive was air-thinned until a glossy immobile film formed.

Figure 5
Light polymerization of the adhesive for 10 s with Bluephase Style

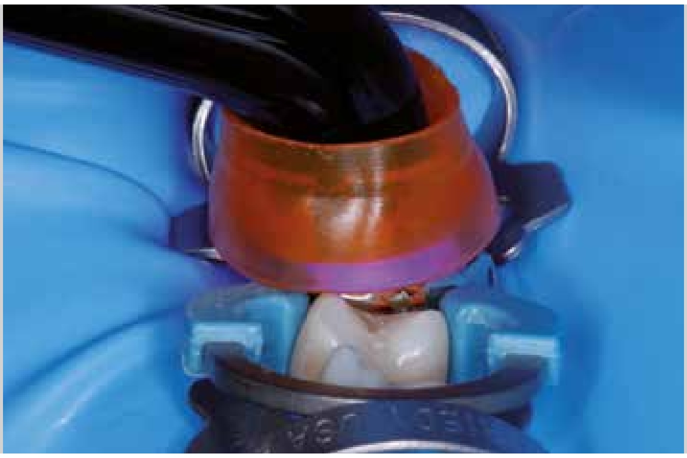

Figure 6
Application of the first layer of Tetric EvoCeram Bulk Fill in the mesial box

Figure 7
The composite was moulded with a microbrush, and the mesial cavity wall was contoured up to the marginal ridge.

Figure 8
Completed mesial wall

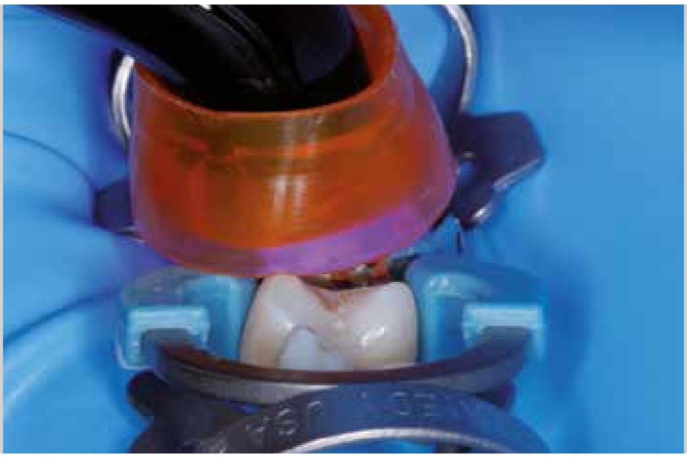

Figure 9
Light polymerization of the composite for 10 s with Bluephase Style

Figure 10
Sculpting of the mesio-palatal cusp

Figure 11
Sculpting of the
mesio-buccal cusp

Figure 12
Sculpting of the
disto-buccal cusp

Figure 13
Sculpting of the
disto-palatal cusp

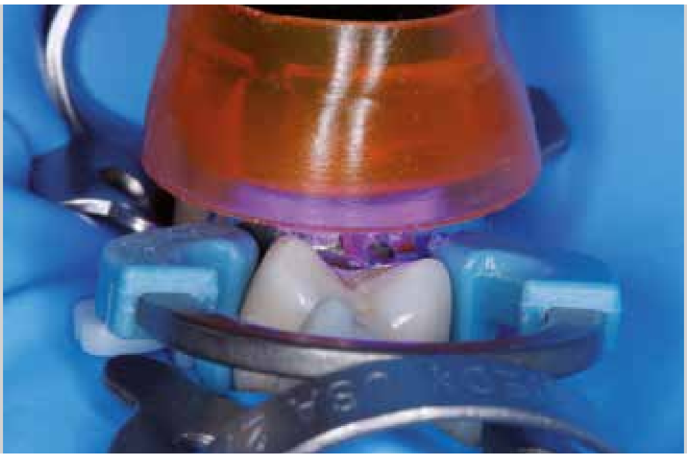

Figure 14
Due to the wide diameter of the Bluephase Style light guide, all the occlusal composite increments could be polymerized simultaneously for 10 s.

Figure 15
The matrix was removed and
the restoration was checked for any irregularities.

Initial situation

Final situation

Figure 16
Finished and high-gloss polished restoration.
The tooth has regained its original appearance and function.

2.4 Bulk-fill composites at a glance

Material	Manufacturer	Capping layer necessary	Max. increment thickness	Organic matrix
Flowable bulk-fill composites (low viscosity)				
SDR (Smart Dentin Replacement)	Dentsply DeTrey	Yes	4 mm	Modified UDMA, TEGDMA, EBPDMA
x-tra base	Voco	Yes	4 mm	Bis-GMA, UDMA
Venus Bulk Fill	Heraeus Kulzer	Yes	4 mm	UDMA, EBPDMA
Filtek Bulk Fill Flowable Restorative	3M Espe	Yes	4 mm	Bis-GMA, UDMA, Bis-EMA, Procrylate resins
Beautifil-Bulk Flowable	Shofu Dental	Yes	4 mm	Bis-GMA, UDMA, Bis-MPEPP, TEGDMA
Sculptable bulk-fill composites (high viscosity)				
Tetric EvoCeram Bulk Fill	Ivoclar Vivadent	No	4 mm	Bis-GMA, Bis-EMA, UDMA
QuiXfil	Dentsply DeTrey	No	4 mm	Bis-EMA, UDMA, TEGDMA, TMPTMA, TCB resin
x-tra fil	Voco	No	4 mm	Bis-GMA, UDMA, TEGDMA
SonicFill	Kerr + KaVo	No	5 mm	Bis-GMA, TEGDMA, EBPDMA
everX Posterior	GC	Yes	4 mm	Bis-GMA, PMMA, TEGDMA
Beautifil-Bulk Restorative	Shofu Dental	No	4 mm	Bis-GMA, UDMA, Bis-MPEPP, TEGDMA

Table 2: *Bulk-fill composites for posterior teeth (abbreviations: Bis-EMA = ethoxylated bisphenol A dimethacrylate; Bis-GMA = bisphenol A glycidyl methacrylate; UDMA = urethane dimethacrylate; TEGDMA = triethylene glycol dimethacrylate;*

