Deep margin elevation

A case report study

Rijkje A. Bresser, MSc
University Medical Center Groningen, University of Groningen, Center for Dentistry and Oral Hygiene, Department of Restorative Dentistry and Biomaterials, Groningen, The Netherlands

Lucas Z. Naves, DMD, PhD
Lecturer, Department of Restorative Dentistry and Biomaterials, University Medical Center Groningen, University of Groningen, The Netherlands

Stephan A. M. van der Made, MDT
Dental Laboratory, Kwalident Dental Studio, Beilen, The Netherlands

Marco S. Cune, DMD, PhD
Professor, Department of Restorative Dentistry and Biomaterials, University Medical Center Groningen, University of Groningen, The Netherlands
St. Antonius Hospital, Department of Oral Maxillofacial Surgery, Prosthodontics and Special Dental Care, Nieuwegein, The Netherlands
University of Utrecht, University Medical Center Utrecht, Department of Oral Maxillofacial Surgery, Prosthodontics and Special Dental Care, Utrecht, The Netherlands

Marco M. M. Gresnigt, DMD, PhD
Head, Department of Restorative Dentistry and Biomaterials, University Medical Center Groningen, University of Groningen, The Netherlands
Martini Hospital, Department of Special Dental Care, Groningen, The Netherlands

Correspondence to: **Rijkje A. Bresser, MSc**
Department of Restorative Dentistry and Biomaterials, Center for Dentistry and Oral Hygiene, University Medical Center Groningen, University of Groningen, Antonius Deusinglaan 1, 9713 AV Groningen, The Netherlands;
Tel: +31 6 13373723; Email: r.a.bresser@umcg.nl

Abstract

Deep subgingival margins are a much-debated topic in adhesive and restorative dentistry. The hydrophobic trait of direct composite resin materials challenges the restorative procedure of cavities with deep subgingival margins since isolation is complicated. A correct indication for a deep margin elevation (DME) treatment is the key to its clinical success, and adequate adaptation of the DME is crucial to its clinical performance. An adequate adaptation of the DME may potentially reduce bacterial accumulation and reduce the incidence of secondary caries as well as maintain periodontal health. The present case report aims to provide a step-by-step overview of the DME technique when applied in combination with a partial indirect glass-ceramic restoration and also provides clinical guidelines to tackle deep subgingival cavities. The indication for a DME and the selection of appropriate materials are explained, supported by the literature.

(Int J Esthet Dent 2023;18:142–160)

Introduction

Class II restorations show an annual failure rate of 4.0% to 4.9%, which implies that nearly half of composite resin restorations need replacement within 10 years.[1,2] The longevity of direct composite resin restorations depends on patient-, tooth-, and operator-related factors. These factors are direct predictors for restoration success or failure.[2-5] The number of included surfaces in direct composite resin restorations seems to have an influence on the longevity of the restoration, since the literature reports significantly more failures in three-surface or multi-surface compared with two-surface restorations.[6,7] Moreover, there is also a correlation between older patients and higher failure rates.[2,4,7] The adhesive protocol and composite resin materials used are other aspects that should be considered when investigating the reasons for direct composite restoration failures. Minor differences in material composition such as filler volume and polymerization shrinkage[8,9] may affect the clinical behavior of composite resin restorations.[6] Lastly, the operator is deemed influential in the increase of restoration failures in terms of skills, experience, and accuracy.[1,4,7]

Secondary caries is considered the predominant cause of restoration failure and seems to occur more often in direct composite resin compared with amalgam restorations.[10] However, the evidence for this presumption is considered of low quality since the studies included in this meta-analysis[10] are heterogenous and the conclusions had to be drawn from studies with a high risk of bias and inconsistency in the results.

Cervical secondary caries of a class II composite restoration is a common clinical situation requiring even deeper subgingival margins in the restoration. Managing a proper contact point, good emergence profile, and adequate marginal seal at the same time in deep and large cavities is often difficult due to proximal concavities at the cervical part of the cementoenamel junction (CEJ).[11,12]

When morphology, particularly proximal anatomy and its emergence profile, becomes more difficult to restore by means of a direct restoration, partial indirect restorations of glass-ceramic material are a good alternative. Data derived from a systematic review and meta-analysis by Morimoto et al[13] exhibit low failure rates of partial glass-ceramic restorations (PGCRs). Extensive research has been conducted on the longevity of inlays and onlays, with reported survival rates of approximately 96% after more than 10 years.[13-15]

Glass-ceramic restorations can be adhesively luted to the tooth substrate. The adhesive strength is significantly enhanced by the application of immediate dentin sealing (IDS) to the exposed dentin surface prior to restorative bonding.[16,17] Clinical studies evaluating PGCRs in combination with IDS show good survival rates over a longer period of time.[17,18]

Cavities can extend in both the buccolingual and occlusocervical directions, often reaching beyond the CEJ. Deep subgingival margins of large cavities pose potential problems and operative challenges regarding proper isolation and the maintenance of periodontal health. Proper isolation of the cavity using rubber dam is important during the adhesive application of direct composite resin materials.[19,20] Deep dentin margins of cavity outlines complicate isolation with rubber dam and might add to the reduced longevity and higher failure rates of margins in dentin.[21,22] In vivo evidence to support the benefits of rubber dam is scarce, and often rubber dam seems to be not as beneficial as relative isolation using cotton rolls.[23,24] However, in vitro research has shown the adverse effects of salivary contamination with the adhesive system of adhesive materials in

terms of adhesive bond strength deterioration in the absence of rubber dam isolation.[25] Recently, a systematic review and meta-analysis showed low-certainty evidence for lower failure rates in restorations fabricated with the use of rubber dam. Moreover, rubber dam isolation increases the visibility of the operatory field, which is beneficial in case of deep cavity outlines in order to check the marginal adaptation of the applied matrix system.[26]

Another problem with a subgingival margin is a potential violation of the biologic width. Invasion of the biologic width occurs when a restoration margin is located in close proximity to the alveolar bone crest, inducing an inflammatory response of the gingival tissue.[27,28] If a margin invades the biologic width, a surgical crown lengthening (SCL) procedure is advised to reestablish adequate distance of the margin to the alveolar bone. This technique is effective to counteract the periodontal inflammatory response; however, possible furcation involvement,[29] enlarged approximal access, and the difficulty in predicting the location of the gingival margin should be thoroughly considered.[30,31] Moreover, the impression procedure is also less of a challenge after surgical intervention since the cervical margin is exposed.

Another minimally invasive and less time-consuming approach would be to perform a deep margin elevation (DME),[32] which elevates the margin of a subgingival cavity to a supragingival position using a direct composite resin material. DME facilitates isolation, impression making, and the adhesive luting procedure of a PGCR.[33] With close consideration of the periodontal properties, a DME is only indicated in cavities with margins extending below the gingival tissue, thereby complicating isolation, although biologic width is not invaded.[27,34] Recently, a retrospective clinical study with a mean follow-up of approximately 5 years and involving 197 posterior restorations reported a survival rate of 95.9% with a standard error (SE) of 2.9%.[35]

The DME technique is operator sensitive. The use of magnification,[36] rubber dam isolation,[20,22] and a gold standard adhesive system[37] are highly recommended. DME should be brought to the attention of and taught to general practitioners, since deep cavity outlines are a common situation in clinical practice.

