EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 70, 1761:1769, APRIL, 2024
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
FIXED PROSTHODONTICS AND DENTAL MATERIALS
Submit Date : 12-02-2024 • Accept Date : 01-03-2024 • Available online: 10-04-2024 • DOI : 10.21608/EDJ.2024.269678.2936

MARGINAL INTEGRITY OF DIFFERENT CAD/CAM MONOLITHIC CERAMIC CROWNS WITH VERTICAL AND HORIZONTAL FINISH LINE PREPARATIONS

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ABSTRACT

Purpose: Evaluate the marginal fit of different monolithic ceramic crowns for prepared teeth with vertical and horizontal finish lines.

Materials & Methods: Sixty monolithic ceramic crowns were fabricated, divided equally into two groups: vertical finish line preparation design (VFL) and horizontal finish line preparation design (HFL). Each group was divided according to the utilized ceramic material into three subgroups (n=10). Subgroup **{CZI}**: Zirconia (Ceramill Zolid), subgroup **{VE}**: Hybrid ceramic (Vita Enamic) and subgroup **{CD}:** Zirconia reinforced Lithium Silicate (Celtra Duo). Vertical gaps of all ceramic crowns were measured at 20 predetermined points without cementation.

Results: All marginal gap results lied within the clinically acceptable range**. {VFL} Group:** {VE}subgroup showed the lowest mean marginal gap followed by {CZI} then {CD}subgroups with statistically significant difference between {VE}&{CD}subgroups. {CZI} showed a non-significant difference with and {VE} and {CD} subgroups. **{HFL} Group:** {VE}subgroup showed the lowest mean marginal gap value followed by {CD} then {CZI}with a statistically significant difference between the three subgroups. All {VFL}, subgroups showed significantly higher marginal gaps compared to their corresponding subgroups in the {HFL} group.

Conclusions: Both finish line preparations offered clinically acceptable marginal gaps for the 3 ceramic materials used, although each material presented significantly different marginal gaps with both preparations.

KEY WORDS: Marginal integrity , Vertical preparation, Horizontal preparation, Ceramic crowns.

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INTRODUCTION

Altering the tooth mechanically (tooth preparation) to regain its healthy normal form by receiving a restoration for proper function, should include removal of caries & tooth structure defects to ensure long term service. As tooth preparation is an irreversible procedure, many conservative preparation trials were conducted to preserve as much tooth structure. Conservative preparations have no exact forms or shapes on the contrary to conventional ones. They have smaller & variable shapes & forms. [1]

For decades, horizontal preparation with definite finish lines was documented as the most acceptable preparation type, but recently vertical preparation without finish line or with an indefinite finish line re-aroused again as a conservative preparation. Vertical preparation is either shoulder-less or edgeless. Historically, shoulder-less preparation was used for Scharp's crown to restore abutments with diverging walls. It has many nomenclatures, according to the rising taper: bevel, chisel edge, feather edge & knife edge. The edgeless vertical preparation is referred to as gingitage which is the rotary gingival curettage, verti-prep or biologically oriented preparation technique (BOPT), in which finish line is eliminated or a subgingival finish line is prepared along with the establishment also of a new emergence profile. [2-4] Literature defined BOPT as a preparation that includes a finishing area where the technician modifies the emergence profile. It was not defined as a knife edge preparation. [5]

Although conservatism is highly demanded, but with no violation to the marginal integrity which is a crucial factor for prolonged serviceability, otherwise failure is expected due to microleakage, cement dissolution, recurrent caries that may extend to pulp affection. [6-9] Schmitt et al (2010), [10] & Cortellini et al (2012),[11] stated that conservative abutment preparation should include conservative indefinite margins. They preferred the vertical preparation to horizontal one, not only for periodontally compromised abutments, but also for other healthier abutments as for abutments in young patients, endodontically treated teeth as well as in case of cervical caries. They mentioned that although vertical preparation was not validated clinically to be advantageous over horizontal preparation, yet it was proved that different margin designs did not cause periodontal alteration from the histological aspect.