Inorganic fillers	Particle size	Filler particles wt%/vol%	Remarks
Ba-Al-F-B-Si glass, Sr-Al-F-Si glass	Average size: 4.2 µm	68/45	2-mm capping layer made of methacrylate-based posterior hybrid composite is necessary, 1 shade (Universal), 20 s polymerization with light intensity of ≥ 550 mW/cm²
		75/-	2-mm capping layer made of methacrylate-based posterior hybrid composite is necessary, 2 shades (Universal, A2), 10–40 s poly-merization depending on the light intensity and shade used: shade Universal:10 s polymerization at light intensity of ≥ 500 mW/cm²; shade A2: 40 s at light intensity of 500–800 mW/cm², 20 s at a light intensit of ≥ 800 mW/cm²
Ba-Al-F-Si glass, ytterbium trifluoride, SiO_2	0.02-5 µm	65/38	2-mm capping layer made of methacrylate-based posterior hybrid composite is necessary, 1 shade (Universal), 20 s polymerization with light intensity of ≥ 550 mW/cm²
ZrO_2/SiO_2, ytterbium trifluoride	ZrO_2/SiO_2: 0.01-3.5 µm (average size 0.6 µm); YbF_3: 0.1-3.5 µm	64.5/ 42.5	2-mm capping layer made of methacrylate-based posterior hybrid composite is necessary, 4 shades (Universal, A1, A2, A3), 10–40 s polymerization, dependent on the light intensity and the shade used: shade Universal: 20 s polymerization at light intensity of 550–1,000 mW/cm², 10 s at light intensity of ≥ 1,000 mW/cm²; shades A1-A3: 40 s at light intensity of 550–1,000 mW/cm², 20 s at light intensity of ≥ 1,000 mW/cm²
F-B-Al-Si glass		60/-	2-mm capping layer made of methacrylate-based posterior hybrid composite is necessasry, 2 shades (Universal, Dentin), 10–40 s polymerization, dependent on the light intensity and the shade used: shade Universal: 20 s polymerization at light intensity of ≥ 500 mW/cm², 10 s at light intenisty ≥ 1,000 mW/cm²; shade Dentin: 40 s at light intensity ≥ 500 mW/cm², 20 s at light intensity ≥ 1,000 mW/cm²
Ba-Al-Si glass, ytterbium trifluo-ride, spherical mixed oxide, prepolymers	Particle size of inorganic fillers: 0.04-3 µm, aver-age size 0.55 µm	76-77/ 53-54	Sculptable nanohybrid composite, 3 universal shades (^{IV}A, ^{IV}B, ^{IV}W), 10–20 s polymerization, dependent on the light intensity used: 10 s polymerization at light intensity of ≥ 1,000 mW/cm², 20 s polymerization at light intensity of ≥ 500 mW/cm²
Fine and coarse glass particles	Fine glass, average size = 1 µm; coarse glass, average size = 10 µm	86/66	Sculptable hybrid composite, 1 universal shade, 10–20 s poly-merization, dependent on the light intensity used: 20 s polymerization at light intensity of 500-800 mW/cm², 10 s polymerization at light intensity of ≥ 800 mW/cm²
		86/70.1	Sculptable hybrid composite, 1 universal shade, 10–20 s poly-merization, dependent on the light intensity used: 20 s poly-merization at light intensity of 500–800 mW/cm², 10 s poly-merization at light intensity of ≥ 800 mW/cm²
SiO_2, glass, oxides		83.5/-	Sculptable nanohybrid composite, 4 shades (A1, A2, A3, B1), extra activation handpiece is needed (KaVo SONICfill, KaVo) ➔ thixotropic effect (temporary change in viscosity from sculptable to flowable through sonic activation with SONICfill activation handpiece), 20 s polymerization at light intensity of ≥ 500 mW/cm²
E-glass fibres, Ba glass, SiO_2	Fibres of 1.3 - 2 mm	74.2/53.6	The occlusal surfaces and outer walls of restorations made of this composite containing glass-fibre reinforcement always have to be covered with a methacrylate-based posterior hybrid composite layer of 1 to 2-mm thickness (to achieve a wear resistant and polishable restoration surface), 1 universal shade, 10–20 s polymerization, depending on the light intensity used: 20 s polymerization at light intensity of 700 mW/cm², 10 s polymerization at light intensity of ≥ 1,200 mW/cm²
F-B-Al-Si glass		70/-	Sculptable hybrid composite, 2 shades (Universal, A), 10–20 s polymerization, dependent on the light intensity used: 20 s at light intensity of ≥ 500 mW/cm²; 10 s polymerization at light intensity of ≥ 1,000 mW/cm²

EBPDMA = ethoxylated bisphenol A dimethacrylate, TMPTMA = trimethylolpropane trimethacrylate, PMMA = polymethyl methacrylate
TCB resin = butane 1,2,3,4 tetracarbon acid bis-2-hydroxyethyl methacrylate resin, bis-MPEPP = bisphenol A polyethoxy dimethacrylate)

The category of bulk-fill composites is divided into two subgroups, which demand different application techniques:

1. Low-viscosity, flowable bulk-fill composites (Table 3) that need to be protected by an additional occlusal capping layer made of a regular hybrid composite [60]. These bulk-fill composites have a low filler content and contain comparatively large fillers in order to lower the polymerization stress. As a result, however, they have poorer mechanical and esthetic properties compared with conventional hybrid composites: for example, lower elastic modulus and wear resistance and increased surface roughness and inferior polishability [23, 24, 51, 57, 64, 105]. In addition, the capping layer allows the occlusal surface to be functionally contoured, as this would be very difficult or even impossible to manage with a flowable material.

2. Regular to high-viscosity, sculptable bulk-fill composites (Table 4) that can be used up to the occlusal surface. They do not require a protective capping layer. Thus, no additional composite material is required.

Both types of bulk-fill composite cannot be cured in layers that are thicker than 4 mm (SonicFill: max. 5 mm ➔ manufacturer's claim). In other words, only the high-viscosity variants can be regarded as true bulk-fill materials when they can be placed at a cavity depth, which corresponds to the maximum depth of cure of the material. If deeper lesions are involved or if flowable bulk-fill composites are used, an additional capping layer will always be necessary.

Low-viscosity flowable bulk-fill composites

Advantages
Wetting ability/excellent adaptation to cavity walls and all internal line and point angles [46]
Self-levelling effect as a result of the flowable consistency
The first increment does not have to be manually adapted (it is simply injected) ➔ no packing instruments are needed
The first flowable increment is quickly placed ➔ highly efficient [76]
No additional flowable composite is needed as a liner
Disadvantages
A 2-mm thick capping layer consisting of a conventional methacrylate-based posterior hybrid composite has to be placed on the flowable bulk-fill composite in order to achieve the required mechanical strength, wear resistance, clinical stability, occlusal contour and esthetic properties [57, 64, 111, 113].
In the treatment of upper posterior teeth, flowable bulk-fill composite may leak into the distal cavity area or out of the cavity altogether ➔ Consequently, there is a risk that the required 2-mm capping layer of posterior composite cannot be applied properly or that the flowable bulk-fill composite has to be cut back in a time-consuming process.
High translucency may impair the esthetic properties

Table 3: *Advantages and disadvantages of low-viscosity flowable bulk-fill composites*

Regular to high-viscosity, sculptable bulk-fill composites

Advantages
No additional occlusal capping layer is needed ➔ true one-layer technique in cavities of up to 4 mm
Only one composite material is needed to place a restoration
The occlusal anatomy is easy to sculpt due to the firm consistency of the material
Disadvantages
The first layer has to be carefully adapted to the cavity walls and all internal line and point angles using a hand instrument
High translucency may compromise the esthetic appearance (material forms the occlusal surface)

Table 4: *Advantages and disadvantages of high-viscosity sculptable bulk-fill composites*

3. Materials science aspects

3.1 Physical properties of dental composites: Correlation between laboratory results and clinical behaviour

It is very costly and time-consuming to perform clinical evaluations of restorative materials. Since the number of different composite resins has grown immensely, most individual materials can no longer be directly compared in clinical studies. Therefore, the demand for laboratory investigations is growing in order to predict the clinical behaviour of materials efficiently and accurately. However, it is impossible to foresee the actual performance of an individual material on the basis of the composite category to which it belongs, since the mechanical properties vary quite considerably within these groups [58, 61].
A number of correlations have been found between the clinical behaviour of bulk-fill composites and their physical properties measured in the laboratory. But, the overall clinical performance of composites depends on many different factors. Therefore, it is impossible to accurately predict their clinical behaviour by simply running a few *in vitro* tests [28, 36]. The clinical success of a restorative material is determined by a complex network of influences: they include the material composition (determined by the manufacturer), the operator (handling of the material by the dental practitioner) and the patient [83] (Table 5).

Studies performed to date have established a correlation between the clinical wear of composites and their flexural strength, the fracture toughness, the primary particle size and the monomer conversion rate. Interactions have also been determined between the marginal integrity of restorations and their fracture toughness. Furthermore, it is assumed that the fracture risk and wear rate of a composite restoration is related to the fatigue resistance of the material. However, the margin quality and bond strength of restorations established in the laboratory show only little correlation with the actual clinical performance of a composite [36].

Long-term studies on the clinical behaviour of composite materials indicate that today's restorations, in contrast to those of the past, fail not only primarily due to secondary caries, but also a rise in material fractures [26, 29, 49, 121, 124, 125]. The reason for

Material	Dentist	Patient
Strength (fractures)	Correct indication	Oral hygiene, diet
Fatigue / Degradation	Cavity preparation (size, type, finish)	Preventive measures, fluoride
Wear resistance (OCA, CFA)	Handling and application (e.g. incremental layering technique)	Compliance/Recall
Bond strength, marginal seal, polymerization shrinkage, postoperative sensitivity	Polymerization (device, time, light sensitivity)	Oral situation (quality of the tooth structure, saliva, etc.) and systemic diseases
Chemical compatibility of the restorative system (adhesive, composite)	Type of finishing and polishing of the restoration	Lesion (size, shape, location) and tooth (number of surfaces, vital vs devitalized, premolar vs molar)
Technique sensitivity	Proper occlusion	Compliance during the treatment
Caries inhibiting effects	Experience (with materials and application protocols) and care	Bruxism, parafunctions, habits

Table 5: *Factors that influence the clinical life of dental restorations [83].*

these failures is manifold and includes the fact that the indications of composites have been extended to include large Class II cavities. In addition, their mechanical properties have tended to decline, especially with regard to the modulus of elasticity, due to the reduction in size of the filler particles in order to meet today's esthetic requirements [35, 58]. A material with a low modulus of elasticity is more prone to deformation. This is particularly the case with composite restoratives when they are used in load-bearing areas (e.g. in posterior teeth). Ultimately, this shortcoming could result in the fracture of the restoration. What is more, a restorative material with a low modulus of elasticity provides less support for the remaining thin cavity walls of the tooth. Therefore, more stress is placed on the adhesive interface and the risk of tooth fractures and marginal defects increases.

