SCIENTIFIC ARCHIVES OF DENTAL SCIENCES (ISSN: 2642-1623)

Volume 6 Issue 3 March 2023

Review Article

The Impact of Deep Marginal Elevation on the Periodontium: A Review Article

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Received: March 12, 2023; **Published:** April 06, 2023

Abstract

Deep marginal elevation (DME) can be defined as restorative exposure of the sub-gingival cavity preparation margin using different restorative materials, when the cavity is exposed sufficiently above the gingival margin to facilitate the final restoration (either direct or indirect). There is an ongoing debate regarding the difference between the impacts of DME and surgical crown lengthening on the periodontium. In surgical crown lengthening, controlled surgical removal of soft tissue and/or bone is carried out to expose the cavity margin while preserving the biological width. In contrast, in DME, depending on proper isolation and adaptation, cavity margin exposure is carried out using a restorative material. Thus, when DME is used, surgical crown lengthening complications and drawbacks can be avoided; however, violation of the biological width may occur. Due to the limitations of previously reported clinical studies and available data, this review was conducted to clarify and discuss the impact of DME on the surrounding periodontium.

Keywords: Deep Marginal Elevation; Crown Lengthening; Periodontium; Biological Width; Orthodontic Extrusion

Introduction

The presence of deep carious margins below the level of the gingiva represents a great challenge for restorative dentistry, either directly or indirectly, due to the gingival tissue occupying the space and the difficulties associated with isolation and gingival bleeding control. There exist a range of treatment options in this situation [1].

These approaches can be divided into two main categories, according to the direction of the approach. The cavity margin can be exposed above the gingival margin or elevated above the gingival margin, generating a new margin using definite restorative material. The critical decision involves choosing between exposure or elevation, each of which has several techniques for application. From a comprehensive point of view, utilizing restorative material to newly establish the cavity margin through elevation and exposure of the deep cavity margin is denoted as deep margin elevation (DME), defined as a restorative strategy which aims to preserve the dental structure and periodontal tissues, especially alveolar bone.

Considering that DME is not only a restorative procedure, Pasquale Venuti [1] has proposed the following classification of procedures:

- Soft tissue retraction: Rubber dam, cord, Teflon (class 1).
- Soft tissue ablation: Blade, diode laser, electrosurgery, soft tissue bur (class 2).
- Bone and soft tissue ablation: Surgical crown lengthening (SCL) (class 3).
- Dental tissue elevation: Orthodontic extrusion, the surgical extrusion technique (SET), and the partial exodontic technique (PET) [2-4] (class 4).

According to the classification of Pasquale Venuti [1], there are four classes-the first class involves restorative elevation of the cavity margin, while the remaining three classes involve exposure of the cavity margin to the oral cavity using a surgical or orthodontic option. In this review, deep marginal elevation (DME) is considered to express restorative marginal elevation only, according to the first class of the classification of Pasquale Venuti.

Deep marginal elevation (DME)

Class 1: Soft tissue retraction is carried out for deep cavity margin exposure, facilitating new restorative margin generation.

The acronym DME, presented originally by Dietschi and Spreafico [5] in 1993, initially referred to elevation of the deep carious margin by composite resin coronal to the gingival margin, in order to form a base for indirect bonded restoration. This simplifies the clinical procedures of impression, adaptation, and cementation, and can be used as an alternative non-invasive substitute for surgical crown lengthening. According to the abovementioned comprehensive point of view, DME cannot be considered accurate terminology for this procedure; instead, it should be denoted as restorative coronal margin relocation (RCMR). In addition to the supragingival elevation of the margin, the adhesive composite resin base is used to seal the dentin, reinforce undermined cusps, fill undercuts, and provide the necessary geometry for inlay/onlay restorations [6-9].

There has been some controversy regarding the properties of the material that can be used for DME, in terms of adaptation and endurance of forces and their effect on marginal integrity or fracture behavior for endodontically treated root; however, this has been denied by a study conducted on endodontically treated mandibular molar, restored with feldspathic ceramic onlays [10].

Restorative coronal margin relocation can be applied using different well-planned and non-irritating materials (e.g. resin-modified glass ionomers, compomers, and flowable composites) and various techniques (e.g. indirect bonded restorations, indirect non-bonded restorations, and direct restorations). The success of DME depends upon a number of factors, including operator skill, degree of saliva and blood isolation, matrix and restorative material adaptation to avoid secondary caries development or restoration failure, and smoothing and finishing of the final restoration [11].

