Original Article

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ASSESSMENT OF MARGINAL INTEGRITY OF PRESSED VERSUS MILLED ZIRCONIA- REINFORCED LITHIUM SILICATE GLASS CERAMICS (An In-Vitro Study)

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ABSTRACT:

Aim: The current research was conducted to analyze how the manufacturing procedure could affect the internal fit and marginal integrity of zirconia reinforced lithium silicate crowns.

Materials and methods: A typodont tooth for mandibular second molar was prepared in accordance with the criteria of all ceramic crown preparations. The prepared tooth was duplicated into 20 epoxy dies that was subsequently classified into 2 groups; Group 1 (n=10) milled zirconia reinforced lithium disilicate (ZLS) crowns and Group 2 (n=10) pressed ZLS crowns. Internal fit was recorded by the replica approach while marginal fit was measured before and after cementation using stereomicroscope.

Results: Concerning marginal integrity, Pressed ZLS crowns recorded higher marginal gap than milled samples, **before and after cementation**, despite the absence of significant difference. Meanwhile, milled ZLS crowns recorded higher internal gap than that of pressed ZLS crowns, nevertheless, there was no significance (p=0.206).

Conclusions: Within the research's constraints, the manufacturing procedure for ZLS crowns had no influence on the crowns' marginal integrity or internal fit. The marginal and internal gaps created by the crowns in both groups were appropriate for clinical use.

Keywords: Marginal integrity; internal fit; milled ceramics; zirconia reinforced lithium silicate; pressed ceramic

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INTRODUCTION:

Full coverage metal free restorations are considered one of the most important and commonly used restorative treatments to repair teeth that have been severely damaged or decayed[1]. Ceramic based crowns can be produced either by computer aided design / computer aided manufacture (CAD/CAM) technology or by pressing[2, 3]. This innovation had revolutionized esthetic dental practice by enabling the creation of highly precise and customized restorations using software and a milling machine[4, 5].

Pressing, on the other hand, is a traditional method of creating restorations, involving the use of a mold and a dental wax pattern. Pressing and CAD/CAM innovations possess numerous benefits, including high marginal and internal fit, high-quality restorations, reduced chair time, increased accuracy, and the ability to create complex restorations that would be difficult or impossible to achieve with traditional methods[6].

One of the esthetic materials in the dental industry is the zirconia reinforced lithium disilicate glass ceramic (ZLS)[7]. It is a high-strength material that combines the aesthetic appeal with the outstanding durability[8]. This material is often used for dental crowns, bridges, and veneers due to its excellent translucency, biocompatibility, and resistance to fracture. The inclusion of zirconia reinforces the lithium disilicate matrix, making it more resistant to chipping and cracking, particularly in high-stress areas of the mouth[9, 10]Zirconia-reinforced lithium disilicate offers a balance of strength, aesthetics, and durability, making it a popular choice for restorative dental treatments.

Marginal integrity is a critical aspect of a crown restoration that guarantees the quality of seal between the crown and the underlying tooth structure[11]. Understanding marginal integrity is essential for dental professionals to guarantee the longevity of the crowns and maintain oral health as a well-sealed margin prevents the ingress of bacteria and other harmful substances, which can lead to secondary caries (tooth decay), pulpal inflammation, or even peri-implantitis[12].

One of the fundamental aspects affecting the internal fit and marginal integrity is the fabrication technique. So, this investigation was conducted to compare between the milled and pressed ZLS single crowns regarding the previously mentioned factors[13, 14]. The study's null hypothesis stated that the fabrication technique has no effect on the marginal integrity and the internal fit of ZLS crowns.

Materials and methods:

Table (1): Material's name, description, manufactures, and LOT numbers.

Material's name	Description	Composition	Manufacturer	LOT number
1-Vita Ambria Ingots	zirconia reinforced lithium disilicate	SiO_2 ; 58 – 66% LiO_2 ;12– 16 % ZrO_2 ; 8 – 12 % $P2O_5$; 2 –6 %	Vita Zahnfabrik ,Bad Säckingen, Germany	73101
2-VitaSuprinity blocks	ZLS	SiO_2 ; 56 – 64% LiO_2 ;15 – 21% ZrO_2 ; 8 – 12 % $P2O_5$; 3 – 8 %	Vita Zahnfabrik, Bad Säckingen, Germany	58030

Epoxy dies construction:

A typodont tooth (Nissin model, Japan), reduction of mandibular second molar was carried out for receiving a ZLS crown using the same standards like all ceramic crowns preparations; 1.5 mm occlusal preparation and axial reduction of 1.2mm ending with a 1mm deep chamfer finish line[15]**.** The prepared acrylic tooth was duplicated into epoxy dies using silicon index and epoxy material (Egypoxy, Egypt).

