DOI: 10.36377/1683-2981-2021-19-3-175-183



# Deep margin elevation: a systematic review

© Z.S. Khabadze[1], I.V. Bagdasarova[1], E.S. Shilyaeva[1], A.P. Kotelnikova[1], D.A. Nazarova[1], Yu.A. Bakayev[1], S.M. Abdulkerimova[2]

[1]"Peoples' Friendship University of Russia" (RUDN University), Moscow, Russia

[2]National Medical Research Center of Dentistry and Oral and Maxillofacial Surgery, Moscow, Russia

**Abstract:**
Deep margin elevation (DME) is a nonsurgical, alternative technique of dental crown lengthening. Portion of direct restoration placed only at the deep apical part of the cavity to elevate the margin to a more coronal and more adequate position for final cementation of indirect restoration.
*Materials and methods.* In this systematic review, we were looking for in vitro studies in which deep margin elevation (DME) technique were used. The electronic databases PubMed and EMBASE were used for the search. The search began on July 29, 2021 and ended on August 10, 2021. We have analyzed the materials and methods of each research and entered them in the appropriate tables to give a clearer assessment of the obtained results.
*Results.* Analysis of marginal quality showed the best results when indirect restorations luted to dentin directly and with DME technique with three consecutive layers of resin composite. In groups without DME there were fewer microleakage. DME did not statistically significantly influence the fracture strength.
*Conclusions.* We conducted a systematic review that included 12 in vitro studies. Even though samples without DME showed better results in in vitro studies, the difference between samples with and without DME was not statistically significant. However, in clinical practice, DME facilitates the insertion of indirect restorations. Therefore, further studies and clinical observations are necessary.

**Keywords:** deep margin elevation, proximal box elevation, cervical margin relocation, onlay, inlay.

**Received:** 18.05.2021; **revised:** 22.08.2021; **accepted:** 30.08.2021.

**Conflict of interests:** The authors declare no conflict of interests.

**For citation:** Z.S. Khabadze, I.V. Bagdasarova, E.S. Shilyaeva, A.P. Kotelnikova, D.A. Nazarova, Yu.A. Bakayev, S.M. Abdulkerimova. Deep margin elevation: a systematic review. Endodontics today. 2021; 19(3):175-183. DOI: 10.36377/1683-2981-2021-19-3-175-183.

## INTRODUCTION

Deep proximal carious cavities are very difficult in daily clinical practice. Restorative dentistry attaches great importance to aesthetic restorations in combination with a long-term perspective of tooth service. Currently, indirect ceramic restorations are used to restore large cavities, as a good treatment alternative to direct composite fillings [1]. Unfortunately, the adhesive fixation of these restorations requires perfectly dry conditions for a relatively long time, which makes it difficult to insert them directly to the dentin in deep proximal boxes [2].

When the proximal caries extends close or below the cement-enamel junction (CEJ) in decayed teeth, a deep margin will be observed [3]. The deep margin [4] is a subgingival margin of the prepared carious cavity, which is formed after removing unsound tooth tissues from deep structural defects. Generally, these proximal boxes have a limited or complete absence of enamel [3]. In such situations, it is challenging to create dry conditions for further impression taking and adhesive cementation [5–9]. Moreover, the excess of material is hardly detectable and removable, because of the deep subgingival level.

Surgical crown lengthening can be a way to solve this problem by relocating the cavity margin to a supragingival position to create dry conditions during the luting procedure [5]. Unfortunately, it can lead to the destruction of the biological width, and since attachment loss is created, the clinical crown is lengthened, and part of the root including furcations and root concavities may become exposed [10].

There is an alternative solution that helps in avoiding surgical intervention and in producing tooth restoration in a single visit, the idea is based on the relocation of the subgingival proximal margin to a supragingival level [6–8] which occurs due to the use of a composite filling material. This technique was introduced by Dietschi and Spreafico [11] over 25 years ago and nowadays is called deep margin elevation (DME) [8]. It's also known as proximal box elevation or cervical margin relocation [5]. It is a nonsurgical technique which uses direct restorations placed only at the deep apical portion of the preparation to elevate the margin to a more coronal and more conducive position for final cementation of indirect restoration [8]. DME leaves the composite filling material exposed to the oral environment [12]. To place the direct resin composite in the deep cavity floor, a metal interproximal matrix is used [13].

This procedure provides several advantages, one of them is a faster, higher-quality and more convenient isolation with rubber dam, and maintaining dry conditions during the whole adhesive fixation of indirect restoration [6, 7]. Furthermore, the removal of excess luting composite is better controlled when the margin is relocated supragingivally [9]. The supragingival margins provide a simplified approach to optical and conventional impression taking [3, 7]. At last, liner or base is placed underneath inlays and onlays to avoid excess tissue preparation, which is necessary to fulfill geometrical restrictions of indirect restorations; which functions as a protective layer for pulpo-dentin complex under temporary fillings [11, 14].

However, there is some debates that DME can affect fracture strength and marginal quality, therefore, this review was conducted.

### Objectives

The primary goal of this systematic review was to evaluate the effect of deep margin elevation on the marginal quality of DME composite with indirect restoration and DME composite with tooth tissues. Secondarily, the review aimed at determining the fracture resistant of teeth with DME.

**MATERIALS AND METHODS**

The concept of this review is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Selection criteria

Publications that met the following selection criteria were included:

1. Full-text articles in English, not older than 10 years.
2. The articles should contain detailed information about the results and parameters of the study.
3. The articles contain studies conducted in vitro on human teeth.
4. The articles contain studies conducted using Deep Margin Elevation technique.
5. The object of study was either marginal quality or fracture resistant.

Publications that were not related to the topic of the study, literature reviews, as well as articles that did not have sufficient and specific data for the analysis were excluded.

**Information sources**

The electronic databases used for the search were PubMed and EMBASE. It was not necessary to contact the authors to access the articles.

**Search and Selection of Studies**

A search in English with no time limit was performed by 3 independent people. The following search query was used: [deep margin elevation OR deep proximal relocation OR cervical margin relocation AND technique].

The studies were filtered and selected in several stages. Firstly, they were evaluated by titles. Secondly, individual documents at the first stage were additionally assessed by reading the abstracts and full-text articles. The difference in the choice was resolved through discussion among the readers.

**Data collection process**

The data from different studies were extracted from studies according to the interests of the current review.

**Data items**

Data from the included articles were extracted and filled in tables (Table 1, Table 2, Table 3 and Table 4) with the following information: table 1: author, year, kind of study/study material, number of specimens, kind of teeth, kind of indirect restoration; table 2: author, design of cavity, deep of proximal cavity, experimental groups, measurements of study, evaluation method; table 3: author, cavity surface conditioning, restorative material for DME, material of indirect restoration, indirect restoration surface conditioning, indirect restoration fixation; table 4: author, test conditions, results.