The aims of the present case report are:

- To state when a DME is indicated and what materials to use.
- To provide a step-by-step overview of the DME technique and give clinical guidelines to tackle deep subgingival cavities.
- To provide a protocol on how to adhesively bond a PGCR after performing a DME.

Case 1

Indication and treatment planning

The patients in the present case report were treated by one of the authors (MMMG) at the center for special dental care of the Martini Hospital, Groningen, The Netherlands. Written informed consent was obtained from both patients for the use of all clinical photographs, radiographs, and impressions for the field emission gun scanning electron microscopy (FEG SEM) images.

In October 2021, a 28-year-old female patient presented with secondary caries on the mesial side of the maxillary left second molar (Fig 1). The old composite restoration had been in function for 8 years, which is congruent with the previously mentioned survival rates of direct composite restorations.[1,2] A radiograph confirmed the diagnosis of secondary caries beneath the mesial direct composite restoration and provided some insight into the extent of the cavity (Fig 2). Treatment of the caries lesion was indicated to prevent progression of the

Fig 1 Initial situation of secondary decay on the mesiopalatal side of the maxillary left second molar.

Fig 2 Preoperative radiographic image of secondary caries.

decay toward the pulp. If tooth material is lost, one can opt for an indirect restoration. The cavity was expected to extend subgingivally and beyond the CEJ, thereby complicating isolation and restorative procedures. This molar cannot be repeatedly restored after this restorative procedure due to the severity of the deep cervical part of the cavity. It was therefore proposed to treat this medium- to large-sized cavity with a DME and a PGCR to optimally restore the tooth and increase its life span to a maximum.

Firstly, infiltration anesthesia was given (1.2 ml Ultracain D-S Forte; Sanofi, Frankfurt, Germany) and the shade-taking procedures for the PGCR were performed using a cross-polarized photograph with a gray card as reference.[38] The entire treatment was performed with the aid of an operative microscope (OPMI Pico; Zeiss, Jena, Germany) using 4-25× magnification. A putty impression (Provil Novo Medium fast set; Heraeus Kulzer, Hanau, Germany) with detailed liner (Provil Novo Light fast set; Heraeus Kulzer) was made to provide the patient with a temporary restoration after the preparation procedure. The teeth in the maxillary left quadrant were isolated using a clamp (KSK 26; Dentech, Tokyo, Japan) on the second molar and rubber dam (Non-Latex Heavy Dental Dam; Isodam, Michigan, USA). The rubber dam was inverted on the entire quadrant to prevent any leakage of intraoral fluids to the operative field.[20]

Preparation

The old composite restoration was removed using a pear-shaped green coarse diamond bur (830L; Komet Dental, Lemgo, Germany) but leaving the marginal ridge intact to protect the neighboring tooth during preparation and caries removal (Fig 3). The approximal wall of composite was safely removed using an ultrasonic device with a mesial divergent diamond-coated tip (SONICflex; KaVo Dental, Biberach, Germany). After the removal of the approximal composite, the caries lesion was clearly visible and extended below the rubber dam, complicating isolation of the operatory field (Fig 4). A round carbide bur (H1SE.014; Komet Dental) was

used to clean the carious dentin, and Teflon tape was packed at the cervical part of the cavity to maintain adequate isolation. Caries removal was checked with a caries detector dye (Caries Detector; Kuraray Dental, Tokyo, Japan) and the cavity was continuously monitored until a clean peripheral seal was visible (Fig 5). After caries removal, the cavity was further cleaned by sandblasting 30-µm Al_2O_3 particles on the tooth substrate to later enhance the shear bond strength of the composite resin to the dentin surface[39] (Aquacare; Velopex, London, UK), while the neighboring tooth was protected with a sectional matrix shield (A–M, Palodent; Dentsply Sirona, Pennsylvania, USA). It is of the utmost importance in this treatment phase to assess the distance from the cervical cavity outline to the marginal alveolar bone, to determine whether the margin of the restoration might interfere with the biologic width. A bone-sounding procedure was performed by placing a periodontal probe along the mesial side of the tooth, and the average distance of 2.04 mm for the biologic width was respected according to Gargiulo et al.[27] Alternative treatments such as SCL procedures should be considered if there is any possible jeopardization of the biologic width.

Immediate dentin sealing

The Teflon tape was removed after the cavity preparation to facilitate matrix placement. Several matrix systems have been proposed to perform DME.[40,41] A recent article introduced the use of a perforated, contoured metal matrix (Tor VM matrix; TOR VM, Heidelberg, Germany) with excellent marginal adaptation and a good emergence profile.[42] In the cases reported here, a Tor VM matrix was used to elevate the subgingival margin to a supragingival position (Fig 6). Note the marginal seal and emergence profile in the deep cavity, ensuring proper isolation. After

Fig 3 Accessing the caries lesion and leaving the marginal ridge intact.

Fig 4 The caries lesion extends below the CEJ and rubber dam isolation is difficult to achieve.

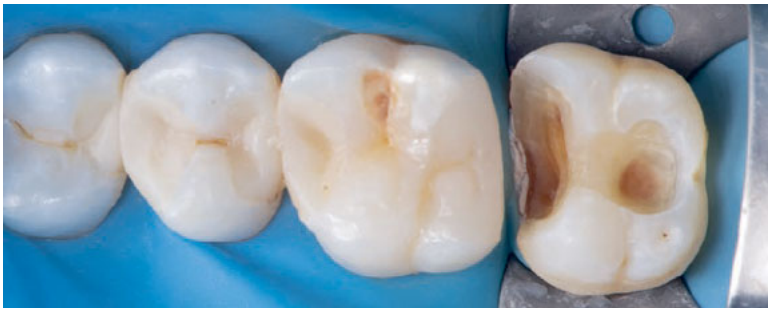

Fig 5 The cleaned cavity with proper isolation maintained cervically due to the packed Teflon tape.

Fig 6 Clinical situation after Tor VM matrix placement. The cavity was cleansed with water to see whether the matrix was placed correctly, which explains the remaining liquid in the cavity.

Fig 7 Injecting flowable composite with an elongated tip.

Fig 8 Finishing the cervical margin of the composite resin to the tooth substrate with an EVA handpiece (LTA-30/2 Diamond White).

placement of a wedge to ensure marginal adaptation of the matrix, IDS was applied to the exposed dentin surface to enhance the bond strength of the restoration to dentin.[43] A three-step etch-and-rinse system (OptiBond FL; Kerr, Orange, CA, USA) was used to perform IDS. First, the enamel and dentin surfaces were etched for 30 s and 10 s, respectively, with 37% phosphoric acid (UltraEtch; Ultradent, St Louis, MO, USA), then rinsed thoroughly with water for 15 s. The surface was air-dried for 3 s, without desiccating the dentin, and a primer was rubbed into the dentin for 15 s (OptiBond FL Primer; Kerr) and lightly air-blown for 5 s. A thin layer of adhesive (OptiBond FL Adhesive; Kerr) was carefully applied onto the dentin surface with a microbrush and spread with a dental probe.[16] The deep enamel in the mesial box was also covered with adhesive to ensure proper bonding of the DME to the tooth substrate. The adhesive layer was photopolymerized using a high-power curing unit (> 1000 mW/cm^2) (SmartLight Pro; Dentsply, Milford, USA) for 20 s to complete IDS.

