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INFLUENCE OF VERTICAL VERSUS HORIZONTAL MARGIN CONFIGURATION ON FRACTURE RESISTANCE OF ZIRCONIA COPINGS RESTORATIONS WITH VARIED OCCLUSAL THICKNESS

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ABSTRACT

Objectives: To compare the influence of vertical (featheredge) margin configuration versus horizontal (deep chamfer) margin configuration on fracture resistance of zirconia copings with the different occlusal thicknesses (0.5mm and 1mm).

Materials and methods: Two stainless steel master dies were designed and then milled to mimic the coping preparation of the upper first premolar tooth and duplicated by means of epoxy resin to yield forty dies. 40 epoxy dies were distributed into two groups (n=20) in relation to the margin configuration types; feather edge (F) group (n=20) and deep chamfer (DC) group (n=20). Each group was subdivided into two subgroups (n = 10) concerning varied occlusal thickness (0.5 and 1 mm). Copings were fabricated from zirconia blank. For the testing of fracture resistance, a universal testing machine was used by subjecting the samples to a fixed load till failure occurred. Statistical analysis was then performed.

Results: Feather edge margin with (1mm) occlusal thickness registered the highest mean fracture load (1117.81±124.90N) followed by deep chamfer margin with (1mm) occlusal thickness (1000.73±148.84N). While the feather edge margin with (0.5mm) occlusal thickness registered the lowest mean fracture load (282.31± 45.69N) with no significant difference between groups.

Conclusions: Vertical margin configuration margin has a more promising fracture resistance than horizontal margin configuration, especially in (1mm) occlusal thickness. Although (0.5mm) restorations occlusal thickness exceeds the maximum chewing forces reported in the literature.

KEYWORDS: Feather edge, Deep chamfer, Zirconia, Fracture resistance.

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INTRODUCTION

In times past, all-ceramic restorations had liable to fracture when situated in posterior area. So that, a strong ceramic core material has been introduced to maintenance the fragile veneering ceramic materials. Zirconia (ZrO_2) has been developed as an alternative to metal free core structure for immovable prostheses because of its greater mechanical properties related to the transformation toughening mechanism. In addition, its superior physical properties, excellent biocompatibility and chemical stability. [1]

The increasing availability of dental laboratory-equipped CAD-CAM restorations due to rapid modification in materials and equipments led to the use of ZrO_2 copings and framework materials. [2] The good mechanical consistency of partially stabilized ZrO_2 together with its superior toughness allows it to be used as thinner substrates and longer span all-ceramic bridges in posterior regions. [3]

Over the years, the gold standard for margin configurations of all ceramic restoration is deep chamfer and shoulder margins. But, they considered aggressive margins related to more elimination of healthy dental structure that is serious for biological and cosmetic ideas. [4, 5] The idea of minimally invasive dentistry with higher fracture toughness of ZrO_2 permit clinicians to reconsider reduction rules for instance decreasing the thickness of coping from 0.5 mm to 0.3 mm and altering margin configuration from deep chamfer to feather edge margins. [6,7]

The thickness of the margin is significant owing to it can detect the amount of sound tooth structure eliminated during reduction to get proper cosmetics effects and structural integrity of the tooth-crown system.[8] In addition, long-term prognosis of the tooth would be increased by reducing preparation at the cervical region of the tooth and hence preserve pulp vitality consequently maintaining host abutment tooth.[9]

Vertical preparation permits the usage of zirconia restorations in clinical situations for instance periodontally and endodontically treated tooth, young individuals with vital teeth and at the cervical one-third of the clinical crown affected by caries. [10]

Fracture resistance is essential parameters in restoration success. It is main property that should be present in brittle materials as failure of all-ceramic restorations often occurs due to fracture of ceramic material. The greater the fracture resistance of the ceramics, the more the fracture postponed and the restoration show greater stability. [11]

There is inadequate data about how to reduce both the margin (from horizontal to vertical) and occlusal thickness of restorations and to what extent reducing the thickness of restoration affects fracture resistance of the restoration against mechanical loading particularly in the more demanding posterior area. Accordingly, the objective of the current study was directed to compare the influence of margin configuration types (featheredge and deep chamfer) on fracture resistance of zirconia copings with different occlusal thickness.

