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Review

Cervical margin relocation in indirect adhesive restorations: A literature review

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ABSTRACT

Purpose: The aim of this review was to summarize the existing scientific literature investigating on cervical margin relocation technique (CMR) performed prior to the adhesive cementation of the indirect restorations.
Study selection: An electronic search with no date restriction was conducted in the MEDLINE database, accessed through PubMed. The following main keywords were used: "*cervical margin relocation*", "*coronal margin relocation*", "*deep margin elevation*" and "*proximal box elevation*".
Results: Seven *in vitro* studies and 5 clinical reports investigating on CMR are taken into consideration for the present review. The most frequently investigated parameter in almost all of the *in vitro* studies was the marginal adaptation of the indirect restorations. One study additionally assessed the influence of CMR on the fracture behavior of the restored teeth and one study assessed the bond strength of the indirect composite restoration to the proximal box floor. Clinical reports provided documentation with a detailed description of the treatment protocol. In the current literature no randomized controlled clinical trials or prospective or retrospective clinical studies on CMR technique could be found.
Conclusions: On the basis of the reviewed literature, it can be concluded that currently there is no strong scientific evidence that could either support or discourage the use of CMR technique prior to restoration of deep subgingival defects with indirect adhesive restorations. Randomized controlled clinical trials are necessary to provide the reliable evidence on the influence of CMR technique on the clinical performance, especially on the longevity of the restorations and the periodontal health.

1. Introduction

Restoring large posterior defects with proximal caries extending below the cemento-enamel junction (CEJ) and cavity margins located beneath the gingival tissues represents a very common clinical situation. Due to advances in adhesive technology, development of modern materials and increasing aesthetic requests, a treatment plan in such cases often includes indirect adhesive restoration [1,2]. Unfortunately, when restoring cavities with deep cervical margins two major clinical problems may occur: problems of biological nature and technical-operative problems [3].

The biological problems refer to the possible violation of the "biological width", a recommended distance of 3 mm or more between the restorative margins and the alveolar crest that is considered necessary in order to avoid detrimental effects on neighboring soft and hard periodontal tissues [4]. If the principle of biologic width is not respected, it is suggested to obtain the necessary space in one of two ways: surgically, by surgical crown lengthening [5] or orthodontically, by tooth extrusion [6].

The technical-operative problems start with difficulties in tooth preparation in subgingival areas and are followed with a series of challenges in the impression taking, the adhesive cementation of the restoration and the successive phases of finishing and polishing of the margins [7]. Most of the above mentioned issues are related to inferior insight and access to the deep parts of the cavity and impossible or inadequate isolation of the operating field with a rubber dam, which leads to inappropriate moisture control and blood and/or saliva contamination throughout the clinical procedures [8].

To make the clinical procedures simpler and less fault-prone, Dietschi and Spreafico in 1998 introduced a technique named "cervical margin relocation" (CMR) [9]. In 2012 Magne and Spreafico

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referred to the same technique as “deep margin elevation” (DME) [10]. Similar names, such as “coronal margin relocation” and “proximal box elevation”, could also be heard among the practitioners and found in the literature. This technique proposes application of composite resin in the deepest parts of the proximal areas in order to reposition the cervical margin supragingivally, which is supposed to facilitate the isolation and improve impression taking and adhesive cementation of indirect restorations [9,10]. The CMR technique could be considered, to a certain extent, as a non-invasive alternative to a surgical crown lengthening.

The problem of extensive subgingival defects that still remains, regardless of the technique applied, is limited or no enamel present at deep cervical margins, leaving only dentin and cementum as the main substrates for adhesion. Adhesive bonding to the etched enamel is proved to be efficient and stable [11]. Adhesion to dentin, on the other hand, depends on numerous factors related to the substrate morphology [12], on the type of the adhesive [13] and on the sensitive application technique [14]. Therefore, adhesive bonding to deep cervical dentin and maintaining the margins of the adhesive restoration sealed throughout the time could not be considered entirely predictable and safe.

Whether the CMR technique is the most optimal treatment option for the restoration of deep cavities reaching below CEJ, how the proposed advantages and possible disadvantages could affect the clinical performance of the indirect restorations and which are the most appropriate materials and techniques that should be applied in such situations are the topics extensively discussed among clinicians. Nevertheless, not much scientific support could be found in the currently available literature. Therefore, the aim of this review was to summarize the existing scientific knowledge on CMR technique performed prior to the adhesive cementation of the indirect restorations.