Deep margin elevation

After IDS, a small amount of flowable composite (G-aenial Universal Injectable; GC, Leuven, Belgium) was injected into the deep cavity to elevate the deep subgingival margin to a supragingival position. The tip of the injectable composite was in contact with the cervical outline of the cavity to ensure that no air bubbles were imbedded in the DME (Fig 7). The flowable composite was photopolymerized for 40 s to ensure proper polymerization of the composite resin material in the deep cavity. The Tor VM matrix was removed and the composite resin adjusted and polished at the buccal and palatal sides using an EVA handpiece to ensure proper adaptation of the composite resin to the tooth (Fig 8). Note the position of the rubber dam at the cervical part of the cavity before and after the DME. Isolation was reestablished and a predictable adhesive technique could be applied at the placement appointment, which is one of the main benefits of DME (Fig 9). A radiograph was taken to verify the adaptation of the DME to the cervical outline (Fig 10) because the clinical success of the restoration is directly related to the marginal seal and marginal adaptation of the DME to the tooth. A

proper marginal seal and adaptation reduces bacterial accumulation, prevents secondary decay, and contributes to periodontal health.[28,44]

Next, it was important to check whether the IDS covered all the exposed dentin but not the enamel of the preparation. It is very difficult, or even impossible, to only remove IDS from the enamel and not from the dentin structure. Therefore, a very small part of dentin was exposed or left uncovered with the IDS. Any adhesive or composite remnant on the enamel surface was removed using a polisher (Brownie; Shofu Dental, Ratingen, Germany). This step is particularly important because it will allow etching and bonding to 'fresh' etched enamel when luting the ceramic restoration at the final stage of the restoration placement. The marginal sealing obtained by bonding to the non-obstructed enamel surface will provide a strong and stable bond strength to reinforce the chain effect,[45] which may help to protect the entire outline perimeter of the restoration. When all the surroundings have a stable bonding to enamel, it may help to overcome the limitations of bonding to dentin in a deep proximal area.[21]

Additionally, glycerin gel (K-Y; Johnson & Johnson, Heidelberg, Germany) was applied. The resin was polymerized again to eliminate the oxygen-inhibition layer. An impression was made using an addition silicone material with two viscosities in duplicate (Aquasil Medium and Light Body; Dentsply Sirona, Pennsylvania, USA). The macro aspect of the cavity after IDS and DME can be seen in Figure 11a and b. Higher magnification (871×) of the elevated proximal box can be seen in Figure 11c. The composite surface at the proximal margin of the cavity should also be free of any surface obliteration to avoid any impairment to the bonding procedures at this critical area. The composite should be as clean and free of debris and contaminants as possible, like the enamel shown in Figure 11d; considering this, the area should also be included when using the polisher (step described above) to clean the enamel margins. Thereafter, a self-curing provisional restoration (Protemp; 3M ESPE, Seefeld, Germany) was made with the putty impression to protect the tooth and reduce the risk of mesial migration and eruption of the prepared tooth and its adjacent elements. It was cemented with a polycarboxylate material (Durelon; 3M ESPE).

Fig 9 Result of the preparation and DME on the mesial aspect.

Fig 10 Midoperative radiograph to check the marginal adaptation of the flowable composite to the cervical dentin.

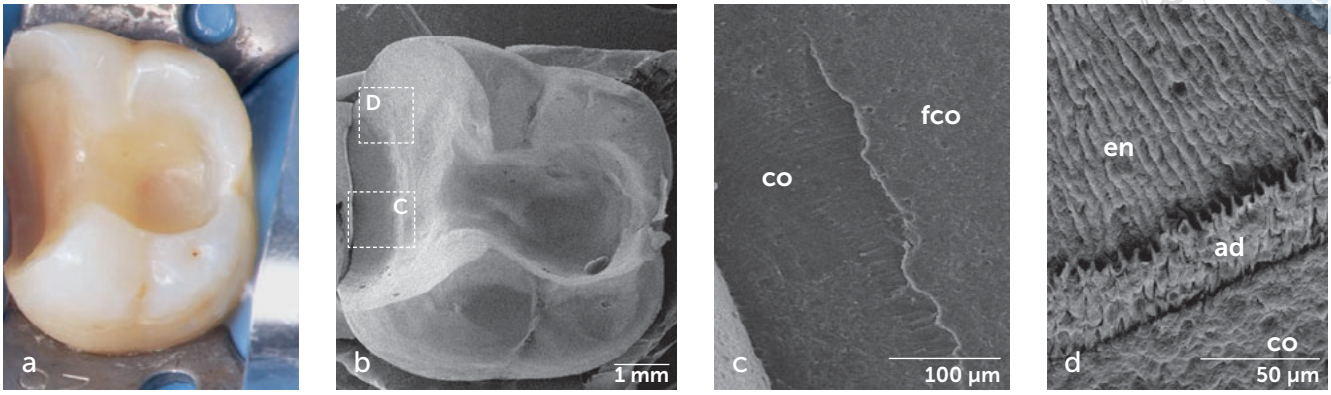

Fig 11 (a) Clinical situation from where the replica impression was taken. Note the clean cavity after phosphoric acid etching, ready for the bonding procedure to fixate the indirect restoration. (b) SEM magnification (21x) equivalent to the clinical image shown in 'a'. (c) Close-up magnification (871x), indicating the bottom of the mesial proximal cavity, showing the composite (co) of the DME and its boundary to the flow composite (fco) also used during the IDS technique. (d) Close-up magnification (2007x) showing the DME margin to the enamel surface (co: composite; fco: flow composite; ad: adhesive bond; en: enamel).

Adhesive luting of the partial glass-ceramic restoration

Intraoral fitting of the PGCR

The PGCR was fabricated and glazed following the manufacturer's guidelines. The restoration was checked on the gypsum cast for marginal discrepancies, mesial contact point, and occlusion prior to the patient's arrival. The provisional restoration was removed with a scaler and the patient's tooth was wedged prior to fitting. The restoration was fitted using glycerin gel, with special attention given to marginal adaptation, proximal contact point, color, and occlusion with the opposing arch.

