

# Impact of Deep Margin Elevation Procedures Upon Periodontal Parameters: A Systematic Review

## Keywords

Inflammation  
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## ABSTRACT

*Introduction:* Deep margin elevation (DME) is an emerging technique attempting to minimize the need for surgical procedures (i.e., crown lengthening [CL]), deliver indirect restorations in one clinical session and reduce overall treatment time. The present study evaluated the impact of DME upon periodontal measurements based exclusively on human studies. *Methods:* A literature search was performed by two independent reviewers in several databases including PubMed, EMBASE, and Cochrane Central up to March 2022. This review searched for randomized human trials, cohort (prospective/retrospective) and/or case series studies using DME, reporting periodontal (i.e. marginal bone levels [MBL], probing depths [PD], bleeding on probing [BoP], recession [REC], clinical attachment level [CAL]), and the type of approach (non-surgical or surgical) with at least >3 months of post-operative outcomes. *Results:* None of the included studies reported MBL, REC or CAL, and thus, results were limited to PD and BoP. BoP was increased when the distance between restorative margin and alveolar bone was approximately <2mm. Non-surgical and surgical DME approaches led to different outcomes in PD (0.26±0.77mm vs -0.39±0.85mm) and BoP (31.50% vs -22.33%). *Conclusions:* Limited findings of the present systematic review can be drawn and thus, the impact of DME upon the periodontium remains inconclusive.



## INTRODUCTION

Technical advances in restorative materials have promoted the rationale for minimally invasive dentistry. Often, this concept is associated with biomimetics, a philosophy that advocates tissue preservation and use of materials (e.g. composite resins, adhesive systems, ceramics) based on biomechanical principles.<sup>1</sup> These restorative materials should possess physical-mechanical properties similar to the applied surface (e.g. dentin, cement, and enamel) and as a result, adhesion will benefit from enhanced shear bonding strengths,<sup>2,3</sup> margin integrity,<sup>4-6</sup> and fracture resistance.<sup>7</sup>

The restoration of extensive caries lesions with loss of interproximal contact and subgingival margins is a real challenge for experienced clinicians.<sup>8</sup> Presence of deep proximal margins compromises the execution of several operative steps including caries removal, cavity preparation, impression techniques, rubber dam isolation, and detection and removal of excess cement during a prosthesis delivery.<sup>5,8,9</sup> The integrity of the margin interface can be significantly affected by surface contamination with saliva, blood, and gingival crevicular fluid leading into the formation of a layer that reduces surface stress and adhesive wettability.<sup>10,11</sup> Thus, bonding techniques are significantly decreased and affecting the longevity of the restorative margin.<sup>12</sup>



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Furthermore, a positive relationship between the location of restorative margin and gingival health has been established.<sup>13,14</sup> The presence of subgingival margins and overhanging restorations can lead to biofilm accumulation, dysbiosis and an increased risk for periodontal breakdown evidenced by inflammation (e.g., bleeding on probing [BoP]), increasing probing depths (PD), loss of clinical attachment level (CAL) and radiographic bone loss.<sup>15-17</sup> Severe signs of inflammation are likely to occur as the restorative margin is located 0.75 mm or less from the base of the gingival crevice.<sup>13</sup>

Surgical modalities (e.g. gingivectomy, crown lengthening [CL]) have been commonly implemented to facilitate operative steps, relocate the restorative margin and creating an environment favoring periodontal health.<sup>5,18,19</sup> Deep margin elevation (DME) is an emerging technique following the principles of biomimetics.<sup>9,20,21</sup> This approach consists in the application of direct resin composite upon natural tooth structure using a pre-molded metal matrix to relocate the margin for an indirect bonded restoration.<sup>4,22,23</sup> The technique attempts to minimize the need for CL, deliver indirect restorations in one clinical session and reduce overall treatment time.<sup>5,21,24</sup> Nonetheless, clinical evidence supporting DME is scarce and its impact upon periodontal structures remains uncertain.

To the knowledge of the authors, no systematic review has evaluated the periodontal status of sites undergoing DME. The aim of the present study was to evaluate the impact of DME upon the periodontal measurements based exclusively on human clinical data.

## METHODS

### INFORMATION SOURCES

An electronic and manual search of the literature was performed by two independent researchers (EC and CGP) in several databases including PubMed, EMBASE and Cochrane Central Register of Controlled Trials databases for articles published in English up to March 2022. The present protocol was registered in an international database of systematic reviews (PROSPERO) under the ID number: CRD42020193181.

### REVIEW (PICOS) QUESTION

The present review formulated a focus question using the PICOS criteria. Do human subjects (P) treated with DME (I) compared to sites without DME or CL (C) have different clinical and radiographic periodontal outcomes (O)?