**Risk of bias**

Risk assessment of bias was undertaken during the data extraction process. For the included studies, it was conducted using the Cochrane Collaboration's ROBINS-I tool for assessing the risk of bias [15-17]. Overall risk of bias was then assigned to each trial, according to Higginset al. [16]. The levels of bias were classified as follows: low risk, if all the criteria were met; moderate risk, when only one criterion was missing; high risk, if two or more criteria were missing; and unclear risk, if there were very few details to make a judgement about a certain risk assessment.

**Synthesis of results**

As mentioned, tables were presented with the columns as data items.

**Statistical analysis**

No meta-analysis could be performed due to the high heterogeneity between the studies and low number of studies.

**RESULTS**

**Study selection**

A total of 229 articles were identified by keywords and resumes. Duplicate studies were excluded. 48 articles were identified as potentially relevant articles by checking the titles and abstracts, then a full-text of 25 articles analysis

*Table 1.* **Characteristics of the studies included in this analysis.**

| # | Author | Year | Kind of study, study material | Number of pecies | Kind of teeth | Kind of indirect restoration |
|---|---|---|---|---|---|---|
| 1 | Bresser RA [18] | 2020 | In vitro, human teeth | 60 | Sound mandibular molars | Inlay and onlay |
| 2 | Müller V [19] | 2017 | In vitro, human teeth | 24 | Carious-free, intact, unrestored molars | Inlay |
| 3 | Frankenberger R [8] | 2013 | In vitro, human teeth | 48 | Intact, non-carious, unrestored third molars | Inlay |
| 4 | Roggendorf MJ [6] | 2012 | In vitro, human teeth | 40 | Intact, non-carious, unrestored third molars | Inlay |
| 5 | Ilgenstein I [9] | 2015 | In vitro, human teeth | 48 | Mandibular molars with similar dimensions at the cemento-enamel junc-tion (CEJ), but without any evidence of caries or fractures. Teeth were endodontically treated after selection. | Onlay |
| 6 | Da Silva Gonçalves D [2] | 2017 | In vitro, human teeth | 25 | Caries-free third molars | Inlay |
| 7 | Grubbs TD [20] | 2020 | In vitro, human teeth | 75 | Caries-free first or second mandibular molars | Onlay |
| 8 | Zhang H [21] | 2021 | In vitro, human teeth | 80 | Caries-free premolars Teeth were endodonti-cally treated after extraction | Crown (endocrown) |
| 9 | Köken S [22] | 2018 | In vitro, human teeth | 39 | Intact, healthy, similarly sized molars without visible cracks, cavities, or restorations | Overlays |
| 10 | Spreafico R [23] | 2016 | In vitro, human teeth | 40 | Molars with no decay or prior restorations, endodontically treated after selection | Crown |
| 11 | Juloski J [24] | 2020 | In vitro, human teeth | 14 | Intact, sound, similar sized molars without any visible cracks, cavities or restorations | Overlay |
| 12 | Rocca GT [14] | 2012 | In vitro, human teeth | 32 | Third molars without carious lesions | Inlay and onlay |

*Table 2.* **Parameters of experimental samples, measurements and evaluation methods.**

| # | Author | Design of cavity | Deep of proximal cavity | Experimental groups | Measurements of study | Evaluation method |
|---|---|---|---|---|---|---|
| 1 | Bresser RA [18] | Class II (MOD cavities: isthmus depth – 5 mm, from the highest cusp; isthmus width – 3 mm) | below CEJ | 4 groups 1. inlay without DME 2. inlay with DME 3. onlay without DME 4. onlay with DME | 1. Fracture strength | 1. Classification (optical microscope and digital photographs) 2. Scanning electron microscope (SEM) |
| 2 | Müller V [19] | Class II (standardized MOD cavities) | 2 mm below the CEJ | 3 groups: G1: Scotchbond Universal/ Rely X Ultimate G2: Syntac/Variolink II G3: No pretreatment needed/Panavia SA Cement | 1. Analysis of marginal quality | 1. Scanning electron microscope (SEM) |
| 3 | Frankenberger R [8] | Class II (standardized MOD cavities: isthmus occlusal depth – 3 mm, from the highest cusp; isthmus bucco-lingual width – 4 mm, 2 mm in depth at the bottom of the proximal box) | Mesially: 2 mm above the CEJ Distally: 2–3 mm below the CEJ | 6 groups: DME was in 5/6 experimental groups G1: RelyX Unicem G2: G-Cem G3: Maxcem Elite G4: Clearfi Majesty Posterior (1 layer) G5: Clearfi Majesty Posterior (3 layer) G6: no DME | 1. Analysis of marginal quality | 1. Scanning electron microscope (SEM) |
| 4 | Roggendorf MJ [6] | Class II (standardized MOD cavities: isthmus occlusal depth – 3 mm, from the highest cusp; isthmus bucco-lingual width – 4 mm, 2 mm in depth at the bottom of the proximal box) | Mesially: 2 mm above the CEJ Distally: 2–3 mm below the CEJ | 6 groups: DME was in 5/6 experimental groups G1: RelyX Unicem G2: G-Cem G3: Maxcem Elite G4: Clearfi Majesty Posterior (1 layer) G5: Clearfi Majesty Posterior (3 layer) G6: no DME | 1. Analysis of marginal quality | 1. Scanning electron microscope (SEM) |
| 5 | Ilgenstein I [9] | Class II (standardized MOD cavities: with an occlusal width of half of the intercuspal dimension) | Mesially: 1 mm above the CEJ Distally: 2 mm below the CEJ | 4 groups: G1: DME + ceramic restorations G2: DME + resin nano-ceramic restorations G3: only ceramic restorations G4: only resin nano-ceramic restorations | 1. Analysis of marginal adaptation 2. Fracture strength 3. Fracture behavior of ceramics and composite indirect reestorations | 1. Stereomicroscope 2. Scanning electron microscope (SEM) |
| 6 | Da Silva Gonçalves D [2] | Class II (standardized MOD cavities: isthmus occlusal depth – 2 mm, from the highest cusp; isthmus bucco-lingual width – 3 mm, 4 mm in depth at the bottom of the proximal box) | 1 mm below the CEJ | 4 groups: G1: No DME/RelyX ARC G2: DME/RelyX ARC G3: No DME/G-Cem G4: DME/G-Cem | 1. Microtensile bond strength | 1. Stereomicroscope 2. Scanning electron microscope (SEM) |
| 7 | Grubbs TD [20] | Class II (mesio-occlusal-distal (MOD) cavity) | Mesially: 1 mm above the CEJ Distally: 2 mm below the CEJ | 5 groups: G1: Fuji IX placed in a single 3-mm increment G2: resin-modified glass ionomer (RMGI) – Fuji II placed in two 1.5-mm increments G3: resin-based composite (RBC) – Filtek Supreme Ultra placed in two 1.5-mm increments G4: bulk-fill (BF) – Filtek Bulk Fill Posterior Restorative placed in a single 3-mm increment G5: control (no DME) | 1. Analysis of marginal adaptation 2. Fracture strength | 1. Scanning electron microscope (SEM) |
| 8 | Zhang H [21] | Class II (standardized MOD cavities: 5 mm in buccal-lingual extension, 2 mm width at the cervical area) | 2 mm below the CEJ (E1, E2, E3 groups) 3 mm below CEJ (E4 group) | 4 groups: G1: DME (bulk-fill Smart Dentin Replacement), subgingival proximal margins G2: DME (conventional resin composite), G3: no DME, subgingival proximal margins G4: no DME, supragingival proximal margins | 1. Fracture strength | 1. Stereomicroscope |
| 9 | Köken S [22] | Class II (standardized MOD cavities: axial walls had a thickness of 2 mm and were reduced for a cuspal coverage; proximal box: 1.5 mm in the mesiodistal and 4 mm in the buccolingual direction) | Mesially: 1 mm below the CEJ Distally: 1 mm above the CEJ | 3 groups: G1: DME in two increments of 1 mm with a viscous composite (Essentia) G2: DME in two increments of 1 mm with a flowable composite (G-ænial Universal Flo) G3 (control): no DME | 1. Evaluation of marginal seal 2. Analysis of microleakage | 1. Digital microscope |
| 10 | Spreafico R [23] | Class II (standardized 4-mm-wide MOD cavity) | Mesially: 2 mm below the CEJ Distally: 1 mm above the CEJ | 4 groups: (material of: DME/Indirect restoration) G1: Filteck Flow Supreme XTE/LAVA Ultimate G2: Filteck Supreme XTE/LAVA Ultimate G3: Filteck Flow Supreme XTE/PS e.max G4: Filteck Supreme XTE/IPS e.ma | 1. Analysis of marginal quality | 1. Scanning electron microscope (SEM) |