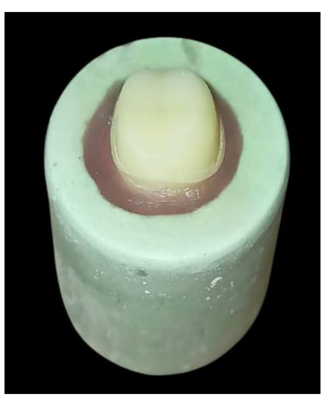

figure 1 (a)

figure 1 (b)

Figure 1; prepared acrylic tooth with a base, (a) proximal view, (b) buccal view

Fabrication of pressed ZlS crowns:

Scanning of the epoxy die was performed by an intra-orally based scanning device (CEREC Omnicam, Dentsply Sirona, USA)[16], thenrecorded as a Standard Tessellation Language (STL) file which was processedby a software (Exocad polived 2.4, exocad GmbH, Germany) to make a crown design with 50µ spacer[17]. Then, transferring this design to the milling machine (vhf K5+ ,vhf cam facture AG, Germany) and 10 wax patterns were milled from CAD wax (Aidite wax blank, Aidite, China) (figure; 2)[18]. The wax patterns were seated over the epoxy dies and margination process was done over a band of 1mm width for guaranteeing favorable wax marginal adaptability[19].

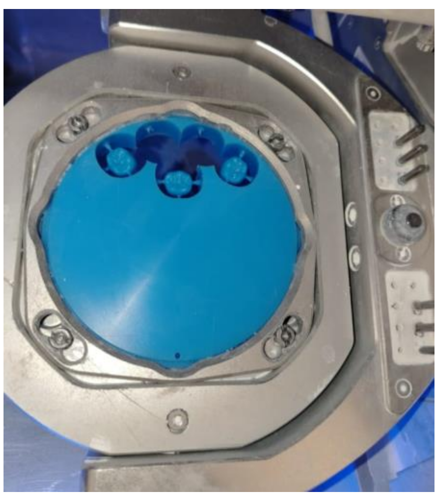

Figure 2; milling crowns from CAD wax

Spruing and investing of wax patterns were accomplished according to the supplier guidelines and burnout procedure was carried out then the Vita Ambria ingots were introduced into the mold utilizing the furnace (Ivoclar Programat EP 3010, Ivoclar Vivadent)[20]Separating and eliminating of the investment were carried out by a fine grit diamond abrasive tool, red coded, was used for contouring. Next, the crowns were washed using a steam jet and an ultrasonic cleaner and the Vita Ambria crowns were checked on the epoxy dies.

Fabrication of milled ZLS crowns:

The STL file was utilized to design the crowns (figure; 3) via software (CEREC premium 4.4 software, Dentsply Sirona, USA). The cement spacing was fixed at 50 µm.All the Zirconia crowns were milled by wet milling process from Vita Suprinity blocks utilizing milling machine (CEREC MC XL, four axis milling unit, Dentsply Sirona , America) (figure; 4) . A fine grit diamond abrasive tool, red coded, was used for contouring. Then, the restorations were cleaned with a steam jet and an ultrasonic cleaner. Post milling crystallization was carried out in CEREC speed fire furnace at 800° C for 20 minutes.

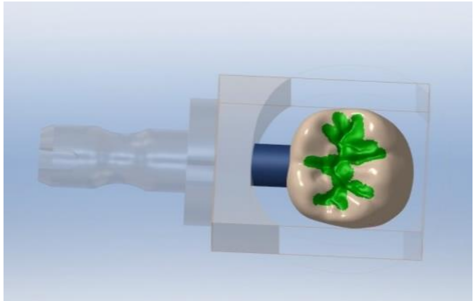

Figure 3; designing a crown on Vita Suprinity blocks

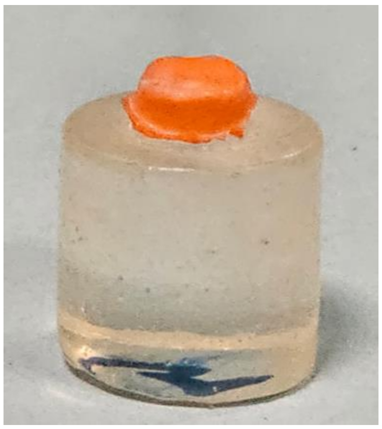

Figure 4; the set light material attached to the die

Interior fitting valuations:

Internal fitting was determined utilizing the silicone replica approach[21]. Each crown was packed with a light body silicone substance (Zhermack Spa, Italy) and seated on the epoxy die under a constant load using a holding device[22]. Following setting of the light-body silicone (figure 5), the crown was taken away , and a heavy-body silicone (Zhermack Spa, Italy) was employed for supporting the light-body silicone as well as to prevent it from disintegrating during recovery.

The silicone replica was subsequently established and put on graph paper, with intercrossing lines exactly at 90 degrees.

The duplicates were delicately divided into four equal parts with a razor blade (no. 15). Two opposing parts from each replica were utilized to test internal fit, with seven places assessed on every segment, totaling 14 internal measures for each coping.

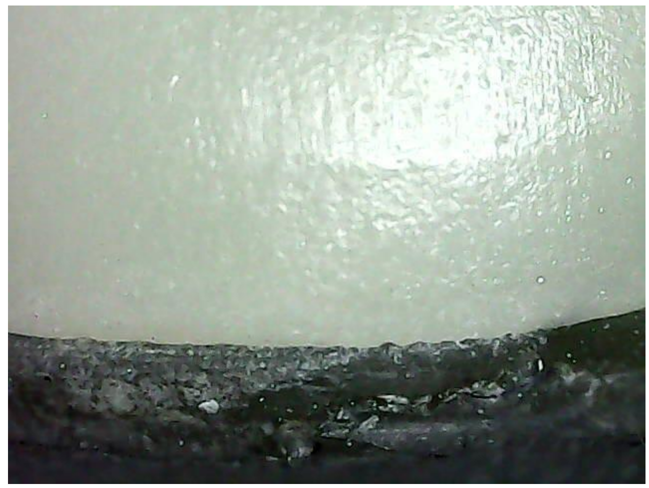

Figure 5; Morph metric measures were taken for each image using three equally situated points.

Marginal adaptation measurements:

Marginal adaptability was assessed twice: prior to and following cementation. **Before cementation:** Each crown was set on its appropriate epoxy die and secured in place with a specific holding mechanism. Each item has been captured utilizing a USB digital microscopy with integrated camera; the photos were captured using the subsequent image gathering tools; A digital photographic device (U500x Digital Microscope, Guangdong, China) with a pixel density of 3 Mega Pixels is set vertically 2.5 cm from the specimens. The angle between the lens axis and the light sources is roughly 90 degrees. The illumination was provided by 8 LED bulbs customized via controller ring), with a color index of approximately 95%. Photographs were captured at the highest possible resolution (2272 · 1704 pixels) and linked to an IBM compatible computer with a set magnification of 40X.Images were captured at a resolution of 1280 × 1024 pixels each. A computer-based imaging evaluation platform (Image J 1.43U, National Institute of Health, USA) was utilized for measuring and assessing the gap width. In the Image J program, all limitations, dimensions, frames, and measurable parameters are given in pixels. As a result, device adjustment was used to transform the pixels into absolute real-world units. Standardization was performed by contrasting an object of established dimensions (a ruler in this case) to a scale provided by the Image J program. Each species was photographed at its edges (figure 6). Morphometric assessments were then taken for each picture [three equal distance markers along the perimeter of each surface]. The measurements at every location were done three times. The data were then gathered, collated, and statistically analyzed.

Cementation of crowns over dies: Hydrofluoric acid 9.5% (BISCO ,Inc, Schaumburg, IL,USA) was employed for surface treatment of the crowns intaglio surface for 20s, then rinsed, dried, treated by silane coupling agent (BISCO ,Inc, Schaumburg,IL,USA) for 60s and air thinned[23]**.** A dual cure resin cement (Breez, Pentron, U.S.A) was used to cement the crown over the die. The crown die assembly was placed in the holding device, a mass of 4 Kg was placed over the device, excessive cement was eliminated and the cement was light cured for 40S from the buccal and lingual sides. Then marginal fit was re-measured with the same method as before cementation.