2. Study selection

2.1. Search strategy

For the identification of the studies to be included in this review, an electronic search with no date restriction was conducted in the MEDLINE database, accessed through PubMed. The following main keywords were used: “*cervical margin relocation*”; “*coronal margin relocation*”; “*deep margin elevation*” and “*proximal box elevation*”. A further manual search was performed as well; checking for eligible papers in the bibliographies of the initially retrieved articles and exploring the websites of the relevant journals.

2.2. Inclusion criteria

The present review sought only for articles where composite resin materials were used as materials for relocation of the cervical margin. Only articles considering indirect adhesive restoration, as a type of final restoration, were included. Because no randomized controlled clinical trials (RCTs) existed in this field, descriptive studies that made reference to the CMR clinical procedure were also included. The search was limited to the articles published in English language.

2.3. Exclusion criteria

Publications focusing on relocation of the cervical margin using glass ionomer cements were not included in the present review. Studies that used teeth without a restoration or teeth restored with a direct composite restoration with subgingival cervical margin were also excluded. Articles in any language other than English were left out.

The search and the selection process carried out by two review authors independently finished on 1st June 2017. After the screening of the titles and the abstracts, full texts of all reviewed articles were obtained and carefully read. Upon the discussion between the authors, on the basis of the reported inclusion and exclusion criteria, 7 *in vitro* studies, 1 review article with a case report and 4 articles describing the CMR technique were selected for the present literature review.

3. Results

The results of the reviewed studies were categorized and presented in two main parts: (1) review of *in vitro* studies and (2) review of clinical reports.

3.1. Review of in vitro studies

In the current scientific literature 7 *in vitro* studies investigating on CMR are taken into consideration for the present review [15–21]. The most frequently investigated parameter in almost all of the studies was the marginal adaptation of the indirect restorations [15–19,21]. Only one study additionally assessed the influence of CMR on the fracture behavior of the restored teeth [18] and one study assessed the bond strength of the indirect composite restoration to the proximal box floor [20]. The overview of the main characteristics, the materials employed and the designs of the reviewed studies are reported in Table 1.

3.1.1. Marginal adaptation

All 6 studies that evaluated the influence of CMR on the marginal quality of the adhesively luted restorations performed the analysis using the scanning electron microscopy (SEM), observing the margins on gold-sputtered epoxy resin replicas of the teeth at 50× [19] and 200× magnification [15–18,21]. The marginal integrity was calculated in the same way, as the percentage of continuous margin in relation to the individual assessable margin, following the well-established protocol consistent with previous studies [22]. The quality of the marginal adaptation was assessed before and after thermo-mechanical loading (TML) [15–19,21]. However, the adhesive interfaces that were observed and analyzed were not always the same in all of the studies.

Most of the studies supported the fact that no differences existed in marginal quality of the restorations placed directly on dentin, following the conventional luting procedure, or on composite restorations used for relocation of the cervical margin [15,17–19,21]. One study recorded that, only after being subjected to TML, conventional technique showed superior marginal adaptation compared to CMR technique [16]. Moreover, in most of the studies TML was found to significantly deteriorate the integration at enamel and dentin margins [15–17] and at onlay/luting composite interface [18]. But it was also recorded that TML did not result in inferior marginal quality, regardless of the materials tested [19,21].

With regard to the materials employed for CMR, one study investigated on the performance of flowable and conventional restorative composite materials when used for CMR [19]. No significant differences in the marginal integrity were found between traditional or flowable composite, before or after TML, for either ceramic or composite CAD/CAM crown [19]. The potential use of self-adhesive resin cements as material for CMR, although deviant from their original indication spectrum, has been explored due to their easy clinical manipulation that could be appealing for dental practitioners [15,16]. Based on the discouraging results obtained and significantly inferior quality of the marginal adaptation to dentin, they were not recommended for

this indication in clinical practice, although differences were noticeable among various self-adhesive cements [15,16].