McLean & Von Fraunhofer (1971),[6] criteria are considered till now the main reference for the clinically accepted marginal gap that ranges 100-120µm. Researchers [12-14] deducted that the design of the finish line had a marked influence on the marginal sealing of fixed restorations. Many controversies were proposed concerning the relation between the finish line design & marginal discrepancy. Some researchers,[12, 15] found crown seating on a 90 º shoulder finish line to be better than feather edge & 90 º shoulder with bevel, while Vaswani et al (2017),[13] found a non-significant difference between 90° shoulder & 45° chamfer preparations. Tantray et al (2018),[16] recorded that, crowns sealing in case of 90º shoulder with bevel finish line is better than 90 º shoulder & chamfer finish line. Other researchers,[17] reported that the feather edge preparation provided better sealing followed by 45 º shoulder then 90 º shoulder.

Dental ceramics' evolution & technology development rate were very fast & efficient to enable the construction of esthetic restorations comparable in mechanical properties to metal-ceramic restorations & with optimum & satisfactory esthetics. This was clearly presented when using CAD/CAM technology for milling precise & accurately fitting monolithic restorations from different ceramic materials. Zirconia ceramic formulations evolved to achieve optimum mechanical properties without compromising esthetics. Zirconia reinforced lithium silicate, monolithic zirconia and hybrid ceramics

were presented as a solution for the mechanical & esthetic problems used to rise with relatively weaker glass ceramics as well as veneering ceramics bonded to zirconia cores.[18-20]

Evolution of dental materials supported & encouraged for the introduction of various conservative attempts targeting minimal loss of hard tooth structure, taking into consideration not to risk marginal adaptation & integrity. But still the influence of margin type on marginal fit of these restorations not well documented & presented many controversies. [20,21]

This study aimed to investigate the effect of the indefinite vertical preparation & the conventional horizontal preparation on marginal fit of three CAD/CAM monolithic ceramic crowns made of three different ceramic materials. The null hypothesis was that neither the margin type nor the ceramic material will significantly affect the marginal fit of the ceramic crowns.

MATERIALS & METHODS

Samples grouping:

Two mandibular second molar typodont teeth (Frasaco GmbH, Tettnang, Germany) were prepared with (5.5 mm) height, (12˚) total convergence angle and 2mm occlusal reduction. Molar tooth with (HFL) was prepared with deep chamfer margin (1mm) while the molar tooth with (VFL) was prepared with feather edge margin (0.1mm). [20] Sixty ceramic crowns were fabricated and divided into two groups (30 crowns each) according to margin design. Then each group was divided into three subgroups (10 crowns each) according to utilized material. Subgroup **{CZI}:** Zirconia (Ceramill ® Zolid, Amann Girrbach AG, Austria), **Subgroup {VE}:** Hybrid ceramic (Vita Enamic®, Zahnfabrik,Bad Sackingen, Germany) and **Subgroup{CD}:**Zirconia reinforced lithium silicate (Celtra Duo, Dentsply,Sirona,GmbH,Germany)

Fabrication of ceramic crowns:

Scanning of prepared teeth

The prepared two mandibular second molar teeth were digitally scanned using E2 Lab scanner (3 shape, Copenhagen, Denmark). Obtained scans were transformed to STL format then sent to the lab directly.

Designing & milling of ceramic crowns

Designing of monolithic crowns was conducted using software (Dental system 2016 v 1.6.3, 3Shape, Copenhagan, Denmark), **Fig.(1)**. Data was sent to the computer connected to a 5-axis milling machine (vhf CAM 5-S1; vhf camfacture AG, Ammerbuch, Germany). After milling of 60 monolithic crowns. The {CD}crowns were polished with diamond polishing rubbers without addition of glaze firing according to manufacturer recommendation; {VE} crowns were polished using (VITA ENAMIC Polishing Set). {CZI} crowns were milled with an enlargement of 25% to recompense for the sintering shrinkage. Sintering was performed in (Ceramill® Therm 3; Amann Girrbach AG, Austria) sintering furnace at 1450°C and holding period 120 minutes, a total of 7.5 hours. Then all crowns were examined for full seating on their respective prepared teeth.