Surface conditioning of the ceramic intaglio

The glass-ceramic restoration was approved and the intaglio surface conditioned in multiple steps to optimize adhesive strength. First, the surface was etched for 60 s with 9% hydrofluoric acid (Porcelain Etch; Ultradent) to dissolve the superficial glass matrix and form small porosities within the ceramic, which allows a good adhesive bond formation. The hydrofluoric acid was rinsed off in a bath of neutralizing powder (Neutralizing Powder; Ivoclar Vivadent, Schaan, Liechtenstein), and the surface of the restoration was cleaned again with 37% phosphoric acid (Ultra-Etch) and an ultrasonic bath (5 min in demineralized water) to remove the remaining contamination on the inside of the restoration. After cleaning the ceramic, a silane (Bis-Silane; Bisco, Schaumburg, USA) was applied to the surface of the restoration and dried in an oven at 100°C for 3 min. All surface conditioning steps of the ceramic restoration are shown in Figure 12.

Surface conditioning of the tooth

The second quadrant was then isolated with rubber dam and the surface of the tooth thoroughly cleaned with a hand scaler to remove the polycarboxylate cement from the IDS and enamel. The adjacent tooth was protected from conditioning using a

sectional matrix. The IDS, DME, enamel, and uncovered dentin were conditioned by sandblasting with silica-coated Al_2O_3 particles (AquaCare Cosil; Velopex) at a pressure of 3 bar,[46,47] rinsed thoroughly with water, and air-dried in order to clean the entire preparation from possible contamination with the polycarboxylate cement of the temporary restoration. Thereafter, the enamel was etched with 37% phosphoric acid (Fig 13a) for 30 s and rinsed thoroughly. The surface aspect shown in Figure 13b depicts the etched and clean surface, showing the enamel prism aspect on its topography. To ensure proper bonding to uncovered dentin with IDS, a primer (OptiBond FL Primer) was rubbed into the preparation for 15 s and lightly air-blown for 5 s. The sectional matrix was removed and replaced with a piece of Teflon tape to enable placement of the glass-ceramic restoration but still prevent adhesive conditioning of the neighboring tooth. The IDS and DME were silanized and left to dry for 3 min. The filled adhesive (OptiBond FL Adhesive) was applied to the surface of the ceramic restoration and on the preparation, but not photocured.

Adhesive luting procedure

The indirect restoration was adhesively luted with a preheated composite resin material (HFO UD1; Micerium, Avegno, Italy). The preheated composite was placed in the cavity with a slight excess and evenly distributed to ensure that all crevices were filled during restoration placement. Then, the restoration was placed into the cavity and pressure was applied to allow the removal of excess composite resin from the marginal outline (Fig 14). A hand instrument (Fissure; LM-Arte, Parainen, Finland) was used to remove the excess composite prior to photopolymerization. Pressure application and the removal of excess composite resin was repeated until no more composite resin material could be removed. The buccal and

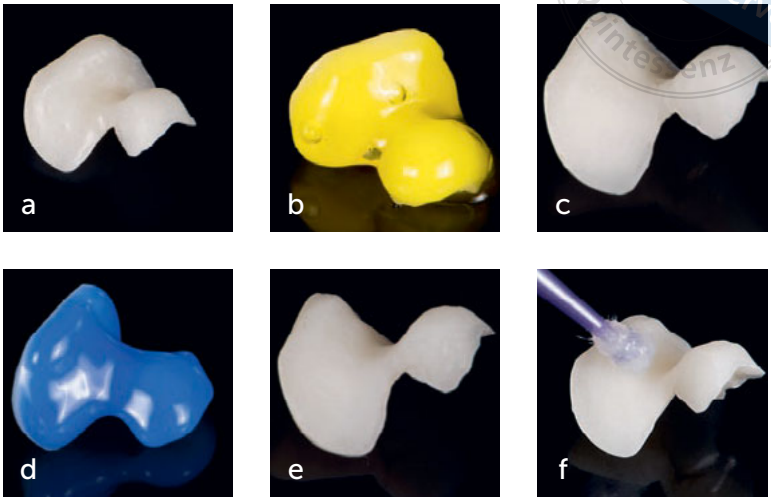

Fig 12 (a) Surface of the PGCR prior to surface conditioning. (b) 9% hydrofluoric acid etching. (c) Surface of the restoration after hydrofluoric acid etching. (d) Cleaning the restoration using 37% phosphoric acid. (e) Surface after 5 min in an ultrasonic bath with demineralized water. (f) Application of silane.

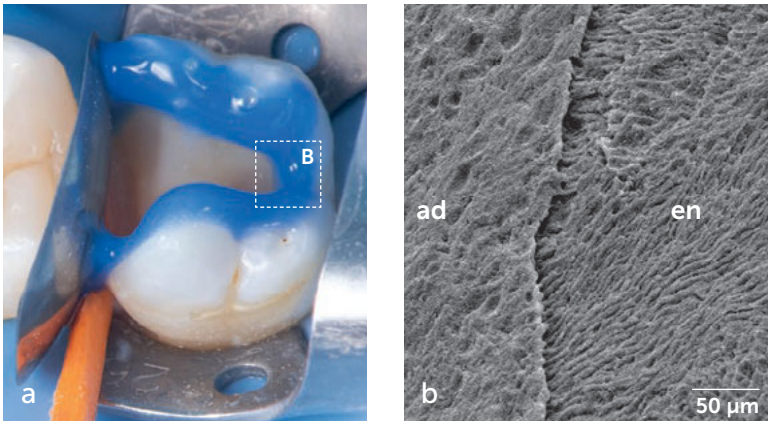

Fig 13 (a) Selective enamel phosphoric acid etching. (b) SEM micrography (667x) showing the margin between the etched enamel and the adhesive sealing (IDS) (en: enamel; ad: adhesive bond).

Fig 14 Excess composite resin material along the entire outline.

Fig 15 Excess composite resin removed, showing the result after finishing and polishing.

Fig 16 Fluorescent image showing the transition between the tooth and the indirect restoration.

Fig 17 Postoperative radiograph to check for excess luting composite cement and the marginal adaptation.

palatal sides were photopolymerized for 10 s and glycerin gel was applied to eliminate an oxygen-inhibition layer. The restoration was further photopolymerized for 40 s at each side to cure the luting composite completely after the excess composite resin material was removed. The remaining excess composite resin was removed with the use of a surgical 12D blade and a scaler. The outline was further optimized with the use