3.2 Materials science of bulk-fill composites

In terms of their chemical composition bulk-fill composites do not really represent a new category of materials. They are actually very similar to hybrid composites. They contain an organic matrix composed of common monomer systems, such as Bis-GMA (bisphenol A glycidyl methacrylate), EBPDMA (ethoxylated bisphenol A dimethacrylate), UDMA (urethane dimethacrylate) and TEGDMA (triethylene glycol dimethacrylate), in addition to well-known inorganic fillers [61, 64].

The different application techniques (with or without an occlusal capping layer) of the bulk-fill composites are determined by the significantly inferior mechanical properties of the low-viscosity bulk-fill materials (Table 6). The two types of bulk-fill composites show considerable differences in their modulus of elasticity. The modulus of elasticity of highly viscous bulk-fill composites is very similar to that of microhybrid composites and significantly higher than that of other composite types. Flowable bulk-fill composites and flowable regular composites exhibit statistically similar values and the lowest modulus of elasticity of the examined materials categories. Nanohybrid composites are somewhere in the medium range. In the micro-mechanical Vickers hardness test, highly viscous bulk-fill composites show the highest values, followed by nanohybrid and microhybrid composites, while the low-viscosity bulk-fill composites exhibit significantly lower hardness values than flowable regular composites (Table 6). It is important to note that the Vickers hardness of most composite materials is similar to that of human dentin. However, it is considerably lower than that of human enamel. The difference between low-viscosity and high-viscosity bulk-fill composites is more distinct in the microscopic than in the macroscopic range, with the Vickers hardness being more than twice as high in high-viscosity compared with low-viscosity bulk-fill composite materials.

The statistical evaluation of the filler content reveals that high-viscosity bulk-fill composites have the highest values and the low-viscosity bulk-fill composites show the lowest values of all composite types examined (Table 6), which corresponds to the measured mechanical properties.

Type of composite	σ (MPa)	$E_{modulus}$ (GPa)	HV (N/mm²)	Filler particles vol%	Filler particles wt%
Microhybrid	$131,2^{BC}$ (29,8)	$7,3^{c}$ (2,6)	$87,0^{c}$ (28,8)	$62,8^{B}$ (12,5)	$78,5^{b}$ (4,0)
Nanohybrid	$121,9^{AB}$ (32,6)	$5,9^{b}$ (2,1)	$90,9^{c}$ (35,6)	$63,8^{AB}$ (8,7)	$78,2^{b}$ (7,9)
Low-viscosity bulk-fill	$128,4^{ABC}$ (12,7)	$4,7^{a}$ (1,1)	$53,0^{a}$ (19,2)	$46,0^{D}$ (8,0)	$68,1^{d}$ (3,8)
High-viscosity bulk-fill	$135,0^{C}$ (17,3)	$7,4^{c}$ (2,4)	$105,0^{d}$ (31,5)	$65,5^{A}$ (4,5)	$83,4^{a}$ (2,9)
Flowable	$119,3^{A}$ (25,8)	$4,2^{a}$ (1,3)	$65,8^{b}$ (28,9)	$51,1^{C}$ (10,6)	$69,9^{c}$ (8,2)
Dentin			58,3 (16,0)		
Enamel			407,1 (100,0)		

Table 6: *Comparison of the mechanical properties of different types of composites (Data from [57] and the latest evaluations based on the data compiled by Prof. Dr Ilie, Munich Dental Clinic). Three-point bending strength (σ), elastic modulus ($E_{modulus}$) and Vickers hardness (HV). The filler content is expressed in volume percent (vol%) and weight percent (wt%). Superscripts identify significant subgroups (Tukey's HSD Test, α = 0.05). The Vickers hardness (VH) test involved a direct comparison with human enamel and dentin (HV).*

The depth of cure of bulk-fill composites is enhanced over that of conventional composites mostly by increasing the translucency of the materials [57]. This is achieved by matching the refractive index of the fillers to that of the polymer matrix and by varying the filler content and the size of the filler particles [57], since a linear correlation between the translucency of a composite and its filler content is known to exist [72]. Under otherwise identical conditions, a lower amount of filler will produce a more translucent product with a higher depth of cure. Low-viscosity bulk-fill composites contain a considerably smaller amount of fillers in comparison with conventional nonhybrid and microhybrid composites (Table 6) [64]. Furthermore, many of the bulk-fill materials (x-tra fil, x-tra base, SDR, SonicFill) feature much larger fillers (≥20 μm) than regular composite resins [57]. Compared with the smaller fillers, the same amount (wt%) of these larger particles significantly reduces the overall surface area of the filler and therefore the interface between the inorganic fillers and the organic matrix. Since the larger filler particles reduce the number of transitions where light can pass between the matrix and the fillers, less light can escape and more photons, which activate the light-sensitive initiator system, can penetrate the material and thereby increase the depth of cure of bulk-fill composites [57]. In composites containing small fillers below the visible light range (380–780 nm), light is neither scattered nor absorbed by the small particles. This increases the translucency of the composite as well as the ability to sufficiently polymerize deep areas of the restoration [68, 89]. However, a low filler content and comparatively large filler particles compromise the mechanical and esthetic properties of the material. In addition, they lower the composite's wear resistance and increase its surface roughness and impair its polishing properties [23, 24, 51, 57, 64, 105].

Due to an advanced photo-initiator, which is extremely sensitive to incoming photons, Tetric EvoCeram Bulk Fill offers the 4-mm depth of cure that is characteristic of bulk-fill composites even though the material is highly filled with small particles (Table 2).

Flexural strength is a significant parameter in load-bearing restorations. Commercially available bulk-fill composites exhibit flexural strength values between 120.8 MPa and 142.8 MPa [57]. This corresponds to the average flexural strength of nanohybrid and microhybrid composites [57, 58, 64] and by far exceeds ISO 4049 [2] of 2009, which establishes a minimum of 80 MPa.
The restorative technique with flowable bulk-fill composites and the polymerization shrinkage stress associated with this method are not known to be responsible for cusp deformation or deflection in posterior restorations [17, 46, 92], despite the fact that these materials demonstrate volume shrinkage of 3 to 3.5% [33]. In comparison, volume shrinkage of 1.9 to 2.3% has been determined for sculptable bulk-fill composites [56].

Bulk-fill composites show very little shrinkage stress during polymerization [30, 59]. They exhibit acceptable deformation behaviour (creep) under loading, in other words, high dimensional stability, which is comparable to that of conventional composites. These properties are fundamental to producing long-lasting restorations and restoration margins that will withstand the conditions in the oral cavity [32].

Bulk-fill composites and the corresponding adhesive systems can be used to effectively seal cavity floors, which considerably helps to prevent postoperative sensitivity in patients [46]. Correctly used, bulk-fill composites will produce restoration margins that are just as tight as those of restorations placed with regular layering composites [4, 16, 46, 88, 107, 112, 117]. In a laboratory study on the marginal adaptation of Class II restorations, the results of both low-viscosity and high-viscosity bulk-fill composites were comparable to those of conventional composites [16].