Moreover, in order to evaluate whether polymerization shrinkage of composite material used for CMR could affect the quality of the margins, 3 investigations were performed applying one or more layers of composite on the cervical margin of the proximal boxes [15–17]. Two 1.5-mm increments of a fine hybrid composite (Tetric A2; Ivocalr Vivadent, Schaan, Liechtenstein) applied for CMR did not perform any better then did one 3-mm increment, in terms of marginal adaptation of the final restoration [17]. On the contrary, results of another two studies [15,16] showed that marginal integration to dentin of a restorative composite (Clearfil Majesty Posterior; Kuraray, Noritake Dental Inc., Tokyo, Japan) is improved when composite is layered in three consecutive 1-mm increments than in one 3-mm increment for CMR. Although initially no difference existed among group without CMR and groups where composite was layered in one or three increments, after TML significant degradation of the interface was noticed and statistically significant differences emerged among the groups [15,16]. In particular, bonding directly to dentin without CMR was found to be comparable to CMR composite layered in 3 increments but significantly better than CMR applied only in one layer [15]. In a subsequent study of the same group of authors [16], the results were slightly different. Conventional luting technique directly to dentin performed significantly better even than dentin covered with 3 layers of composite, which was also significantly better than CMR applied only in one layer. Therefore, the authors concluded that, although conventional luting procedure is considered as the most effective over time, the CMR technique could be accepted a valid procedure and application of composite in more layers achieved better performance in terms of marginal quality to dentin compared to a single layer application [15,16].

Table 1
Overview of the *in vitro* studies.

Author/ reference	Groups (study design)	CMR adhesive/composite material	Number of CMR composite layers	Luting agent of final restoration	Type of final indirect restoration
Marginal adaptation					
Roggendorf et al. [15]	5 groups: (1) and (2) CMR with self-adhesive cements (3) CMR in 1 layer; (4) CMR in 3 layers; (5) without CMR.	2 self-adhesive resin cements: (1) Maxcem Elite (Kerr), (2) G-Cem (GC Corp.); (3) and (4) self-etch adhesive AdheSe (Ivoclar, Vivadent) + Clearfil Majesty Posterior (Kuraray)	1 layer (3 mm); 3 layers (3 × 1 mm)	Total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent) + resin cement Variolink II (Ivoclar Vivadent)	Laboratory made composite MOD inlay Clearfil Majesty Posterior (Kuraray)
Frankenberger et al. [16]	6 groups: (1), (2) and (3) CMR with self-adhesive cements (4) CMR in 1 layer; (5) CMR in 3 layers; (6) without CMR.	3 self-adhesive resin cement: (1) Maxcem Elite (Kerr), (2) G-Cem (GC Corp.), (3) RelyX Unicem (3M ESPE); (4) and (5) self-etch adhesive AdheSe (Ivoclar, Vivadent) + Clearfil Majesty Posterior (Kuraray)	1 layer (3 mm); 2 layers (2 × 1.5 mm)	Total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent) + resin cement Variolink II (Ivoclar Vivadent)	CAD/CAM-fabricated MOD inlay: leucite-reinfirced glass-ceramic IPS Empress CAD (Ivoclar Vivadent)
Zaruba et al. [17]	4 groups: (1) margin in enamel; (2) margin in dentin, CMR in 1 layer; (3) margin in dentin, CMR in 2 layers; (4) margin in dentin, without CMR.	Total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent) + fine hybrid composite Tetric A2 (Ivoclar Vivadent)	1 layer (3 mm); 2 layers (2 × 1.5 mm)	Total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent) + fine hybrid composite Tetric A2 (Ivoclar Vivadent)	CAD/CAM-fabricated MOD-inlay: feldspatic ceramic (Vitablocs Mark II, Vita)
Spreafico et al. [19]	4 groups: 2 groups based on restorative material used for CMR and 2 subgroups based on material used for fabrication of the crowns.	(1) 3-step total-etch adhesive Optibond FL (Kerr) + Filtek Flow Supreme XTE (3M ESPE); (2) 3-step total-etch adhesive Optibond FL (Kerr) + Filtek Supreme XTE (3M ESPE)	2 layers (2 × 1 mm)	Total-etch adhesive Optibond FL (Kerr) + RelyX Ultimate (3M ESPE)	CAD/CAM-fabricated crowns: (1) resin composite with nanoceramic fillers (Lava Ultimate, 3M ESPE); (2) lithium disilicate (IPS e.max CAD, Ivoclar Vivadent)
Müller et al. [21]	3 groups: based on material used for luting the inlays	Scotchbond Universal Adhesive (3M ESPE) in total-etch mode + Filtek Supreme XTE (3M ESPE)	Not specified (layers of 2 mm)	(1) Scotchbond Universal Adhesive (3M ESPE) in total-etch mode + RelyX Ultimate (3M ESPE); (2) total etch adhesive Syntac Primer, Syntac Adhesive, Heliobond + Variolink II (Ivoclar Vivadent); (3) self-adhesive resin cement Panavia SA Cement (Kuraray)	CAD/CAM-fabricated MOD-inlay: resin composite with nanoceramic fillers (Lava Ultimate, 3M ESPE)
Marginal adaptation and fracture behaviour					
Ilgenstein et al. [18]	4 groups: 2 groups based on presence or absence of CMR and 2 subgroups based on material used for fabrication of the onlays.	3-step total-etch adhesive Optibond FL (Kerr) + Tetric EvoCeram (Ivoclar Vivadent)	2 layers (2 × 1 mm)	Scotchbond Universal Adhesive (3M ESPE) in total-etch mode + RelyX Ultimate (3M ESPE)	CAD/CAM-fabricated MOD-onlay: (1) feldspatic ceramic (Vitablocs Mark II, Vita): (2) resin composite with nanoceramic fillers (Lava Ultimate, 3M ESPE)
Microtensile bond strength					
Da Silva Gonçalves et al. [20]	4 groups: 2 groups based on presence or absence of CMR and 2 groups based on resin cement used for luting the inlays.	Total-etch adhesive system Adper Scotchbond 1 XT (3M ESPE) + Filtek Z250 (3M ESPE)	2 layers (2 × 1 mm)	(1) total-etch adhesive system Adper Scotchbond 1 XT (3M ESPE) + Relyx AEC; (2) self-adhesive resin cement G-Cem (GC Corp.)	Indirect laboratory made composite inlay (Gradia Indirect; GC Corp.)

