Fracture Resistance of Molars with Class II MOD Cavities Restored with CAD/CAM Ceramic Onlays: Impact of Deep Marginal Elevation

Ali I. Alqurshi,[1] Ali A. Elkaffas,[2] Salah H. Mahmoud,[3]

Abstract:

Objective: This study evaluated the effect of deep marginal elevation (DME) using an ion-releasing material, resin-modified glass ionomer, and nano-hybrid flowable composite on the fracture resistance of molars with Class II MOD cavities restored with CAD/CAM ceramic onlays. **Materials and Methods:** Fifty molar teeth were randomly assigned to one of five groups (n=10/group): Enamel (EN), Cementum (CE), Cention forte (CF), Tetric-N flow (TF), and Resin modified glass ionomer (RM) groups. Specimens were prepared for a standard MOD cavity with margins located 2 mm below the CEJ for CF, RM, TF, and CE groups, while the EN group had margins located 1 mm above the CEJ. DME was used to elevate the margins to 1 mm above the CEJ. For the CE group, the ceramic onlay was placed without DME. Standardized IPS e.max ZirCAD ceramic onlays were fabricated with CAD/CAM and bonded on all specimens with G-cem Capsule. All teeth were subjected to 10,000 cycles of thermocycling (5°C/55°C). The fracture resistance of each group was measured using a universal testing machine. Data was statistically analyzed using a one-way ANOVA test. **Results:** Fracture strength values were subjected to one-way ANOVA revealed statistically non-significant differences among experimental groups (p=0.08). **Conclusions:** Within the parameters of this study, the materials had a non-significant difference in fracture resistance. Therefore, collective findings suggest that these materials were suitable for DME.

Introduction:

Every dentist faces challenging clinical decisions when planning and restoring severely damaged teeth. Deep proximal surface destruction presents additional restorative complexities. With the lack of enamel for durable adhesive bonding, the presence of root concavities, and gingival tissue interferences, clinicians might elect adjunctive procedures when restoring teeth with deep proximal boxes.[1]

Surgical crown lengthening or orthodontic extrusion provides predictable restorative outcomes in teeth with deep surface destruction. Considering all possible restorative options provides treatment to the patient's needs. To simplify the restoration process, it is typically recommended that teeth with damage below the gingiva undergo surgical crown lengthening.[1]

A conservative alternative to the former procedure is the deep marginal elevation (DME) technique. The DME technique was initially purposed by Dietschi and Spreafico.[2] DME has been revisited and refined by several authors.[3–12] The DME procedure has the potential to save time, resources, and biological tissue.[7] Indirect restoration preparation and delivery have inherent complexities, especially for onlays and inlays, which can be further complicated by deep proximal defects.[7,8] When utilizing DME, a simplified preparation design gives rise to a more manageable tooth and restoration's internal surfaces. According to the literature, DME is typically completed with a resin-based composite and a bonded occlusal indirect restoration.[13] An alternative box elevation material, one that is water-based, and hydrophilic placed in the subgingival area in conjunction with the open-sandwich technique is logical to implement when performing DME.[13,14]

Additionally, computer-aided design/computer-aided manufacturing (CAD/CAM) advances have given clinicians the ability to create definitive indirect ceramic restorations in one visit, appeasing the patient's desire for an immediate return on investment. CAD/CAM eliminates the need for traditional impressions, stone casts, and, sometimes, provisional restorations.[15]

A Study on the weakening of teeth following MOD cavity preparations and the effect of restorations in strengthening the remnant tissue have been conducted experimentally.[16] The force that may induce fracture of the tooth-restoration complex has been determined using the fracture resistance test. This enables a suggestion of the preparation design and restorative material that provide the greatest resistance to fracture.[17]

The question is which appraisable restorative material can be used to elevate the margin for final restoration fabrication? Therefore, this present study aimed to evaluate the effect of deep marginal elevation using an ion-releasing material, resin-modified glass ionomer, and nano-hybrid flowable composite on the fracture

[1]*Postgraduate MSc student, Department of Conservative Dentistry, Faculty of Dentistry, Mansoura University 35516, Mansoura, Egypt.* ali7ihsan93@gmail.com
[2]*Lecturer, Department of Conservative Dentistry, Faculty of Dentistry, Mansoura University 35516, Mansoura, Egypt.*
[3]*Professor, Department of Conservative Dentistry, Faculty of Dentistry, Mansoura University 35516, Mansoura, Egypt*