Statistical analysis:

The mathematical information were given as mean and standard deviation (SD) measurements. They were assessed for normality via Shapiro-Wilk's test and had normal distribution. Internal fit data were measured utilizing an independent t-test. Marginal adaptation data were recorded utilizing a two-way mixed model ANOVA followed by simple effects comparisons. PP-values were processed for multiple analyses via the False Discovery Rate (FDR) approach. The The significance degree was established at $p < 0.05$. The statistical investigation was carried out using R software for statistics version 4.4.2 for Windows[24].

Results

Marginal adaptation

The impact of numerous factors and their interactions:

Table (2) shows how different factors and their interactions affect the marginal gap (µm). On all surfaces, only cementation demonstrated a substantial influence on the marginal gap.

Table (2): Impact of numerous factors and their interactions on the marginal gap (µm).

Surface	Source	Sum of Squares	df	Mean Square	f-value	p-value
Buccal	Method of fabrication	71.11	1	71.11	**0.25**	**0.616ns**
	Cementation	3369.70	1	3369.70	**12.06**	**0.001***
	Method of fabrication * Cementation	1.29	1	1.29	**0.00**	**0.946ns**
Lingual	Method of fabrication	92.41	1	92.41	**0.54**	**0.465ns**
	Cementation	4058.18	1	4058.18	**23.82**	**<0.001***
	Method of fabrication * Cementation	67.49	1	67.49	**0.40**	**0.532ns**
Mesial	Method of fabrication	0.56	1	0.56	**0.01**	**0.935ns**
	Cementation	4075.67	1	4075.67	**49.11**	**<0.001***
	Method of fabrication * Cementation	31.58	1	31.58	**0.38**	**0.540ns**
Distal	Method of fabrication	0.37	1	0.37	**0.00**	**0.970ns**
	Cementation	3781.96	1	3781.96	**14.65**	**<0.001***
	Method of fabrication * Cementation	172.47	1	172.47	**0.67**	**0.418ns**
Overall	Method of fabrication	0.43	1	0.43	**0.00**	**0.963ns**
	Cementation	15263.56	1	15263.56	**77.95**	**<0.001***
	Method of fabrication * Cementation	197.46	1	197.46	**1.01**	**0.316ns**

df degree of freedom, * significant (p<0.05), ns not significant.

Interactions:

Effect of method of fabrication: regardless of cementation effect and surface, marginal gaps measured in pressed ZLS crowns were higher than those of milled ZLS crowns. Nevertheless, the variation wasn't of statistical significance (p-value = 0.963).

Effect of cementation: regardless of fabrication method and surface, marginal gaps increased significantly after cementation (p-value<0.001).

Internal fit

Comparisons and summary statistics of internal fit (µm) for different fabrication methods are presented in Figure (6). The internal gap measured in milled samples (82.94±11.81) (µm) was higher than that of pressed samples (72.71±10.22) (µm) with no significance in difference (p=0.206).