Bulk-fill composites	σ (MPa)	$E_{modulus}$ (GPa)	HV (N/mm²)
Tetric EvoCeram Bulk Fill	120,8^{a} (12,7)	4,5^{AB} (0,8)	78,4^{C} (6,7)
x-tra fil	137,0^{b} (14,4)	9,5^{E} (0,6)	133,5^{D} (32,0)
QuiXfil	138,6^{b} (20,5)	8,7^{E} (2,6)	126,1^{D} (19,6)
SonicFill	142,8^{b} (12,9)	6,9^{D} (0,6)	82,0^{C} (4,7)
Filtek Bulk Fill Flowable Restorative	122,4^{a} (9,6)	3,8^{A} (0,4)	48,4^{B} (1,3)
Venus Bulk Fill	122,7^{a} (6,9)	3,6^{A} (0,4)	38,1^{A} (11,8)
SDR	131,8^{ab} (5,8)	5,0^{BC} (0,4)	54,2^{B} (1,9)
x-tra base	139,4^{b} (7,0)	6,0^{CD} (0,9)	85,1^{C} (11,2)

Table 7: *Mechanical properties of bulk-fill composites (Data from [57] and the latest evaluations based on the data compiled by Prof. D. Ilie, Munich Dental Clinic): Three-point bending strength (σ), elastic modulus ($E_{modulus}$) and Vickers hardness (HV). Superscripts identify significant subgroups (Tukey's HSD Test, α = 0.05). The low-viscosity bulk-fill composites are shown in the grey shaded part of the table.*

Concerns about insufficient microhardness have been raised with regard to certain products [27]. However, only the flowable type of bulk-fill composites are affected, and these materials should be covered with an occlusal increment of a posterior hybrid composite in any case [57].

High-performance curing lights should be used and the polymerization times indicated by the manufacturer must be observed in order to obtain reliable curing results at the bottom of 4-mm layers [5, 11, 25, 30, 31 , 47, 48, 60, 69, 106, 130]. A correlation is known to exist between the monomer conversion rate of a composite and the material's clinical wear resistance [38]. In occlusal load-bearing areas, therefore, the conversion rate of a dimethacrylate-based composite should not be below 55% [114]. The conversion rate of double bonds during the polymerization of bulk-fill composites is comparable to that of conventional hybrid composites [6,75]. Bulk-fill composites show a significantly higher double bond conversion rate at the bottom of 4-mm thick layers compared with regular composites. This is due to the excellent light transmission properties of bulk-fill composites, which enhances the polymerization of thick increments [48]. Bulk-fill composites are comparable to their conventional counterparts in terms of their biocompatibility [40].

A comparison of composite categories rather than individual materials reveals that high-viscosity bulk-fill composites have a similar modulus of elasticity to traditional hybrid composites, which is considerably higher compared to that of low-viscosity bulk-fill composites [64]. With regard to the Vickers hardness and the modulus of indentation, high-viscosity bulk-fill composites show the significantly highest values, followed by those of the microhybrid and nanohybrid composites. Low-viscosity bulk-fill composites exhibit lower hardness values than traditional flowable composites [12,64].

Table 7 provides a summary of the mechanical properties of bulk-fill composites.

3.3 Light transmission of bulk-fill composites

Various mechanisms are responsible for improving the depth of cure of the different bulk-fill composites. Nevertheless, enhanced translucency compared with conventional composites is the common characteristic of most bulk-fill composites. The light transmission properties of dental composites determine the way in which the materials have to be polymerized. Research studies confirm that regular composites [95, 96] as well as bulk-fill composites [39, 60, 62, 63] exhibit a material-dependent sensitivity to variations in light under simulated clinical conditions.

Under ideal laboratory conditions, less than 200 mW/cm² irradiance could be measured at the bottom of 2-mm thick layers of regular nanohybrid composites after curing with a high-performance polymerization light (1,650 mW/cm²). Furthermore, it was found that hardly any light could penetrate through 4-mm layers. With regard to 6-mm increments, some composite materials were shown to be completely impenetrable (Table 8).

The energy density of light in the absorption spectrum of the photo-initiators of dental composites (360 – 540 nm), which penetrates 2-mm and 4-mm increments is significantly higher in bulk-fill composites than in regular composites: This raises the probability of an adequately cured material in thicker increments. SonicFill represents an exception in this category, in that its translucency is similar to that of conventional composites (Table 8).

A direct comparison of bulk-fill composites with the corresponding microhybrid and nanohybrid composites of the same manufacturer reveals the different composition strategies of bulk-fill composites.

The most striking difference exists between Venus Diamond and Venus Bulk Fill. Six-mm thick layers of the highly translucent bulk-fill composite have better light transmission properties than 2-mm increments of the nanohybrid composite (Figure 1).

Tetric EvoCeram Bulk Fill also exhibits a higher translucency than the conventional Tetric EvoCeram. Nevertheless, the difference in this case is not as dramatic. The lower translucency of the material, which enables Tetric EvoCeram Bulk Fill to blend in more smoothly with the posterior dentition, without showing the greyish tinge otherwise associated with this materials group, is effectively compensated by the new and very sensitive Ivocerin light initiator system [51,71]. Due to its high absorption rate in the visible light range, Ivocerin demonstrates enhanced quantum efficiency and high light reactivity [94]. Therefore, composite layers can be cured to a relatively deep level with a lower photon density [15].

Type of composite	Composite	Irradiance mW/cm²		
		2 mm	4 mm	6 mm
Low-viscosity bulk-fill	x-tra base	$262,5^{E}$ (8,2)	$79,2^{e}$ (4,1)	$27,7^{E}$ (4,2)
	SDR	$410,3^{B}$ (5,7)	$167,8^{b}$ (6,4)	$73,7^{B}$ (2,7)
	Venus Bulk Fill	$711,4^{A}$ (13,9)	$354,6^{a}$ (10,6)	$202,7^{A}$ (10,5)
	Filtek Bulk Fill Flowable Restorative	$220,4^{F}$ (6,9)	$56,3^{f}$ (1,4)	$18,3^{F}$ (1,8)
High-viscosity bulk-fill	x-tra fil	$370,3^{C}$ (11,1)	$124,1^{c}$ (2,0)	$53,8^{C}$ (3,7)
	SonicFill	$118,8^{J}$ (14,1)	$19,1^{k}$ (2,8)	$0,0^{H}$ (0,0)
	Tetric EvoCeram Bulk Fill	$317,9^{D}$ (15,3)	$110,8^{d}$ (2,6)	$40,7^{D}$ (4,1)
Nanohybrid	GrandioSO	$157,7^{H}$ (12,3)	$22,7^{j}$ (2,5)	$5,2^{G}$ (4,3)
	Premise	$55,4^{K}$ (3,1)	$1,7^{l}$ (3,5)	$0,0^{H}$ (0,0)
	Tetric EvoCeram	$183,7^{G}$ (11,0)	$35,1^{i}$ (1,8)	$14,0^{F}$ (11,3)
	Venus Diamond	$193,1^{G}$ (15,5)	$39,6^{h}$ (4,5)	$6,5^{G}$ (5,5)
	CeramX mono+	$138,7^{I}$ (6,4)	$20,7^{j,k}$ (1,3)	$0,0^{H}$ (0,0)
Flowable	Clearfil Majesty Flow	$222,7^{F}$ (20,3)	$44,3^{g}$ (3,5)	$6,1^{G}$ (5,1)
	GrandioSO Heavy Flow	$164,1^{H}$ (11,1)	$21,6^{j,k}$ (0,9)	$0,0^{H}$ (0,0)

Table 8: *Light transmittance [12] (360 – 540 nm) of different materials, measured at the bottom of 2, 4 and 6-mm thick layers. Superscripts identify significant subgroups (Tukey's HSD Test, α = 0.05). The initial irradiance (light intensity of the curing device at the surface of the test specimen) was 1,650 mW/cm².*

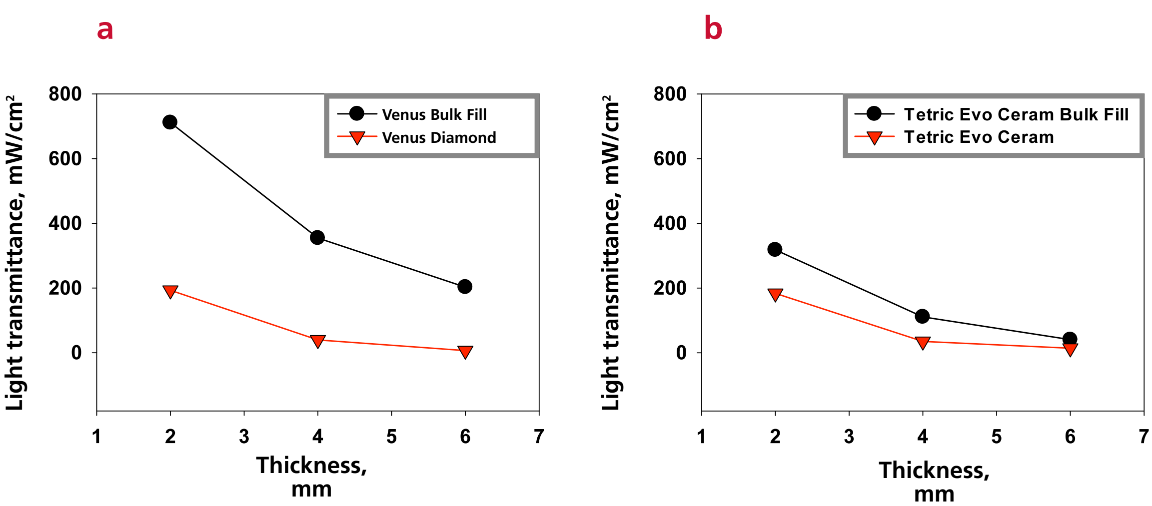

Figure 1: *Comparison of the light transmittance of bulk-fill composites and that of conventional composites of the same manufacturer: a) Heraeus Kulzer; b) Ivoclar Vivadent.*