MATERIALS AND METHODS

Ethical considerations

The study was approved by the institutional ethics committee of Research Ethical Commission (REC) of the Faculty of Dental Medicine for Girls, AL-Azhar University (Approval No: P-PD- 23-06).

Sample size computation

Sample size was computed by the help of the G statistical power analysis program (G. power 3.19.7) as well as relying on former studies.[7, 12] An entire sample size of 40 (20 in each group, were subdivided to 10 in each subgroup) were adequate to note a great influence size (d) = 0.91 with real power (1-β error) of 0.8 (80%) and a significance level (α error) 0.05 (5%) for two-sided hypothesis test.

Model construction

Engineering lathe machine (CNC 350; Arix, Taiwan) was used to design and mill two stainless steel master dies for mimicing the preparation of zirconia copings of upper first premolar tooth. Both dies had the identical dimensions of 8mm gingival diameter with 5 mm occluso-cervical height, 6° axial taper for each wall (a total convergence of 12°) and 45°occlusal bevel on one side of die except of dissimilar finish line configuration. [6,9] One die was prepared with feather edge finish line (0.2mm) and another with deep chamfer finish line (1mm) as shown in (Diagram 1).

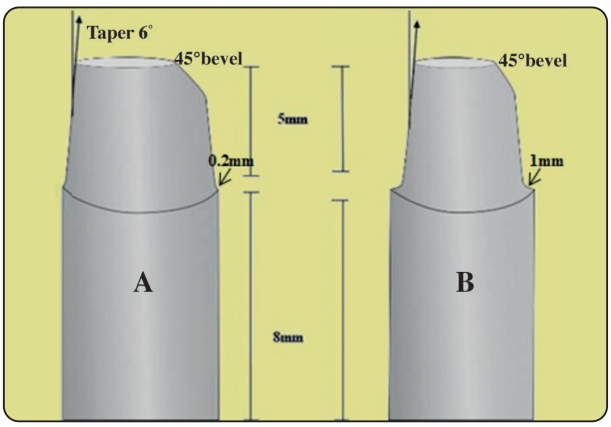

Diagram (1): Schematic diagram showing the identical dimensions of both master dies; (A) Die with feather edge vertical preparation design. (B) Die with deep chamfer horizontal preparation design.

A precision surveyor (Dentsply Ney Dental Surveyor, USA) was used to attach each die with its long axis vertical to the upper surface of a 1.5cm breadth plastic mold full of polymethyl methacrylate polymer cold cure material (Acrostone, Cold cure, Egypt). For duplication of each die with 20 similar epoxy resin dies (20 dies for each finish line design); two silicon molds were fabricated at first by a hard-duplicating addition silicone (Replisil 22 N, lonsee, Germany) through impression taking for each die. After that, each silicon mold was poured 20 times by epoxy resin material (Kemapoxy 150, CMB, Egypt). Separating dies from their silicon molds was occurred after 1day to confirm complete polymerization of resin dies.

Experimental design

Forty epoxy resin dies were allocated into two main groups (n = 20) in relation to the type of margin configuration: **Group (F):** Twenty epoxy resin dies were prepared with feather edge margins (0.2± 0.05 **mm). Group (DC):** Twenty epoxy resin dies were prepared with deep chamfer margins (1± 0.1mm).

Each group was additionally allocated into two subgroups (n = 10) in relation to varied occlusal thickness of the restorations into: **Subgroup (0.5mm):** Restorations fabricated with 0.5 mm occlusal thickness. **Subgroup (1mm):** Restorations fabricated with 1mm occlusal thickness.