- Population: Adult patients with a tooth undergoing DME procedures due to extensive caries
- Intervention: DME
- Comparison: Non-DME sites (control) or CL procedures

- Outcomes: >3 months post-operative outcomes related to marginal bone level (MBL), PD, BoP, recession (REC) and CAL as primary outcomes and plaque index (PI) or equivalent, gingival index (GI) or equivalent, margin integrity, distance of newly-established restorative coronal margin to apical margin of composite (CM-AMR) and to the base of the pocket (CM-APP), restoration survival rate, complications and time of follow-up as secondary outcomes
- Study design: Human randomized clinical trials (RCTs), prospective/retrospective cohorts and case series (>10 patients)

## SCREENING PROCESS AND SEARCH STRATEGY

A systematic search was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>25</sup> For the selected databases, a combination of terms and keywords, where “[tiab]”, “[tw]” and “[mh]” represents titles/abstracts, title, and MeSH terms, respectively, as depicted in Table 1.

Furthermore, a hand search was carried out in restorative and periodontal-related journals, which included: Journal of Dentistry, The American Journal of Esthetic Dentistry, Operative Dentistry, Journal of Prosthodontic Research, Journal of Periodontology, Journal of Clinical Periodontology and International Journal of Periodontics and Restorative Dentistry to ensure a thorough screening process up to March 2022. Also, we reviewed the reference lists of the included articles for full-text analysis and literature review articles. Google Scholar was used to identify potential articles among gray literature that were not included in the listed databases.

## ELIGIBILITY CRITERIA

RCTs, prospective/retrospective cohorts and case series (>10 patients) involving human subjects were included if DME was considered for the delivery of indirect restoration or single crown. In order to address the previously formulated PICOS questions, multiple pre-operative and post-operative variables were evaluated including MBL, BoP, PDs, REC and/or CAL, PI or equivalent, GI or equivalent, margin integrity, distance of CM-AMR and CM-APP, restoration survival rate, complications and time of follow-up. Articles were excluded if (I) DME was not performed, (II) published material in the form of *in vitro* studies, case series (<10 patients), literature reviews, letters, personal opinions, book chapters, or (III) articles in a language other than English (Table 1).

## DATA EXTRACTION AND ANALYSES

The same two independent authors (EC and CGP) performed the full-text evaluation based on the previously mentioned inclusion and exclusion criteria. Any disagreement was resolved by discussion between the two authors. Whenever the two authors fail to reach an agreement, a third reviewer (JG) was consulted.

**Table 1. Search strategy and selection criteria.**

Focused question	Do human subjects treated with DME (I) compared to sites without DME or CL (C) have different clinical and radiographic outcomes (O) as evidenced from human clinical studies (S)?
<b>PICOS</b>	Population: Patients with a tooth affected with extensive caries
	Intervention: DME
	Comparison: Non-DME sites (control) or CL procedures
	Outcomes: >3 months PD, MBL, BoP, CAL, REC, PI, GI, margin integrity, distance of CM-AMR, restoration survival rates, complications and time of follow-up
	Study Design: RCTs, prospective/retrospective cohorts, case series (>10 patients)
<b>Source</b>	PubMed: deep margin elevation [tiab] OR crown margin elevation [tiab] OR proximal box elevation [tiab] OR cervical margin relocation [tiab] OR proximal margin elevation [tiab] OR open sandwich technique [tiab] OR margin elevation technique [tiab] AND "treatment outcome" [MeSH] OR treatment outcome [tw] OR patient-relevant outcome [tw] OR patient relevant outcome [tw] OR patient-relevant outcomes [tw] OR clinical effectiveness [tw] OR treatment effectiveness [tw] OR rehabilitation outcome [tw] OR treatment efficacy [tw] OR clinical efficacy [tw]
	EMBASE: 'deep margin elevation':ti,ab OR 'proximal box elevation':ti,ab OR 'cervical margin relocation':ti,ab OR 'proximal margin elevation':ti,ab OR 'open sandwich technique':ti,ab OR 'margin elevation technique':ti,ab AND 'treatment outcome'/exp OR 'medical futility':ti,ab OR 'outcome and process assessment (health care)':ti,ab OR 'outcome and process assessment, health care':ti,ab OR 'outcome management':ti,ab OR 'patient outcome':ti,ab OR 'therapeutic outcome':ti,ab OR 'therapy outcome':ti,ab OR 'treatment outcome':ti,ab OR 'patient relevant outcome':ti,ab OR 'patient relevant outcomes':ti,ab OR 'clinical effectiveness':ti,ab OR 'treatment effectiveness':ti,ab OR 'rehabilitation outcome':ti,ab OR 'treatment efficacy':ti,ab OR 'clinical efficacy':ti,ab
	Cochrane CENTRAL: #1 (deep margin elevation):ti,ab,kw (Word variations have been searched), #2 (crown margin elevation):ti,ab,kw, #3 (proximal box elevation):ti,ab,k, #4 (proximal margin elevation):ti,ab,kw, #5 (open sandwich technique):ti,ab,kw, #6 (margin elevation technique):ti,ab,kw, #7 {OR #1-#6}, #8 MeSH descriptor: [Treatment Outcome] explode all trees, #9 (Treatment Outcome):ti,ab,kw, #10 (Patient-Relevant Outcome):ti,ab,kw, #11 (Patient Relevant Outcome):ti,ab,kw, #12 (Patient-Relevant Outcomes):ti,ab,kw, #13 (Clinical Effectiveness):ti,ab,kw, #14 (Treatment Effectiveness):ti,ab,kw, #15 (Rehabilitation Outcome):ti,ab,kw, #16 (Treatment Efficacy):ti,ab,kw, #17 (Clinical Efficacy):ti,ab,kw, #18 {OR #8-#17}, #19 #7 AND #18
	Journals: Journal of Dentistry, The American Journal of Esthetic Dentistry, Operative Dentistry, Journal of Prosthodontic Research, Journal of Periodontology, Journal of Clinical Periodontology and the International Journal of Periodontics and Restorative Dentistry
<b>Selection criteria</b>	Inclusion: Studies using DME for the treatment of extensive subgingival caries RCT, prospective/retrospective cohorts, case series
	Reported MBL, BoP, CAL, REC and/or PD as primary outcomes. PI, GI margin integrity, distance of CM-AMR and CM-APP, restoration survival rate, complications and time of follow-up as secondary outcomes
	Exclusion: Studies including < 10 patients DME was not performed Published material in the form of in vitro studies, literature reviews, letters, personal opinions, book chapters or in a language other than English