| # | Author | Design of cavity | Deep of proximal cavity | Experimental groups | Measurements of study | Evaluation method |
|---|---|---|---|---|---|---|
| 11 | Juloski J [24] | Class II (standardized MOD cavities: axial walls had 2 mm of thickness, and they were reduced for a cuspal coverage; proximal box: 2 mm in the mesio-distal and 5 mm in bucco-lingual direction) | 1 mm below the CEJ (both mesially and distally) | 2 groups: G1: DME/ Optibond FL/ Premise flowable/NX3 G2: DME/ Adhese Universal/ Tetric EvoFlow® Bulk Fill/ Variolink Esthetic | 1. Analysis of marginal quality 2. Analysis of microleakage | 1. Scanning electron microscope (SEM) 2. Digital microscope |
| 12 | Rocca GT [14] | Class II cavities (two surfaces, OD or OM: width – 4.0 mm, depth at the bottom of the proximal box – 2.0 mm, width and depth for the occlusal isthmus – 3.0 mm. | 1.0 mm below the CEJ | 4 groups: G1 (control): without DME G2: Premise Flow A2/ Prophy-Jet G3: Premise Flow A2/ Airborne particle abrasion G4: Premise A2/ Airborne particle abrasion | 1. Analysis of restoration margin 2. Analysis of internal adaptation | 1. Scanning electron microscope (SEM) |