Confirmation of the finish line thickness:

The finish line thickness of each die was confirmed before milling the copings by measuring one point in the mid of the finish line at each surface of each prepared die using digital calibration of the Exocad designing software (Exocad software GmbH, Germany).

Fabrication of zirconia copings:

40 zirconia copings were fabricated according to subsequent procedure;

- ***Optical impression:*** Three-dimensional optical scanner (Smart optic scan box, GmbH, Germany) was used to capture a digital image for each resin die. (Figure 1 A).
- ***Digital coping design:*** The margin of each resin die was traced. The CAD system designed the coping by means of designing software. Tools were used to set the desired dimensions of the copings; Criteria of coping design was illustrated in (Table 1) and (Figure 1 B and C).

TABLE (1): Criteria of coping design.

(Groups) Finish line thickness	Margin thickness	(Subgroups) occlusal thickness	Cement space
(F)	0.2mm	0.5mm	50µm
		1mm	
(DC)	1mm	0.5mm	50µm
		1mm	

Milling of the copings: After finishing the design, milling out of zirconia blank (Katana, medium translucent, Japan) was performed by a five-axis milling machine (DWX50 Roland DG Corporation, Japan). (Figure 1 D).

Sintering and glazing of milled copings: subjecting the milled copings to the sintering procedure for 90 min at 1.450°C. After that, each coping was supported over a piece of thermal cotton and the glazing material (Cerabien ZR, Japan)was applied over each coping, then inserted on the tray of the Ivoclar Vivadent furnace (Programat P510 Ivoclar Vivadent, Germany) for glazing cycle according to the producer commands. (Figure 1 E).

Checking copings' seat on the prepared die: Finally, copings were checked for idealistic seat on their conforming dies. The intaglio surfaces of the copings of all specimens were then air abraded. (Figure 1F).

