

Large composite restorations in the posterior region

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Introduction

In many countries composites are considered the standard material for direct and indirect restorations in the anterior and posterior region. The range of indications for indirect ceramic and direct composite restorations is increasingly overlapping. While in the early days composite materials were predominantly used for small restorations, they are now becoming ever more popular for the fabrication of extensive restorations, including the reconstruction of cusps (Deliperi and Bardwell 2006, Kujis et al. 2006). In our day, the decision whether or not to restore a cavity with a direct or indirect restoration largely depends on the ability of the practitioner to solve a technically challenging situation with an adequate intraoral treatment option (Figures 1 and 2).

Current developments in material technology are aimed at further reducing the shrinkage and shrinkage stress of composite materials as well as streamlining the adhesive technique. However, not all recently developed materials provide restorations with improved quality. The following report sheds light on the decisive parameters in the restoration of large cavities with composite materials and offers advice on the application procedure in the dental practice.

Preparation

The precept that the preparation margins should be bevelled is a widespread and, unfortunately, misleading generalization of the preparation guidelines for composite restorations. It is true that enamel bevelling is required to optimize adhesion. Yet, the bevel should not be aligned in relation to the horizontal or vertical. Rather, the bevel should be inclined in relation to the direction of the enamel

rods (Shimada et al. 2003, Ikeda et al. 2002). Generally, this corresponds to a preparation angle of 45° to the tooth surface. As this can hardly be accurately determined in clinical situations, the following preparation guidelines apply:

Vertical preparation should be performed in areas of the cusp slopes which are inclined towards the central fissures. It is important to observe a minimum distance of 1 mm to the cusp tips. If the distance is shorter than this, the corresponding cusps should be shortened (Figures 3 and 4).

Proximal, oral and vestibular shoulders should be bevelled. In the middle third of the crown, bevelling should be performed at a 30° angle to the horizontal axis and in the cervical crown third, the aim should be to achieve a 40° angle.

Proximal (as well as buccal and oral) vertical margins should be provided with an angle of approx. 45° in relation to the surface.

Normally, labial, lingual and occlusal surfaces can be prepared with rotating diamonds and drills without any difficulty. By contrast, appropriate preparation of proximal surfaces with rotating instruments without accidentally cutting the adjacent teeth is hardly possible. Seventy to 100% of all neighbouring teeth are damaged during the preparation of Class II cavities or crowns (Lussi 1995, Moopnar and Faulkner 1991, Qvist et al. 1992). Lussi and Gygax (1998) observed that 100% of the teeth adjacent to conventional Class II box preparations showed iatrogenic damage and frequently the damage extended to deep dentin.

Accidental cutting of adjacent tooth surfaces during proximal preparation can be minimized by using sonoabrasive, oscillating instruments (Hugo and Stassinakis 1998, Krejci et al. 1998, Hugo 1999, Wicht et al. 2002). These instruments are used in conjunction with tips that are coated with diamonds on only one side for proximal cavity preparation (Figure 5). It is recommended that dental practitioners use the system from KaVo. The following tips

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Figure 1: Initial situation. Inadequate amalgam restorations with fractured lingual wall.



Figure 2: Situation after direct restoration of the teeth with Tetric EvoCeram, A3 (Ivoclar Vivadent).



Figure 3: Preparation through the cusp tips: Disintegration of the enamel-composite cement bond and fracture of the disto-lingual cusp in the indirect restoration.

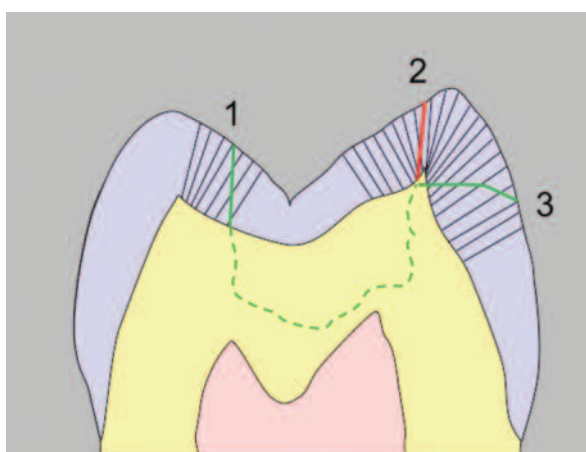


Figure 4: Schematic representation of preparation design in the occlusal area. 1 = correct preparation in the area of the cusp slopes; 2 = incorrect preparation; too close to the cusp tips and, consequently, mostly parallel to enamel rods; 3 = correct preparation, to avoid situation 2.