The influence of CMR on the marginal integrity of indirect restorations made of different materials was the issue investigated and discussed in two studies [18,19]. In both studies the restorations were prepared by CAD/CAM technology. One study tested onlays milled of feldspathic ceramic (VITABLOCS Mark II, Vita Zahnfabrik, Bad Säckingen, Germany) and composite resin blocks with nanoceramic fillers (LAVA Ultimate; 3M ESPE, St. Paul, MN, USA) [18], while another study used the same composite blocks (LAVA Ultimate) to fabricate crowns and compared their behavior to crowns made of lithium disilicate (IPS e.max, Ivoclar Vivadent, Schaan, Liechtenstein) [19]. These two studies reported, to a certain extent, conflicting results. While Spreafico et al. [19] found no significant differences in marginal integrity between margins with and without CMR for both types of crowns, before or after TML, Ilgenstein et al. [18] revealed that composite inlays exhibited overall better marginal integrity compared to ceramic inlays. In particular, at the tooth/composite interface after TML, composite inlays luted directly to dentin measured significantly higher percentage of continuous margins than any other group. In addition, comparing only the groups with CMR at the onlay/luting composite interface, before and after TML, a significant reduction in marginal quality was detected in specimens restored with ceramic onlays, while degradation of the margin was not observed for teeth restored with composite onlays. It should be mentioned that the restorative material LAVA Ultimate CAD/CAM used for fabrication of crowns [19], the manufacturer no longer indicates for crowns. The material continues to be indicated only for restorations with an internal retentive design element (such as inlays and onlays) and veneer restorations. This is to be considered when interpreting the results of the studies investigating on crowns made of this material.

The study by Müller et al. focused on the material for luting the inlays, when bonded directly to dentin of deep proximal cavities and when bonded to restorative composite material used for CMR [21]. No difference was observed in terms of marginal integrity for luting the inlays directly to dentine or composite used for CMR. Also, no significant reduction of integrity was found after TML and all investigated materials showed promising results for luting the indirect restorations. Therefore, this study suggests that there is no difference in bonding the inlay to dentine or composite used for CMR. However, the critical interface between the dentin below CEJ and CMR composite was the matter of interest of this study.

3.1.2. Fracture behavior

The study by Ilgenstein et al. [18] additionally investigated the impact of CMR and material of CAD/CAM onlays on the fracture behavior of endodontically treated molars. After TML the teeth were subjected to load until failure in order to determine the resistance to fracture and the fracture pattern. The lowest mean fracture value was recorded for group without CMR and feldspathic ceramic onlay and the highest mean value for group without CMR and composite resin onlay. Between these two values there were the two groups that have undergone cervical margin relocation, which both revealed similar fracture resistance regardless of the material used for the onlay restoration. The only statistically significant difference in load to fracture was noticed between two groups without CMR. Additionally, the study demonstrated that ceramic restorations tend to have less severe fractures that do not involve tooth itself, whereas composite restorations transfer more stress to tooth structure causing catastrophic fractures below the bone level.