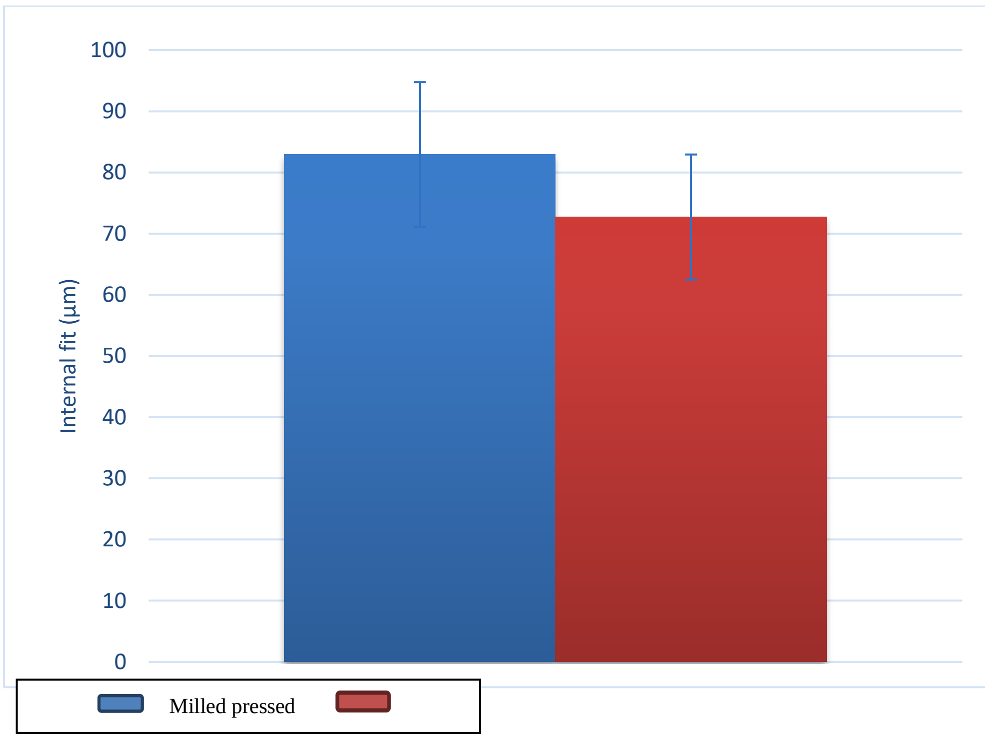

Figure (6): The bar chart displays the mean and standard deviation (error bars) of internal fit (µm) for several manufacturing processes.

Discussion:

Full coverage ceramics based crowns are widely utilized in dental care as a replacement for older ceramo-metal choices for a variety of reasons, particularly their superior cosmetics[25]. Multiple varieties of zirconia-reinforced ceramic restorations have been accessible for contemporary dental reconstruction and rehabilitation of teeth using a range of manufacturing processes, not ably (CAD/CAM) [26, 27].

While zirconia (Zi) offers favorable mechanical qualities for a range of dental applications, the material's white colour and low translucency have historically barred its use for complete contoured restorations[28];Al Hamad, 2022 #597}. Recently, transparent tooth-colored Zi has been created, allowing restorations to be fabricated without the need of veneering porcelain[29]. In dental treatment, lithium disilicates have been widely used to make total coverage crowns[21, 30], and they may be pressed or machined using CAD/CAM. In recent years, a modified version of this substance, called ZLS, was developed[31:Soares-Rusu, 2021 #602:Soares-Rusu, 2021 #602].

The ZLS material comprises the lithium silicate particles in a glassy framework in conjunction with 8–12% zirconia particles, that work to limit crack progression and boost fracture resistance by phase change[32]. Heat pressing and CAD/CAM innovations are two of the most regularly utilized approaches for producing crowns, both of which may generate all ceramic restorations with excellent lifespan and clinical efficiency[33]**.** So, the goal of our research was to assess if the manufacturing technique influenced the effectiveness of ZLS in regard to marginal integrity and internal fit.

In our investigation, epoxy dies were used as abutments for the crowns as it offers strength, detail reproduction and resistance against wear throughout the production cycle and data gathering[34, 35]**.**

The die was prepared with a 1mm deep chamfer finish line because it possesses more thickness and rounded internal angles, allowing for more exact seating, avoiding tensile stresses, and consequently preventing fracture of the fragile material[36, 37]**.**Anatomical occlusal reduction, allowed for correct crown positioning on the die based on specifications and giving a constant dimension, hence facilitating improved ceramic fluidity during thermal pressing[38]**.**

The scanner employed in the current investigation delivered superior accuracy and trueness scores than the extra-orally usedones[26]. A single die scanning was employed for crown manufacturing of all ceramic crowns in both research groups to assure consistency and prevent mistakes caused by numerous scans[39]. The imaginary spacer was adjusted to 50 µm, as indicated in the guidelines for ceramic crowns[27, 28].

Using CAD/CAM technology to mill the wax pattern in the heat pressed ceramic group resulted in a typical spacer setting value of 50 µm, as opposed to freehand wax buildup with variable spacer thickness on the die[40]. Furthermore, milled wax patterns prevent dimensional imperfections caused by the expulsion of thermal tensions formed in the pattern during prior heating and cooling of the wax[41].

In this investigation, the direct view approach was employed to evaluate the vertical marginal adaptations of the crowns on the epoxy die. It is the most popular approach in the existing research[29]. This technique does not involve any steps on the crown-die assembly, like separating or duplication of dies before assessing the gap, thereby eliminating the error buildup that might arise from several steps[42]. Also, marginal fit of the crowns after cementation must be measured as it represents the actual clinical situation in which crown is cemented on its corresponding abutment tooth[43].