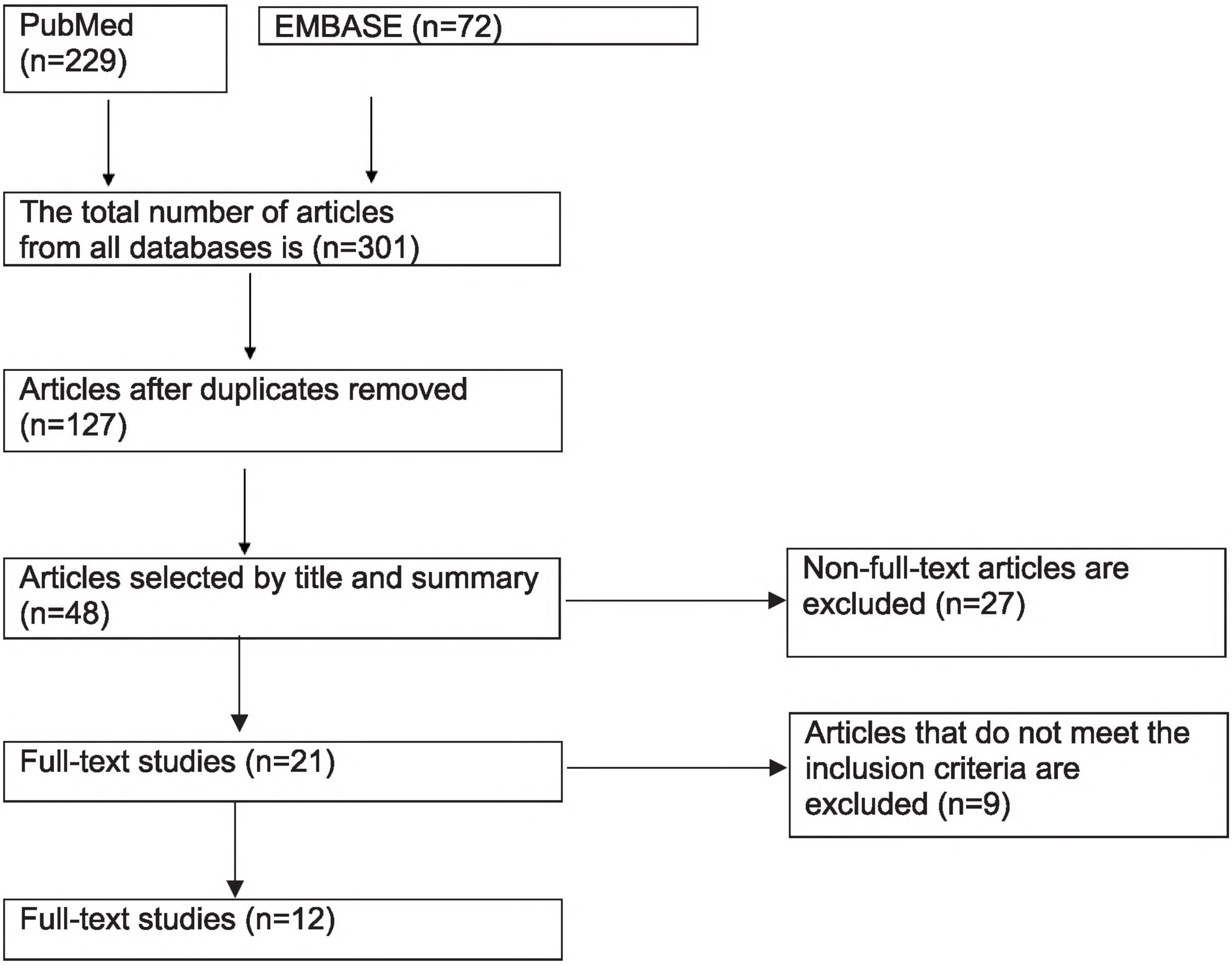


*Fig. 1.* **Research selection process**

was carried out, including materials and methods, for compliance with the inclusion criteria. Articles that didn't meet the inclusion criteria were excluded from this review. As a result, after applying the inclusion and exclusion criteria, twelve full-text articles were included and analyzed in the systematic review. After evaluating the selection of articles in accordance with the inclusion criteria, a final analysis of individual studies was conducted. The process of sampling and analyzing studies is presented in the block schematic diagram (fig.1).

Risk of Bias within Studies and Across Studies

After summarizing the risk of bias for each study, most of the studies were classified as an unclear risk. A few studies were considered as having a low risk of bias. There were several limitations present in the current review, including studies written in English only, which could introduce a publication bias. There were various degrees of heterogeneity in each study design, materials and methods and treatment provided among the studies.

**Analysis of marginal quality**

In the studies included in the systematic review analysis of marginal quality was carried out [6, 8, 14, 19, 23, 24]. To evaluate this parameter specimens of experimental groups have been exposed to TML (Thermal-mechanical loading).

Before performing TML, the results of the studies differed: in one study, higher percentage of continuous margins were detected in specimens without DME compared with DME-groups [9], other studies showed that it showed no difference in margin quality between the groups [14, 20].

After TML, a deterioration of the marginal integrity was detected in all groups in comparison to the data before TML [8, 19, 20], moreover, this was observed both in enamel [8] and in dentine [6, 8, 14]. Marginal quality in enamel was not different among groups with or without DME [6, 8, 14].

After TML, the results in dentin were adequate in the following groups: gap-free margins were 79%-92% when ceramic luted to dentin directly [6, 8] and 77%-84% gap-free margins with DME technique with three consecutive layers of resin composite [6, 8].

Results obtained in the groups with DME using cement and one layer of resin composite were significantly worse.

*Table 3.* **Materials used in research.**

| # | Author | Cavity surface conditioning | Restorative material for DME | Material of indirect restoration | Indirect restoration surface conditioning | Indirect restoration fixation |
|---|---|---|---|---|---|---|
| 1. | Bresser RA [18] | 3 step adhesive system (Optibond FL) IDS was made directly after cavity design optimization and before DME | Light-cured composite with high flowability + Light-cured radiopaque universal composite restorative (Essentia Universal composite) | Lithium disilicate (IPS e.max) | | Microhybrid, radiopaque light-curing composite (Enamel Plus HFO UD2) |
| 2. | Müller V [19] | G1: Scotchbond Universal Etchant + Adhesive G2: Total Etch + Syntac Primer + Heliobond | Filtek Supreme XTE (Universal Restorative, A2 Enamel Shade, 3M ESPE, Neuss, Germany) | Composite resin blocks (Lava Ultimate, 3M ESPE) | G1: sandblasting + Scotchbond Universal Adhesive G2: sandblasting + Monobond Plus | G1: Rely X Ultimate G2: Variolink II G3: Panavia SA Cement |
| 3. | Frankenberger R [8] | AdheSE | G1: RelyX Unicem G2: G-Cem G3: Maxcem Elite G4and G5: Clearfi Majesty Posterior | PS Empress CAD glass–ceramic inlays (Absolute Ceramics, Leipzig, Germany) | 5% hydrofluoric Acid + air–water spray + ultrasonic bath 90% ethanol + Monobond S + Syntac | Variolink II |
| 4. | Roggendorf MJ [6] | AdheSE | G1: RelyX Unicem G2: G-Cem G3: Maxcem Elite G4and G5: Clearfi Majesty Posterior | Clearfil Majesty Posterior resin composite inlays (Kuraray, Tokyo, Japan) | 5% hydrofluoric Acid + air–water spray + ultrasonic bath 90% ethanol + Monobond S + Syntac | Variolink II |
| 5. | Ilgenstein I [9] | Ultra-etch, Optibond FL | Tetric EvoCeram | G1 and G3: feldspathic ceramic blocks (Vita Mark II, Vita Zahnfabrik, Bad Säckingen, Germany). G2 and G3: composite resin blocks (Lava™ Ultimate, 3 M ESPE). | G1 and G3: 9.5 % hydrofluoric acid + G2 and G4:Cojet System + Scotchbond universal adhesive | RelyX Ultimate |
| 6. | Da Silva Gonçalves D [2] | adhesive system Adper Scotchbond 1XT | Filtek Z250 | Resin composite Gradia Indirect (GC, Tokyo, Japan) | Sandblasting + ultrasonic bath with ethanol + Adper Scotchbond 1XT | RelyX ARC or G-Cem |
| 7. | Grubbs TD [20] | Scotchbond Universal Adhesive | G1: Fuji IX G2: Fuji II G3: Filtek Supreme Ultra G4: Filtek Bulk Fill | Lava Ultimate onlays (LAVU) (n=75) (3M ESPE) | | RelyX Ultimate |
| 8. | Zhang H [21] | Monobond Plus | G1: bulk-fill SDR flowable composite G2: Filtek Z350 XT conventional resin composite | Ceramic Endocrowns from lithium disilicate reinforced ceramic (IPS e.max CAD; Ivoclar Vivadent, Schaan, Liechtenstein) | 96% ethanol + 5% hydrofluoric acid + silane | Variolink II |
| 9. | Köken S [22] | GC Etchant (only enamel) G-Premio Bond | Group 1: viscous composite Essentia MD; Group 2: flowable composite G-ænial Universal Flo | GC Cerasmart | Sandblasting + G-Multi primer | G-CEM LinkForce |
| 10. | Spreafico R [23] | Optibond FL system | Filteck Supreme XTE or Filteck Flow Supreme XTE | IPS e.max (lithium disilicate) Or LAVA Ultimate (silica, zirconia nanomers | 5% hydrofluoric acid + sonicating + silane | RelyX Ultimate (3M ESPE) |
| 11. | Juloski J [24] | G1: 3 Optibond FL, system G2: Adhese Universal | G1: Premise flowable G2: Tetric EvoFlow® Bulk Fill | GC Cerasmart | Sandblasting + silane (G1: Silane Primer, G2: Monobond Plus) | G1: NX3 Nexus™ Third Generation G2: Variolink Esthetic DC |
| 12. | Rocca GT [14] | Optibond FL system | Premise Flow A2 or Premise A2 | microhybrid composite Premise A2 | Sandblasting + Monobond S + Optibond FL (Adhesive) | Premise A2 |

**Analysis of microleakage**

In the studies included in the systematic review analysis of microleakage was carried out [22, 24].