Received October, 2022; Accepted November, 2022.
DOI: 10.21608/MJD.2023.302002

Table 1: Restorative materials used in the current study

Brand	Specifications	Composition	Manufacturer	Batch Number	Steps of Application
IPS e.max ZirCAD	Yttrium stabilized zirconium oxide	ZrO_2, Y_2O_3, HfO_2, Al_2O_3	Ivoclar Vivadent, Schaan, Liechtenstein	Y43302	1. Snadblasting with Al_2O_3, 25-70µm, 1 bar to the internal surface of ceramic. 2. Rinse and dried. 3. Bond by G-Cem Capsule.
Tetric-N Flow	Light-cured, flowable composite	Barium glass, UDMA, Bis-GMA, ytterbium trifluoride, TEGDMA, mixed oxide (SiO_2/ZrO_2), barium-aluminium-fluorosilicate glass	Ivoclar Vivadent, Schaan, Liechtenstein	635780	1. Etch proximal box wall with N-Etch for 15s. 2. Rinse thoroughly for 20s and dry for 3s. 3. Apply the adhesive and rub for 10s then dry for 3s. 4. Light cure for 20s. 5. Place Tetric-N Flow and light cure for 20s.
Cention Forte	Self-cured, glass ionomer	UDMA, initator, glass filler, pigments	Ivoclar Vivadent, Schaan, Liechtenstein	740829	1. Actively scrub and agitate the primer for 10s. 2. Dry with compressed air until a glossy thin immobile layer remains. 3. Activate the capsule. 4. Extrude directly by capsule applier. 5. Self-cure, optionally speed up the process by light cure for 15s.
Fuji II LC	Light-cured, resin-modified glass ionomer	Polyacrylic acid 20-30%, 2-HEMA 30-35%, Distilled water 20-30%, Initiator	Hasunuma-cho, Itabashi-ku Tokyo, Japan	1009041	1. Activate the capsule. 2. Mix it with an amalgamator for 10s. 3. Injected directly by capsule applier. 4. Light cure for 20s.

UDMA, urethane dimethacrylate; Bis-GMA, bisphenol A-glycidyl methacrylate; TEGDMA, triethylene glycol dimethacrylate.

resistance of molars with Class II MOD cavities restored with CAD/CAM ceramic onlays.

The null hypotheses tested will be that there is no significant difference in fracture resistance between ion-releasing material, resin-modified glass ionomer cement, and nano-hybrid flowable composite used for marginal elevation of molars with Class II MOD cavities restored with CAD/CAM ceramic onlays.

Materials and Methods:

Materials Utilized in the current study:

1. RMGI (Fuji II LC, Hasunuma-cho, Itabashi-ku, Tokyo, Japan).
2. Tetric-N Flow (Ivoclar Vivadent AG, Shaan, Liechtenstein).
3. Cention Forte (Ivoclar Vivadent AG, Schaan, Liechtenstein).
4. G-Cem Capsule (Hasunuma- cho, Itabashi-ku,Tokyo,Japan).
5. IPS e. max ZirCAD blocks (Ivoclar Vivadent AG, Shaan, Liechtenstein).

Brand names, specifications, manufacturers, compositions, and application steps of the restorative materials are listed in Table 1. A luting resin composite system was used in the current study, its composition and application steps are presented in Table 2.

Study Design: This laboratory study evaluated fracture resistance of CAD/CAM fabricated ceramic onlays using one independent variable; the restorative material used for marginal elevation (RMGI, Cention Forte, and Tetric N-Flow).

Specimen Preparation: Fifty non-carious, cracks-free extracted human molars will be acquired in the current study, the teeth were collected from the outpatient clinic of the Faculty of Dentistry The collected teeth were extracted for periodontal.

Table 2: Luting resin composite system used in the current study

Luting System	Composition	Manufacturer	Batch Number	Steps of Application
Try-In Paste	Glycerine, mineral fillers and dyes	Ivoclar Vivadent, Schaan,Liechtenstein	740513	1. Apply to the internal surface of ceramic. 2. Seat the ceramic and check the inner surface of the ceramic.
N-Etch	Phosphoric acid (37% wt.% in water), thickening agent and colour pigments	Ivoclar Vivadent, Schaan,Liechtenstein	S24978	1. Apply for 15s. 2. Remove it with vigorous water spray for 5s, excess moisture removed.
Liquid Strip	Glycerine gel	Ivoclar Vivadent, Schaan,Liechtenstein	740436	1. Apply to entire margin before light polymerization. 2. Light cure for 10s per segment. 3. Rinse and dried.
Tetric N-Bond Universal	Methacrylates, ethanol, water, highly dispersed silicon dioxide, initiators and stabilizer	Ivoclar Vivadent, Schaan,Liechtenstein	669855	1. Apply one layer with brush using a light scrubbing motion. 2. Gentle air drying for 5s. 3. Light cure for 10s.
Cention Primer	Ethanol, 3-trimethoxysilylpropyl methacrylate silane, methacrylated phosphoric acid ester, sulphide methacrylate	Ivoclar Vivadent, Schaan,Liechtenstein	740833	1. Apply for 60s with Cention brush. 2. Disperse any remaining excess with a strong stream of air.
G-Cem Capsule	Powder: fluoroaluminosilicate glass, initiator, pigment. Liquid: dimethacrylate, 4-methacryloxyethyl trimellitic acid, phosohoric acid ester monomer, water, urethane dimethacrylate, silica powder, initiator, stabilizer 65-70%wt	Hasunuma-cho, Itabashi-ku Tokyo, Japan	141928	1. Activate the capsule. 2. Mix it with an amalgamator for 10s. 3. Apply the cement onto the internal surface of the ceramic. 4. Seat the ceramic and fix/hold it in place. 5. Remove excess cement by a brush. 6. Light cure for 40s on each surface.