The internal gap was assessed with the silicone replica method. This approach has been frequently employed due to its shown validity[30]. It is a simple approach for replicating the whole cement area without damaging the specimen. It was selected rather than sectioning approach because cross sectioning needs duplication of die, sacrifice of samples, and increasing factors that may alter the measurement mean value[21].

Based on the findings of this investigation, both null hypotheses were accepted since the production process (heat pressing versus milling) had no effect on the internal fit or marginal integrity of the ZLS crowns.

A marginal gap of 100-120 µm is satisfactory in terms of adaption[31]. In the current investigation, marginal adaptation between heat-pressed and milled crowns was not a significantly different. The marginal gap mean value for the milling group before cementation was (33.21±10.63 µm), whereas the heat pressed group was (35.14±14.82 µm), both within the clinically approved range. After cementation, Pressed samples (52.70±14.73) (µm) had a higher marginal gap than milled samples (49.49±15.66) (μm), yet the difference also was not statistically significant (p=0.369).

The absence of statistical significance between the two production procedures in terms of marginal adaptation could be linked to the excellent precision of milling in CAD/CAM technology and the optimum wax marginal adaptability thermal pressing approach. These findings were consistent with other earlier studies that claimed that variations in marginal adaptation were insignificant regardless of the implemented fabrication technique[44, 45].

However, **Elrashid et al.**[24]and **Vasiliu et al.**[46]found that CAD/CAM created all ceramic crowns had significant superior marginal adaptation than heat pressing techniques. The variations in findings between earlier investigations and the current study might be attributed to changes in the milling equipment employed and sample size.

Moreover, **Azar et al.**[32]**and Neves et al.**[47]discovered that heat pressing crowns performed better in terms of marginal adaptability than CAD/CAM technology. The disparities in outcomes might be attributable to variances in the ceramic material investigated or changes in a technique of measuring marginal gaps. Regarding the interior fit, the permissible internal gap varies between 50 and 100μm **.** In the current investigation, the heat pressed group had statistical insignificant lower internal gaps than the milling group. The mean internal gap value for the heat pressed group was 72.71±10.22 μm, while that of the milled group was 82.94±11.81 μm, both within the therapeutically appropriate limits. The outcomes of the present research may indicate that the flow of high-pressure ceramic material into the mold when pressured by the plunger results in a superior interior fit. This might also be attributable to limitations related to the software in planning restorative solutions and hardware limits in the milling device, leading to minor flaws in the CAD/CAM approach in regard to of internal fit with inconsequential outcomes.

These results were consistent with numerous researches in the literature**, Mously et al.**[27]**and Guess et al.** [33]**,**however **Vasiliu et al.**[46]published contradictory findings, claiming that milled all-ceramic crowns had considerably less internal gaps than thermally-pressed crowns. The disparities in findings could be attributable to variances in the approach of measuring internal gaps or milling units. Another element that might explain the discrepancy in outcomes is the process of wax pattern production.

It is crucial to highlight that there is a relationship between internal and marginal gaps, since narrower internal gaps may allow the crown to bind with the die, preventing the restoration from entirely seating[48, 49]. This is congruent with the present investigation, in which the heat-pressed group exhibited fewer internal gaps and slightly higher marginal misfit. The CAD/CAM group, with a larger internal gap, exhibited improved marginal fit.

There are some constraints in the current investigation. For starters, because this is an in vitro study, the circumstances in the mouth cavity cannot be perfectly replicated. Furthermore, crowns were not exposed to thermo cycling in order to replicate the aging process.

Concluding remarks:

- Given the results of the current in vitro investigation and within its constraints, it is possible to conclude that:
- The production method of ZLS had no impact on the marginal adaption of tested crowns.
- Manufacturing approach had no effect on the crown internal fit.
- The studied crowns exhibited consistent marginal adaptation across all surfaces.

RECOMMENDATIONS:

1. Further studies with a larger number of samples are recommended.
2. Future studies including oral environment simulation are proposed.

CONFLICT OF INTEREST

The authors declare a lack of conflict of interest

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This research was not funded by any public, commercial, or non-profit organization.

ETHICS

The Research Ethics Committee (REC) of the Faculty of Dentistry, Cairo University, Egypt, approved the study proposal on June 28, 2022. **Approval number: (17622)**

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