Results of the research showed lower microleakage scores in groups without DME compared to the groups with DME [22, 24]. Direct placement of the indirect restoration

*Table 4.* **Tests and results.**

| # | Author | Test conditions | Results |
|---|---|---|---|
| 1 | Bresser RA [18] | 1. TML: 1.200.000 (1.7 Hz) at 50N, 8000x in 5 °C and 55 °C, dwell time of 30 s (Chewing Simulator SD Mechatronik GmbH, Germany) 2. Fracture test: Universal Testing Machine (MTS 810, Eden Prairie, USA): t an angle of 15°, maximum force 1 mm/1 min | - All samples with or without DME survived the ageing procedure. - Statistically, DME did not significantly influence the fracture strength. - No significant interaction effect was observed between DME and preparation design (onlay/inlay). - Onlays with DME were stronger compared to inlays without DME - Inlays without DME predominantly consisted of ceramic fractures; Inlays with DME consisted of an equal number of ceramic fractures and of crown-root fractures; Onlays without DME and Onlays with DME presented with crown-root fractures. - Statistical preparation design significantly influenced the repairability of the fractures. |
| 2 | Müller V [19] | 1. TML: mechanical stress for 1.2 Mio cycles with 50 N at 1.6 Hz using a ceramic ball (10 mm in diameter) as an antagonist occluding the crown center and thermal stress was simultaneously applied during 6000 cycles between 5 and 55 °C by filling the chambers with water for 2 min in each temperature. (Simulation of 5 years clinical wear) | - All groups showed a deterioration of the marginal integrity after ageing procedure, the reduction was not statistically significant. - No significant difference was found for luting the inlays to dentine or to DME composite. |
| 3 | Frankenberger R [8] | TML: “Quasimodo” chewing simulator, University of Erlangen, Germany; obliquely occluded against a multicomponent semi-porous crystalline ceramic material) antagonist (6 mm in diameter) for 100,000 cycles at 50 N at a frequency of 0.5 Hz. The specimens were simultaneously subjected to 2,500 thermal cycles between +5°C and +55°C by filling the chambers with water in each temperature for 30 s. | - All groups showed a significant deterioration of marginal quality for both enamel and dentin margins after ageing procedure, in enamel it was not different among groups. - Defects between the ceramic/luting resin composite and between DME composite/luting composite ranged below 2%. - The measured luting gap widths were not significantly different for all luting systems. - After ageing procedure there were 92% of gap-free margins in dentin when ceramic luted to dentin directly. - Covering dentin with three consecutive layers of resin composite and bonding the ceramic inlay to the sandblasted resin composite achieved 84% gap-free margins and was not significantly worse. - The percentages of gap-free margins were much higher compared with direct techniques. |
| 4 | Roggendorf MJ [6] | TML: “Quasimodo” chewing simulator, University of Erlangen, Germany; obliquely occluded against a multicomponent semi-porous crystalline ceramic material) antagonist (6 mm in diameter) for 100,000 cycles at 50 N at a frequency of 0.5 Hz. The specimens were simultaneously subjected to 2,500 thermal cycles between +5°C and +55°C by filling the chambers with water in each temperature for 30 s. | - All groups showed a deterioration of the marginal quality in dentine after ageing procedure, in enamel it was not different among groups - Defects between inlay/luting resin composite and DME composite/luting composite ranged below 2%. - The measured luting gap widths were not significantly different for all luting systems. - After ageing procedure there were 79% of gap-free margins in dentin when ceramic luted to dentin directly. - Covering dentine with three consecutive layers of resin composite and bonding the ceramic inlay to the sandblasted resin composite achieved 77% gap-free margins and was not significantly worse. |
| 5 | Ilgenstein I [9] | TML: computer-controlled masticator (CoCoM 2, PPK, Zürich, Switzerland) for 1.2 Mio cycles with 49 N at 1.7 Hz with cusps of human molars as antagonists, thermal stress was applied simultaneously via 3,000 thermocycles between 5 °C and 50 °C. (Simulation of 5 years clinical wear). Load to fracture: universal testing machine – 6-mm diameter steel sphere was positioned on the central fossa at an angle of 15° relative to the long axis of the tooth. The load was applied at a crosshead speed of 0.5 mm/min until failure. | - Before aging procedure, a significantly higher percentage of continuous margins at the “tooth–composite” interface was detected in group with direct luted resin restoration. Groups with ceramic restoration with or without DME showed lower percentage of continuous margins. - After aging procedure a lower percentage of continuous margins in groups with DME were observed compared with the preaging assessment, these differences were not statistically significant. - In group with direct luted resin restoration there was a high level of marginal quality after aging procedure. - In ceramic onlay groups there was a significant reduction in marginal quality at the “onlay–luting composite” interface after aging procedure. - The highest mean fracture value was recorded for group with direct luted resin restoration, groups with DME revealed similar values regardless of the material used. - Specimens restored with ceramic onlays predominantly exhibited fractures solely within the restoration, while in teeth restored with composite onlays, the percentage of catastrophic failures increased. |
| 6 | Da Silva Gonçalves D [2] | Microtensile bond strength test: a device for microtensile testing (Loctite Super Glue-3 gel; Germany) and a universal testing machine (Instron 3345, Instron Corp, USA) at a crosshead speed of 0.5 mm/min. | - The DME improved the bond strength of composite inlays luted with G-Cem (group DME/GCem showed higher bond strength values) and didn't change it with RelyX ARC, there were no statistical differences. - Groups with DME failed predominantly to interface between dentin/composite filling level (DME/RelyX ARC, 84.6 %; and DME/G-Cem, 76.5 %). - For DME/inlay failures, the predominant failure was the adhesive between the cement and the inlay for both cements. |
| 7 | Grubbs TD [20] | Cyclic Fatigue: mechanical loading under a 65 N, 1.2 Hz cyclic load for 100,000 cycles in a water bath at a constant 37 C. The load was higher than normal chewing forces, it was applied at the onlay central fossa with a 4-mm steel sphere. | - Before aging procedure, the margin quality was significantly lower for the group with resin-modified glass ionomer DME than the group without DME. DME with other materials showed no difference in dentin margin quality as compared with no DME group. - No statistical significance was observed among groups after aging procedure. All groups (with or without DME) had comparable decreases in continuous margins except for the resin-modified glass ionomer DME group. However, it was not statistically significant - No statistically significant difference was observed for fracture resistance among groups or fracture mode by material used. |