disease reasons. The collection of teeth was subjected to infection control standards approved by the Faculty of Dentistry Ethical committee. After removal of soft tissue remnant with a hand scaler, teeth were stored in 1% chloramine-thymol solution (Chloramine-T) for 72 hours at room temperature and then stored in distilled water until use. Teeth were cleaned using a rubber cup and fine pumice water slurry.

The teeth had their roots embedded in cylindrical polymerization of vinyl chloride PVC ring (1. 4 × 2 cm) using an auto polymerizing acrylic resin (Acrostone, Cairo, Egypt), up to 3 mm below the cementoenamel junction (C.E.J). To mimic the periodontium, the roots of the teeth were demarcated 3 mm below CEJ using a red pencil, then dipped into melted wax to produce a 2mm to 3mm layer approximately equal to the average thickness of the periodontal ligament.
The teeth were mounted in acrylic resin cylinders using a centralization guide device. After the acrylic resin setting, each tooth was removed from the cylinder. The wax spacer was removed from the root surface using hot water and a wax knife. Polyether impression material (Impregum soft, 3M ESPE, St. Paul, Minnesota) was delivered into acrylic resin alveolus. Excess polyether material was removed with a scalpel blade to provide a flat surface 3 mm below the CEJ of each tooth.[17]

The specimens were divided randomly into five main groups of 10 specimens each as follows: Group 1: enamel margin (EN); Group 2: cementum margin (CE); Group 3: Cention Forte margin (CF); Group 4: Tetric N-Flow margin (TF); and Group 5: RMGI margin (RM) as shown in, Figure.1.
Cavities were cut using coarse diamond and finishing diamond burs (Onlay Prep-Set, Intensiv, Viaganello-Lugano, Switzerland) for preparation of standardized class II MOD onlay cavities, in a high-speed handpiece (Sirona T3, Bensheim, Germany) under copious air-water cooling. One operator performed all the steps of preparation using the recommended sequence of

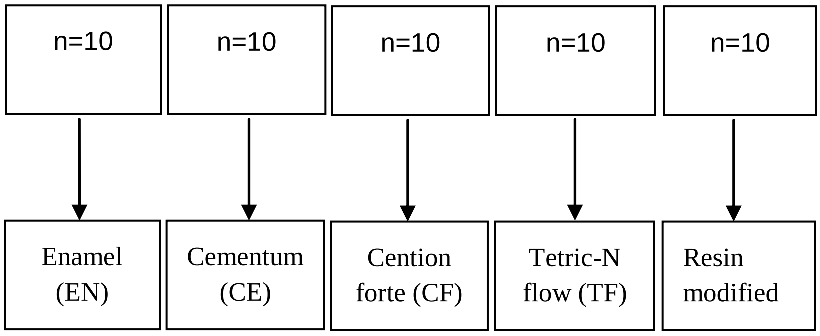

Figure 1. Flowchart showing experimental sequence and allocation of groups

.

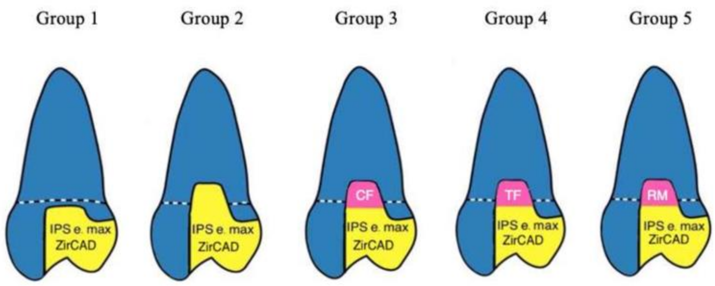

Figure 2. Restoration designs used in this study.

specific diamond instruments. To ensure cutting efficiency, each used diamond instrument was replaced after four preparations.