Significant technical and operative challenges that may lead to drawbacks in deep margin elevation include [6]:

1. Isolation of the operatory field using a rubber dam, with risk of overhanging restoration.
2. Adhesive procedures, such as difficulty in removing excess cement after hardening or adhesion of composite cement to composite in DME.
3. Impression taking (traditional or optical) and adhesive luting.

According to Magne Pascal [6], there are 11 elements that are fundamental for successful RCMR:

1. Matrix selection: A curved matrix with greater curve is preferred, especially at CEJ level. Traditional matrix can be used, but insufficient marginal profile and contour may be generated.
2. Matrix stability is essential, depending on sufficient residual buccal and lingual wall, especially at extended elevation in the buccal and lingual directions.
3. Reduction of matrix height to be slightly higher than the desired elevation, in order to allow easy subgingival sliding and sufficient sealing (as wedging is not possible); for example, reducing the matrix height to 2 - 3 mm.
4. For endodontically treated teeth, sealing with glass ionomer over the canal orifice should be performed. DME can be carried out before endodontic treatment for proper isolation.
5. Matrix adaptation and seal: No gingival tissue and/or rubber dam should be present between the matrix and tooth structure.
6. Cavity margin finishing should be carried out using a fine diamond bur or oscillating tips (e.g. Hemisphere or Prep Ceram tips; KaVo) with abundant water spray.
7. Etching, bonding, and incremental application are conducted after matrix application, in order to relocate the margin coronally to about 2 mm.
8. Different types of composite resin can be used, such as microhybrid, nanohybrid, traditional, or flowable types. Composite pre-heating is recommended, which will facilitate incremental application. Final polymerization is conducted using glycerin gel.

9. Finishing of the elevated margin using a sickle scaler or no. 12 blade, checking the overhanging using interdental floss, and re-preparation of all enamel margins to remove excess adhesive resin.
10. Finally, radiographic evaluation using a bitewing radiograph, in order to check for overhanging composite resin or slippage of the resin apically compromising the gingival tissue [7].
11. The matrix-in-a-matrix technique represents the final option in the case of an extremely deep and localized lesion. This technique consists of sliding a sectioned fragment of metal matrix between the margin and existing matrix.

Deep marginal relocation remains a challenge; however, with the evolution of equipment (e.g. loops, microscopes, and even perioscopes) and restorative materials, DME has become more feasible and applicable. As such, the avoidance of SCL in acquiring a deep sub-gingival margin-that is, due to caries-is simply an issue of skills and expertise at present.

Surgical crown lengthening

Class 2: Soft tissue ablation: Blade, diode laser, electrosurgery, soft tissue bur.

Class 3: Bone and soft tissue ablation: Surgical crown lengthening (SCL).

Surgical crown lengthening can be performed by gingivectomy (Soft tissue ablation, class 1) and ostectomy with or without apically positioning the flap (Bone and soft tissue ablation, class 3), in order to facilitate restorative procedures. This provides a clinical tooth structure enabling the placement of restorative margins (either coronal or equigingival) and prevents pathological periodontal injuries in teeth with structurally inadequate clinical crowns. Blade, diode laser, electrosurgery, soft tissue bur, and piezosurgery can be used for surgical crown lengthening.

The apically positioned flap technique with osseous resection has been recommended, as relevant results indicated coronal movement of the gingival margin in the cases of gingivectomy alone led to relapse, while stability of the free gingival margin was noticed when conducting osteotomy procedures with apical positioning of the flap [13].

Aesthetic Crown Lengthening was classified by Ernesto [14] into four classes, mainly according to the surgical technique, such that it includes the surgical excision of the gingival tissue with or without removing the alveolar bone and the presence or absence of the biologic width violation.

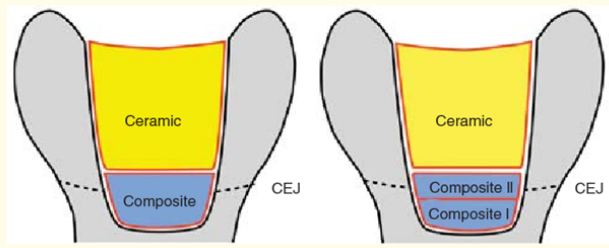

Figure 1: Depiction of deep marginal elevation (image created by Zaruba., *et al*. [12]).