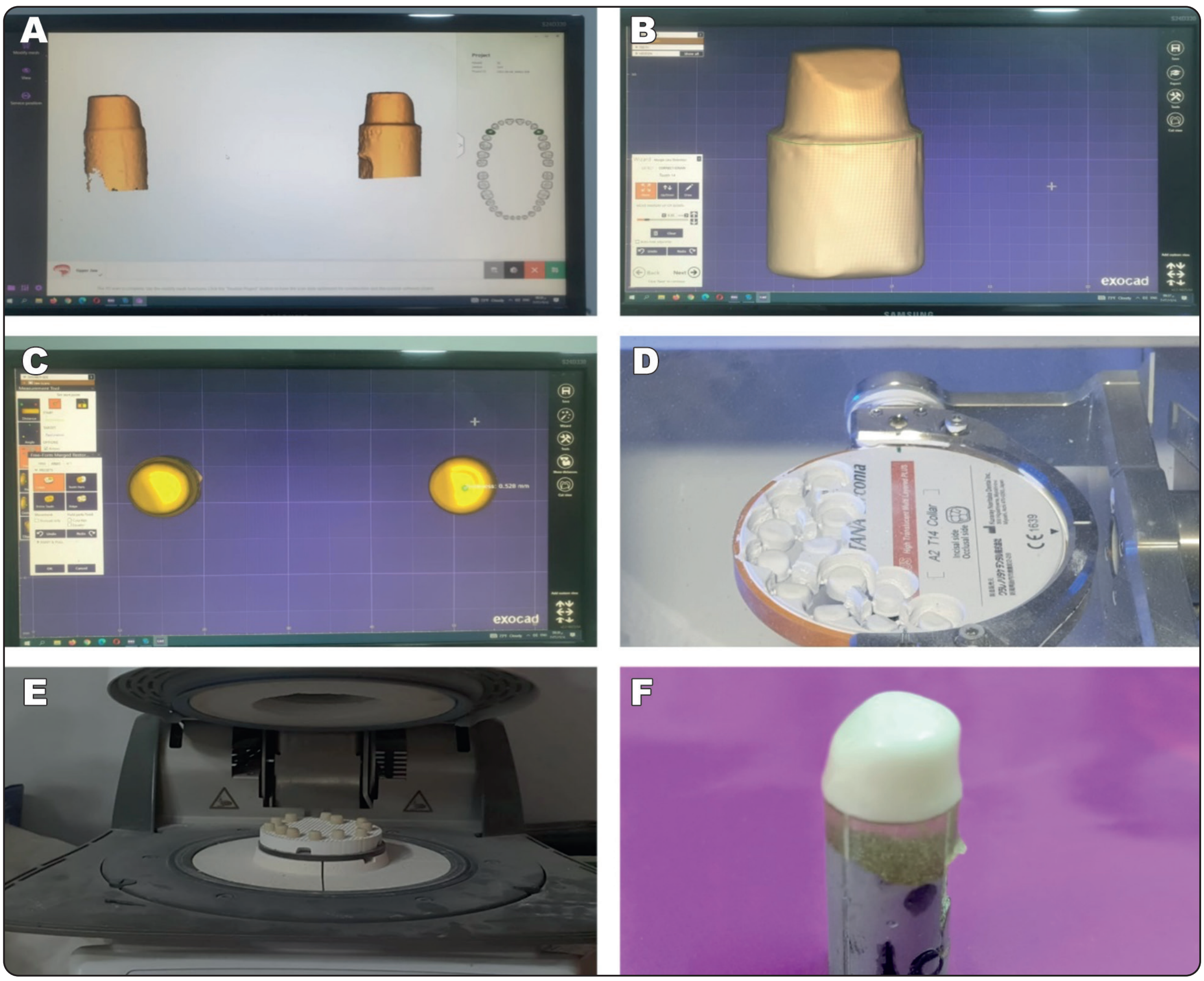

Fig. (1): (A) Optical impression of dies. (B) Tracing of preparation margin. (C) Adjusting occlusal thickness. (D) Milling of copings. (E) Glazing of copings. (F) Zirconia coping' seated on its die.

Testing procedures

Fracture resistance

Each sample was separately attached to a computer-controlled testing device (Model 3345; Instron Industrial Products, USA) with 5kN weight cell. The compressive load was applied vertical on the mid of the central fissure of the occlusal surface to test fracture load for each sample. Fracture mode analysis was then performed using a magnifying lens (10X) (Optics Co, China) to classify the fracture mode according to Burk's classification [13] as represented in (Table 2).

TABLE (2) Burke's classification of mode of fracture of all ceramic's restorations.

Mode of fracture	Description of each mode
Code 1	Minimal fracture or crack in coping.
Code 2	Less than half of coping lost.
Code 3	Coping fracture through midline (half of the coping is displaced or lost).
Code 4	More than half of the coping is lost.
Code 5	Sever fracture of epoxy resin die and/ or coping.

Statistical Analysis

Statistical analysis was calculated by the help of statistical package for Social Sciences (SPSS) version 18. An examination of the distribution of the data, Kolmogorov-Smirnov and Shapiro-Wilk tests were used to explore the data. Independent t test was used to compare among groups. All p-values are two-sided, significant value when P-values ≤0.05.

RESULTS

Effect of margin configuration (regardless to occlusal thickness)

Feather edge margin (group **F**) registered higher mean fracture load in compared to deep chamfer margin (group **DC**) with non-significant difference among groups.

Effect of occlusal thickness (regardless to margin configuration)

Subgroup with (1mm) occlusal thickness registered higher mean fracture load in compared to subgroup with (0.5mm) occlusal thickness with statistically significant difference between both subgroups (p= 0.0001).

Effect of both variables

Feather edge margin with (1mm) occlusal thickness registered the highest mean fracture load (1117.81±124.90N) followed by deep chamfer margin with (1mm) occlusal thickness (1000.73±148.84 N). While (0.5 mm) occlusal thickness of feather edge margin registered the lowest mean fracture load (282.31± 45.69 N) with no significant difference between groups as represented in (Table 3) and (Figure 2).