| # | Author | Test conditions | Results |
|---|---|---|---|
| 8 | Zhang H [21] | Fracture resistance testing: Repeated mechanical stress: under a computer-controlled masticator for 1,200,000 cycles, using tungsten carbide spheres (5.0 mm radius of curvature) of 49 N at 1.7 Hz. (Simulation of 5 years clinical wear) and universal testing machine, to produce a static compression force onto the tooth by a 5 mm steel sphere. The crosshead speed was set at 0.05 mm/s until fracture occurred. | - The fracture resistance level in groups with DME was significantly increased compared to direct luted restoration with subgingival margins. - Group with supragingival proximal margins showed the highest resistance and least catastrophic fracture, followed by DME group with bulk-fill SDR. There was no statistical significance between two filled groups with DME. - The worst fracture was in group G3, and the least fracture was in group G4. - Groups with DME fractured mainly at the interface between dentin/composite layer or within the resin composite layer for DME, while groups without DME fractured from the surface to the interface through all layers vertically. |
| 9 | Köken S [22] | Teeth were placed in a test tube with diluted ammoniacal silver nitrate solution for 24 h and after that rinsed in water for 10 min. Each tooth was placed in a test tube with the diluted photo-developer solution (Kodak, USA; 1:10 ratio of photo-developer solution to distilled water). After 8 h, teeth were thrice rinsed in water for 10 min. | - Group without DME showed significantly less nanoleakage (score 1 0% to 20% of gingival floor interface showing nanoleakage;) The median leakage score was 2 for both composites and 1 for the control group, with no CMR. No significant difference in leakage scores at the dentin\DME composite interface between the two composites. - Leakage significantly differed between the two bonding interfaces (enamel and dentin). In all three analyses, leakage scores were significantly higher at the dentin interface than (as compared) at the enamel interface. |
| 10 | Spreafico R [23] | TML: A CS-4.4 chewing simulator: A 6-mm-diameter steatite sphere was applied using an occlusal load of 50 N, a frequency of 1 Hz, and a downward speed of 16 mm/s. The test was performed for 72 h, which corresponded to 240,000 cycles. During the test, the specimens were subjected to 7800 thermal cycles between +5°C and +55°C by filling the chambers with water of the appropriate temperature for 30 s. | No significant differences in the marginal integrity were found for the different resin composites between margins with and without DME for RNC and LD crowns, the thickness of resin cement to be similar and no gaps were evident between the cement and the restoration. |
| 11 | Juloski J [24] | Teeth were placed in a test tube with diluted ammoniacal silver nitrate solution for 24 h and after that rinsed in water for 10 min. Each tooth was placed in a test tube with the diluted photo-developer solution (Kodak, USA; 1:10 ratio of photo-developer solution to distilled water). After 8 h, teeth were thrice rinsed in water for 10 min. | - No trace of leakage was noticed at the overlay/luting cement and luting cement/ flowable composite DME interfaces, variable leakage was only recorded at the dentin interfaces. - Significantly lower microleakage score in specimens without DME as compared to the specimens with DME. - The DME technique impaired the sealing at the cervical margins. - Direct placement of the restoration on dentin without DME resulted in significantly lower marginal leakage and therefore better marginal seal than that obtained with DME technique. |
| 12 | Rocca GT [14] | Fatigue machine: under a pressure of 14.1 cm H2O. All specimens were subjected to 1,000,000 cycles with 100 N eccentric occusal loading force. The axial force was applied at a 1.5-Hz frequency following a one half-sine wave curve. These conditions are taken to simulate about 4 years of clinical service. | - The marginal adaptation to enamel has shown no influence of the DME presence. - After loading, perfect adaption percentages decreased. - The marginal adaption to cervical dentin has shown no influence on the DME presence. - There was no difference evidenced for internal adaption between the different interface segments, however, more gaps were found on the proximal preparation shoulder (cervical dentin), gaps were located above the hybrid layer. - No defect between flowable or restorative composite base and luting composite was observed in either group or sample. |

*TML* – Thermal-mechanical loading*

on dentin without DME resulted in significantly lower marginal leakage and therefore better marginal seal than that obtained with the DME technique [24].

Leakage significantly differed between the two bonding interfaces (enamel and dentin). In all three analyses, leakage scores were significantly higher at the dentin interface [22, 24] than at the enamel interface [22, 24].

**Fracture strength**

In the studies included in the systematic review analysis of fracture strength was carried out [9, 18, 20, 21].

DME did not statistically influence the fracture strength [18, 20]. When ceramic restorations were fixed directly to the dentin, specimens showed the highest resistance and least catastrophic fracture, followed by DME-group with bulk-fill SDR [21].

Onlays presented with higher fracture strength as compared to inlays, also onlays with DME were stronger compared to inlays without DME [18]. At the same time, the highest mean fracture value was recorded for onlays without DME [18].

The material of DME did not statistically influence the fracture strength [21].

In groups with DME all fractures had a vertical orientation [9] and were mainly at interface between dentin/composite layer or within resin composite for DME [21].

The material of indirect restoration also had an influence on fracture resistance: in teeth restored with composite onlays (both with and without DME), the percentage of catastrophic failures increased, compared to groups with ceramic restorations, where predominantly exhibited fractures solely within the restoration [9].

In the group where resin composite restoration was directly fixed on dentine, all fractures had a vertical orientation [9, 21]. However, in group with ceramic restoration without DME the results were different: both horizontal fractures of the ceramic restoration at the level of the cuspal reduction [9] and vertically fractures through all layers from the surface to the interface were observed [21].

**Microtensile bond strength**

In one study included in this systematic review analysis of microtensile bond strength was evaluated [2].

The DME improved the bond strength of composite inlays but only luted with G-Cem.

When resin composite inlays were luted with RelyX ARC to DME composite, bond strength values were similar with luting directly to dentine, at the same time, the DME did not decrease bond strength. However, there were no statistical differences between the two cements [2].