Different tissue biotypes affect the amount of coronal displacement of the gingival margin, where a thick biotype may lead to more significant coronal displacement, compared to thin biotype, while may be due to the nature of the healing process. It should be noted that various factors, including the used surgical technique (e.g. with or without bone reduction), creation of a positive osseous architecture, timing of restoration, and plaque control, affect the coronal re-attachment of the gingival margin after surgical crown lengthening [13,15,16].

The decision of surgical crown lengthening must be completely evaluated and the balance between the benefits and risks must be estimated, as crown lengthening can lead to many complications, such as the following [17,18]:

1. Surgical loss of the periodontal attachment.
2. Anatomical complications such as the proximity of root concavities and furcations.
3. The possibility of coronal displacement of the gingival margin.
4. A negative impact of the underlying advantage of SCL on the ferrule effect when the clinician is forced to drill further at the peri-cervical part of the tooth, which is the most critical area from a biomechanical point of view.

Class 4: Dental tissue elevation: Orthodontic extrusion, surgical extrusion technique (SET), and partial exodontic technique (PET).

Partial exodontic technique

This includes partial extrusion of the tooth structure with minimal surgical trauma, mainly using a periotome. The surgical procedures are as follows: After local anesthesia, atraumatic extraction is performed using the periotome, with application of a walking action to cut the periodontal ligament without producing alveolar bone trauma. Simple extrusion is carried out using a hemostat. Tooth fixation is conducted using a simple interrupted suture and periodontal pack. Final restoration is performed after 2 months [19,20].

Orthodontic tooth extrusion/forced eruption

This technique is dependent upon orthodontics principles and osteophysiology, through application of continuous pulling forces to produce slow or rapid extrusion according to the used technique. This aims to expose the sound tooth for optimal placement of the restoration margin structure, allowing for preservation of the biological width and esthetics [21,22].

In slow orthodontic eruption, a light orthodontic force is applied, leading to slow extrusion of the tooth structure. Coronal migration of the gingiva, periodontal ligaments, and the bone also occurs due to the light tension on the periodontal ligament, causing osteoblast activation and deposition of new bone. After the desired crown length is achieved, surgical osteotomy is carried out, providing the advantage of preservation of the periodontium of the surrounding teeth, by virtue of new bone deposition, giving a key advantage over conventional crown lengthening [23,24].

In rapid orthodontic extrusion, the gingiva, periodontal ligaments, and alveolar bone are prevented from coronal migration with tooth structure extrusion. The prevention of bone migration is achieved through repeated fiberotomy procedures. The rationale of this procedure depends on maintaining inflammation at the gingiva, which prevents coronal movement of the alveolar bone [21].

Circumferential fiberotomy is carried out using a scalpel to resect the supracrestal fibers under infiltration anesthesia. This procedure is repeated each 7 to 10 days, in order to maintain inflammation at the marginal bone area [21].

Rapid tooth extrusion is preferred over slow tooth extrusion, as there is no need for the surgical osteotomy procedure [25]. Orthodontic tooth eruption is the preferred procedure for conventional crown lengthening, especially for esthetic areas, as it mainly preserves the periodontium of the adjacent teeth. However, it is an interdisciplinary treatment option, requiring continuous co-operation between the endodontist, periodontist, orthodontist, and prosthodontist [21].

Orthodontic extrusion is not possible in the following cases [21,26]:

a) Unfavorable axial tooth position;
b) Compromised periodontal health;
c) Short roots, resulting in inadequate crown-to root ratio;
d) Tapered roots;
e) Wide internal root form.

DME and the periodontium

Garguilo., *et al*. [27] have described the dimensions and relationship of the dentogingival junction in humans. In their study, the biologic width-which is the zone of the root from the crest of alveolar bone to the junction epithelium-averaged 2.04 mm. Meanwhile, Vacek., *et al*. [28] measured it to be 3.25 mm. These dimensions may vary from tooth to tooth, but it is present in all healthy dentition [29].