DME: Deep margin elevation; CL: Crown lengthening; RCT: Randomized clinical trials; MBL: Marginal bone level; PD: Probing depth; BoP: Bleeding on probing; CAL: Clinical attachment level, REC: Recession; PI: Plaque index; GI: Gingival index; CM-ARM: Distance from new restorative margin to apical margin of composite; CM-APP: Distance from the new restorative margin to base of the pocket; tiab: Title/abstract; tw: Title; mh: MeSH term

MBL changes, PD, BoP, REC and CAL were considered as the primary outcomes of DME procedures, whereas PI, GI, margin integrity, restoration survival rates, distance of CM-AMR and CM-APP, complications and time of follow-up were considered as secondary outcomes. Additionally, restorative parameters including material, bonding techniques, type of prosthesis were also recorded. All parameters were recorded and evaluated at 1) prior DME, and 2) after DME. Due to limited reported outcomes of the included investigations, only a qualitative synthesis was performed and systematically reviewed using tables. A high heterogeneity was noticed preventing a quantitative analysis, and thus, a meta-analysis was not possible. The reported data of this systematic review adhered to the PRISMA guidelines.<sup>25</sup>

## RISK OF BIAS AND QUALITY ASSESSMENT OF THE SELECTED STUDIES

The risk of bias and quality assessment was performed following the Cochrane Handbook for Systematic Review of Interventions.<sup>26</sup> The Newcastle-Ottawa Scale (NOS) was considered for non-randomized cohort studies,<sup>27</sup> and a critical appraisal checklist by the Joanna Briggs Institute (JBI) was used for case series.<sup>28</sup> Two authors (EC and CGP) evaluated the selected studies independently and resolved any disagreements by discussion to produce final scores. In brief, a low risk of bias was given when plausible bias is unlikely to alter the results or bias was low in all domains. An unclear risk of bias was estimated when plausible bias raised some doubts about the results or bias was unclear in one or more key domains. Ultimately, a high risk of bias was estimated when plausible bias seriously weakens the confidence in the results or bias was high in one or more key domains.<sup>26</sup>

## RESULTS

### STUDY SELECTION

Screening of the selected databases yielded a total of 30 articles, whereas 13 articles were identified through a manual search. Overall, 27 investigations were subject for further analysis after the elimination of duplicated articles. After screening of title/abstracts, 14 potential studies were reviewed in full-text analysis. Eleven articles failed to fulfill the inclusion criteria and were subsequently excluded (Supplemental Table 1). Finally, three articles fulfilled the inclusion criteria and were eligible for a qualitative analysis (Figure 1).

### CHARACTERISTICS OF THE INCLUDED INVESTIGATIONS

The characteristics of the included human studies were compiled in Table 2. Among the three articles, two of them were prospective cohort studies,<sup>19,29</sup> and one case series<sup>21</sup> that evaluated periodontal outcomes while using the DME technique. Control groups included sites not undergoing DME, but instead, proceeding with restorations with subgingival margins. One

study<sup>21</sup> proposed two forms of DME techniques including non-surgical and surgical approaches, whereas a gingival flap was required for access and facilitate complete isolation for the DME protocol. Papilla preservation techniques and magnification were encouraged when performing these procedures.<sup>21</sup>

Restorative materials for DME techniques included both flow and resin composite placed under self-etching bonding techniques for indirect restorations (e.g. onlays) or single crowns. Follow-up of included prospective cohort studies did not extend beyond 12 months while the case series study had an observation period for up to 5 years. None of the included studies provided information in regards the margin integrity, complications, or survival rates of the final restorations.