The dimensions of cavity preparation were standardized so that the pulpal floor depth was 2. 5 mm from the occlusal surface. The occlusal isthmus width was 2. 5 mm, and buccolingual widths on the mesial and distal boxes were also 2. 5 mm. The gingival floor depth of each box was 1. 5 mm and the axial wall height was 2 mm. In addition, the palatal cusp was reduced by 2 mm according to the anatomical shape of the occlusal surface, and the palatal margin was finished as a 1 mm rounded shoulder design.

For the enamel margin group, the gingival margin of the preparation was placed 1 mm above the CEJ on the enamel tooth structure. In the remaining four groups, the preparation was end 2 mm below the CEJ in cementum. All teeth in the Cementum margin group, Cention Forte margin group, Tetric N-Flow margin

group, and RMGI margin group had 2 mm of deep margin elevation to the CEJ as shown in ,Figure. 2.

Restoration procedure for proximal box elevation: Three different restoration materials were selected for this study. Hence, it was used according to the manufacturer's instructions.All polymerization performed in this study was accomplished using a Bluephase N light-curing unit (Ivoclar Vivadent, AG, Shaan, Liechtenstein). For controlling the light output of the Bluephase N, a radiometer (Bluephase Meter II, Ivoclar Vivadent, AG, Shaan, Liechtenstein) was used

to prove that the power was always at 1000 mW/cm2. Specimens in the Cention Forte, Tetric N-Flow, and RMGI marginal groups underwent the deep marginal elevation to raise the gingival margin by 3 mm, resulting in a material gingival floor location 1 mm above the CEJ using Tofflemire matrix band (Henry Schein, Melville, NY, USA).

Regarding Group 3 (Cention forte marginal group) place in a single 3 mm increment, conditioning of the proximal box by Cention Primer. Afterward activated and mixed in the capsule, the material was injected into the deep proximal box with nominal manipulation to minimize voids and allowed to self-cure.

Regarding Group 4 (Tetric N-Flow marginal group) place in a single 3 mm increment, etch and rinse adhesive system used for all specimens group comprise N-Etch later Tetric N-Bond Universal. Afterward, the material was placed in the deep proximal box followed by light polymerized. Regarding Group 5 (RMGI marginal group) placed in two 1. 5 mm increments, after activating and mixing the capsule, the material was injected into the deep proximal box, it is vital to submerge the tip end of the capsule under the material surface to prevent any air bubble formation.

Digital impression: Following specimen preparation and margin elevation, fifty preparations were scanned with an intraoral scanning device (Cerec Omnicam, Dentsply Sirona, Charlotte, NC, USA). Furthermore, fifty yttrium stabilized zirconium oxide onlays were designed and milled from IPS e. max ZirCAD blocks using the CEREC system.

Digital impression: Following specimen preparation and margin elevation, fifty preparations were scanned with an intraoral scanning device (Cerec Omnicam, Dentsply Sirona, Charlotte, NC, USA). Furthermore, fifty yttrium stabilized zirconium oxide onlays were designed and milled from IPS e. max ZirCAD blocks using the CEREC system.

Fabrication of onlay restorations: A technician fabricated all restorations using a standardized technique following the manufacturer's instructions. All indirect restorations were manufactured using a Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) workflow. The samples were scanned before and after preparation, using intraoral scanning. The software designed indirect restorations based on the Biogeneric Copy function of the Cerec software so that the prepared samples are restored to their original shape. The indirect restorations (IPS e. max ZirCAD) are made using a milling machine (InLab MC XL, Dentsply Sirona, Bensheim, Germany). The indirect restorations are subsequently sintered at a temperature of 1500℃ glazed and finally fired at temperature of 710℃ (Program at EP 5000, Ivoclar Vivadent, Schan, Lichtenstein)

Adhesive bonding of onlay restorations: All procedures were performed according to the following manufacturer's instructions. The restorations are tried-in using the Try-in paste to ensure proper marginal fit. Thereafter; removed possible residua of the Try-in paste from the cavity and the restoration. After the try-in procedure, the internal surface of each onlay was cleaned by sandblasting.

Onlays were bonded with self-adhesive cement (G-Cem Capsule). All margins were covered with Liquid Strip to avoid oxygen-inhibited layer formation followed by light Polymerized. Finally, smooth out the cement lines using finishing and polishing strips (OptraPol, Ivoclar Vivadent).