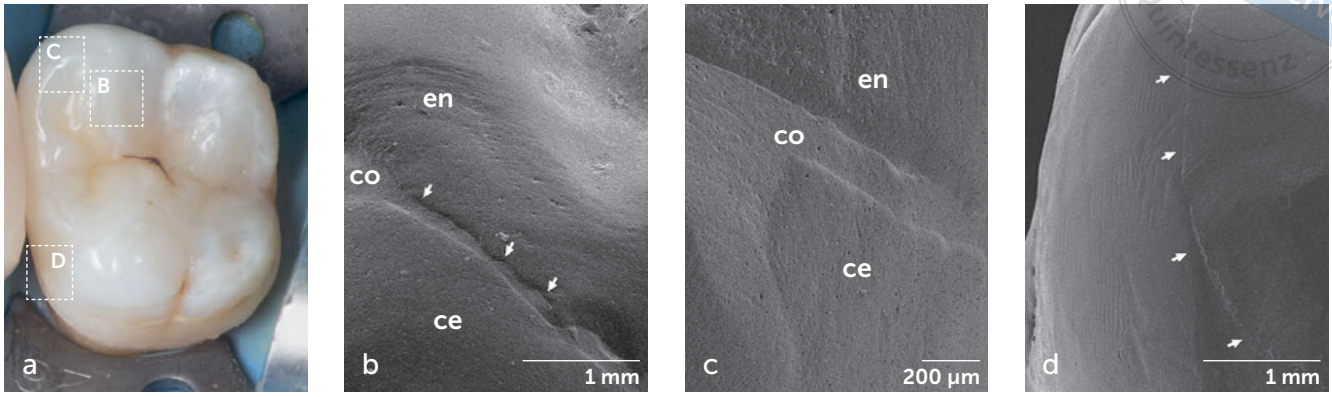

Fig 18 (a) Postoperative photograph after finishing and polishing. (b) SEM micrography (90x) showing the interface of ceramic and enamel. A minimal interfacial luting composite can be seen (arrows). (c) SEM micrography (226x) showing a higher magnification of the same interface, but here at the marginal ridge. Note the area of adhesive continuity (AAC) or a smooth transition among enamel/composite/ceramic. (d) SEM micrography (97x) showing the bonding interface at the palatal–proximal site after 6 months. Images 'b' and 'c' represent a bonding interface with and without a marginal mismatch, respectively (co: composite; en: enamel; ce: ceramic).

of an EVA handpiece and an Arkansas stone bur. Then, the outline of the restoration was polished with a Brownie, EVA polishers (red and white), and a ceramic polisher (CeraGloss; Edenta, Au, Switzerland) (Fig 15). The outline of the restoration was checked for excess adhesive material using fluorescence (Fig 16). The rubber dam was removed and the occlusion checked. A final radiograph was taken to check for excess cement and the marginal adaptation of the partial indirect restoration (Fig 17), and a postoperative clinical photograph was taken after 3 months of clinical service (Fig 18a). The final aspects of the bonding interface under ultra-high magnification are shown in Figure 18b and c, where an area of adhesive continuity (AAC) with a smooth transition from the enamel surface to the ceramic restoration can be seen.[48] Figure 18d depicts the marginal interface at the proximal site after 6 months of clinical service. The finishing and polishing procedures are key to decreasing biofilm retention and promoting optimal integration with the surrounding hard and soft tissue.

FEG SEM analysis

Representative clinical situations were analyzed utilizing FEG SEM.[49] An impression (Aquasil Ultra-Light and Heavy Body; Dentsply) was made from polyvinyl siloxane (PVS) after cleansing the surface with absorbent paper and sodium hypochlorite 0.5%. Impressions were poured with cold mounting epoxy resin (EpoxyCure 2; Buehler, Lake Bluff, IL, USA). After final curing, the replicas were sputter-coated with a 3-nm–thick layer of gold (80%)/palladium (20%, 90 s, 45 mA) (Balzers SCD 030; Balzers, Liechtenstein), and analyzed using a dual beam FEG SEM/FIB microscope (LyraTESCAN; Tescan, Brno, Czech Republic). The evaluation focused on marginal and surface integrity, homogeneity, and continuity along the bonding interface and ceramic surface (Fig 18).

Fig 19 Clinical pre-restorative situation of the maxillary left first molar.

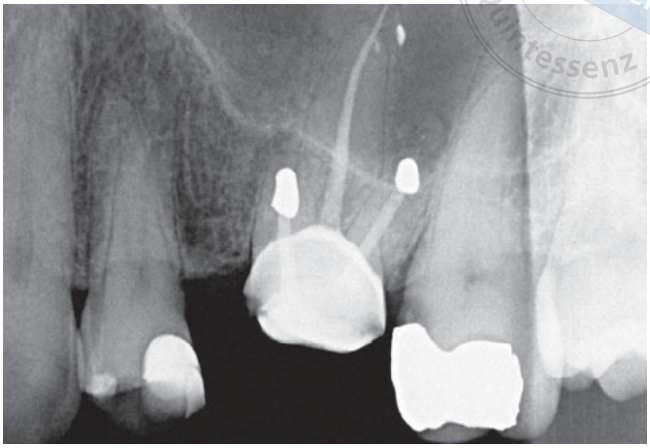

Fig 20 Radiographic image to check the approximal marginal adaptation of DME to the dentin. Note the secondary caries lesion in the second molar.

Fig 21 Clinical situation after DME and before placement of the indirect restoration.

Fig 22 Clinical situation after adhesive luting of the crown.

Case 2

This case illustrates the applicability of DME to a more extensive caries lesion and was treated entirely according to the adhesive protocol described for case 1. This female patient was referred to the clinic for extraction therapy of the maxillary left first molar (Fig 19). The poor prognosis of the molar was discussed with the patient; however, she wanted to keep the tooth by all means possible. The aim was therefore to restore this endodontically treated molar one last time by performing DME and providing the tooth with a circumferential crown of lithium disilicate. The decay was extensive in the cervical and buccopalatal directions and included all sides of the tooth. Isolation with rubber dam was not possible, and therefore, after the bone-sounding procedure, DME

was performed according to the previously described protocol using a circular matrix (AutoMatrix; Dentsply Sirona, Charlotte, USA). The adaptation of the DME was checked with a periapical radiograph (Fig 20) and the caries lesion at the mesial side of the maxillary left second molar was treated with a direct composite restoration. To clarify, no endodontic retreatment was performed. Impressions were made and sent to the dental laboratory, and a crown of lithium disilicate was fabricated. The margin of the cavity could now easily be isolated (Fig 21) prior to adhesive luting of the indirect restoration. The lithium disilicate crown was adhesively luted to the preparation (Fig 22) according to the previously described protocol. Marginal adaptation of the indirect restoration to the DME was checked with a radiograph (Fig 23).

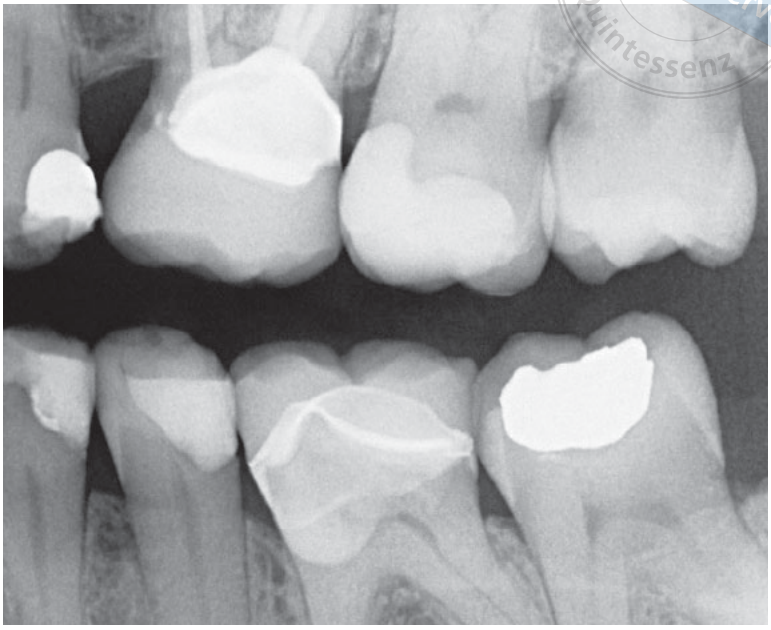

Fig 23 Radiographic image after adhesive luting of the crown.