## QUALITY ASSESSMENT AND RISK OF BIAS OF INCLUDED STUDIES

The quality assessment and risk of bias for all included studies is shown in Figure 2 and Supplemental Tables 2-3. Most non-randomized studies included adequate exposed and non-exposed cohorts, ascertainment of exposure, demonstrated that outcomes were not present prior starting the study and comparable controls. Nonetheless, the ascertainment and measurement of the outcome were unclear or incomplete. Adequacy of follow-up and protocols were not standardized and subject for unclear bias. On the other hand, the risk of bias of the case series was deemed unclear in almost all categories due to incomplete reporting of data.

## PERIODONTAL OUTCOMES

A summary of the main findings from the present study were included in Tables 3 and 4. Among the most reported outcomes were PD and BoP while signs of inflammation and amount of plaque were measured using different indexes, which prevented further comparisons. Preoperatively, PDs among the included studies ranged between 1.95 - 3.60 mm with BoP ranging between 0 - 100%, and fairly associated with low levels of biofilm. Furthermore, none of the included studies reported MBL, REC nor CAL, and lack of a definitive pre-operative periodontal diagnosis.

The distance between CM-AMR was 5.59 mm immediately after DME and the CM-APP was 5.14 mm after 3 months indicating the cervical edge of the restoration was within the attachment apparatus as reported only in one study.<sup>29</sup> It was estimated that DME sites had restorative margins approximately 2 mm deep from the free gingival margin.

Among the included studies, reduction in PDs and signs of inflammation (i.e., BoP, full-mouth bleeding scores [FMBS]) was observed after 3 months<sup>29</sup> and 1-year of DME procedures.<sup>21</sup> Conversely, a slight increase within the same parameters were noted in another study.<sup>19</sup> Only one study reported findings extending up to 5.6 years without significant differences from the 1-year data.<sup>21</sup> Seemingly, BoP was increased when the distance between restorative margin and alveolar bone was approximately 2 mm or less.<sup>19</sup>