Measurement of Vertical Marginal Gap Distance

The vertical marginal gap distance was evaluated between each crown and the prepared molar tooth without cementation.[22] For consistent measurements, a holding jig was constructed specially to keep the crowns securely on their respective molar teeth.[23] Each crown was viewed by a digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) at 90X magnification. Vertical gaps between each crown margin and finish line were measured using image analysis software at twenty points chosen for each crown. Five equidistant points / surface (buccal, mesial, distal and lingual). Then the resulted data was collected and tabulated for statistical analysis.

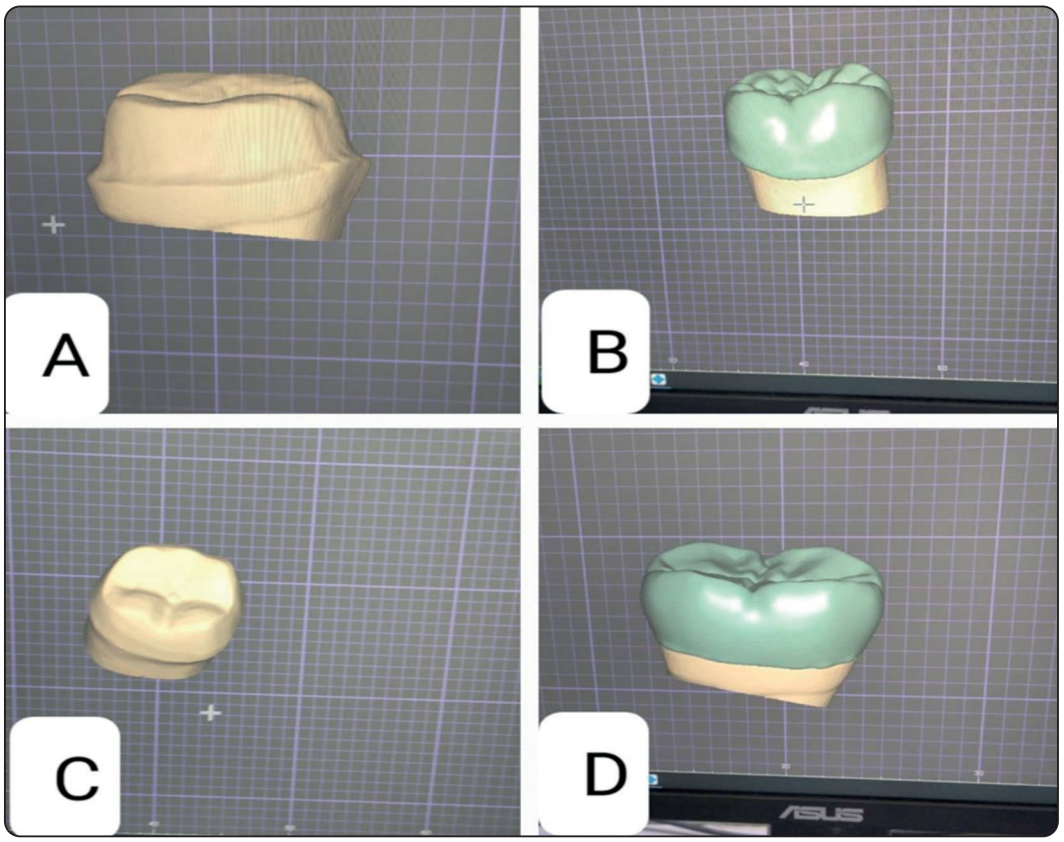

Fig (1) **A**- Digital scanning of horizontal margin, **B**-Digital designing of crown with horizontal margin, **C**- Digital scanning of vertical margin, **D**- Digital designing of crown with vertical margin

Statistical Analysis

The data was analysed using Independent sample t-test for comparing two groups, while One-way ANOVA followed by Tukey post hoc test were conducted for comparing more than two groups. Kolmogorov-Smirnov & Shapiro-Wilk tests were used to assess data normality.

RESULTS

Marginal gap distance results:

Within the {VFL} Group:

Results showed a statistically significant difference between {VE}&{CD}subgroup where (p=0.002). No statistically significant difference was found between {CZI} and each of {VE} and {CD} subgroups where (p=0.054) and (p=0.153), respectively.

{VE} subgroup showed the lowest mean marginal gap value (63.90 ±1.06µm) followed by {CZI} crowns (66.73±1.66µm) then {CD}crowns (68.90±2.21µm) with statistically significant difference (p=0.002).