According to the concept of DME, the intracrevicular placement of the restorative margins violates the biological width, which may lead to elevated plaque accumulation and microbiological shifting, further leading to gingival and periodontal inflammation, manifesting as gingival redness, bleeding, pain, true pocket formation, and clinical attachment loss. Furthermore, bone loss and furcation involvement may occur, due to both extension of the inflammation to the bone and apical shifting of the bone to maintain the biological width [13,30,31]. Furthermore, Flores-de-Jacoby., *et al*. [17] have reported increased amounts of spirochetes, fusiforms, rods, and filamentous bacteria in the sub-gingival plaque.

The biological width is already interrupted by the carious lesion and, as a normal protective response by the vital tissue-that is, the epithelium, connective tissue (CT), and alveolar bone-a biological reaction occurs as the caries expands apically, the whole biologi-

<table>
<tr><th></th><th>Gingivectomy</th><th>Surgical crown lengthening SCL (osteotomy)</th><th>Deep marginal relocation</th><th>Orthodontic extrusion</th><th>Surgical extrusion</th></tr>
<tr><td>Indication</td><td>Gingival enlargement

Suprabony pocket

PD ≥ 5 mm</td><td>PD ≤ 4 mm

Bone removal is necessary</td><td>Substitute to conventional surgical crown lengthening, even with violation of BW.

Narrow and short extension of caries not more than 2 mm below CEJ.</td><td>Can be used as a substitute for conventional crown lengthening.

Can almost be used in almost all situations.</td><td>Can be performed by re-implantation of tooth or by minimally invasive technique using periotome.

Indicated mainly in single rooted teeth or remaining root.</td></tr>
<tr><td>Advantages</td><td>Easy

Rapid

No bone removal

Less painful, compared to SCL</td><td>Low relapse

Rapid outcome

No violation of biological width</td><td>No surgical intervention.</td><td>Easy

• Can be used when two surfaces or more of tooth structure are involved.

• Maintains the whole volume of bone and soft tissue.</td><td>• Rapid and easy surgical procedures.</td></tr>
<tr><td>Limitations</td><td>When bone removal is indicated

Periodontally compromised tooth</td><td>Closed roots

Molar with short trunk

Root curvature

Periodontally compromised tooth</td><td>Violation of BW without clinical complications is still controversial.

Only case reports or series support it.</td><td>• When it is difficult to apply orthodontic appliance or taking anchorage.

• Unfavorable axial tooth position.

• Compromised periodontal health.

• Tapered roots.

• Wide internal root form.</td><td>• Medically compromised patients.

• Patient acceptance.</td></tr>
<tr><td rowspan="2">Disadvantages</td><td colspan="2">Surgical trauma, post-operative complications (e.g., pain, bleeding), medical contraindication of surgery and patient acceptance.

• May compromise attached gingiva zone.

• Esthetic concern.</td><td rowspan="2">Limitations and challenges:

• Isolation.

• Cementation.

• Overhanging rest.

• Impression taking.

• Operation skills.</td><td rowspan="2">• Even rapid version requires time.

• In both types, surgical intervention is needed.</td><td rowspan="2">Surgical trauma and its complications.

• Risk of tooth ankylosis.

• Need to wait at least 2–3 months before completion of restorative procedures.

• Primary fixation failure.</td></tr>
<tr><td>High rate of relapse due to coronal movement of gingival margin.</td><td>Risk of exposing furcation areas affecting the adjacent teeth. This could be risky in patients with high caries risk profile. Possibility of ferrulization.</td></tr>
</table>

Table 2: *Comparison between different classes in the Pasquale Venuti classification.*

cal system moves apically (started by bone resorption), followed by apical movement of the CT and epithelium [32,33]. Thus, the carious cavity will always be slightly coronal to the bone level and, most of the time, coronal to the CT. The reason for this is that the only structure that undergoes a biological reaction after the 'restorative invasion' is the connective attachment [34].

Connective tissue and epithelium differ in their attachment to tissues or surfaces. Connective tissue is selective, attaching to the root cementum on one side and the bone on the other side. Histologically, adhesion of fibroblasts and connective tissue to restorations is still controversial. In contrast, attachment of the epithelium is not selective, as it can easily shaped by simple apposition of epithelial structures through the hemi-desmosomes on a surface, as long as the surface is hard, smooth, and clean [34,35].