TABLE (3) Comparison of mean fracture load (N) between groups and subgroups.

	Subgroup (0.5mm)	Subgroup (1mm)	P value between subgroups
Group (F): Feather edge margin	282.31± 45.69	1117.81± 124.90	0.0001*
Group (DC): Deep chamfer margin	312.37± 77.67	1000.73± 148.84	0.0001*
P value between groups	0.305 ns	0.072 ns	

Significance level p≤0.05, * significant, ns=non-significant

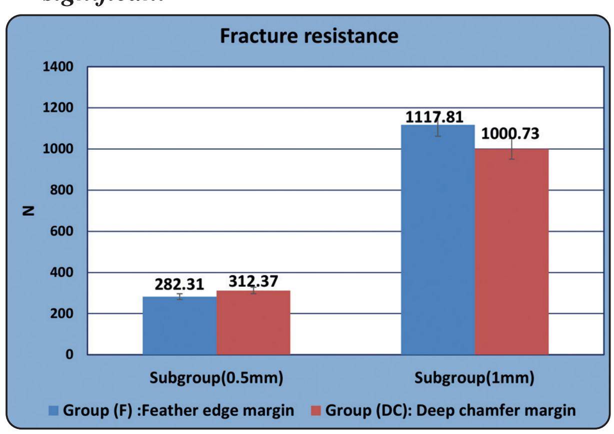

Fig. (2): Bar chart illustrating mean fracture resistance (N) in both groups (F and DC) and subgroups (0.5mm and 1mm).

TABLE (4) Fracture mode assessment after fracture resistance test.

Groups	Subgroups	Fracture mode				
		Code 1	Code 2	Code 3	Code 4	Code 5
Feather edge margin	**(F- 0.5mm)**	0	0	9	1	0
	(F- 1mm)	0	0	6	2	2
Deep chamfer margin	**(DC- 0.5mm)**	0	0	8	0	2
	(DC- 1mm)	0	0	5	3	2

Fracture mode analysis:

Code 3 fracture was the most common mode of fracture in both groups. Chi square test revealed that the difference between groups was not significant. Data are represented numerically in (Table 4).

DISCUSSION

Excellent cosmetic outcomes with maintaining the biological structure involved as much as possible is the task at the present time that facing reconstructive dentistry. Nowadays the clinician and the technician have the materials and methods which make it potential to restore cosmetics and function that work in a simpler and more expectable manner. [14]

With the request for a more conservative restoration, the usage of vertical finish lines with minimal occlusal thickness ascends. The development of high strength ceramics has permitted the clinician to use this preparation in full ceramic restorations. In comparison to other non-metallic materials, the zirconia material has amplified attraction in recent times due to its higher mechanical properities, biocompatibility and adequate cosmetics. [15]

The superior effective scientific outcomes of fracture resistance of minimum occlusal thickness of zirconia restorations than other free- metallic materials due to its high-flexural strength (>1,000 MPa). [16]As there are little information about how the resistance of zirconia restoration to fracture with feather edge margin configuration as well as dissimilar occlusal thickness, it was critical to determine the minimal restoration's thickness with two kinds of margin design (feather edge versus deep chamfer) which guarantees a successful restoration.

In the current study, two stainless steel dies that mimic the preparation of zirconia copings of upper first premolar tooth with different margin configurations were milled with height 5mm and 12° total occlusal convergence angle as mentioned in former investigations. [6, 9]

For duplicating stainless steel dies; material from epoxy resin was designated as a material for dies as the modulus of elasticity of epoxy resin material is like to the documented modulus of human dentin. [17] To imitative clinical situations more closely than resin abutments, the usage of extracted natural teeth as specimens has been found. But, standardization of natural teeth is problematic because of numerous influences for example shape, size, anatomy, age and storage time after extraction. [9]