are particularly suitable in conjunction with composite restorations:

Slot cavities: SONICflex bevel tip nos 58 + 59

Large cavities: SONICflex micro (hemisphere, large), nos 31 + 32

Deep proximal shoulders: SONICflex prep ceram

Conventional preparation diamonds (90 µ grit size) result in crack formation in the adjacent enamel (Xu et al. 1997). To eliminate these microcracks, all enamel margins should be re-finished with finishing diamonds. Tooth surfaces that are prepared with oscillating instruments do not require re-finishing because of the fine grit size of these tips.

Adhesive technique

Self-etch adhesives, including what are known as all-in-one products, are employed increasingly more frequently in

composite restorations. However, the studies carried out to date have consistently shown that optimum enamel adhesion can only be attained in conjunction with phosphoric acid etching (Gaur et al. 2004, Gomes et al. 2004, Frankenberger and Tay 2005, Frankenberger et al. 2008). Placing a composite restoration without phosphoric acid etching may considerably reduce the bonding quality of large restorations in particular, as these restorations are subject to increased polymerisation shrinkage stresses. It is recommendable to use conventional etch-and-rinse adhesives (previously known as total-etch adhesives). The enamel should be conditioned with phosphoric acid for at least 30s and the dentin for no longer than 10s.

Those dental professionals who prefer to use a self-etch adhesive should not, under any circumstances, utilize an all-in-one system. Rather, they should opt for a self-etch



Figure 5: Preparation of the proximal marginal bevel with an oscillating tip (SONICflex no. 59).

system that involves the application of a primer and bonding agent in two individual, consecutive steps (Frankenberger and Tay 2005). In addition, the enamel should first be selectively etched for 30s. If this procedure is followed, the advantages of phosphoric acid etching on enamel can be combined with the advantages of the self-etch technique on dentin, e.g. low technique sensitivity (Schulze et al. 2002, Giachetti et al. 2006) and low postoperative sensitivity (Unemori et al. 2004, Frankenberger et al. 2008).

Polymerization

The appropriate polymerization of the individual composite layers is, at present, probably one of the most critical aspects affecting the longevity of a composite restoration. Insufficient polymerization results in inferior physical properties, such as reduced flexural strength, compressive strength, wear resistance and shade stability. Generally, curing lights which produce light intensities of less than 400 mW/cm² are unfit for clinical applications and fail to provide appropriate polymerization. In Germany, a study, which is considered representative (Ernst et al. 2006), showed that more than 25% of the curing lights used in dental practices fail to achieve the minimally required value.

The Total Energy Concept is a useful tool to determine the appropriate light-curing time of composite materials (Koran and Kürschner 1998). This concept is based on the fact that a composite material requires, on average, an energy dose of 12,000 to 16,000 mJ to properly polymerize on the surface. If we assume that a value of 12,000 mJ/cm² (or mWs/cm²) presents a sufficiently high energy dose, a light-curing unit which provides an energy density of 1,200 mW/cm² has to be allowed an emission time of 10 seconds to ensure an appropriate cure. Accordingly, if a



Figure 6: Defective light guide. The dark fibres are no longer capable of transmitting light.

curing light with an output performance of 600 mW/cm² is used, the curing time is 20 seconds. The manufacturer's light output data always indicate the light output at the light emission window of the light guide. However, as the beam path diverges when the light leaves the light emission window, the actual light density decreases with increasing distance between the light emission window and the restoration. When modern curing lights, particularly in conjunction with what are known as turbo or focussing light guides, are used, this loss in light intensity is approx. 50% if the distance between the light guide tip and composite surface is 5 mm. If the distance to the restoration surface is 1 cm, the loss in intensity may be in the region of 80% and higher (Felix and Price 2003). Hence, two important rules come into play when polymerizing composite materials:

1. The light guide should be held as close to the restoration surface as possible.
2. As it is impossible to avoid a gap in many situations (e.g. first composite layer in a proximal box), the curing time, which has been determined with the help of the Total Energy Concept, should be prolonged by a factor of 1.5 to 2.