Thus, the use of a hard, smooth, and clean surface is the key. Under healthy conditions, such a surface is represented by the enamel, cementum, and dentine while, in the context of DME, it is represented by the restorative material [34,36]. Material adaptation and surface texture play significant roles in the periodontal inflammatory response to sub-gingival restorations, where a smoother and more adapted restorative material means less inflammation [37-39].

In DME, soft and rough carious cavities, filled with bacteria, food debris, and decayed tissue, are replaced with the clean, smooth, and highly finished surfaces of the restorative material [34]. Therefore, after DME, we should expect the bone to maintain the same pre-operative marginal level. The improved environment surrounding the bone and the soft tissues allows for the formation of a healthy biological width [34].

There has not been a sufficient number of studies focused on the interaction between periodontal tissues with materials used more recently in the field of restorative dentistry. Dragoo [40] has proposed that the ideal characteristics of a sub-gingival restorative material include biocompatibility, dual-cure set, adhesiveness, fluoride release, radiopacity, compactness, surface hardness, insolubility in oral fluids, absence of microleakage, a low coefficient of thermal expansion, and low cure shrinkage. Unfortunately, it is difficult to find a material with all of these properties that can be readily used at present.

Oppermann., *et al*. [41] have compared deep marginal elevation (test group) and surgical crown lengthening (control group) for proximal carious cavities at pre-molar or molar teeth, in a randomized clinical trial using a split mouth study design. Visible plaque (VP), bleeding on probing (BOP), periodontal probing depth (PPD), and clinical attachment loss (CAL) were evaluated at baseline and at 45, 90, and 180 days, as well as by transperiodontal probing at baseline and at 180 days for ten patients. There were significant differences between all study parameters along the study periods, with no significant difference between the two study groups. In conclusion, proximal bonded restorations infringing on the PBW may not require clinical crown lengthening.

The systematic review by Mugri Maryam H., *et al*. [42] has evaluated the treatment prognosis of restored teeth with crown lengthening vs. deep margin elevation, from which it was concluded that DME has a better survival ratio, compared to crown lengthening, in vital and non-vital teeth using indirect restorations, However, the initial survival rate may degrade over time. This systematic review utilized only two studies on DME by the same author, where the first study evaluated the survival rate of 197 indirect restorations in 120 patients with a follow-up period of up to 12 years. There were eight failed restorations (only one was due to periodontal breakdown), while 50% of cases presented bleeding on probing [43].

A systematic review was conducted by Chun., *et al*. [44] using only human studies with at least 3 months follow up periods, to evaluate the impact of DME on periodontal tissues by measuring different periodontal parameters such as the PPD, CAL, recession (REC), BOP, and types of approach (non-surgical or surgical), while the radiographical measurements included the marginal bone levels (MBLs). No changes were found regarding the MBL, REC or CAL, but when the restoration margin was below 2 mm, the PD and BOP increased.

Bertoldi, Carlo., *et al*. [45] have clinically and histologically compared the response of supracrestal periodontal tissues to sub-gingival composite restorations versus natural root surfaces. A total of 29 subjects with a single tooth requiring sub-gingival restoration by a DME procedure using direct composite resin were included. Plaque score and bleeding score for all teeth were recorded. Furthermore, focal probing depth (PD) and clinical attachment gain, measured using the coronal marked (CM) point as reference point, were obtained at baseline and after 3 months. In the second stage, surgical crown lengthening was carried out for the treated teeth, and gingival samples were taken during surgery. The histological inflammation degree was evaluated in gingival tissue areas adjacent to the composite (group B) and adjacent to the natural surface of each single tooth (group A). Their results indicated significant decreases in plaque index, bleeding index, and PD, with significant attachment gain after 3 months. The inflammation level of gingival tissue was similar in groups A and B. The sub-gingival restoration results were compatible with gingival health, with levels similar to that of untreated root surfaces. In terms of clinical relevance, the deep margin elevation procedure produced favorable clinical and histological outcomes, allowing for its routine utilization in reconstructive dentistry.

By analyzing the study of Bertoldi, Carlo., *et al*. [45] a number of positive points were found regarding the results, as well as negative points regarding the study design. One of the important findings is the re-connection between the periodontal tissue and the composite resin material used in the DME through clinical attachment. However, with consideration of the study design, it was found that the bleeding and plaque indices were measured with respect to the whole mouth; however, it would be better to measure the selected tooth, in order to avoid overshadowing the results. Furthermore, in the selection of cases, the authors chose to clearly preserve the biological width, which reduced the presence of a clear challenge and led to result directing, as well as choosing wide carious cavities, thus facilitating the processes of filling and polishing.