3.1.3. Bond strength

One study aimed to evaluate the influence of CMR on the microtensile bond strength (MTBS) of composite inlays to the proximal box floor [20]. The groups with proximal cervical margin located in dentin 1 mm below the CEJ were compared with those where cervical margins were relocated 1 mm above CEJ using a restorative composite (Filtek Z250; 3M ESPE) applied in two 1-mm thick increments. Further aim of this study was to compare the bond strength of inlays luted with two different cements: resin cement used with total-etch adhesive (RelyX ARC used in combination with Adper Scotchbond 1XT; 3M ESPE) and self-adhesive resin cement (G-Cem; GC Corp., Tokyo, Japan).

The results showed that MTBS values increased when the proximal cavity floor was elevated with a composite. However, this difference in bond strength was statistically significant only when self-adhesive resin cement was used for the cementation of the inlay. When resin cement with a total-etch adhesive was used for luting there was no significant difference between the groups with and without CMR. According to the authors, the main reason for such a result could be the good interaction between the resin composite used for CMR and the self-adhesive resin cement. When two luting cements were compared within the same location of the cervical margin, no significant differences in bond strength were recorded, regardless of their different mechanism of adhesion to dentin. However, one should also take into consideration that the failures during MTBS testing happened at the different interfaces. In both groups with CMR the most frequent mode of failure was adhesive failure between dentin and composite used for CMR, which supports the fact that good bonding is achieved between resin cement and CMR composite, as well as the fact that bonding to cervical dentin still remains challenging and unpredictable [11]. Also, noticeable difference in failure modes was reported in groups without CMR. While 60% of specimens cemented with self-adhesive resin cement failed adhesively between dentin and resin cement, the same percentage of specimens luted with a total-etch adhesive and a resin cement showed mixed adhesive failures.

3.2. Review of clinical reports

In the current literature no randomized controlled clinical trials or prospective or retrospective clinical studies on CMR technique could be found. One review article that specifically concentrated on this topic and that reported a clinical case was identified [23]. One article presented the principles of the technique [10]. In addition, several review articles on indirect adhesive restorations in posterior areas looked back also on the CMR technique [3,24,25]. These articles provided clinical documentation with a detailed description of the treatment protocol. The protocols suggested and described in the above mentioned articles became the matter of this part of the present review (Table 2).

3.2.1. CMR material

With regard to the most appropriate adhesive system and composite material employed for the supragingival relocation of the cervical margin, various recommendations were found in the current literature. Most of the reviewed articles consider a traditional 3-step total-etch adhesive as the preferred adhesive system [10,23,25], such as OptiBond FL (Primer and Adhesive, Kerr Corp., Orange, CA, USA) [10] or Syntac (Primer, Adhesive and Heliobond, Ivoclar Vivadent, Lichtenstein) [23]. In order to avoid over-etching of dentin in the subgingival area where enamel is usually very thin, if any is present, Rocca et al. suggest simultaneous etching of thin interproximal enamel in this area together with dentin only for 5–10 s, or, as an alternative, 2-step self-etch adhesive systems can be used without performing selective enamel etching [25].

Furthermore, both flowable as well as traditional viscous restorative composites could be selected for CMR technique, according to the mentioned studies. Specifically, in a case presented by Kielbassa and Philipp, a base of flowable composite

(Gaenial Universal Flo, GC Corp.) was applied, followed by small portions of filled viscous composite resin (Gaenial, GC Corp.) [23]. On the other hand, flowable composite in 1–1.5-mm thickness was proposed by Veneziani [3] and up to 2 mm thickness of the flowable or traditional restorative composite, in 1 or 2 increments, was suggested by Magne and Spreafico [10]. Besides, it was also noted that, if microhybrid or nanohybrid restoratives are to be used, they should be preheated, to facilitate placement and minimize the risk of interlayer gaps [10]. Moreover, two articles specify that highly filled flowable composites (e.g, Premise Flow; Kerr Corp.) or bulk fill flowables (e.g, SureFil SDR Flow; Dentsply Pty. Ltd., Victoria, Australia) are highly recommended for CMR, due to its consistency and ease of use [24,25]. Flowables should, however, not be used in thick layers, and their thickness should be limited to 1–1.5 mm [24,25]. As the margin should be relocated to at least 0.5 mm over the free gingival margin [25], if more material is needed, a combination of flowable and traditional restorative composite is proposed [24]. The light curing of the final composite increment should be protected by a thick layer of glycerin gel [10,25], as to eliminate the superficial oxygen inhibition layer, which can interfere with the setting of some impression materials [26].