3.4 How much light do bulk-fill composites need to polymerize adequately?

An *in vitro* study has established that the conversion rate and the mechanical properties of bulk-fill composites remain constant at depths of 4 and 6 mm if the material is sufficiently light polymerized [25].

Under clinical conditions, however, the full amount of light which is used to polymerize a composite does not always reach the restoration due to problems related to accessing the restoration in tight areas of the oral cavity or the angle of the light guide, particularly in posterior dentition. Consequently, only a part of the light dose is available for polymerization purposes. Nevertheless, excessively long polymerization intervals using high light intensity should also be avoided to prevent thermal pulp damage [8, 10, 65, 98, 129].

Therefore, it is important to find out how tolerant bulk-fill composites are towards different light doses and to establish certain limits which will nonetheless produce good polymerization results. To date, efforts to precisely quantify the amount of light needed to polymerize bulk-fill materials have been made in only two studies, which were performed under simulated clinical conditions [62, 63]. It is generally accepted that the maximum depth of cure of a composite under specific polymerization conditions is obtained when 80% of the hardness measured at the top of the increment is measured at the bottom of the layer [5, 22, 41, 74, 104, 116]. This increment is considered to be adequately polymerized. Table 9 shows the maximum depth of cure of high-viscosity bulk-fill composites obtained under various polymerization conditions (different curing modes of the polymerization light, 0 vs 7 mm distance of the light guide to the composite surface).

Polymerization mode	Distance (mm) between ight guide and sample surface	Energy (J/cm²) at sample surface	Depth of cure (mm)		
			x-tra fil	Tetric EvoCeram Bulk Fill	Sonic Fill
5s Standard	0	5,88	4,5^{bcde} (0,54)	3,7^{DE}(0,11)	2,7^{cdef}(0,30)
20s Standard		23,51	6,0^{f} (0,00)	5,6^{IJ}(0,46)	4,3^{i}(0,23)
40s Standard		47,03	6,0f (0,00)	6,0^{J}(0,00)	5,4^{k}(0,38)
3s High		5,30	3,7^{abc} (0,58)	3,2^{BCD}(0,20)	2,2^{abcd}(0,17)
4s High		7,06	4,4^{bcd} (0,45)	3,4^{CD}(0,22)	2,7^{def}(0,18)
8s High		14,13	4,7^{cde} (0,50)	4,9^{GH}(0,27)	3,6^{gh}(0,26)
3s Plasma		10,25	4,9^{def} (0,64)	4,2^{EF}(0,22)	3,0^{ef}(0,09)
6s Plasma		20.50	5,8^{f} (0,26)	5,7^{IJ}(0,27)	4,0^{hi}(0,09)
5s Standard	7	3,23	3,0^{a} (0,65)	2,7^{AB}(0,30)	2,2^{abc}(0,14)
20s Standard		12,93	5,9^{f} (0,12)	5,3^{HI}(0,23)	3,9^{hi}(0,23)
40s Standard		25,85	6,0^{f} (0,00)	5,9^{J}(0,27)	4,8^{j}(0,22)
3s High		2,63	2,9^{a} (0,90)	2,4^{A}(0,26)	1,8^{a}(0,22)
4s High		3,50	3,6^{ab} (0,59)	2,9^{ABC}(0,27)	2,2^{ab}(0,26)
8s High		7,00	5,6^{ef} (0,49)	4,2^{EF}(0,28)	3,2^{fg}(0,17)
3s Plasma		5,25	3,8^{abc} (0,30)	3,2^{BCD}(0,17)	2,5^{bcde}(0,11)
6s Plasma		10,50	5,5^{def} (0,38)	4,4^{FG}(0,36)	3,8^{hi}(0,20)
Vickershardness reference value	0	47,03	133,5^{a}(32,0)	78,4^{c}(6,7)	89,4^{b} (10,1)

Table 9: *Maximum depth of cure (in mm) as a function of the polymerization conditions and the material [62]. LED polymerization light VALO (Ultradent Products Inc., South Jordan, UT, USA). Superscripts identify significant subgroups (Tukey's HSD Test, **σ α** = 0.05). The significantly highest mechanical properties were obtained at depths greater than 2 mm with polymerization intervals of 20 and 40 s (Standard Power mode / 1,176 mW/cm²) for both light-curing distances (0 and 7 mm), which was reflected by a high depth of cure. In a few cases, the above-mentioned polymerization conditions were equivalent to a light exposure time of 8 s (High Power mode / 1,766 mW/cm²) or 6 s (Plasma / 3,416 mW/cm²). Shorter polymerization intervals (5 s Standard Power mode, 3–4 s High Power mode, and 3 s Plasma) resulted in a shallower depth of cure. The light intensity of the polymerization light used (VALO) was measured with a spectrometer (USB4000 Spectrometer, Managing Accurate Resin Curing System; Bluelight Analytics Inc., Halifax, Canada).*

4. Clinical data

4.1 Published clinical studies

The best reference for a composite is its clinical long-term performance in the patient's mouth. The limited data that has come out of clinical studies on bulk-fill composites to date reveals satisfactory to very good intraoral performance [19, 43, 66, 84, 85, 123]. A three-year clinical evaluation by VAN DIJKEN did not report any failures in restorations placed with the flowable material SDR in combination with the nanohybrid composite CeramX mono. The reference composite used showed an annual failure rate (AFR) of 1.3% [123]. In a user study involving dental practitioners, 68 restorations placed with Tetric EvoCeram Bulk Fill were evaluated after one year *in situ*. Only one restoration fracture (AFR = 1.5%) was recorded. Apart from this failed restoration, the clinical properties were deemed to be excellent [3]. In a clinical study on Tetric EvoCeram Bulk Fill, all the posterior restorations were given mostly excellent ratings after an observation period of one year. None of the restorations had to be replaced [103]. After one year *in situ*, YAZICI did not determine any significant differences between restorations placed with Tetric EvoCeram Bulk Fill and the nanocomposite Filtek Ultimate [120]. GREGOIRE reported excellent clinical performance of Tetric EvoCeram Bulk Fill restorations after one year in a comparison with incrementally placed posterior restorations using Gradia Direct [120]. Data gathered by our working group in Munich showed that the clinical performance of the high-viscosity bulk-fill composite QuiXfil (placed in 4-mm increments) did not differ significantly from the traditional hybrid composite Tetric Ceram (placed in 2-mm increments) after four years [85]. After an observation period of ten years, QuiXfil demonstrated an annual failure rate of 1.8%. The AFR of Tetric Ceram of 1.5% was not significantly different [87].

Bulk-fill composites do not consitute a uniform class of materials. Considerable differences exist between the individual products with regard to the composition and the size of the filler particles. In order to achieve a depth of cure of 4 mm, some manufacturers simply reduce the filler content or use larger particles in their bulk-fill composites. This allows light to penetrate more deeply into the material during polymerization. However, this strategy has its drawbacks: negative influence on the mechanical and esthetic properties, increase in the surface roughness and reduction of the wear resistance [23, 24, 64]. No such compromises were made in the formulation of Tetric EvoCeram Bulk Fill. This advanced bulk-fill composite is based on the monomer composition and filler technology of the clinically proven universal composite Tetric EvoCeram. In addition, Tetric EvoCeram Bulk Fill features an innovative photo-initiator called Ivocerin, which is highly reactive to incoming photons and therefore enables the restorative material to cure to a depth of 4 mm. In contrast to many other bulk-fill composites, Tetric EvoCeram Bulk Fill contains comparatively small fillers. Consequently, its surface is very smooth and easy to polish to a high gloss finish. Furthermore, the composite shows good wear resistance and esthetic properties.