It is essential to know how high the actual energy density (intensity) of the light-curing unit in use is to ensure appropriate polymerization. Ernst et al. (2006) showed that, in their advertising materials, many manufacturers indicate energy densities that are clearly too high for their curing lights. Commercial radiometers are currently not suitable for measuring the absolute output value; they are only useful for monitoring the performance of a curing light over time. This means that a source of error, over which the practitioner has hardly any control, is present.

Like any other equipment, modern light-curing lights also require regular maintenance and care to work



Figure 7: Initial situation: The mesio-buccal cusp of tooth 26 has fractured because of the expansion of an existing amalgam filling.

efficiently. It can be assumed that approx. 50% of the light guides used in dental practices are defective and/or soiled with composite or bonding material (Ernst et al. 2006) (Fig. 6). Depending on how severe the defect or soiling is, the light guides may make it impossible for the composite materials to polymerize properly.

Some state-of-the-art curing lights are equipped with soft-start or ramp-cure programs. If these programs are used, the composite material is initially irradiated with a reduced light intensity and exposed to the full light intensity only after 5 to 10s. These methods promote a longer pre-gel phase (Feilzer and Davidson 1997) to allow light-cured composite materials to reduce stress more effectively by internal flow dynamics. However, the clinical relevance of the achievable stress reduction is questionable in modern composites designed for fast polymerization, as the largest proportion of the stress tends to occur only at the end of the post-gel phase and, in addition, the soft-start-induced reduction in stress may sometimes involve a decrease in the conversion rate (Flemming et al. 2007, Hofmann and Hunecke 2006, Lu et al. 2005, Lu et al. 2004a).

Against such a background, polymerization at maximum intensity may be carried out as standard procedure (except for composite layers close to the pulp).

Layering technique and marginal gaps

The layering technique continues to present the most effective method to both compensate for volumetric shrinkage, which occurs during polymerization, and reduce shrinkage-induced polymerization stresses. The more the total material volume of a restoration is divided into individually light-cured increments, the better is the bond to the cavity walls (Nikolaenko et al. 2004, Félix et al. 2007).

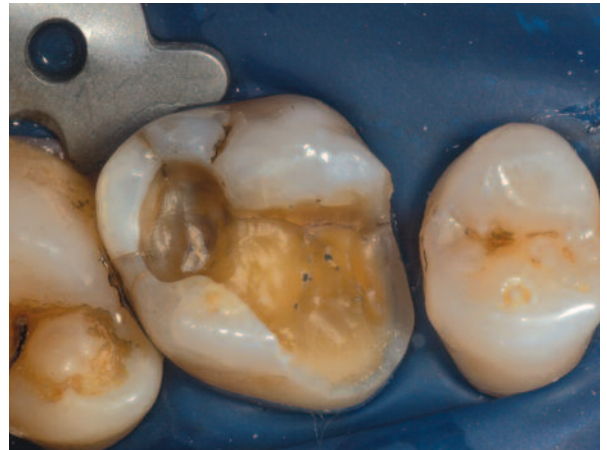


Figure 8: Situation after the amalgam filling has been removed. Cracks have formed in the region of the cavity.

However, shrinkage alone is not the most decisive material-related parameter which comes into play in preventing the formation of marginal gaps (microleakage). Hooke's law provides a useful approximation when looking at the deformation of solid materials. The following equation applies to small deformations:

Stress (i.e. shrinkage stress) = shrinkage x modulus of elasticity

The shrinkage-induced forces, which affect the adhesion to cavity walls (known as shrinkage stress), are essentially influenced by the modulus of elasticity. A high modulus of elasticity, or, in other words, a low degree of elasticity, results in high shrinkage stress during polymerization shrinkage (Kleverlaan and Feilzer 2005, Lu et al. 2004b) and, as a consequence, marginal gap formation is increased (Ferracane and Mitchem 2003). If the modulus of elasticity is too low, only a small amount of shrinkage stress is produced, but such a material would not be able to withstand the masticatory forces in the oral cavity in the long run. For this reason, the modulus of elasticity of composites should range between 8 and 11 GPa in the occlusal load bearing region (Unterbrink and Liebenberg 1999).

The above equation presents a simplification of the actual situation, as it would be necessary to take the dynamic development of the two physical properties into account to provide an accurate statement.