3.2.2. Application technique

According to Veneziani, three different clinical situations can be identified, based on technical-operating and biological parameters [3]. Only in Grade 1, when rubber dam can be correctly placed in the sulcus sufficiently to show the cervical margin, the coronal relocation of the margin could be carried out. In the other two clinical situations, surgical exposition of the

Table 2
Overview of the clinical reports.

Author/ reference	CMR adhesive	CMR composite material	Thickness, number of CMR composite layers	Rubber dam isolation	Matrix and wedge application	Finishing of CMR composite	Treatment prior to bonding of final restoration	Luting agent of final restoration	Type of final indirect restoration	Follow-up period
Veneziani [3]	Not specified	Flowable composite	Flowable composite 1 to 1.5 mm thick	Yes	Circumferential stainless steel matrix and wooden wedge	Not specified	Not specified	Not specified	Composite onlays	Not applicable
Magne and Spreafico [10]	3-step total-etch adhesive (eg, OptiBond FL; Kerr)	Flowable or traditional restorative materials; microhybrid or nanohybrid restoratives should be preheated	2 mm thickness of the CMR composite (1 or 2 increments)	Yes	Modified curved Tofflemire matrix, matrix height reduced to 2 to 3 mm; if necessary matrix-in-a-matrix technique; wedging is typically not possible	Elimination of excess with no.12 blade or a sickle scaler	Cleaning with airborne-particle abrasion	Not specified	Indirect ceramic onlay	Two cases at 9 and 12 years follow-up
Kielbassa and Philipp [23]	3-step total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent)	Flowable composite (Gaenial Universal Flo, GC Corp.), followed by small portions of filled viscous composite resin (Gaenial, GC Corp.)	Not reported	No	Circumferential stainless steel matrix fixed in Tofflemire retainer and wooden wedge	Bucket-shaped diamond burs, flexible discs and polishing strips	Application of a primer (GC Corp.)	3-step total-etch adhesive Syntac Primer, Syntac Adhesive, Heliobond (Ivoclar Vivadent) and Variolink II resin cement (Ivoclar Vivadent)	CAD-CAM-fabricated ceramic inlay (IPS Empress CAD, Ivoclar Vivadent)	3 months
Dietschi and Spreafico [24]	Type of adhesive system not specified	Highly filled flowable composites are recommended (Premise Flow, Kerr) or a bulk fill flowable (eg, SureFil SDR Flow)	The use of flowable up to 1 to 1.5 mm; if more material is needed a combination of flowable and restorative composite is recommended	Yes	Full stainless steel or clear matrix and a wedge	Not specified	Not specified	Highly filled light-curing restorative composite material (eg, microhybrid Tetric, Ivoclar; or a homogenous nanohybrid (Inspiro, EdelweissDR)	CAD/CAM-fabricated restorations made of resin composite with nanoceramic fillers (Lava Ultimate, 3M ESPE)	Not applicable
Rocca et al. [25]	Total-etch or 2-step self-etch adhesive system	Highly filled flowable or hybrid composite	Limit to the minimum (1 to 1.5 mm) needed to bring the preparation supragingivally (at least 0.5 mm over the free gingival margin)	Yes	Curved matrix, full or sectional and a wedge (wedge when possible)	Fine diamond instruments to remove the excess	Sandblasting	Light-curing restorative material	In-lab composite resin onlays (Tetric Evo Ceram, Ivoclar Vivadent)	Not applicable

margin (Grade 2) or surgical lengthening of the clinical crown (Grade 3) is necessary in order to allow for correct isolation of the operating field. In accordance to these recommendations, the CMR technique is indeed contraindicated if the cervical preparation is not perfectly isolated with a rubber dam and a matrix [10,24,25]. Nevertheless, the case reported by Kielbassa and Philipp showed a clinical protocol where rubber dam was not used for relocation of the cervical margin [23]. The isolation with rubber dam did not prevent bleeding and therefore it was removed and the isolation was done using cotton rolls, dry-angles and saliva ejectors under utmost attention to prevent contamination [23].