Within the {HFL} Group:

Results showed a statistically significant difference between {VE}, {CD} and {CZI} subgroups, where (p<0.001).

{VE} subgroup showed the lowest mean marginal gap value (25.78 ±1.47µm) followed by {CD} subgroup (40.25±2.82µm) then {CZI}crowns (44.25±1.83µm) with statistically significant difference (p<0.001). Fig(2)

TABLE (1) The mean, standard deviation (SD) values of marginal gap of different groups & subgroups.

Variables	Marginal gap distance in µm				
	Vertical preparation		Horizontal preparation		p-value
	Mean	SD	Mean	SD	
Vita-Enamic crown	63.90 ^{bA}	1.06	25.78 ^{cB}	1.47	<0.001*
Celtra Duo crown	68.90 ^{aA}	2.21	40.25 ^{bB}	2.82	<0.001*
Ceramill Zi crown	66.73 ^{abA}	1.66	44.25 ^{aB}	1.83	<0.001*
p-value	**0.002***		**<0.001***		

Means with different small letters in the same column indicates significant difference, means with different capital letters in the same row indicates significant difference. *; significant (p<0.05)

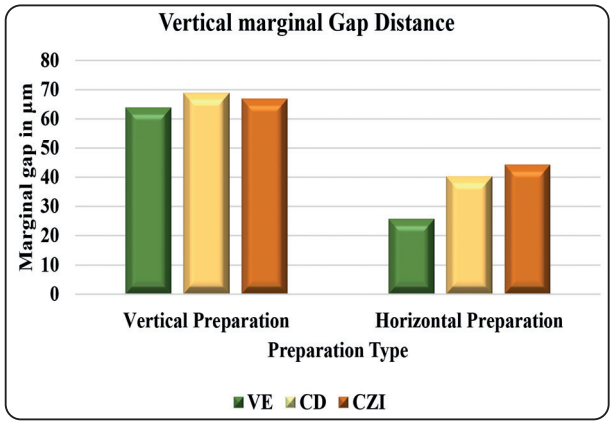

Fig. (2) Bar chart of marginal gap distance for different groups (finish line preparations)

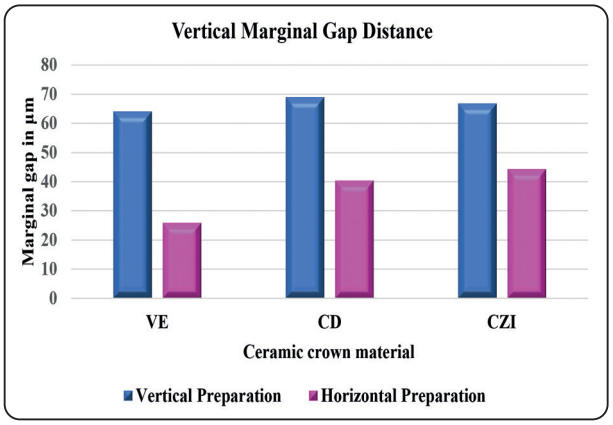

Fig. (3) Bar chart of marginal gap distance for different subgroups (ceramic materials)

Vertical marginal gap of different subgroups having the same material.

In group {VFL}, subgroups {VE}, {CD} and {CZI} showed a significantly higher marginal gaps compared to their corresponding subgroups in the {HFL} group, where (p<0.001). Fig (3)

DISCUSSION

The continual challenge confronted by conservative dentistry to achieve optimal esthetics combined with optimal biological considerations to reduce hazards that might affect vital structures, lead to adopting various preparation concepts that need to be thoroughly evaluated.