Groups with DME failed predominantly at interface between dentin/composite filling level. For DME/inlay failures, the predominant failure was the adhesive between the cement and the inlay for both cements [2].

**Discussion**

In one in-vitro study, the influence of DME on the fracture strength and the fracture pattern of endodontically treated molars was investigated [9]. No significant difference was found between the fracture strength of groups restored with and without DME, independent of the used overlay material [9].

Restorations with and without DME do not differ considerably, regarding their fracture strength [9, 19]. The strength of restorations with DME may be positively influenced by the shorter proximal extensions of the indirect restorations with DME [19].

A deterioration in marginal integrity was detected in all groups after TML, but the best results showed samples when ceramic was luted to dentin directly [6, 8]. However, the groups using the DME technique with three consecutive layers of resin composite had the same results which did not differ statistically, but DME made of other materials showed worse results. The choice of the material for DME is still a controversial issue. Dietschi et al. have received promising results for flowable composites [5], which on the other hand could result in excess material in the deep proximal cavities because of their lower viscosity [25]. Higher filled composites however may have difficulties to adapt in the cavity, because of their higher viscosity. Rocca et al. found that that the type of composite did not have a significant influence on the marginal adaption [6, 14]. A study by Frankenberger et al. reported that the marginal quality to dentine was influenced to a greater extent by a meticulous layering technique, but not the type of material [8]. A study by Roggendorf, M. J. et al. showed that 3 layers of resin composite for DME exhibited a promising result in terms of marginal quality to deep proximal dentine [6]. A meticulous application of hybrid composite layers is the best way to prevent the formation of gaps [8]. On the other hand, Dietschi et al. [5] noted that flowable composites, which are materials with an intermediate modulus of elasticity, having more favorable marginal adaptation compared to packaging composites; Due to the low viscosity, the flowables are easily applied to deep proximal areas, resulting in fewer voids, and perfectly wet the bonding surface [26], which makes them favorable for use in DME. On the contrary, there are studies showing that high-filled composites have an advantage due to their lower contraction stress during polymerization and higher resistance to deformation under load [27]. However, the direct application of a ceramic insert without DME provides a significantly higher number of fields without gaps in in vitro studies [28].

At first glance, there is a misunderstanding in why the DME technique should have any advantages: regardless of whether it is filled in a direct or indirect way, the deep proximal box remains the same. Even though the adhesion of indirect restorations shows promising results [8, 29], isolation in deep proximal boxes remains very difficult. Nevertheless, if we focus on the clinical data, we can conclude that bonding a small portion of resin composite to the proximal box floor is a significantly faster procedure when compared to luting of indirect restorations [30, 31]. The absolute advantage of using the DME is the facilitation of the stages of fixing indirect restorations, for example, rubber dam isolation will be simplified and faster for creating dry conditions just as finding and removing of excess luting composite after the direct restoration insertion. DME provides smaller restoration size and decreases its depth, which makes the light polymerization process of the luting composites easier [32, 33]. Moreover, it is much easier to take conventional silicone or optical impression when the margin of the preparation is located at supragingival level [19].

In the present study, teeth with composite onlay restorations and DME showed a poorer marginal integrity at the dentin interface following TML, when compared with specimens without DME. DME hasn't proven to influence the marginal quality of the specimens restored with ceramic onlays, while fracture resistance seemed to be slightly increased (though this increase was found to be insignificant)

Among the ceramic specimens, DME led to vertical fracture lines only, while restorations without DME exhibited horizontal fracturing of the distal proximal wing at the level of the cuspal coverage. These findings may be due to a combination of an unfavorable cavity design with a greater concentration of tensile stress at the transition between the occlusal and proximal boxes and the rigidity of the ceramic material [9].

If we're going to discuss the predominant failure mode, then in groups with DME it was located at the interface between the composite for DME and the dentin [2].

The level of microleakage during the DME technique depended on the type of tissue of the preparation margin. For example, there was almost no leakage at the enamel-bonding interface. Probably, the distinguishing prismatic structure of the enamel after etching provides a reliable micromechanical interlocking. On the contrary, leakage at the dentin-bonding interface was observed in all the studied samples [22]. These results were observed with various filling materials and didn't have statistically significant differences, although the flowable composite showed slightly better efficiency than that of the hybrid composite [22]. Several previous studies also showed that there was no significant difference between the two composites for DME in terms of margin quality [5, 14, 23]. The studies included in our review showed that direct placement of indirect restorations on dentin (without DME) led to better results of marginal sealing when compared to DME groups. Unfortunately, these results cannot be confidently extrapolated to clinical practice since the conditions in the oral cavity differ from those in vitro.

The DME technique is called into questioning by the polymerization shrinkage of the applied polymer composite; But this aspect is not the main problem, the mechanical load by the stiffer ceramic part, a different modulus of elasticity and, possibly, weak transition zone between resin composites, are of greater interest and involve some questions about the durability of this procedure [34].

**Limitations:**

During our systematic review, various research results could be obtained. Firstly, various materials were used to prepare the surface of the hard tissues of the tooth for DME. Secondly, the DME in each study was carried out from different materials. Thirdly, the design of the shape and the material of the indirect restoration, as well as the preparation of its surface and luting procedure, differed. Moreover, the samples were subjected to various thermomechanical loads. In order to give a confidently objective assessment of the DME technique, it is necessary to conduct further studies with uniform established measurement parameters.

**CONCLUSIONS**

We conducted a systematic review, which included 12 in vitro studies. Two main parameters were evaluated: the effect of DME on marginal quality, and on fracture resistant. The samples with DME showed similar results to the samples where indirect restorations were directly applied to the tooth tissue, but the experimental groups without DME showed better results. On the other hand, in clinical practice, DME contributes to a simpler, faster, and more reliable fixation of indirect restorations. Therefore, further research and clinical observations are needed.