Case 2:
Replacement of an amalgam restoration in an upper molar

The second case shows how an esthetic Tetric EvoCeram Bulk Fill restoration was placed and then polished to a high-gloss finish.

Initial situation

Figure 1
Three-surface amalgam restoration in an upper first molar

Figure 2
Situation after the removal of the old restoration

Figure 3
After excavation and fine-grit finishing, a rubber dam was placed to create a dry working field.

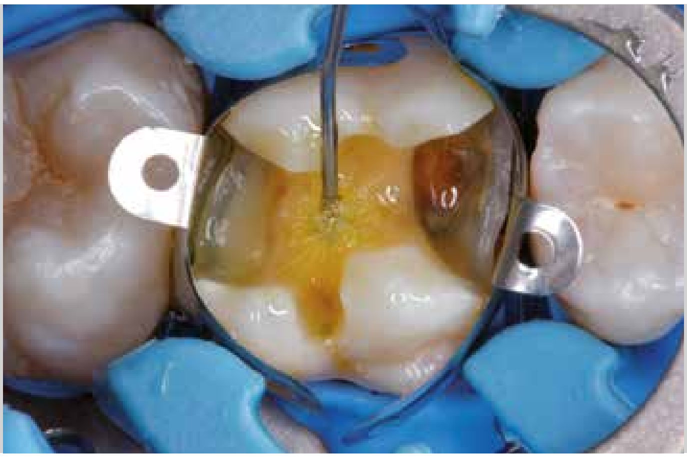

Figure 4
The tooth structure was conditioned with Adhese Universal using the self-etch technique (reaction time 20 s)

Figure 5
Light polymerization of the adhesive
with Bluephase Style for 10 s

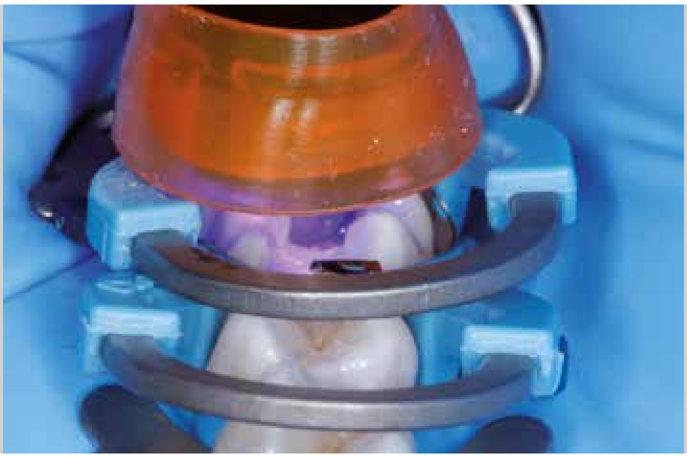

Figure 6
The first composite increments
of Tetric EvoCeram Bulk Fill were used
to build up the mesial and distal
proximal walls of the cavity.

Figure 7
Light polymerization of the composite
with Bluephase Style for 10 s

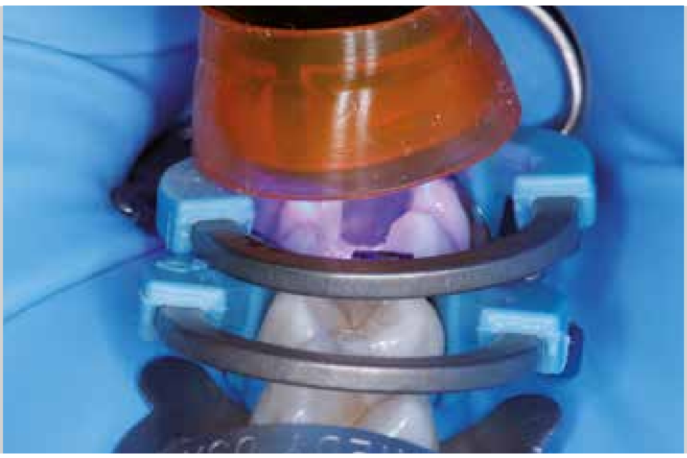

Figure 8
Once the proximal composite walls were sufficiently polymerized, the matrix was removed completely.

Figure 9
Next, both proximal boxes were filled with Tetric EvoCeram Bulk Fill up to the isthmus of the cavity.

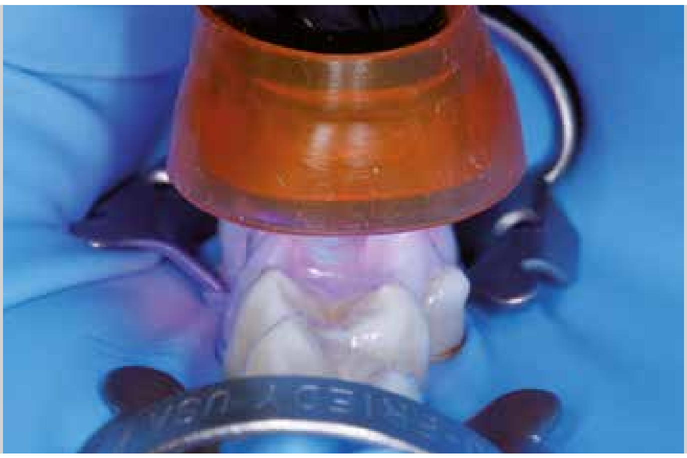

Figure 10
Light polymerization of the composite for 10 s

Figure 11
Application of Tetric EvoCeram Bulk Fill for building up the buccal cusps

Figure 12
Sculpting of the buccal cusps

Figure 13
Light polymerization of the buccal cusps for 10 s

Figure 14
Sculpting of the palatal cusps

Figure 15
Light polymerization of the palatal cusps for 10 s

Figure 16
View of the restoration after finishing and the adjustment of the static and dynamic occlusion

Initial situation

Final situation

Figure 17
Finished and high-gloss polished restoration.
The tooth has regained its original appearance and function.

Since Tetric EvoCeram Bulk Fill is closely related to Tetric EvoCeram from the same manufacturer, some careful predictions regarding the long-term performance of the bulk-fill material can be made on the basis of the clinical data available from the literature on Tetric EvoCeram.

In one clinical study, Tetric EvoCeram showed excellent wear resistance in occlusal load-bearing posterior restorations [20]. After an observation period of five years, CETIN did not establish any significant differences between direct posterior restorations placed with Tetric EvoCeram and indirect composite inlay restorations [21]. The *in vivo* wear behaviour of Tetric EvoCeram in posterior cavities after five years fulfilled the stringent ADA standard for posterior composites [1] (vertical wear <50µm/year) [101]. BOECKLER reported an excellent survival rate of 98.8% for Tetric EvoCeram in Class I and II cavities in molars and premolars after a period of two years [9]. In a three-year clinical trial, PALANIAPPAN established a 100% survival rate of Tetric EvoCeram in posterior teeth [100]. BARABANTI also reported a survival rate of 100% for posterior Tetric EvoCeram restorations studied in a five-year trial [7]. The findings of MAHMOUD in a two-year clinical evaluation also confirmed the excellent clinical performance of Tetric EvoCeram restorations in posterior dentition [79]. VAN DIJKEN recorded an annual failure rate (AFR) of 2.1% for Tetric EvoCeram restorations in Class II cavities after six years in [122]. These results correspond to the 2.2% annual failure rate of composite restorations in posterior teeth which was published in a comprehensive meta-analysis [83].

The mentioned studies all confirm the excellent clinical performance of Tetric EvoCeram as a posterior restorative material. Since Tetric EvoCeram Bulk Fill is similarly engineered to Tetric EvoCeram, one can conclude that this bulk-fill composie will perform just as well as its regular counterpart..