The use of either circumferential or sectional matrix, either stainless steel or clear matrix is strongly advocated [3,10,23–25]. Specifically, curved matrices are recommended, as the curvature allows convergence, adequate emergence profile and a tight subgingival fit [10,25]. Moreover, reducing the height of the matrix to 2–3 mm is suggested, so it is slightly higher than the height of the CMR and in that way the matrix could slide subgingivally and seal the margin more efficiently [10]. In addition, in cases of extremely deep and localized subgingival cavities, the final option could be the matrix-in-a-matrix technique [10].

Regarding the wedging, although it was reported that wedging is typically not possible [10] or that it is not always possible [25], in most of the clinical cases presented in the published articles, matrix in combination with a wooden wedge was anyway applied [3,23,24].

3.2.3. Treatment of CMR prior to bonding of final restoration

In order to obtain well-defined margins, finishing and polishing of the restorative material placed at the cervical margin are required as the last step before impression taking. Elimination of the excess composite material could be done using a scalpel or a sickle scaler [10]. Fine diamond rotary instruments are suggested for removing the excess material, for finishing and polishing, as well as for obtaining the optimal cavity design [23,25]. Besides, finishing of the relocated cervical margins was also completed using flexible discs of decreasing grit and polishing strips [23]. However, the question remains how deeply subgingival interproximal margins could be reached by any of the mentioned materials and instruments.

Before proceeding with the final impression, Magne and Spreafico advise a bitewing radiograph to evaluate the adaptation of the CMR composite resin in the subgingival area and to make sure that there are no gaps or overhangs [10].

After taking digital or analog impression and fabrication of the final restoration, different protocols for treatment of the relocated margin were described. Most of the articles suggest cleaning the composite by sandblasting, using airborne-particle abrasion [10,25]. In one case the CMR composite resin was primed (GC Primer, GC Corp.) prior to adhesive luting of the final restoration, in order to achieve safe bonding, as reported by the authors [23].

3.2.4. Follow-up

The clinical case of left second maxillary molar restored with the CMR and CAD/CAM ceramic inlay presented by Kielbassa and Philipp [23] was followed up for 3 months. Clinical appearance showed no signs of inflamed papilla, probing did not reveal increased probing depth, no bleeding was observed on probing and no discomfort was reported by the patient.

Long-term clinical view and corresponding radiographs of two different cases, 9 and 12 years after treatment with CMR and indirect ceramic restorations, are available in the article by Magne and Spreafico [10].

4. Discussion

The idea to overcome the difficulties associated with the placement of restorations in the areas difficult to access by applying a base that is open to the oral environment underneath, originates from the “open sandwich technique” in direct composite Class II restorations. Initially, glass-ionomer cements (GICs) were proposed as a base material [27] and later, with advancements in dental material technology, resin-modified GICs [28], polyacid-modified resin composites [29] and flowable composites [30] were investigated. Frese et al. [31] described the restoration of extensively damaged teeth in two clinical steps and called it the “two-step R2-technique”. In the first step layers of flowable and viscous composites were applied to relocate the gingival margin supragingivally and in the second step a direct composite restoration was placed [31]. Similarly, CMR technique was proposed as an analog approach to be applied underneath the indirect adhesive restorations and for that purpose only composite resin materials were indicated [9].

The *in vitro* investigations analyzed in this review used composite materials of various manufacturers, chemical compositions and viscosities (Table 1). Based on the reported findings, the overall conclusion could be that the marginal integrity of the indirect restorations was not significantly influenced by the application of CMR. Also, the viscosity of the composite resin was not found to be crucial for the quality of the margins, whereas the application of composite in several thinner layers could be considered advisable. Regarding the influence of the restorative material used for fabrication of final indirect restoration on the integrity of the relocated cervical margins, no conclusive evidence could be found.

Nevertheless, the quality of marginal adaptation, as observed under a microscope, does not necessarily have to correspond to the quality of the marginal seal of the adhesively bonded composite material. Inadequate sealing ability may cause leakage of oral fluids and microorganisms along the tooth/composite interface, which represents one of the major causes of failure of composite restorations [32]. Microleakage at the gingival margins of direct Class II composite restorations [33,34], as well as of indirect restorations, both ceramic [35] and composite [36], has been well documented. In addition, application of flowable composite on the gingival margin as a liner in direct composite restorations did not reduce microleakage or improve clinical performance of the restorations [37]. Based on the available evidence, it could be assumed that applying a layer of composite underneath an indirect restoration would not prevent leakage. However, no study so far assessed the leakage at the gingival margins that have been relocated above CEJ with a composite resin. This would certainly be worth investigating in order to obtain more relevant information regarding the *in vitro* performance of the CMR.