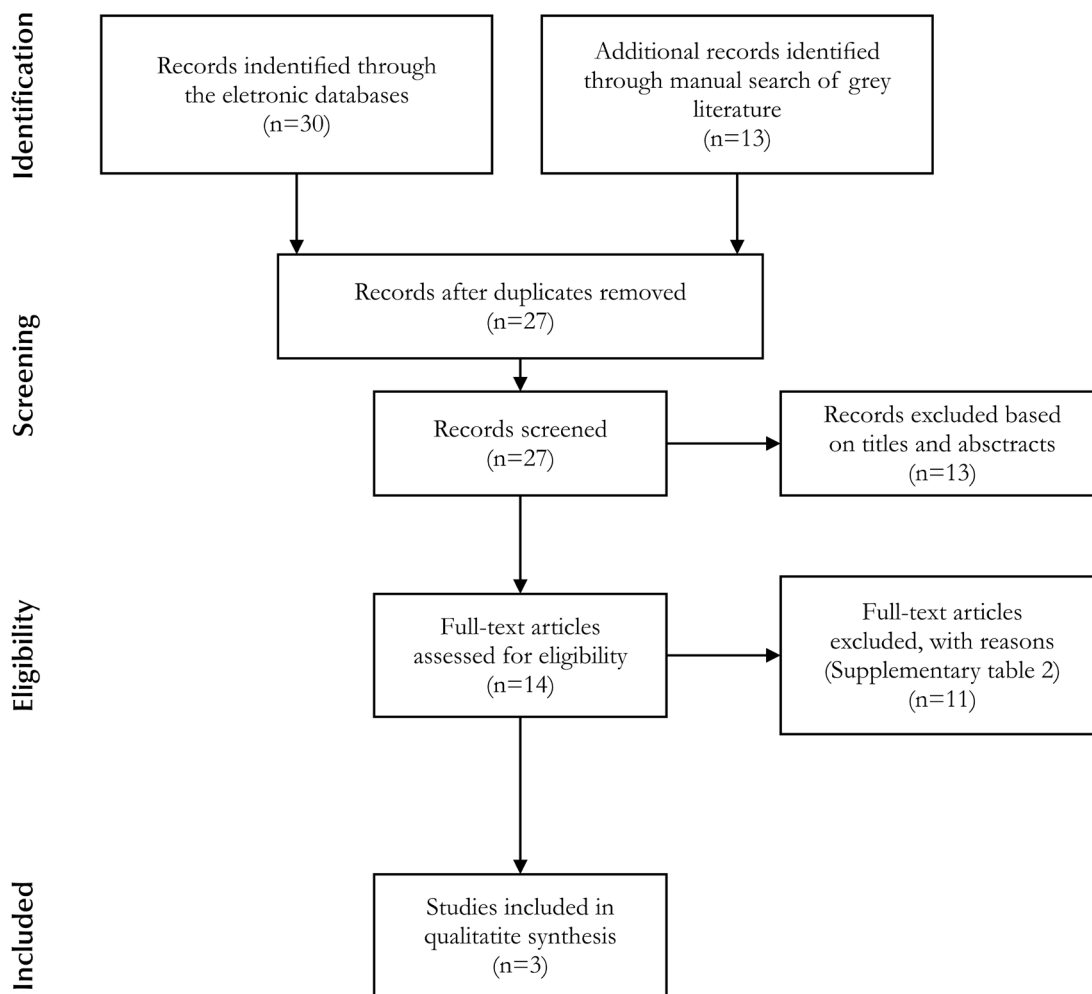


Figure 1: Flow chart

Table 2. Characteristics of the included articles

Study	Type of study	Sample Size (subject)	Sample Size (tooth)	Age (SD) (years)	Groups	Hx of periodontal disease (Yes/No, %)	Smokers (Yes/No, %)	Mean Follow-up (SD) (months)	Restorative materials for DME	Type of restoration
Ferrari et al. (2018) <sup>19</sup>	Prospective cohort	35	35	48.5 (3.7)	Non-DME group	No	N/A	12	Flow composite	Onlay
				43.2 (5.3)	DME group					
Ghezzi et al. (2019) <sup>21</sup>	Prospective case series	5	5	N/A	Non surgical DME	N/A	N/A	68.4 (N/A)	Nanohybrid composite	Onlays
					Flap access DME					
					Osseous/CL					
Bertoldi et al. (2020) <sup>29</sup>	Prospective cohort	29	29	45.3 (12.4)	Control Test (DME group)	Yes (N/A)	No	3	Composite	Crowns

SD: Standard deviation; DME: Deep margin elevation; CL: Crown lengthening; N/A: Not available

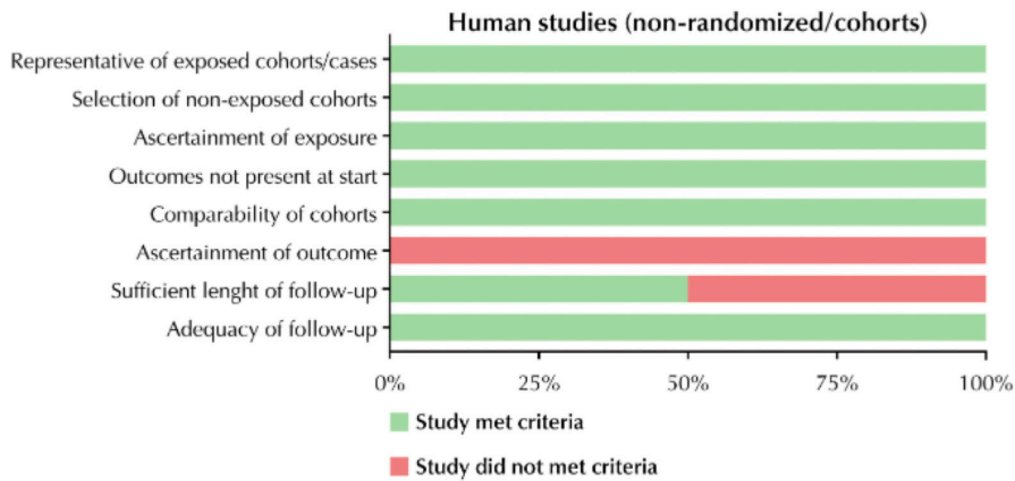


Figure 2: Assessment of quality and risk of bias

Table 3. Clinical and radiographic parameters prior DME procedures.

Study	Groups	PD (mm)	BoP (%)	MBL (mm)	GI (Score)	PI (%)	FMPS (%)	FMBS (%)	CM-AMR
Ferrari et al. (2018) <sup>19</sup>	Control	2.40 (0.25)	0.0 (N/A)	N/A	0.0 (N/A)	0.0 (N/A)	N/A	N/A	N/A
	DME	2.30 (0.40)	0.0 (N/A)		0.0 (N/A)	0.0 (N/A)			
Ghezzi et al. (2019) <sup>21</sup>	Non-surgical DME	3.00 (0.71)	100 (N/A)	N/A	N/A	N/A	N/A	N/A	N/A
	Flap access DME	3.60 (1.14)	100 (N/A)						
	Osseous/CL	3.60 (0.71)	100 (N/A)						
Bertoldi et al. (2020) <sup>29</sup>	Control	1.95 (0.64)	N/A	N/A	N/A	N/A	13.01 (1.12)	9.27 (2.10)	N/A
	DME	2.57 (0.61)							