In the present study, a single preparation was used for each marginal preparation (vertical & horizontal) using two typodont mandibular second molars prepared to receive a full coverage crown. The performed preparations had a 12° total angle of convergence, as it was claimed to attain the best accuracy of ceramic crowns. [24,25]

Marginal fit was evaluated by measuring the vertical marginal gap of the constructed crowns, which is unlikely to be corrected after crown fabrication. [26] The only available option is to seal it with the luting cement, that will be subjected to dissolution with all other known consequences leading to failure. [6, 27] That's why vertical marginal gap evaluation is crucial, representing high

clinical relevance.[28] Marginal gap measurement was performed at five points per crown surface to have the total of twenty readings per crown, to increase reliability of data. [26] Crowns were not cemented to the prepared abutment, so that the effect of the cement film thickness was eliminated, as it was proved to increase the marginal gap [22]. Also, CAD/ CAM milling was chosen, to eliminate any human variations during construction,[29,30]as milling is capable of constructing restorations from prefabricated ceramic blocks with high degree of precision & margin adaptation provided by CAD/ CAM software, [26] {CD} crowns being constructed from a fully crystallized ceramic, were only polished without addition of a glaze to avoid subjecting them to additional glazing cycles & subsequently unavoidable marginal variations. Specially that the manufacturers claim that ZLS ceramics attain acceptable margins after restorations milling. [31-34] It was declared that firing as well as glaze cycles might negatively affected the restorations marginal gap. [35]

The current investigation showed complete rejection of the null hypothesis, as although all the recorded marginal gaps lie within the clinically acceptable range, but statistical analysis showed a significant effect of marginal preparation type on the marginal gap distance of the three selected crown materials. Although, within the vertical marginal preparation group, only {VE} showed a significantly lower marginal gap compared to {CD}, but it was insignificant with {CZI}. Also, {CZI} showed a significantly lower marginal gap than {CD}. While in case of horizontal marginal preparation, different materials significantly affected the marginal gap of crowns, and still {VE} has the least marginal gap followed by {CD} then {CZI}. On the other hand, horizontal marginal preparation achieved a significantly better marginal fit for the three selected materials compared to the vertical marginal preparation.

According to the manufacturer's instructions, Vita Enamic required no further sintering after restorations' milling, they were only polished. {VE} crowns attained their final physical properties immediately after milling ensuring a high degree of dimensional accuracy. This might explain the lower marginal gap of {VE} compared to {CD} & {CZI} having the same margin preparation whether vertical or horizontal.

Within the vertical preparation group, the insignificantly higher marginal gap of {CZI} crowns compared to {VE} might be explained as {VE} crowns were wet milled on the contrary to {CZI} crowns that were dry milled, which might affect marginal accuracy. [36] Moreover, within the horizontal preparation group the significantly higher marginal gap of {CZI} compared to the other two subgroups {VE} & {CD} might be attributed to sintering shrinkage of the monolithic zirconia crowns to compensate the oversized milled restorations, as reported by many researchers. [37-39]

Horizontal marginal preparation showing significantly better marginal fit results for the three selected materials compared to vertical marginal preparation, agreed with many researchers, who already recorded clinically acceptable marginal gaps related to both marginal preparations. **Elsherbini et al (2023),**[40] reported that feather-edge preparation negatively influenced the marginal gap of monolithic zirconia & zirconia reinforced lithium silicate FPDs. They also recorded that marginal fit was affected by the type of the ceramic. **Rizonaki et al (2021),**[41] found that although the knife edge preparation resulted in the best internal adaptation of lithium disilicate (glass) ceramic crowns yet, it significantly resulted in the highest marginal gap compared to chamfer & shoulder finish lines. They concluded that CAD/CAM glass ceramic full coverage crowns made on a feather-edge preparation do not fulfil the essential criteria of a successful restoration. They related this significant difference to different

ceramic composition & cumulative fabrication errors. [42-44] Jalalian et al (2018),[45] proved that owing to the zirconia ceramic high strength, as the thickness increased, post milling heat treatment insignificantly affected thick restoration marginal adaptation.

Other researchers found better marginal fit with chamfer finish line compared to shoulder. [46,47] These results contradict with many researchers who reported a non-significant effect of the margin design on the marginal gap.[48] Other researchers related the best marginal seal of zirconia crowns to knife-edge preparation compared to chamfer & shoulder finish lines.[2, 49]

CONCLUSIONS

Within the limitations of this study, it was concluded that:

- Both finish line preparations offered clinically acceptable marginal gaps for the 3 ceramic materials used, although each material presented significantly different marginal gaps with both preparations.

Recommendations

- Further investigations are required to compare physical & mechanical behaviour of ceramic restorations constructed on vertical & horizontal finish line preparations.

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