Fracture resistance test: All the specimens will be subjected to thermocycling for a total number of 10,000 cycles between 5°C and 55°C to simulate thermal changes that occur within the oral cavity. The dwell time at each temperature will be 30 seconds, and the transfer time from one bath to the other will be 2seconds. After a week of distilled water storage since the luting procedure, all samples were subjected to axial compressive loading in a universal testing machine (Instron 3345, Canton, Massachusetts) using a metal sphere of 8-mm diameter applied vertically in contact with the cusp slopes at a crosshead speed of 0.5 mm/min until failure to evaluate the level of failure. The force required to induce fracture was recorded in Newton (N).

Statistical analysis: Statistical analysis was performed for fracture resistance, data was statistically analyzed using Shapiro-Wilk and one-way ANOVA tests. Shapiro-Wilk test was used to test for the normality distribution of force at maximum compressive stress. Values of $p<0.05$ were accepted as statistically significant. The data from the fracture resistance tests were graphically displayed as box-and-whisker plots.

Results:

The Shapiro-Wilk test was used to test the normality distribution of force at maximum compressive stress (Newton) and it was non-significant for all groups of the study as shown in Table 3. Additionally, one-way ANOVA revealed statistically non-significant differences among experimental groups ($p=0.08$) within force at maximum compressive stress (Newton):

Comparison between EN, CE, CF, TF, and RM groups (1801. 23 ± 226. 85, 1626. 00 ± 465. 20, 1899. 30 ± 374. 12, 1808. 78 ± 223. 95 and 2018. 76 ± 238. 74 respectively). The CE group had a higher ceramic fracture rate compared to other groups; however, non-significant differences between them were detected as shown in Table 4 and Figure 3.

Table 3: Shapiro-Wilk test for EN, CE, CF, TF and RM groups

		Statistic	P
Force at Maximum pressive Stress(N)	EN	.895	.260
	CE	.852	.078
	CF	.952	.694
	TF	.973	.920
	RM	.894	.189

P: Probability *: significance <0.05

Discussion:

Our study evaluated the effect of deep marginal elevation (DME) using an ion-releasing material, resin modified glass ionomer, and nano-hybrid flowable composite on the fracture resistance of molars with Class II MOD cavities restored with CAD/CAM ceramic onlays. Also, this study searched for an answer to the question of whether the appraisable restorative material can be used to elevate the margin for final restoration fabrication. Fracture resistance was the outcome measure to evaluate each material's performance. The results of this study revealed that there were no significant differences in fracture resistance among experimental groups. Therefore, the null hypothesis that there would not be a significant difference in fracture resistance between ion-releasing material, resin-modified glass ionomer, and nano- hybrid flowable composite