DME: Deep margin elevation; CL: Crown lengthening; PD: Probing depths; BoP: Bleeding on probing; MBL: Marginal bone level; GI: Gingival index; PI: Plaque index; FMPS: Full-mouth plaque scores; FMBS: Full-mouth bleeding scores; CM-AMR: Crown margin to apical margin of restoration; N/A: Not available

While considering the type of approach for DME techniques (Figure 3, Supplemental Table 4), non-surgical DME procedures lead to a slight increase in PDs ( $0.26 \pm 0.77\text{mm}$ ) and BoP (31.50%) whereas surgical approaches displayed a modest reduction in PDs ( $-0.39 \pm 0.85\text{mm}$ ) and BoP (-22.33%). Conversely, CL procedures revealed more significant reductions in both PDs ( $-1.20\text{ mm}$ ) and BoP (-60 %) when compared to DME techniques.

## DISCUSSION

The reconstruction of posterior proximal caries lesions presents with numerous clinical complexities including limited access, difficulty for proper isolation, controlling material adaptation, and an adequate emergence profile

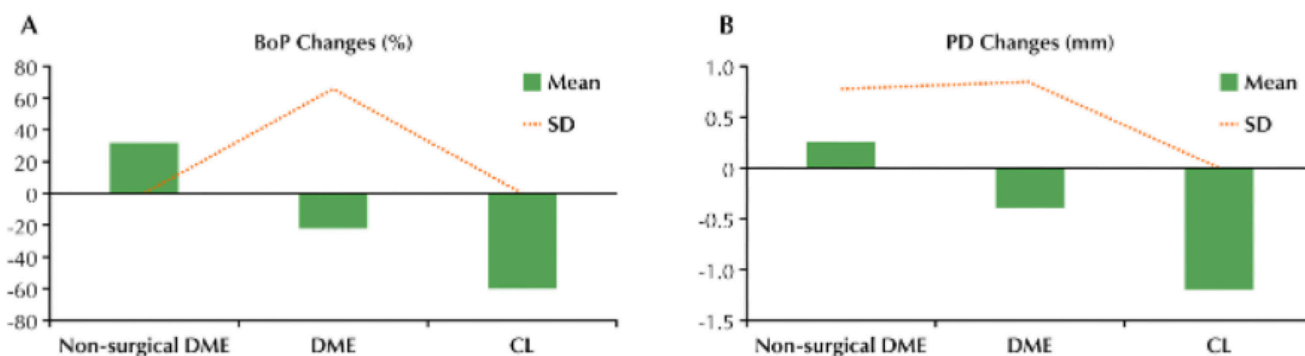
for an efficient interdental cleaning. To overcome these limitations, DME procedures have been suggested for the placement of base restorative materials in areas with difficult access to minimize detrimental effects on adhesion and adjacent periodontal structures.<sup>9,22,23,30-32</sup> Glass-ionomer cements (GIC) were proposed as the first base material,<sup>33</sup> and later, with advancements in dental material technology, newer base materials were introduced such as resin-modified GICs,<sup>34</sup> polyacid-modified resin composites<sup>35</sup> and flowable composites<sup>36</sup> to achieve to purpose of DME procedures.

Indirect restorations placed at sites treated with DME have shown a cumulative survival rate of 95.9% up to 12 years.<sup>37</sup> Eight out of 197 restorations suffered from absolute failures correlated with recurrent caries, fracture of restoration/tooth, debonding of restoration, root caries and pulpal necrosis.

**Table 4. Post-operative outcomes after DME procedures.**

Study	Groups	Follow-up 1 (months)	PD (mm)	BoP (%)	MBL (mm)	GI (Score)	PI (%)	FMPS (%)	FMBS (%)	CM-APP (mm)	Survival rate (%)	Follow-up 2 (months)	PD (mm)
Ferrari et al. (2018) <sup>19</sup>	Non-DME group	12	3.2 (0.35)	31.5 (N/A)	N/A	N/A	8.3 (N/A)	N/A	N/A	N/A	100	N/A	N/A
	DME group		3.1 (0.25)	53.0 (N/A)			20.0 (N/A)						
Ghezzi et al. (2019) <sup>21</sup>	Non surgical DME	12	2.4 (0.55)	40 (N/A)	N/A	N/A	N/A	N/A	N/A	N/A	100	62.4 (N/A)	2.0 (0.0)
	Flap access DME		2.8 (0.84)	40 (N/A)									
	Osseous/CL		2.4 (0.55)	40 (N/A)									
Bertoldi et al. (2020) <sup>29</sup>	Control	3	1.66 (0.56)	N/A	N/A	N/A	N/A	11.48 (1.89)	7.48 (2.24)	N/A	N/A	N/A	N/A
	Test (DME group)		2.21 (0.68)					5.14 (2.10)					

DME: Deep margin elevation; CL: Crown lengthening; PD: Probing depths; BoP: Bleeding on probing; MBL: Marginal bone loss; GI: Gingival index; PI: Plaque index; FMPS: Full-mouth plaque scores; FMBS: Full-mouth bleeding scores; CM-APP: Crown margin to most apical position of pocket; N/A: Not available.