In actual fact, the degree of shrinkage stress does not correlate with the degree of shrinkage. However, a close relationship exists between the shrinkage stress and modulus of elasticity (Feilzer et al. 1990, Aarnts et al. 1999).

The shrinkage of composites can be reduced by increasing the amount of inorganic fillers. However, an increase in the amount of inorganic fillers leads to an increase in the modulus of elasticity and shrinkage stress

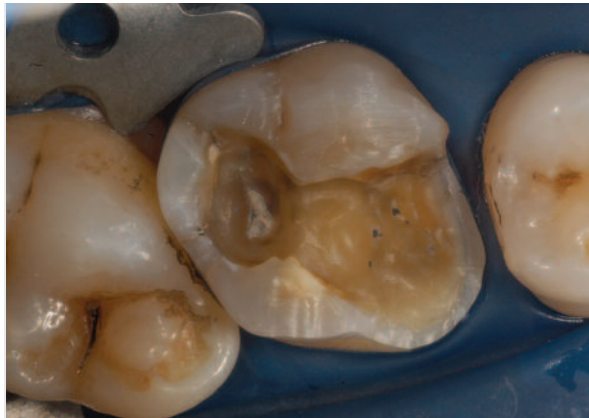


Figure 9: Completed preparation. The cusps have been shortened by approx. 1.5 mm and the marginal areas have been finished with finishing diamonds. The proximal margins have been bevelled with an oscillating instrument (SONICflex, hemisphere, large, KaVo).



Figure 10: Situation after placing a matrix band (ComposiTight, Garrison). Selective enamel etching with phosphoric acid.



Figure 11: Situation after application of self-etch primer liquid. The primer has to be thoroughly dried after completion of the reaction time. Like all self-etch materials, the primer contains water as solvent. The vapour pressure of water is relatively low (47mm Hg at 37° C, Weast 1970) and therefore water evaporates rather slowly. Evaporation has to be helped with an air syringe, as residual water may prevent the formation of an optimum hybrid layer.



Figure 12: Situation after application of two-component AdheSE bonding agent. Pooling of excess bonding liquid on the proximal shoulder should be avoided, as bonding agents are not radiopaque and, if present in excess, may look like gaps on bite-wing radiographs.

(Sabbagh et al. 2002, Kleverlaan and Feilzer 2005, Lu et al. 2004, Condon and Ferracane 2000).

Therefore, the marginal gap behaviour of a composite material that demonstrates low shrinkage but a high modulus of elasticity may not be better than that of a composite with more shrinkage but a lower modulus of elasticity. While the marketing statements of most manufacturers aim at presenting low shrinkage values; such information is not useful if the modulus of elasticity is not included.

The C-factor (configuration factor) is the most decisive non-material-related parameter, affecting the resulting shrinkage stress to a larger extent than any other factor. The C-factor describes the ratio of the bonded surface area to the unbonded surface area of a composite restoration (Feilzer et al. 1987):

$$C = \text{bonded surface area} / \text{unbonded surface area}$$

The higher the C-factor is, i.e. the ratio of the bonded surface area to the unbonded surface area, the more cavity walls compete for adhesion and the more shrinkage stress is produced (Feilzer et al. 1987, Choi et al. 2004, Nikolaenko et al. 2004, Wattanawongpitak 2006, Moreira da Silva et al. 2007).

An average Class I restoration features a C-factor of approx. 4 (Macorra and Gomez-Fernandez 1996). By contrast, the C-factor of a Class IV restoration is usually lower than 1.

If a restoration is built up using a layering technique, the C-factor of each individual increment should, in theory, be considered. However, as composite materials are subject to post-shrinkage upon completion of the exposure time and 90% of the total shrinkage is only achieved after 5 minutes



Figure 13: Situation after application of an initial thin layer (< 0.5 mm) of flowable Tetric EvoFlow composite. The flowable composite is first applied to the cavity floor, then distributed on all cavity walls with a brush and polymerized.