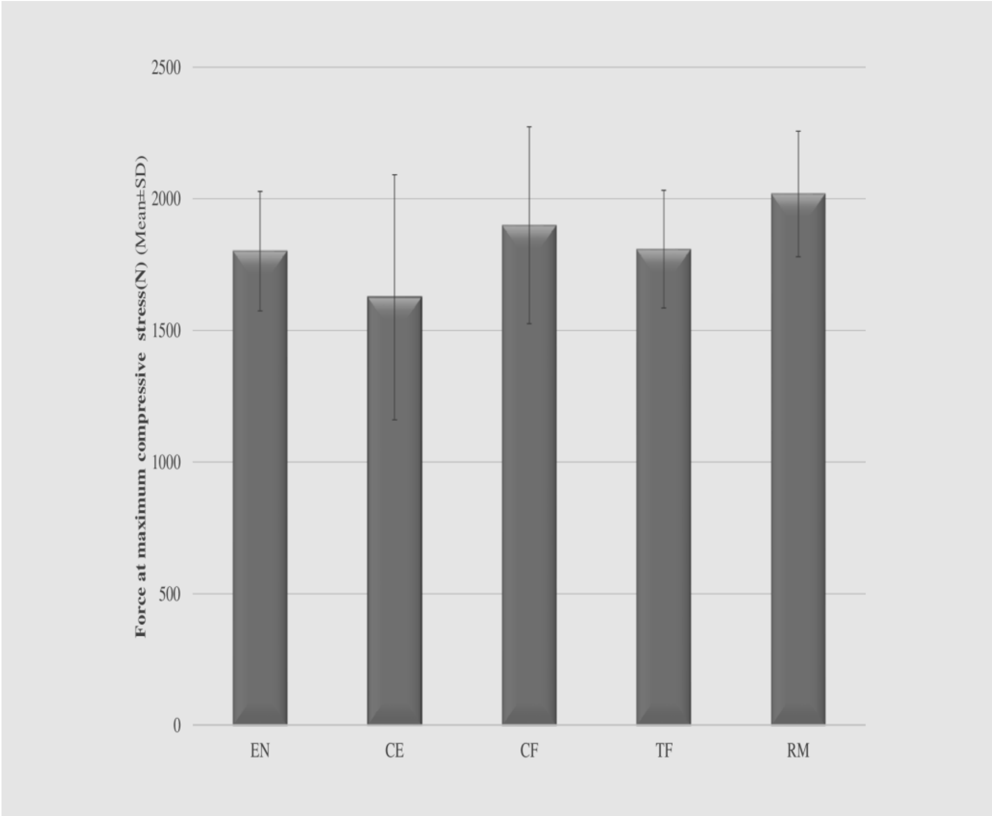

Figure 3. Mean ± SD of Force at maximum compressive stress (N) between EN, CE, CF, TF and RM groups.

Table 4: Comparison of Force at maximum compressive stress (N) between EN, CE, CF, TF and RM groups

	EN group	CE group	CF group	TF group	RM group	P value
Force at maximum compressive stress (N)	1801.23 ±226.85	1626.00 ±465.20	1899.30 ±374.12	1808.78 ±223.95	2018.76 ±238.74	0.08

Data expressed as mean ± SD
SD: standard deviation
P: Probability *: significance <0.05
Test used: One way ANOVA

used for marginal elevation of molars with Class II MOD cavities restored with CAD/CAM ceramic onlays was accepted. Placing indirect restoration margins on direct restorative materials instead of sound tooth structure is in contradiction to concepts that have been taught for decades, hence the title of Mange's study.[18] The DME technique has met resistance due to concerns that

failure of margin elevated restorations arises from the additional restorative material interface between ceramic and direct restorative material.[3] Kielbassa's systematic review on deep marginal elevation showed various restorative materials to be successful at maintaining clinically acceptable margins using the DME technique, yet still recommended high-quality clinical trials to confirm benchtop outcomes.[19] Interestingly, one sample group in this study, the cementum margin group, with tall occluso-gingival ceramic onlay heights, demonstrated a lack of ceramic structural integrity that was different than the other four groups. This finding exposes a potential additional benefit of DME beneath ceramic onlays that the act of placing a direct restoration on the gingival floor inherently shortens the occluso-gingival height of the proximal portion of the onlay. And, based on logistic regression extrapolation of the data found in this study, shorter heights of proximal ceramic onlays are less associated with ceramic fracture.

Deep marginal elevation did not affect the fracture strength of ceramic restorations, although the data of the current study tentatively suggests that restorations with and without DME do not differ considerably regarding their fracture strength. One earlier in-vitro study on the fracture strength of teeth restored in conjunction with DME is in concordance with these results.[4] The strength of restorations with DME may be positively influenced by the shorter proximal extensions of the indirect restorations with DME. This facilitates full seating of the restoration to the preparation margin.[20] A better marginal adaptation may serve to avoid tooth fracture by loading in the long term as well.[21]

All specimens in the current study fractured within the range of 1626–2018.76 N as shown in Table 4. Fracture resistance, regardless of DME materials used, was similar to the control group. Therefore, DME within this study's parameters may resist a maximum bite force of 600–1200N and withstand forces during normal mastication.[22] Moreover, collective findings suggest that these materials were suitable for DME.

In the same vein, we were unable to fully simulate the oral environment and clinical realities of restoration placement. The main reason for implementing the DME technique in daily practice is to eliminate the inherent difficulty of capturing a deep margin with an impression, optically or otherwise. Our technique did not consider the patient variable, the need for gingival tissue management, material placement, or restricted access. Ideal conditions (i. e., contamination-free and uninterrupted access) were used during specimen preparation. Depending on the clinical situation, materials like GI or RMGI may offer better clinical success due to their moisture forgiveness and chemical adhesion to dentin.[13,14,23] A flowable composite is considered a bad choice as it has higher polymerization shrinkage and may not be resistant to deformation under load.[6,8] However, caution is recommended in extrapolating our findings to clinical situations.

Future investigation is recommended before specific protocols of deep marginal elevation can be universally recommended in patients. Laboratory results encourage the success of DME, but a clinical trial would bring reliable box elevation outcomes to the forefront. The disadvantages of DME shown in the literature are most recently noted in an in vivo 12-month study showing increased bleeding on probing associated with the procedure.[24]

The mean fracture strength values of this study (1626-2018 N) exceeded the reported voluntary maximum axial bite forces in dentate women and men (480-788 N), by far.[25] Normal masticatory forces vary between 17 N and 450 N[26] and are lower compared to the voluntary maximum axial bite force.[27] Patients with bruxism tend to produce involuntary forces of up to 400-1100 N.[28] However, reported in-vitro values are derived from axial loading while chewing is composed of both axial and lateral movements and forces. As a result, a fracture resistance above 1100N is needed to maintain good clinical performance and this agrees with this study.