**Figure 3:** Changes between controls (non-DME), non-surgical and surgical DME sites. (A) BoP and (B) PD

Interestingly, the occurrence of fractures was heavily associated with the presence of endodontic treatment. Observations from *in vitro* studies have shown that there is no influence of DME upon the fracture resistance of indirectly restored teeth.<sup>38</sup> As a matter of fact, studies evaluating the marginal quality of restorations with DME were not different when compared with restorations cemented directly on dental structure.<sup>5,24,39</sup>

Clinical trials included the present review used flowable, conventional and nanohybrid composites while performing DME procedures. When performed with packable composite resins, three consecutive 1 mm layers resulted in a better performance than a single increments in relation to the marginal quality.<sup>4</sup> In case DME is performed in a single increment, bulk-fill resin composite is recommended.<sup>40</sup>

Studies comparing the marginal quality of elevated margins with flowable and packable resin found no difference.<sup>39,41,42</sup> Although flowable resin composite have a superior internal adaptation to those that are more viscous, it reduces the risk of interfacial defects when using single 1 mm increments.<sup>43</sup>

Surgical procedures, such as CL, are usually recommended when the distance from the restorative margin to the alveolar crest is less than 3.0 mm,<sup>8,44</sup> in order to avoid invasion of supracrestal tissue height (STH) and prevent gingival inflammation over time.<sup>45,46</sup> Still, this concept has been subject of discussion as clinical reports have recorded an absence of inflammation after 12 months in teeth associated with margins below the recommended distance.<sup>47</sup> Gingival rebound, reestablishment of STH and changes in CAL promoted by surgical CL has questioned the dimensions of the STH for an

adequate environment associated with health.<sup>48,49</sup> According to Ghezzi *et al* (2019), it is important to establish a minimum space of 1.5 to 2 mm between the restoration margin and the alveolar bone crest.<sup>21</sup> This distance is necessary to allow for isolation and, at the same time, provide the space for the connective tissue of the STH.

In this sense, a myriad of studies shown a degree of tolerance between periodontal tissues and composite resins as long as adequate bonding protocols and proper isolation are being performed.<sup>50</sup> An inadequate superficial roughness of the restoration can lead to the accumulation of bacterial biofilm and consequently, periodontal breakdown is likely to occur.<sup>51,52</sup> As such, DME consider to be a technique-sensitive procedure.

Most of the included studies did not provide an accurate periodontal status, collect baseline measurements at different timepoints (before or immediately after DME procedures) or shared information in regards the susceptibility for disease (i.e., history of periodontitis, systemic diseases and/or environmental habits [smoking]) among the recruited subjects. This information is essential to perform a proper periodontal risk assessment. Patients with history or presence of known risk factors associated with periodontitis possess a higher risk for recurrence of periodontitis.<sup>53</sup> Moreover, limited follow-ups, the lack of MBL and CAL measurements prevented to acknowledge the presence and/or progression of periodontal disease and properly evaluate the effects of the invasion of STH.

In regards the post-operative outcomes of DME, a slight PD reduction (0.36 - 1 mm) was observed within two studies after 3 to 12 months,<sup>21,29</sup> whereas a 0.8mm increase PDs was noted in another study.<sup>19</sup> A possible explanation for PD changes could be related to pre-operative plaque scores and signs of inflammation (i.e., BoP, GI scores). Ferrari *et al.* (2018) reported a lack of inflammation (0% BoP and GI) and biofilm (0% PI) at baseline and a significant increase in both BoP (53.0%), GI (0.42 score) and PI (20.0%) 12 months post-DME.<sup>19</sup> On the other hand, Ghezzi *et al.* (2019) noted a significant reduction in PD (1 mm) and BoP (60%) 12 months after DME when initial BoP were 100%.<sup>29</sup> Although it remains unclear if the establishment or resolution of inflammation is due to the invasion of the STH, the removal of the biofilm or the caries lesion, it is well known that if the distance between restorative margin and alveolar bone is approximately 2 mm or less, more signs of inflammation are expected as noted in classic periodontal literature.<sup>14,15,19,54</sup>

From a histologic point of view, it is clear that no true attachment could be attained upon the restorative material and the presence of subgingival restorations could lead to periodontal breakdown and recurrence of caries lesions. However, limited studies have identified that with adequate restorative protocols, the establishment of a STH composed of a long junctional epithelium adjacent to the restorative material is still possible.<sup>55</sup>