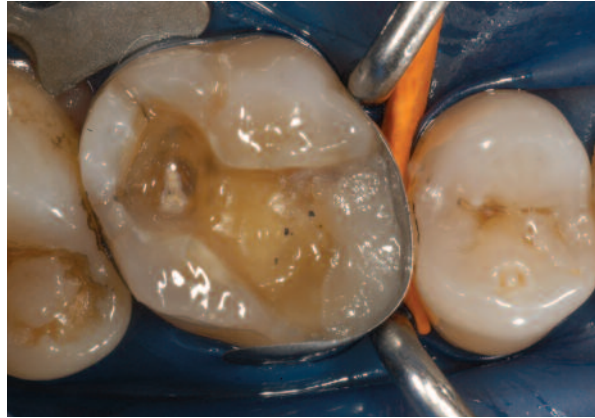


Figure 14: The first layer of a nano-optimized fine-hybrid composite is applied horizontally.

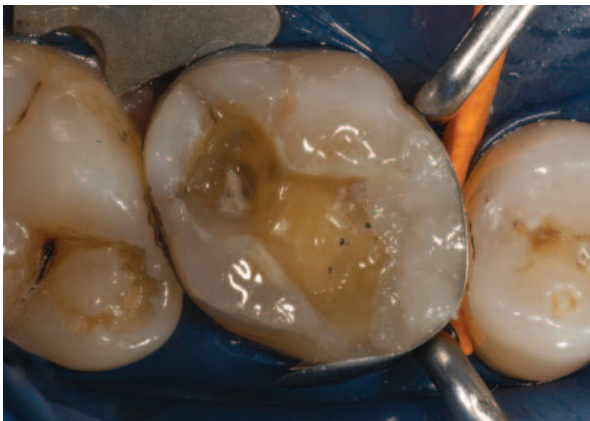


Figure 15: Additional increments are placed at an angle to build up the proximal walls. Correct reconstruction of the height of the proximal ridge is important to minimize the necessity for final adjustments. The marginal ridge of the neighbouring tooth can be used as point of reference for this purpose.

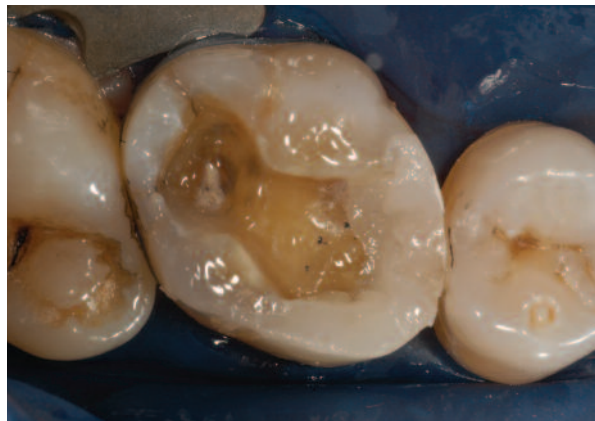


Figure 16: After the proximal wall has been re-built, the matrix band may be removed to obtain a better view of the treatment area.

(Sakaguchi et al. 1992), the restoration is prone to shrinkage "en bloc" to a certain degree regardless of the shrinkage of the individual layers. Therefore, the C-factor of the entire cavity is also of relevant importance. In this context, the restoration of large cavities including the build-up of cusps appears to offer an advantage as the C-factor of such a restoration is considerably lower because the natural cusps are shortened and built-up with composite material.

The ideal thickness of the increment is 2 mm when the layering technique is used. Layer thicknesses larger than 3 mm should be avoided at any cost, as most composites cannot be appropriately polymerized when applied in thick layers. Opaque dentin shades in particular should not be applied in layers thicker than 2 mm.

A number of studies have shown that the application of an initial thin layer of a flowable composite has a favourable effect on the marginal quality of composite

restorations (Unlu et al. 2003, Yazici et al. 2003, Wattanawongpitak 2006, Cunha et al. 2006). However, the presence of this effect is not undisputed in the scientific literature (Lindberg et al. 2005). If an initial layer of a flowable composite is applied, the thickness of this layer should not exceed 0.5 mm.

Clinical procedure

Generally, it is preferable to apply a rubber dam. The use of a rubber dam does not have an effect on the survival rate of composite restorations (Raskin et al. 2000); however, rubber dam application provides a better view of the treatment area and enables a more efficient working procedure (Figures 7 and 8).

The preparation is performed according to the above described guidelines. The cusps should be shortened by approx. 1.5 mm (Figures 8 and 9), if the preparation margin



Figure 17: The main axis of the cusp slopes should be determined before starting to build up the cusps.