Composite	σ (MPa)	$E_{modulus}$ (GPa)	HV (N/mm²)
Tetric	$153,6^{F}$ (21,2)	$9,3^{E}$ (1,7)	$98,0^{H}$ (4,8)
Tetric Ceram	$134,7^{E}$ (10,9)	$7,9^{D}$ (0,9)	$82,4^{F}$ (2,3)
Tetric Ceram HB	$122,4^{CDE}$ (21,1)	$6,6^{C}$ (0,4)	$86,0^{G}$ (3,3)
Tetric EvoCeram	$115,3^{BC}$ (11,3)	$6,7^{C}$ (1,1)	$70,9^{C}$ (3,2)
Tetric EvoCeram Bulk Fill	$120,8^{CDE}$ (12,7)	$4,5^{B}$ (0,8)	$78,4^{E}$ (6,7)
IPS Empress Direct Dentin	$132,1^{DE}$ (13,7)	$5,3^{B}$ (0,9)	$73,5^{D}$ (1,7)
IPS Empress Direct Enamel	$104,8^{B}$ (8,5)	$4,5^{B}$ (0,8)	$85,6^{G}$ (3,1)
IPS Empress Direct Opal	$73,8^{A}$ (5,3)	$2,9^{A}$ (0,2)	$35,6^{A}$ (2,9)
Tetric Flow	$118,1^{BCD}$ (9,9)	$5,1^{B}$ (0,4)	$50,1^{B}$ (2,4)
Tetric EvoFlow	$104,2^{B}$ (10,2)	$2,8^{A}$ (0,4)	$37,4^{A}$ (1,5)

Table 10: *Comparison of the mechanical properties of various Ivoclar Vivadent composites (Evaluated on the basis of the data compiled by Prof Dr. Ilie, Munich Dental Clinic): Three-point bending strength (σ), elastic modulus ($E_{modulus}$) and Vickers hardness (HV). Superscripts identify significant subgroups (Tukey's HSD Test, α = 0.05).*

4.2 Comparison of Tetric EvoCeram Bulk Fill with other Ivoclar Vivadent composites

In order to further assess the clinical behaviour of Tetric EvoCeram Bulk Fill, the results of this material were compared with the *in vitro* data of nine other clinically time-tested composites from Ivoclar Vivadent (Table 10).

With regard to the flexural strength, no statistically significant difference was established between Tetric EvoCeram Bulk Fill and the trusted composites Tetric Ceram, Tetric EvoCeram and Tetric Ceram HB. The modulus of elasticity of Tetric EvoCeram Bulk Fill, however, was found to be significantly lower than that of the other high-viscosity Tetric products. Nonetheless, the value is within the range of the IPS Empress Direct Dentin and IPS Empress Direct Enamel materials. In the Vickers hardness tests, Tetric EvoCeram Bulk Fill showed significantly higher values than the regular Tetric EvoCeram. This data highlights the competitive *in vitro* properties of Tetric EvoCeram Bulk Fill in comparison with other composites from Ivoclar Vivadent. Moreover, on the basis of a comprehensive analysis of the *in vitro* data available today, one can cautiously conclude that the new bulk-fill composites will be able to hold their own against regular composites and achieve successful clinical results, provided that they are used properly and in accordance with the directions of the manufacturer [46, 51, 92, 97, 107, 108, 115].

Nevertheless, the clinical behaviour of bulk-fill composites has to be studied in greater depth and more evidence needs to be collected [78]. Even though the demand for more clinical long-term data is justified, this type of information cannot be supplied at present. Due to the fact that this type of material is a recent development, long-range results can only be expected in the future.

5. Indication spectrum of bulk-fill composites in permanent and deciduous dentition

Bulk-fill composites are primarily used to place direct restorations in permanent posterior teeth.

The **low-viscosity, flowable bulk-fill composites** are approved for the following indications:

- Dentin build-up, i.e. bases of up to 4 mm per increment in Class I and II cavities (2-mm capping layer of posterior hybrid composite is needed)
- Cavity liner:
  Lining of the cavity floor and internal line and point angles as a first thin layer under direct restoratives in Class I and II cavities
- Fissure sealant (no capping layer is needed)
- Small Class I restorations (no capping layer is needed)
- Undercut blockout
- Core build-ups (no capping layer is needed)

The **high-viscosity, sculptable bulk-fill composites** are approved for the following indications:

- Direct restorative for Class I and II cavities (incl. replacement of cusps)
- Preventive resin restorations
- Core build-ups
- Class V cervical restorations
- Restorations in deciduous teeth

In this context, however, it is important to note that not every bulk-fill composite available on the market in the different categories (flowable and sculptable) is approved for all the mentioned indications by its respective manufacturer.

Case 3:
Replacement of a ceramic inlay in a lower molar

The third case shows how a large restoration with cusp involvement was placed in a lower first molar using Tetric EvoCeram Bulk Fill.

Initial situation

Figure 1
Insufficient ceramic inlay in a lower first molar

Figure 2
In the past, a large ceramic restoration was used to replace the mesio-buccal cusp.

Figure 3
View after the removal of the old restoration, the excavation and finishing of the cavity and the placement of the rubber dam

Figure 4
Application of a circumferential metal matrix

Figure 5
Conditioning of the tooth structure with Adhese Universal using the self-etch technique (reaction time 20 s).

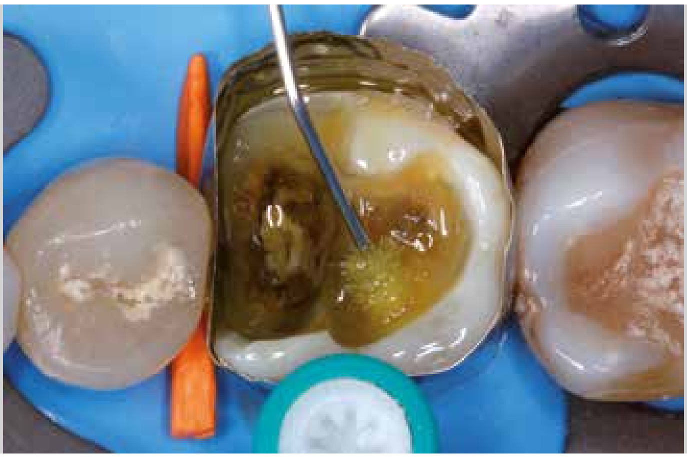

Figure 6
The cavity has been appropriately conditioned and shows an even shiny surface. This seals the dentinal tubules and prevents postoperative hypersensitivity.

Figure 7
Application of the first composite layer of Tetric EvoCeram Bulk Fill

Figure 8
The first composite increment
was used to build up the mesial proximal wall
and the mesio-buccal contour.

Figure 9
Light polymerization of the composite
with Bluephase Style for 10 s

Figure 10
Next, Tetric EvoCeram Bulk Fill
was applied to create the entire occlusal surface,
and the tooth anatomy was sculpted.

Figure 11
Light polymerization of the composite for 10 s.

Figure 12
Situation after the matrix
and the rubber dam were removed
and the restoration was finished

Figure 13
Prepolishing of the composite restoration
with OptraPol silicone polishers

Figure 14
High-gloss polishing with an
Astrobrush silcone carbide brush

Figure 15
Final adjustment of the static
and dynamic occlusion

Figure 16
Final situation: Finished
and polished restoration.
The tooth has regained its
original appearance and function.

Initial situation

Final situation

Figure 17
Mesial view of the outstanding reconstruction of the tooth with cusp replacement

Restorative technique with bulk-fill composites
Advantages
Heightened efficiency due to a fast restorative protocol and the elimination of time-consuming layering ➔ more economical [128]
Easier handling [113]
Fewer increments ➔ fewer or no transitions between layers ➔ fewer problems at imperfect boundary surfaces (voids, gaps) between different composite increments [55] and overall minimization of the risk of entrapping voids.
No time-consuming shade selection
Streamlined logistics ➔ less stock of materials has to be kept

Table 11: *Advantages of the restorative technique with bulk-fill composites*

It goes without saying that sculptable bulk-fill composites can also be placed in 2-mm increments according to the conventional layering technique. Because of their higher translucency and light reactivity compared with hybrid composites, these materials offer more reliable polymerization results: for example, in the event of unfavourable light curing conditions as a result of restricted opening of the mouth, which prevents the light guide of the curing device from being optimally positioned [60]. At an increment thickness of 2 mm, the polymerization shrinkage stress is considerably lower than that of conventional composites. This has a positive effect on the restoration, the tooth and the adhesive bond [34, 51, 59].