If clinicians are able to control detrimental factors impairing adhesion protocols, it is plausible that DME procedures might reduce the need for surgical interventions and esthetic concerns as a result from CL procedures. As such, non-surgical and surgical DME approaches have been compared to traditional CL procedures. Ghezzi *et al.* (2019) reported changes in PD and BoP were fairly similar at sites treated with non-surgical DME, surgical DME with no ostectomy and CL.<sup>29</sup> As a matter of fact, the data presented in this study suggests that non-surgical DME can cause a slight increase in PD and BoP, whereas surgical DME and CL have an opposite effect being more pronounce with CL procedures. Despite CL procedures have been historically desired to achieve a restorative material-tooth interface that is biologically compatible with the periodontium, DME can be considered as conservative approach as no ostectomy is required while preserving the integrity of the periodontal structures and prevent recession in esthetic areas.

There is no strong scientific evidence related the use of DME procedures.<sup>56</sup> The lack of radiographic data, preoperative periodontal status/conditions and well-controlled studies represents the major limitation of the studies included in the present systematic review. Thus, randomized and high-quality longitudinal studies are necessary to further explore the impact of DME procedures upon the periodontium. Future studies should consider performing a pre-operative comprehensive (clinical and radiographic) periodontal exam and proper risk assessment to fully understand the correlation between known risk factors (i.e., history of periodontitis, uncontrolled diabetes, smoking) and the long-term outcomes of DME. The findings of the present study should be carefully interpreted as future research is still required to validate the observations depicted here.

## CONCLUSIONS

In summary, the response of the periodontal tissues to DME procedures remains inconclusive. Limited findings of the present systematic review suggests that non-surgical DME may cause detrimental changes in the periodontium, whereas surgical DME might be performed without causing evident signs associated with periodontal breakdown, yet only limited to PD and BoP.

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## MANUFACTURERS' DETAILS

- Flow composite (Product name not reported, GC Co. Tokyo, Japan)
- Nanohybrid composite (Enamel plus Hri, Micerum, Avegno, Italy)
- Composite (Esthet-X HD, Dentsply, York, PA, USA)

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## SUPPLEMENTAL TABLES 1 - 4

**Supplemental Table 1. Excluded articles.**

Authors	Reason for exclusion
Andersson-Wenckert <i>et al.</i> 2002	No clinical or radiographic data were reported
Lindberg <i>et al.</i> 2003	No clinical or radiographic data were reported
Lindberg <i>et al.</i> 2007	No clinical or radiographic data were reported
Garcia-Godoy <i>et al.</i> 2010	No clinical or radiographic data were reported
Magne & Spreafico 2012	Case reports
Frese & Staehle 2014	Case report and critical review
Kielbassa & Phillip 2015	Case report and systematic review
Dablanca-Blanco <i>et al.</i> 2017	Case reports
Sarfati & Tirlet 2018	Case reports and critical review
Bresser <i>et al.</i> 2019	No clinical or radiographic data were reported
Alhassan & Bajunaid 2020	Case report

**Supplemental Table 2. Quality assessment of non-randomized studies based on the Newcastle-Ottawa Scale (NOS).**

Cohort studies	Selection			Comparability		Outcome		Total stars	
	Representativeness of the exposed cohort	Selection of the non-exposed cohorts	Ascertainment of exposure	Demonstration that outcome of interest was not present at the start of the study	Comparability of cohort on the bases of the design or analysis	Ascertainment of outcome	Follow-up long enough for outcomes to occur		Adequacy of follow-up of cohorts
Ferrari <i>et al.</i> 2018	*	*	*	*	*	/	*	*	7
Bertoldi <i>et al.</i> 2020	*	*	*	*	*	/	/	*	6

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability. /: Study did not meet criteria, \*: Study met criteria.

**Supplemental Table 3. Quality assessment of included human case series studies based on The Joanna Briggs Institute (JBI) critical appraisal checklist.**

Item	Publication	1	2	3	4	5	6	7	8	9	10	Risk of Bias
1	Ghezzi <i>et al.</i> 2019	1	1	1	1	1	1	1	1	0	1	Unclear

**Supplemental Table 4. PD and BOP changes between controls (non-DME), non-surgical and surgical DME sites.**

Author	Groups	PD changes (mm)	BOP changes (%)
<b>Ferrari et al. 2018</b>	Non-DME group	0.8 (N/A)	31.5 (N/A)
	DME group	0.8 (N/A)	53.0 (N/A)
<b>Ghezzi et al. 2019</b>	Non surgical DME	-1.0 (N/A)	-60.0 (N/A)
	Flap access DME	-1.0 (N/A)	-60.0 (N/A)
	Osseous/CL	-1.2 (N/A)	-60.0 (N/A)
<b>Bertoldi et al. 2020</b>	Control	-0.29 (N/A)	N/A
	Test (DME group)	-0.36 (N/A)	N/A