Figure 18: A line of composite is administered directly from the Cavifil into the preparation. The material is applied in the direction of the main axis of the cusp.



Figure 19: The microbrush is the most important sculpting instrument, both for forming the cusps and for adapting the proximal layers.



Figure 20: The crista transversa is reconstructed first.



Figure 21: Reconstruction of the mesio-buccal cusp.



Figure 22: Completion of the mesio-palatal cusp. Generally, the fissures should be reconstructed to be as deep as possible. This reduces the C-factor of the restoration and helps to obtain a correct occlusion more easily.

is situated too close to the cusp tips or if cracks, which may have been caused by the expansion of previous amalgam restorations, are present in the tooth structure. When the matrix band is placed, care should be taken to

make sure that the height of the matrix band does not exceed the height of the marginal ridge of the neighbouring tooth in order to maintain an unobstructed view of the treatment area (Figure 8).



Figure 23: Reconstruction of the disto-palatal cusp.



Figure 24: Contouring of the marginal ridge.



Figure 25: The fissures may be characterized with a composite shade.

As described above, the adhesive technique may be performed with an etch-and-rinse adhesive or with a two-component self-etch adhesive combined with selective enamel etching (Figures 10 – 13). If, subsequently, a first layer of a flowable composite is applied (Figure 13), this layer should be polymerized before continuing with the layering technique.

Next, the proximal walls are reconstructed using a fine hybrid or nanofiller composite. For this purpose, the first layer should be positioned horizontally to facilitate the adaptation of the material (Nikolaenko et al. 2004). Subsequently, the proximal walls are completed with additional increments, which are placed at an angle (Figures 14 – 16).

To reconstruct the occlusal surface of deep cavities, the deepest areas are first built up with composite material. The cusps are reconstructed similar to the wax-up technique. Each cusp is built up individually with composite and shaped as accurately as possible (Figures 17 – 25). It is

advisable to use a composite in a Cavifil or single-dose delivery form for this purpose, so that the material can be administered directly from the container onto the tooth surface (Figure 18). The volume of the individual increment plays a less important role when reconstructing the cusps, as the C-factor of these increments is very low. However, it may be necessary to light-cure the individual increments from two sides to ensure an appropriate polymerization.

The best modelling instrument is a microbrush, since this instrument enables easy shaping of the final cusp anatomy and adaptation of the composite even in the area of the proximal marginal bevels. Even if the microbrush is not wetted with bonding agent, the composite does not stick to it (Figure 19). Wetting modelling instruments with bonding liquid is a widespread technique to facilitate material adaptation. As long as only a minimal amount of liquid is used (if a microbrush is utilized, the brush should be wiped off on paper), this technique may be considered acceptable.

If a single-component adhesive is used, wetting the modelling instruments is, as a general rule, not permissible. All of these adhesives contain a solvent (alcohol, water or acetone), which would be applied repeatedly, each time the brush is dipped into the adhesive. Finishing is performed with Soflex discs, finishing diamonds to fine-tune the occlusion and silicone polishers. Abrasive brushes are employed for final high-gloss polishing (Figures 26 and 27).

Application of enamel and dentin shades

Posterior restorations may be layered with a variety of shades, i.e. dentin materials, to optimize the esthetic appearance of the restoration. However, it is important to be aware of the fact that patients do not benefit from such an optimization as the optical and esthetic improvements achieved in the posterior region cannot be



Figure 26: Completed restoration.



Figure 27: Occlusal check.

seen by them. Furthermore, using several shades increases the amount of material and time required to complete the restoration. Therefore, it is normally appropriate to use only one shade for the fabrication of posterior restorations. If necessary, dentin shades may be used to mask severely discoloured areas.

Shrinkage-free composites – do they exist?

At present, shrinkage-free composites are not available. Recently, a silorane-based composite (Filtek Silorane, 3M Espe) has been introduced for the first time. The polymerization-induced volumetric shrinkage of this material is said to be below 1% (with a modulus of elasticity of approx. 10 Gpa). The chemistry embodied in this material is based on a cationic polymerization mechanism, rather than radical polymerization. For this reason, this composite can only be used together with the accompanying adhesive. Experience with large composite restorations are not yet available for this material.

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