Sculptable bulk-fill composites can also be used to restore deciduous posterior teeth. Due to the size of these teeth and the dimensions of the lesions, most of the cavities can be restored with a single layer. This technique shortens the chair time and is particularly welcome in the treatment of uncooperative children.

6. Outlook

The need for composite-based direct restorative materials is predicted to grow in the future. Therefore, high-quality, scientifically tried-and-tested and clinically documented permanent posterior restorative materials will be in much demand. The results of an extensive review have shown that the annual failure rate of composite restorations in posterior teeth (2.2%) is not statistically different from that of amalgam restorations (3.0%) [83]. Minimally invasive treatment protocols in conjunction with the possibility of detecting carious lesions at a very early stage are having a positive effect on the survival rate of this type of restorations. Nonetheless, a high-quality direct composite restoration with excellent marginal adaptation continues to be dependent on a number of prerequisites: for example, careful placement of the matrix (if proximal areas are involved), effective and correct application of the dentin adhesive, appropriate handling of the restorative material and sufficient curing of the composite.

The growing economic pressure on the health system and a lack of financial means on the part of patients are creating a need for reliable, fast and easy-to-use restorative options as an alternative to the time-consuming high-end solutions (polychromatic multi-layer composite restorations bonded with a dentin adhesive in conjunction with an etch-and-rinse protocol involving preliminary enamel and dentin etching with phosphoric acid). In addition to the universal hybrid composites, which are available in various shades and levels of opacity, new bulk-fill composites have lately emerged on the market. They are designed for use in posterior dentition, where they produce esthetically pleasing restorations. The placement procedure is more economical than that of conventional hybrid composites [14, 84].

Case 4:
Replacement of two insufficient restorations in the lower posterior dentition

The fourth case shows how a composite and an amalgam restoration were replaced in the lower posterior dentition using Tetric EvoCeram Bulk Fill

Initial situation

Figure 1
Fractured amalgam restoration and worn composite restoration in the lower posterior teeth

Figure 2
View after the removal of
the old composite restoration and the
excavation of the caries in the first molar

Figure 3
After the finishing procedure
a dry working field was created with a rubber dam.

Figure 4
Application of a
sectional matrix

Figure 5
Selective enamel etching
with phosphoric acid for 30 s.

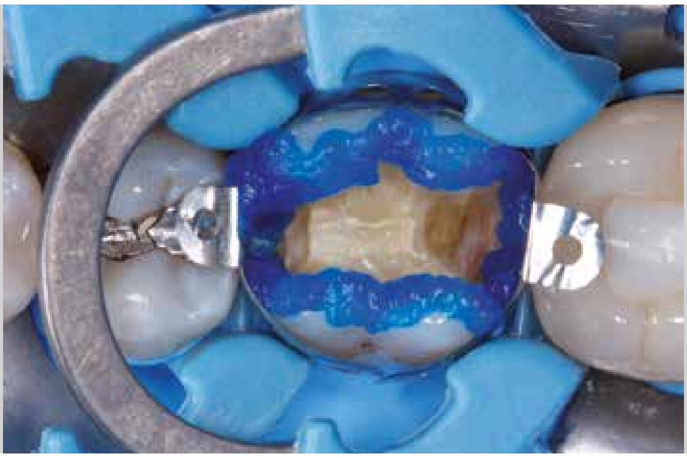

Figure 6
Conditioning of
the tooth structure with Adhese Universal
using the selective-etch technique (reaction time 20 s)

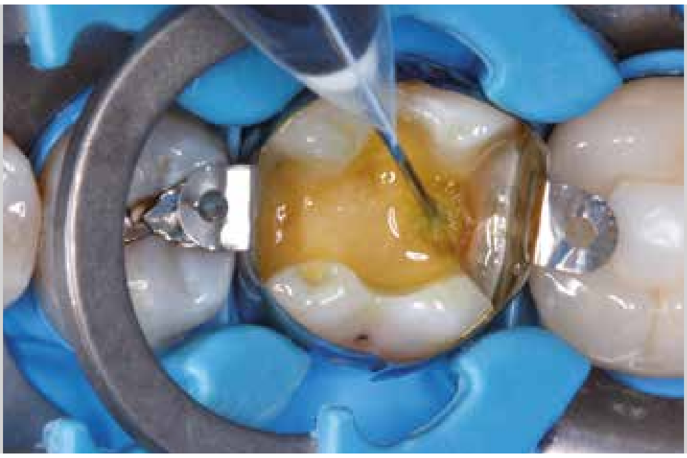

Figure 7
The adhesive was dispersed with air
until a shiny, immobile film
formed.

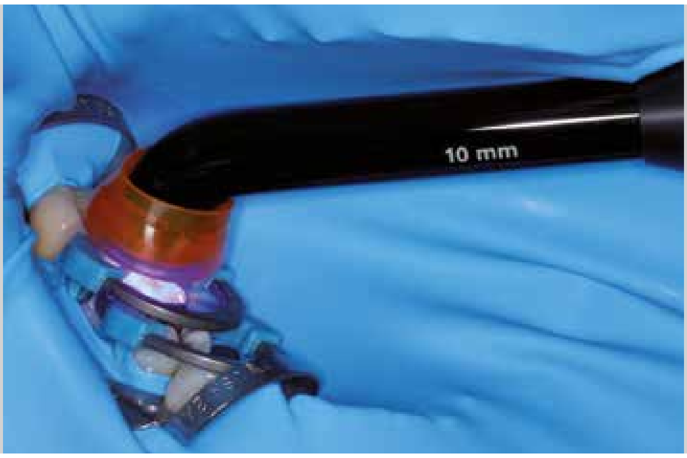

Figure 8
Light polymerization of the adhesive with Bluephase Style for 10 s

Figure 9
The cavity has been appropriately conditioned and shows an even shiny surface. This seals the dentinal tubules and prevents postoperative hypersensitivity.

Figure 10
The first two composite increments of Tetric EvoCeram Bulk Fill were used to build up the mesial and distal proximal cavity walls. The composite material was shaped with a clean microbrush.

Figure 11
Light polymerization of the composite with Bluephase Style for 10 s

Figure 12
Reconstructed proximal walls before the matrix was removed

Figure 13
Once the proximal composite walls were sufficiently polymerized the matrix system was removed completely. As a result, the operating field became more easily accessible with modelling instruments for the following working steps.

Figure 14
First, the Class II cavity was transformed into a functional Class I cavity.

Figure 15
Next, the two proximal boxes were filled with Tetric EvoCeram Bulk Fill up to the isthmus of the cavity.

Figure 16
Application of Tetric EvoCeram Bulk Fill to build up the remaining portion of the cavity

Figure 17
Sculpting of the occlusal anatomy

Figure 18
A clean microbrush was used to adapt the composite to the marginal areas. The composite does not stick to the "filling instrument".

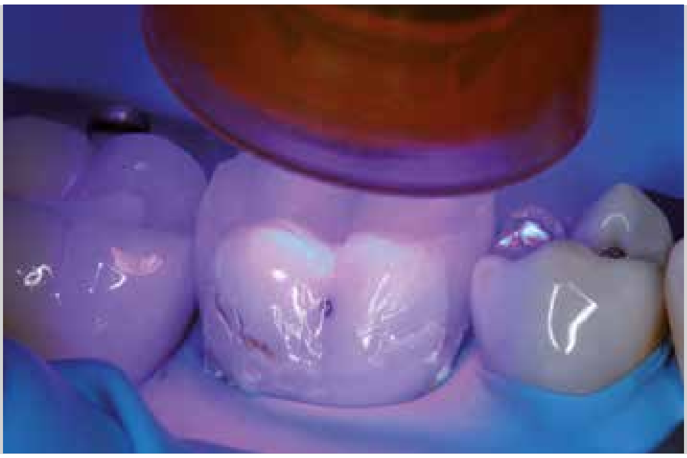

Figure 19
Light polymerization of the occlusal layer for 10 s.

Figure 20
Once the restoration in the first molar was completed, the fractured amalgam restoration in the second premolar was replaced with Tetric EvoCeram Bulk Fill.

Figure 21
View of the restorations after finishing and the adjustment of the static and dynamic occlusion

Figure 22
Final situation: Finished and high-gloss polished restorations. The teeth have regained their original function and appearance.

Initial situation

Final situation

Figure 23
Mesial view
of the restored teeth

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