Although the prognosis of this endodontically treated maxillary first molar is questionable, this case shows the extensive applicability of the DME technique in very different clinical situations with varying levels of difficulty. The patient recently attended a routine check-up at the dental clinic, during which it was observed that the crown and DME remained in good condition even after a duration of 1.5 years. The DME technique is shown as a conservative treatment alternative for a situation where the tooth would otherwise have to be extracted or subjected to more invasive surgical treatments.

Discussion

The present case report provides a clear protocol and indication to perform the DME technique and was applied in two very distinct cases. DME is indicated in preparation outlines below the gingival tissue and for which isolation is difficult. Moreover, the distance from the preparation outline to the alveolar bone should be > 2.04 mm[27] to reduce the possibility of an adverse periodontal reaction. Besides the scientific and practical indications of DME, it might be even more important for the clinician to weigh the benefits and costs of performing these expensive and often time-consuming restorative procedures prior to deciding whether the molar is worth the effort. A prognosis of the premolar should be made prior to DME treatment, for which it is of the utmost importance to view the entire dentition in perspective. DME might be beneficial, but it is relevant to discuss possible complications and (clinical) limitations of the technique and the required materials.

Survival rates of direct composite resin materials after 10 years[1,2] seem significantly lower compared with those of PGCRs.[13] Given these data, clinicians doubt whether placing a direct composite resin restoration below a PGCR is considered good clinical

practice. However, over the past several years, strong adhesive protocols have been developed and optimized to maximize adhesive bond strengths of composite resin to enamel, dentin, and glass-ceramics.[16,47,50] It is unknown whether these protocols were used in the (multicenter) retrospective studies from which survival rates were calculated, and whether the doubts of clinicians are indeed justified. If adhesive and curing protocols are executed accordingly, survival rates might be higher, and the adverse properties of resin-based materials could be tackled, compared with previous studies.[51]

Like any dental material, composite resin has certain adverse properties. These include, among others, polymerization shrinkage and related shrinkage stress, which can result in restoration deterioration and failure due to secondary caries or fractures.[3,52] Polymerization stress, as a result of polymerization shrinkage by bonding to multiple cavity walls, can induce micro gaps of the marginal seal and thereby disrupt the bonded interface.[53] This allows bacteria and water sorption, which can result in marginal staining and secondary caries.[54] To reduce polymerization stress, it is important to keep the C-factor as low as possible by using the incremental technique, in which the composite is layered and cured in increments of < 2 mm.[55] In deep proximal cavities, it is particularly important to be aware of the distance between the light curing unit tip and the composite surface. The intensity of the light from the curing light is inversely proportional to the square of the distance between the light source and the surface of the composite. Often, the dimensions of the cavity do not allow an approximation that guarantees maximal polymerization effectiveness. In these situations, increasing the photoactivation time is recommended to avoid insufficient monomer conversion.[8]

Incomplete conversion of the composite resin monomers to polymers results in elution of monomers and initiators into the oral environment. It modulates the biofilm and activity of Streptococcus Mutans,[56] which is one of the main bacteria causing caries lesions. The elution/degradation of monomers and initiators results in a loss of up to 2% of the initial mass of composite resin material.[57,58]

Besides shrinkage stress and composite degradation, a higher surface roughness of restorative materials also significantly contributes to plaque formation, which might consequently increase the occurrence of secondary caries and periodontal inflammation.[59,60] Due to their material properties, composite resin materials develop bacterial biofilm formation quicker than porcelain or gold restorations.[60] Besides quicker formation, the biofilm of composite resin might also be more viable and susceptible to secondary decay compared with amalgam restorations. Some low-certainty evidence exists to support this statement,[10] while other evidence is scarce and outdated.[61,62] More recent studies even contradict this statement and cannot find a reduced secondary decay formation for amalgam restorations.[63]

Supposedly, an entirely different approach to treat extensive subgingival secondary decay is possible. The biologically oriented preparation technique (BOPT) aims to make a vertical preparation without a finish line to create room for a new emergence profile by the prosthetic crown. The surrounding soft tissue is modified in shape and position by gingival curettage, adapting to the shape of the new prosthetic emergence. BOPT has been shown to provide satisfactory periodontal and restorative results of 93.1% over 6 years.[64,65] However, BOPT is entirely different to DME, and requires a different approach. DME relies on adhesive bond strength and allows the treatment to be minimally invasive, while BOPT relies on retentive strength through circumferential preparations without adhesive bonding. The

invasive nature of the BOPT approach is directly also its major disadvantage in case of local secondary decay, which is why DME was chosen as the appropriate approach in the present case series.

Another alternative to restore deep subgingival preparations in the posterior zone might be to use partial gold restorations. Gold is a predictable restorative material with a long history of success, also in deep dentin outlines, with survival rates of 94.1% over more than 40 years of clinical service.[66,67] Only recently, a new idea was proposed to combine gold with composite resin in deep dentin cavity outlines: a direct gold/composite sandwich restoration.[68] This idea tries to enhance the life expectancy of direct class II restorations by restoring deep dentin with gold foil. Clinical studies are needed to assess whether this combination of materials is a viable treatment option. Such studies should focus mainly on the marginal quality and recurrent caries at the gold and composite interface.

More long-term prospective and retrospective in vivo research and randomized controlled clinical trials are needed to conclude whether DME is a reliable treatment option for deep subgingival cavities in the long run. However, if resin-based materials are applied correctly, and the degree of stress development can be controlled, durable and highly esthetic direct restorations show excellent survival rates over a long period of time.[69]

Overall, all other treatment approaches for severe compromised proximal cavities also have their limitations and contraindications, and most of them also lack the solid scientific evidence needed for them to be established as standard treatment.

Conclusions

In technical terms, DME is indicated in cases in which isolation is difficult to obtain but biologic width is not violated by the margin of the cavity. Besides technical terms, a cost-benefit analysis of the clinical perspective and a prognosis of the concerned tooth prior to treatment is of the utmost importance to overall clinical success. The use of magnification while performing this treatment is highly advisable to deliver restorations with precision and close marginal adaptation, which is a key factor to clinical success. Magnification allows the examination of the adaptation of the matrix system to the cavity margin, enables precise application of the IDS to the dentin structure, and allows the careful and complete removal of the excess luting cement after placement.

When indicated and performed meticulously, DME is an effective adjunctive treatment to the provision of PGCR in cases with deep cervical margins, with a high chance of success.