Some variation in fracture strength between specimens was noted. This could be explained by two factors; some human molars were used and stored in tap water, while others were extracted 6 months before the study and others just a few days before. Literature supports a drastic decrease in the microhardness of extracted teeth when stored for longer than 2 months.[29] That being the case, the variation of fracture resistance to some degree could be explained by this. Furthermore, all molars had slightly different dimensions, yet standardized preparations were performed to achieve equal dimensions of the indirect restorations. Consequently, the indirect restorations were supported by a slight fluctuation in the volume of tooth structure. The samples were randomized into five groups to reduce the effect of both factors on the outcome of this study.

The ceramic used in the study was yttria-stabilized zirconia, which is a glass-free, high-strength polycrystalline ceramic material with a flexural strength greater than 1000Mpa and fracture toughness of 9 to 10 MPa $m^{1/2}$.[30–32] In the study of Saridag S, et al.[33] they found that the lithium disilicate based onlay restoration tooth complex did not withstand compressive loads as high as the zirconia-based onlays.

Resin cement used in adhesive restorations is elastic and tends to deform under stress, resulting in higher resistance to fracture. Therefore, the success of ceramic inlays is dependent on the creation of an uncompromised adhesive-tooth-ceramic interface.[34] Moreover, the elastic modulus of the luting agent may also affect the fracture strength values of the teeth restored with ceramic onlays. Cubas GB, et al.[35] found that luting agents with higher elastic modulus increased the fracture strength values of partial ceramic restorations.

This study also has some limitations. The continuous vertical load applied to the teeth in this study is not typical of clinical loading.[36] In terms of in vivo loading, the masticatory cycle consists of a combination of vertical and lateral forces, subjecting the ceramic to a variety of off-axis loading forces.[37] Cyclic loading may more accurately reproduce fatigue failures observed clinically. Other in vitro tests, such as stress distribution analysis, tension tests, and clinical studies need to be conducted to determine the fracture strengths of various ceramic restorations with and without DME.

Finally, a laboratory study can't simulate the complexities of the oral environment, and can't avoid the difficulty of isolating the clinical operating field on difficult-to-access posterior tooth preparations. Therefore, randomized controlled clinical trials with appropriate recall intervals are needed to corroborate laboratory findings and substantiate new techniques.

Conclusions:

Within the parameters of this study, the materials had no significant difference in fracture resistance. Therefore, collective findings suggest that these materials were suitable for DME

References:

1. Schmidt JC, Sahrmann P, Weiger R, Schmidlin PR, Walter C. Biologic width dimensions - A systematic review. J Clin Periodontol 2013;40(5):493–504.

2. Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998;10(1):47–54.
3. Frankenberger R, Hehn J, Hajtó J, Krämer N, Naumann M, et al. Effect of proximal box elevation with resin composite on marginal quality of ceramic inlays in vitro. Clin Oral Investig 2013;17(1):177–183.
4. Ilgenstein I, Zitzmann N, Bühler J, Wegehaupt F, Attin T, et al. 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):1021–1028.
5. Roggendorf MJ, Krämer N, Dippold C, Vosen VE, Naumann M, et al. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. J Dent 2012;40(12):1068–1073.
6. 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):317–324.
7. Dietschi D, Spreafico R. Evidence-based concepts and procedures for bonded inlays and onlays. Part I. Historical perspectives and clinical rationale for a biosubstitutive approach. Int J Esthet Dent 2015;10(2):210–227.
8. Rocca GT, Rizcalla N, Krejci I, Dietschi D. Evidence-based concepts and procedures for bonded inlays and onlays. Part II. Updated guidelines for cavity preparation and restoration fabrication. J Esthet Dent 2015;10(3):413–392.
9. da Silva G, Cura M, Ceballos L, Fuentes M. Influence of proximal box elevation on bond strength of composite inlays. Clin Oral Investig 2017;21(1):247–254.
10. Müller V, Friedl K, Katrin F, Sebastian H, Handel G, et al. Influence of proximal box elevation technique on marginal integrity of adhesively luted Cerec inlays. Clin Oral Investig 2017;21(2):607–612.
11. Spreafico R, Marchesi G, Turco G, Frassetto A, di Lenarda R, et al. 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):355–362.
12. 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):1385–1393.
13. Andersson WI, van Dijken JW, Hörstedt P. Modified Class II open sandwich restorations: Evaluation of interfacial adaptation and influence of different restorative techniques. Eur J Oral Sci 2002;110(3):270–275.
14. van Dijken J, Kieri C, Carlén M. Longevity of extensive class II open-sandwich restorations with a resin-modified glass-ionomer cement. J Dent Res 1999;78(7):1319–1325.
15. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM Ceramic Restorative Materials for Natural Teeth. J Dent Res 2018;97(10):1082–1091.
16. Lia Mondelli RF, Ishikiriama SK, de Oliveira FO, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. J Appl oral Sci 2009;17(3):161–165.
17. Dina GT, Abdou AF, Salah HM. Fracture resistance of maxillary premolars with class II MOD cavities restored with Ormocer, Nanofilled, and Nanoceramic composite restorative systems. Quintessence Int 2011;42(7):579-587.
18. Magne P, Spreaico R. Deep Margin Elevation: A Paradigm Shift. Am J Esthet Dent 2012;2:86–96.
19. Kielbassa AM, Philipp F. Restoring proximal cavities of molars using the proximal box elevation technique: Systematic review and report of a case. Quintessence Int 2015;46(9):751–764.
20. Sandoval M, Rocca G, Krejci I, Mandikos M, Dietschi D. In vitro evaluation of marginal and internal adaptation of class II CAD/CAM ceramic restorations with different resinous bases and interface treatments. Clin Oral Investig 2015;19(9):2167–2177.
21. Krifka S, Anthofer T, Fritzsch M, Hiller K, Schmalz G, et al. Ceramic Inlays and Partial Ceramic Crowns: Influence of Remaining Cusp Wall Thickness on the Marginal Integrity and Enamel Crack Formation In Vitro. Oper Dent 2009;34(1):32–42.
22. Shinogaya T, Bakke M, Thomsen C, Vilmann A, Matsumoto M. Bite force and occlusal load in healthy young subjects--a methodological study. Eur J Prosthodont Restor Dent 2000;8(1):11–5.
23. Shimazu K, Karibe H, Ogata K. Effect of artificial saliva contamination on adhesion of dental restorative materials. Dent Mater J 2014;33(4):545–550.
24. Ferrari M, Koken S, Grandini S, Ferrari C, Joda T, et al. Influence of cervical margin relocation (CMR) on periodontal health: 12-month results of a controlled trial. J Dent 2018;69:70–76.
25. de Abreu RA, Pereira MD, Furtado F, Prado GP, Mestrine W, et al. Masticatory efficiency and bite force in individuals with normal occlusion. Arch Oral Biol 2014;59(10):1065–1074.
26. Morneburg TR, Pröschel PA. Measurement of masticatory forces and implant loads: a methodologic clinical study. Int J Prosthodont 2002;1591):20–27.
27. Varga S, Spalj S, Lapter V, Anic M, Mestrovic S, et al. Maximum voluntary molar bite force in subjects with normal occlusion. Eur J Orthod 2011;33(4):427–433.
28. van der Bilt A. Assessment of mastication with implications for oral rehabilitation: a review. J Oral Rehabil 2011;38(10):754–780.
29. Aydin B, Pamir T, Baltaci A, Orman M, Turk T. Effect of storage solutions on microhardness of

crown enamel and dentin. Eur J Dent 2015;9(2):262–266.
30. Manicone P, Rossi I, Raffaelli L. An overview of zirconia ceramics: basic properties and clinical applications. J Dent 2007;35(11):819–826.
31. Mehl C, Ludwig K, Steiner M, Kern M. Fracture strength of prefabricated all-ceramic posterior inlay-retained fixed dental prostheses. Dent Mater 2010;26(1):67–75.
32. Tinschert J, Natt G, Mohrbotter N, Spiekermann H, Schulze K. Lifetime of alumina- and zirconia ceramics used for crown and bridge restorations. J Biomed Mater Res B Appl Biomater 2007;80(2):317–321.
33. Saridag S, Sevimay M, Pekkan G. Fracture resistance of teeth restored with all-ceramic inlays and onlays: an in vitro study. Oper Dent 2013;38(6):626–634.
34. Boushell LW, Ritter AV. Ceramic inlays: a case presentation and lessons learned from the literature. J Esthet Restor Dent 2009;21(2):77–87.
35. Cubas GB, Habekost L, Camacho GB, Pereira-Cenci T. Fracture resistance of premolars restored with inlay and onlay ceramic restorations and luted with two different agents. J Prosthodont Res 2011;55(1):53–59.
36. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. J Prosthet Dent 1999;81(6):652–661.
37. Pallis K, Griggs JA, Woody RD, Guillen GE, Miller AW. Fracture resistance of three all-ceramic restorative systems for posterior applications. J Prosthet Dent 2004;91(6):561–569.