## REFERENCES:


1. Mangani F, Marini S, Barabanti N, Preti A, Cerutti A. The success of indirect restorations in posterior teeth: a systematic review of the literature. Minerva Stomatol. 2015;64(5):231-40.
2. Da Silva Gonçalves D, Cura M, Ceballos L, Fuentes MV. Influence of proximal box elevation on bond strength of composite inlays. Clin Oral Investig. 2017;21(1):247-254.
3. Veneziani M. Adhesive restorations in the posterior area with subgingival cervical margins: new classification and differentiated treatment approach. Eur J Esthet Dent. 2010;5(1):50-76.
4. Barone A, Derchi G, Rossi A, Marconcini S, Covani U. Longitudinal clinical evaluation of bonded composite inlays: a 3-year study. Quintessence International. 2008;39:65–71.
5. Dietschi D, Olsburgh S, Krejci I, Davidson C. In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different resinous bases. Eur J Oral Sci. 2003;111(1):73-80.
6. Roggendorf MJ, Krämer N, Dippold C, Vosen VE, Naumann M, Jablonski-Momeni A, Frankenberger R. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. J Dent. 2012;40(12):1068-73.
7. Zaruba M, Göhring TN, Wegehaupt FJ, Attin T. Influence of a proximal margin elevation technique on marginal adaptation of ceramic inlays. Acta Odontol Scand. 2013;71(2):317-24.
8. Frankenberger R, Hehn J, Hajtó J, Krämer N, Naumann M, Koch A, Roggendorf MJ. Effect of proximal box elevation with resin composite on marginal quality of ceramic inlays in vitro. Clin Oral Investig. 2013;17(1):177-83.
9. Ilgenstein I, Zitzmann NU, Bühler J, Wegehaupt FJ, Attin T, Weiger R, Krastl G. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clin Oral Investig. 2015;19(5):1021-8.
10. Magne, Pascal, and Roberto C. Spreafico. Deep margin elevation: a paradigm shift. Am J Esthet Dent. 2012;86-96.
11. Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent. 1998;10(1):47-54.
12. Chen YC, Lin CL, Hou CH. Investigating inlay designs of class II cavity with deep margin elevation using finite element method. BMC Oral Health. 2021;21(1):264.
13. Ferrari M, Koken S, Grandini S, Ferrari Cagidiaco E, Joda T, Discepoli N. Influence of cervical margin relocation (CMR) on periodontal health: 12-month results of a controlled trial. J Dent. 2018;69:70-76.
14. Rocca GT, Gregor L, Sandoval MJ, Krejci I, Dietschi D. In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different resinous bases and interface treatments. "Post-fatigue adaptation of indirect composite restorations". Clin Oral Investig. 2012;16(5):1385-93.
15. Higgins JPT, Altman DG. Assessing Risk of Bias in Included Studies. Hoboken, NJ, USA: Wiley Blackwellm 2008.
16. Higgins JPT, Altman DG, Gøtzsche PeCt,al.The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011; 343: d5928.
17. Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919.
18. Bresser RA, van de Geer L, Gerdolle D, Schepke U, Cune MS, Gresnigt MMM. Influence of Deep Margin Elevation and preparation design on the fracture strength of indirectly restored molars. J Mech Behav Biomed Mater. 2020;110:103950.
19. Müller V, Friedl KH, Friedl K, Hahnel S, Handel G, Lang R. Influence of proximal box elevation technique on marginal integrity of adhesively luted Cerec inlays. Clin Oral Investig. 2017;21(2):607-612.
20. Grubbs TD, Vargas M, Kolker J, Teixeira EC. Efficacy of Direct Restorative Materials in Proximal Box Elevation on the Margin Quality and Fracture Resistance of Molars Restored With CAD/CAM Onlays. Oper Dent. 2020;45(1):52-61.
21. Zhang H, Li H, Cong Q, Zhang Z, Du A, Wang Y. Effect of proximal box elevation on fracture resistance and microleakage of premolars restored with ceramic endocrowns. PLoS One. 2021;16(5):e0252269.
22. Köken S, Juloski J, Sorrentino R, Grandini S, Ferrari M. Marginal sealing of relocated cervical margins of mesio-occluso-distal overlays. J Oral Sci. 2018;60(3):460-468.
23. Spreafico R, Marchesi G, Turco G, Frassetto A, Di Lenarda R, Mazzoni A, Cadenaro M, Breschi L. Evaluation of the In Vitro Effects of Cervical Marginal Relocation Using Composite Resins on the Marginal Quality of CAD/CAM Crowns. J Adhes Dent. 2016;18(4):355-62.
24. Juloski J, KÖken S, Ferrari M. No correlation between two methodological approaches applied to evaluate cervical margin relocation. Dent Mater J. 2020;39(4):624-632.
25. 20. Frankenberger R, Krämer N, Pelka M, Petschelt A. Internal adaptation and overhang formation of direct class II resin composite restorations. Clin Oral Investig. 1999;3:208–215
26. Attar N, Tam LE, McComb D. Flow, strength, stiffness and radiopacity of flowable resin composites. J Can Dent Assoc. 2003;69(8):516-21.
27. Pallesen U, Qvist V. Composite resin fillings and inlays. An 11-year evaluation. Clin Oral Investig. 2003;7(2):71-9.
28. Frankenberger R, Krämer N, Appelt A, Lohbauer U, Naumann M, Roggendorf MJ. Chairside vs. labside ceramic inlays: effect of temporary restoration and adhesive luting on enamel cracks and marginal integrity. Dent Mater. 2011;27(9):892-8.
29. Mehl A, Kunzelmann K, Folwaczny M, Hickel R. Stabilization effects of CAD/CAM ceramic restorations in extended MOD cavities. J Adhes Dent. 2004;6:239–245.
30. Frankenberger R, Reinelt C, Petschelt A, Krämer N. Operator vs. material influence on clinical outcome of bonded ceramic inlays. Dent Mater. 2009;25:960–968.
31. Pallesen U, Qvist V. Composite resin fillings and inlays. An 11-year evaluation. Clinical Oral Investigations. 2003;7:71–9.
32. Soh MS, Yap AUJ, Siow KS () The effectiveness of cure of LED and halogen curing lights at varying cavity depths. Oper Dent. 2003;28:707–715.
33. El-Mowafy OM, Rubo MH () Influence of composite inlay/ onlay thickness on hardening of dual-cured resin cements. J Can Dental Assoc. 2000;66:147.
34. Lutz F, Krejci I, Barbakow. Quality and durability of marginal adaptation in bonded resin composite restorations. Dent Mater. 1991;7:107–113.


## AUTHOR INFORMATION:


*Zurab Khabadze*[1] – Candidate of Medical Sciences, Associate Professor of Department of Therapeutic Dentistry, ORCID ID: 0000-0002-7257-5503.

*Inna Bagdasarova*[1] – Candidate of Medical Sciences, Associate Professor of Department of Therapeutic Dentistry.

*Ekaterina Shilyaeva*[1] – student

*Alexandra Kotelnikova*[1] – student

*Daria Nazarova*[1] – student

*Yusup Bakayev*[2] – resident student

*Saida Abdulkerimova*[2] – resident student

[1]"Peoples' Friendship University of Russia" (RUDN University), Moscow, Russia

[2]National Medical Research Center of Dentistry and Oral and Maxillofacial Surgery, Moscow, Russia

***Coordinates for communication with authors:***

*Zurab Khabadze, E-mail: dr.zura@mail.ru*