Acknowledgments

The authors are grateful to Prof Dr Y Pei, Dr D. Ribas-Gomes, and Dr E. Galinmoghaddam (Applied Physics, Materials Science, Zernike Institute, University of Groningen) for the scientific and technical support with the scanning electron microscopy (FEG SEM).

References

1. Laske M, Opdam NJM, Bronkhorst EM, Braspenning JCC, Huysmans MCDNJM. Ten-year survival of Class II restorations placed by general practitioners. JDR Clin Trans Res 2016:1:292–299.
2. Wierichs RJ, Kramer EJ, Meyer-Lueckel H. Risk factors for failure of direct restorations in general dental practices. J Dent Res 2020; 99:1039–1046.
3. Rasines Alcaraz MG, Veitz-Keenan A, Sahrmann P, Schmidlin PR, Davis D, Iheozor-Ejiofor Z. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth. Cochrane Database Syst Rev 2014;3;CD005620. doi:10.1002/14651858.CD005620.pub2.
4. Demarco FF, Collares K, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Should my composite restorations last forever? Why are they failing? Braz Oral Res 2017; 31(suppl 1):e56. doi:10.1590/1807-3107BOR-2017.vol31.0056.
5. Goldstein GR. The longevity of direct and indirect posterior restorations is uncertain and may be affected by a number of dentist-, patient-, and material-related factors. J Evid Based Dent Pract 2010;10: 30–31.
6. Lempel E, Tóth Á, Fábián T, Krajczár K, Szalma J. Retrospective evaluation of posterior direct composite restorations: 10-year findings. Dent Mater 2015;31; 115–122.
7. Laske M, Opdam NJM, Bronkhorst EM, Braspenning JCC, Huysmans MCDNJM. Risk factors for dental restoration survival: a practice-based study. J Dent Res 2019;98: 414–422.
8. Ferracane JL, Hilton TJ. Polymerization stress – is it clinically meaningful? Dent Mater 2016;32:1–10.
9. Meredith N, Setchell DJ. In vitro measurement of cuspal strain and displacement in composite restored teeth. J Dent 1997;25: 331–337.
10. Worthington HV, Khangura S, Seal K, et al. Direct composite resin fillings versus amalgam fillings for permanent posterior teeth. Cochrane Database Syst Rev 2021;8: CD005620. doi:10.1002/14651858.CD005620.pub3.
11. Nedeljkovic I, De Munck J, Vanloy A, et al. Secondary caries: prevalence, characteristics, and approach. Clin Oral Investig 2020;24:683–691.
12. Patras M, Doukoudakis S. Class II composite restorations and proximal concavities: clinical implications and management. Oper Dent 2013;38:119–124.
13. Morimoto S, Rebello de Sampaio FBW, Braga MM, Sesma N, Özcan M. Survival rate of resin and ceramic inlays, onlays, and overlays: a systematic review and meta-analysis. J Dent Res 2016;95:985–994.
14. Beier US, Kapferer I, Burtscher D, Giesinger JM, Dumfahrt H. Clinical performance of all-ceramic inlay and onlay restorations in posterior teeth. Int J Prosthodont 2012;25:395–402.
15. Malament KA, Margvelashvili-Malament M, Natto ZS, Thompson V, Rekow D, Att W. Comparison of 16.9-year survival of pressed acid etched e.max lithium disilicate glass-ceramic complete and partial coverage restorations in posterior teeth: Performance and outcomes as a function of tooth position, age, sex, and thickness of ceramic material. J Prosthet Dent 2021;126:533–545.
16. van den Breemer CG, Özcan M, Cune MS, Almeida Ayres AP, Van Meerbeek B, Gresnigt MMM. Effect of immediate dentin sealing and surface conditioning on the microtensile bond strength of resin-based composite to dentin. Oper Dent 2019;44:E289–E298.
17. Gresnigt MMM, Cune MS, Schuitemaker J, et al. Performance of ceramic laminate veneers with immediate dentine sealing: An 11 year prospective clinical trial. Dent Mater 2019;35:1042–1052.
18. van den Breemer CRG, Cune MS, Özcan M, Naves LZ, Kerdijk W, Gresnigt MMM. Randomized clinical trial on the survival of lithium disilicate posterior partial restorations bonded using immediate or delayed dentin sealing after 3 years of function. J Dent 2019;85:1–10.
19. Ozer F, Blatz MB. Self-etch and etch-and-rinse adhesive systems in clinical dentistry. Compend Contin Educ Dent 2013;34:12–14.
20. Browet S, Gerdolle D. Precision and security in restorative dentistry: the synergy of isolation and magnification. Int J Esthet Dent 2017;12:172–185.
21. Collares K, Corrêa MB, Laske M, et al. A practice-based research network on the survival of ceramic inlay/onlay restorations, Dent Mater 2016;32:687–694.
22. Heintze SD, Rousson V. Clinical effectiveness of direct class II restorations – a meta-analysis. J Adhes Dent 2012;14: 407–431.
23. Cajazeira MR, De Sabóia TM, Maia LC. Influence of the operatory field isolation technique on tooth-colored direct dental restorations. Am J Dent 2014;27:155–159.
24. Daudt E, Lopes GC, Vieira LC. Does operatory field isolation influence the performance of direct adhesive restorations? J Adhes Dent 2013;15:27–32.
25. Aboushelib MN. Clinical performance of self-etching adhesives with saliva contamination. J Adhes Dent 2011;13:489–493.
26. Peumans M, Politano G, Van Meerbeek B. Effective protocol for daily high-quality direct posterior composite restorations. Cavity preparation and design. J Adhes Dent 2020;22:581–596.
27. Gargiulo AW, Wentz FM, Orban B. Dimensions and relations of the dentogingival junction in humans. J Periodontol 1961;32:261–267.
28. Padbury A Jr, Eber R, Wang HL. Interactions between the gingiva and the margin of restorations. J Clin Periodontol 2003;30:379–385.
29. Dibart S, Capri D, Kachouh I, Van Dyke T, Nunn ME. Crown lengthening in mandibular molars: a 5-year retrospective radiographic analysis. J Periodontol 2003; 74:815–821.
30. Pilalas I, Tsalikis L, Tatakis DN. Pre-restorative crown lengthening surgery outcomes: a systematic review. J Clin Periodontol 2016;43:1094–1108.
31. Lanning SK, Waldrop TC, Gunsolley JC, Maynard JG. Surgical crown lengthening: evaluation of the biological width. J Periodontol 2003;74:468–474.
32. Dietschi D, Magne P, Holz J. Recent trends in esthetic restorations for posterior teeth. Quintessence Int 1994;25:659–677.