It should also be noticed that in 6 laboratory studies investigating on the marginal integrity the interfaces that were examined were not always the same. As a matter of fact, in some of the studies it was not completely clearly described which of the margins were evaluated. Besides, the material adaptation to the enamel margins, judged in some of the studies, could not be considered essential for assessing the influence of the CMR technique on the marginal adaptation of indirect restorations. In the upcoming research more attention should be given to the most critical margin, the one in dentin, below the CEJ. Different aspects related to the adhesion of the composite material used for CMR to dentin and to indirect restorations, as well as to the analysis of the fracture behavior, the expected fracture pattern and the stress distribution could be the matter interest of future laboratory research.

Moreover, the recent meta-analysis indicates that the survival rate of ceramic inlays, onlays and overlays remains high (91%) after 10 years of follow-up time, regardless of the ceramic material, study design and study settings [2]. Another literature review reported 94% average success for ceramic and composite indirect restorations, concluding that the low failure rate prove them to be an excellent choice in treatment of both Class I and II lesions [1]. Nevertheless, the extent of the cavities below gingival margins was not included in any of the analysis and no distinction was made between cavities with proximal cervical margins in enamel and those in dentin, which could considerably affect the clinical outcome. The main problem discovered by the present review is that strong evidence on the clinical performance of teeth restored with CMR technique and an indirect adhesive restoration still does not exist. Only several presentations of the clinical cases could be found (Table 2), which is hardly sufficient for drawing any conclusions on the potential beneficial or harmful effects of this technique. Therefore, upcoming clinical research should focus on important issues related to restoration of Class II cavities extending below CEJ with indirect adhesive restorations and, specifically, to the application of CMR technique in such cases.

One of the possible concerns worth investigating is the response of the periodontal tissues to the coronally displaced margins following the CMR technique, as healthy periodontium is a prerequisite for a successful outcome of any kind of prosthetic or restorative therapy [38]. Although the margins of the final indirect restoration would be positioned supragingivally, another restorative margin, the one between the tooth and the composite used for CMR, remains deep below the gingival margin. This could still produce detrimental effects, such as gingival inflammation, loss of periodontal attachment and bone resorption [39]. Therefore, it is necessary to scientifically prove, through clinical studies, if the CMR technique could indeed represent the alternative to surgical crown lengthening or orthodontic extrusion if there is no compliance with the biological width.

Furthermore, reviewing clinical reports on CMR technique, it was noticed that there is a lack of consensus on the isolation and the application technique. According to several studies, CMR technique should be performed only if the rubber dam, correctly sheathed in the sulcus, is sufficient to show and isolate the cervical margin. Nevertheless, in the clinical cases reported in the literature CMR was also performed without rubber dam isolation. This should, however, not be a matter of discussion, as placing CMR composite material in deep subgingival areas without rubber dam isolation, could seriously threaten the quality of adhesion, particularly having in mind the fact that adhesion to dentin is not as strong and durable as adhesion to enamel [11,40]. In addition, the meta-analyses on clinical outcomes of direct Class II [41] and Class V [42] direct restorations demonstrated that the use of rubber dam significantly influenced the clinical performance and longevity of the restorations. Hence, if it is not possible to isolate the subgingival margins with a rubber dam, an important question that arises is whether or not the CMR technique is indicated.

Finally, after the restoration has been placed and the periodontal tissues have healed, the patient needs to be able to adequately maintain the oral hygiene. If the margins between the tooth and the restoration could not be reached and cleaned in daily oral hygiene routines, no technique could be considered appropriate and successful outcome could not be expected. Therefore, apart from defining more precisely the indication area and strict clinical protocol, future well-designed randomized controlled clinical trials should concentrate on verifying the claimed advantageous features of CMR technique on the long-term clinical outcome of teeth restored with indirect adhesive restorations.

5. Conclusions

On the basis of the reviewed literature, it can be concluded that currently there is no strong scientific evidence that could either support or discourage the use of CMR technique prior to restoration of deep subgingival defects with indirect adhesive restorations. Randomized controlled clinical trials are necessary to provide the reliable evidence on the influence of CMR technique on the clinical performance, especially on the longevity of the restorations and the periodontal health.

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