A pilot study conducted by De Oliveira., *et al*. [46] aimed to examine the clinical and radiographic periodontal conditions in cases with biological width violation caused by overextending restoration margins in restored premolars and molars. The clinical periodontal parameters were analyzed using a computerized periodontal probe, BOP, and the mean plaque index, while the radiographic evaluation used a bitewing radiograph to measure the marginal bone level and intrabony defect. The results showed that 52.3% of resorted teeth had periodontal healthy conditions, 9.5% had gingivitis, 33.3% had mild periodontitis, and 4.7% had moderate periodontitis. The results of this study indicate that the periodontal tissues have an incredible adaptive reflex, depending on the selection criteria used for cases for which overextended and overhanging restorations were implemented.

Study	Study design	Impact of DME on gingival tissue	Study's recommendation regarding DME
De Oliveira., *et al*. (Pilot study)	Clinical and radiographic evaluation of biological width violation using overextending restoration.	Most of the cases have normal and healthy gingiva	Not Applicable
Oppermann., *et al*. (2016)	Compared DME (test group) with surgical crown lengthening (control group). Visible plaque, BOP, PPD, and CAL were measured at 45, 90, and 180 day follow-up periods.	Same as surgical crown lengthening	+ VE
Bertoldi, Carlo., *et al*. (2020)	Clinical and histological evaluation of gingival tissue's response to the composite used in DME versus the gingival tissue response around a sound tooth structure.	Similar clinical and histological responses	+ VE
Mugri Maryam H., *et al*. (Systematic review 2021)	Evaluated the treatment prognosis of DME versus surgical crown lengthening at vital and non-vital teeth.	Better than surgical crown lengthening	+ VE
Chun., *et al*. (Systematic review 2022)	Evaluated the impact of DME on periodontal measurements using only human studies.	NO changes at CAL, marginal bone level, and recession. Increase in PD and BOP	+ VE

Table 3: *Studies' recommendations regarding DME and its impact on gingival tissue.*

Most recent studies considering DME have concentrated on its abilities of proper and excellent adaptation and isolation, as well as smoothening and finishing of the composite resin, while one of the missing aspects is the continuous release over time of resin monomers and other ions, including their impact on the gingival tissue [47,48].

The initial release of free monomers may occur as short- and long-term processes. The short-term release is due to the polymerization process, while the long-term release of leachable substances is generated by erosion and degradation over time [49]. In addition, ion release and proliferation of bacteria at the interface between the restorative material and dental tissues are also implicated in the tissue response. Relevant molecular mechanisms involve glutathione depletion and reactive oxygen species (ROS) production as key factors leading to pulp or gingival cell apoptosis. It has also been shown that the exposure of the free surface of composite resins to oxygen during curing may produce a non-polymerized surface layer that contains formaldehyde; which, by itself, is an additional factor of cell toxicity [50]. Causes for degradation of the polymer include the salivary component of water and enzymatic reaction, chewing forces, thermal changes, chemical dietary changes, and oral microbes [51].

Conclusion

More updated studies focused on DME are required, while past studies need to be re-conducted considering state-of-the-art materials and modifications, taking into account recently proposed filling materials and techniques. This is especially the case regarding the recent widespread availability of magnification, laser, isolation, and adaptation techniques. Furthermore, more histological studies are required, in conjunction with microbiological studies and analyses of gingival crevicular fluid and its components. In this line, the presence and percentages of inflammatory markers (e.g. RANKL and OPG) may help in assessing the impact on bone integrity.

Author Contributions

Conceptualization, M.O.B and E.A.M.; methodology, M.O.B..; formal analysis, M.O.B and E.A.M.; investigation, M.O.B and H.A.B.; writing-original draft preparation, M.O.B.; writing-review and editing, M.O.B, E.A.M. and H.A.B.; project administration, H.A.B. All authors have read and agreed to the published version of the manuscript.

Funding Support

No fund.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data is contained within the article.

Conflicts of Interest

The authors declare no conflict of interest.

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