33. Veneziani M. Adhesive restorations in the posterior area with subgingival cervical margins: new classification and differentiated treatment approach. Eur J Esthet Dent 2010;5:50–76.
34. Gargiulo A, Krajewski J, Gargiulo M. Defining biologic width in crown lengthening. CDS Rev 1995;88:20–23.
35. Bresser RA, Gerdolle D, van den Heijkant IA, Sluiter-Pouwels LMA, Cune MS, Gresnigt MMM. Up to 12 years clinical evaluation of 197 partial indirect restorations with deep margin elevation in the posterior region. J Dent 2019;91:103227. doi:10.1016/j.jdent.2019.103227.
36. Eichenberger M, Biner N, Amato M, Lussi A, Perrin P. Effect of magnification on the precision of tooth preparation in dentistry. Oper Dent 2018;43:501–507.
37. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, van Landuyt KL. State of the art of self-etch adhesives. Dent Mater 2011;27:17–28.
38. Hein S, Zangl M. The use of a standardized gray reference card in dental photography to correct the effects of five commonly used diffusers on the color of 40 extracted human teeth. Int J Esthet Dent 2016;11:246–259.
39. Mujdeci A, Gokay O. The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. J Prosthet Dent 2004;92:245–249.
40. Magne P, Spreafico RC. Deep margin elevation: a paradigm shift. Am J Esthet Dent 2012;2:86–96.
41. Dablanca-Blanco AB, Blanco-Carrión J, Martín-Biedma B, Varela-Patiño P, Bello-Castro A, Castelo-Baz P. Management of large class II lesions in molars: how to restore and when to perform surgical crown lengthening? Restor Dent Endod 2017;42:240–252.
42. Peumans M, Venuti P, Politano G, Van Meerbeek B. Effective protocol for daily high-quality direct posterior composite restorations. The interdental anatomy of the Class-2 composite restoration. J Adhes Dent 2021;23:21–34.
43. van den Breemer CR, Özcan M, Pols MR, Postema AR, Cune MS, Gresnigt MMM. Adhesion of resin cement to dentin: effects of adhesive promoters, immediate dentin sealing strategies, and surface conditioning. Int J Esthet Dent 2019;14:52–63.
44. Santos VR, Lucchesi JA, Cortelli SC, Amaral CM, Feres M, Duarte PM. Effects of glass ionomer and microfilled composite subgingival restorations on periodontal tissue and subgingival biofilm: a 6-month evaluation. J. Periodontol 2007;78:1522–1528.
45. Swift EJ. Enamel bonding. J Esthet Restor Dent 2003;15:325–326.
46. Burrer P, Costermani A, Par M, Attin T, Tauböck TT. Effect of varying working distances between sandblasting device and composite substrate surface on the repair bond strength. Materials (Basel) 2021;14:1621. doi:10.3390/MA14071621.
47. Gresnigt MMM, Kalk W, Özcan M. Clinical longevity of ceramic laminate veneers bonded to teeth with and without existing composite restorations up to 40 months. Clin Oral Investig 2013;17:823–832.
48. Andrade O, Borges G, Kyrillos M, Moreira M, Calichio L, Correr-Sobrinho L. The area of adhesive continuity: A new concept for bonded ceramic restorations. Quintessence Dent Technol 2013;36:9–26.
49. Naves LZ, Gerdolle DA, de Andrade OS, Gresnigt MMM. Seeing is believing? When scanning electron microscopy (SEM) meets clinical dentistry: the replica technique. Microsc Res Tech 2020;83:1118–1123.
50. van den Breemer CRG, Özcan M, Cune MS, van der Giezen R, Kerdijk W, Gresnigt MMM. Effect of immediate dentine sealing on the fracture strength of lithium disilicate and multiphase resin composite inlay restorations. J Mech Behav Biomed Mater 2017;72:102–109.
51. Borgia E, Baron R, Borgia JL. Quality and survival of direct light-activated composite resin restorations in posterior teeth: a 5- to 20-year retrospective longitudinal study. J Prosthodont 2019;28:e195–e203.
52. Ferracane JL. Models of caries formation around dental composite restorations. J Dent Res 2017;96:364–371.
53. Kim RJ, Kim YJ, Choi NS, Lee IB. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. J Dent 2015;43:430–439.
54. Hilton TJ. Can modern restorative procedures and materials reliably seal cavities? in vitro investigations. Part 2. Am J Dent 2002;15:279–289.
55. Bicalho AA, Valdívia AD, Barreto BC, Tantbirojn D, Versluis A, Soares CJ. Incremental filling technique and composite material – part II: shrinkage and shrinkage stresses. Oper Dent 2014;39:E83–E92.
56. Lin NJ, Keeler C, Kraigsley AM, Ye J, Lin-Gibson S. Effect of dental monomers and initiators on Streptococcus mutans oral biofilms. Dent Mater 2018;34:776–785.
57. Braga RR, Ballester RY, Ferracane JL. Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review. Dent Mater 2005;21:962–970.
58. Ferracane JL, Condon JR. In vitro evaluation of the marginal degradation of dental composites under simulated occlusal loading. Dent Mater 1999;15:262–267.
59. Dutra D, Pereira G, Kantorski KZ, Valandro LF, Zanatta FB. Does finishing and polishing of restorative materials affect bacterial adhesion and biofilm formation? A systematic review. Oper Dent 2018;43:E37–E52.
60. Contreras-Guerrero P, Ortiz-Magdaleno M, Urcuyo-Alvarado MS, et al. Effect of dental restorative materials surface roughness on the in vitro biofilm formation of Streptococcus mutans biofilm. Am J Dent 2020;33:59–63.
61. Svanberg M, Mjör IA, Ørstavik D. Mutans streptococci in plaque from margins of amalgam, composite, and glass-ionomer restorations. J Dent Res 1990;69:861–864.
62. Hansel C, Leyhausen G, Mai UE, Geurtsen W. Effects of various resin composite (co)monomers and extracts on two caries-associated micro-organisms in vitro. J Dent Res 1998;77:60–67.
63. Kuper NK, van de Sande FH, Opdam NJM, et al. Restoration materials and secondary caries using an in vitro biofilm model. J Dent Res 2015;94:62–68.
64. Serra-Pastor B, Bustamante-Hernández N, Fons-Font A, Fernanda Solá-Ruíz M, Revilla-León M, Agustín-Panadero R. Periodontal behavior and patient satisfaction of anterior teeth restored with single zirconia crowns using a

biologically oriented preparation technique: a 6-year prospective clinical study. J Clin Med 2021;10: 3482. doi:10.3390/jcm10163482.

65. Agustín-Panadero R, Serra-Pastor B, Loi I, Suárez MJ, Pelaez J, Solá-Ruíz F. Clinical behavior of posterior fixed partial dentures with a biologically oriented preparation technique: a 5-year randomized controlled clinical trial. J Prosthet Dent 2021;125:870–876.

66. Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001;3:45–64.

67. Donovan T, Simonsen RJ, Guertin G, Tucker RV. Retrospective clinical evaluation of 1,314 cast gold restorations in service from 1 to 52 years. J Esthet Restor Dent 2004;16:194–204.

68. Henry DB. A clinical presentation of the direct gold/composite sandwich restoration. Oper Dent 2022;47:123–130.

69. Borgia E, Baron R, Borgia JL. Quality and survival of direct light-activated composite resin restorations in posterior teeth: a 5- to 20-year retrospective longitudinal study. J Prosthodont 2019;28:e195–e203..