To expect both the clinical examination and failure degrees, fracture resistance of restorative materials is critical. Numerous aspects affecting the fracture resistance of ceramic restorations comprising the thickness, type and preparation design of ceramic restorations. In addition, it influenced by thickness of die spacer and the quality of bonding at the restoration-tooth interface. [18]Numerous investigations have discussed whether samples should be cemented before attaining the fracture resistance measurements. [19] In some preceding investigation, cementation had no important outcome on the fracture resistance.[20] While another stated a vital improvement in the fracture resistance.[21] In the current investigation, assessment of fracture resistance was carried out without cementation of the restorations as the objective of this study was directed toward assessing the fracture resistance of zirconia coping had dissimilar margin configurations as well as occlusal thickness without taking into consideration the effect of luting agent which considered a major contributor in the superiority of resistance of restoration to fracture.

There were some variations in views about the value for a clinically acceptable average magnitude of bite force that may be applied to natural teeth in premolar area inside oral environment. Various investigations documented that the maximal bite force measurement in premolar area extending from 222-445 to N. [22, 23] Outcomes of the current comparative investigation revealed that the resistance to fracture of zirconia copings ranges from 282.31N to 1117.81N. These values exceed maximum chewing forces documented in the researches.

Concerned to the effect of margin configurations reported, a non-significant difference found between the resistances to fracture in both margin configurations that is like to preceding research. [4] Furthermore, a clinical research stated that the performance of monolithic zirconia with chamfer as well as feather edge finish lines recorded no variances in survival and success rates later to 4 years of examination. [24]

However, feather edge margin (group F) registered higher mean fracture load in compared to deep chamfer margin (group DC) which is confirmed by preceding investigations.[2,12,25] These promising outcomes were associated with method of stress distribution via increasing the force on the restoration at the feather edge margin design that diffused to the walls of axial surfaces than the margin of the supporting die, causing in stress concentration on the surface of occlusal of the restoration rather than the margin region.

On the other hand, outcomes of the present disagree with former investigations. [7,18] This could be related to the sort of cement in their investigation as well as the usage of epoxy dies. In contrast, the occlusal stresses applied on slight chamfer margin design led to stress concentration at the small part of finish line than a wide part of occlusal surface which may result in early failure of restoration.

Considering to effect of occlusal thickness; the resistance of zirconia copings to fracture is influenced by the thickness of occlusal that may improve survival of restoration as reported in preceding investigations. [16, 26] In the current comparative investigation, when contrasting the similar preparation design group, exchanging the thickness of occlusal from 0.5 to 1 mm caused a significant improvement of fracture resistance for the zirconia copings that agreed with former research. [12]

This provides a sign that feather-edge margin configuration lead to suitable copings that resist fracture load especially with sufficient occlusal thickness (1mm) for the zirconia restoration. Additionally, feather-edge margin configuration is associated to biological benefits as avoiding overcontouring of the restoration's margin as well as reducing removal of sound tooth structure, subsequently not compromising gingival and periodontal health. [15]

Regarding to analysis of fracture, all zirconia coping restorations failed owing to whole bulk fracture of the copings by splitting into numerous parts. No die fracture could be noticed which is like to former zirconia restoration investigation. [12]

One of the restrictions of the current in vitro investigation; the restorations were exposed to static stress fracture test without artificial aging procedures that could deliver more data about the clinical performance of the restoration. However, a lone load to fracture test is still significant and considered as the cornerstone for testing materials as a first step.

CONCLUSIONS

Within the limitation of the current study, next conclusions were drawn:

1. Vertical margin configuration presented a sturdy substitute to horizontal margin configuration.
2. Though the restoration with minimum occlusal thickness has inferior fracture resistance than 1 mm occlusal thickness, the 0.5 mm restorations still can endure occlusal forces that exceeds maximum chewing forces reported in the literature.

RECOMMENDATIONS

It could be recommended to do further investigations to exposing samples to thermo-mechanical aging to be near the restoration in clinical performance. Moreover, extending the outcomes of the in vitro comparative investigation to the clinical level ought to be invigorated.

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