

Evaluation Of CAD/CAM Milled Zirconia Crowns And 3D Printed Permanent Resin Crowns in the term of Adaptation

Dalan Jamal Kamal⁽¹⁾ , Fahd Sudad Ikram⁽¹⁾

ABSTRACT

Background and Objective: This study aimed to evaluate and compare the adaptability in term of internal fitting for both types of computer aided design and computer aided milling (CAD/CAM) milled zirconia crown and 3D printed permanent resin crown in both periods of before and after thermocycling aging to evaluate the clinical performance of both types of crowns.

Method: Forty crowns were manufactured: twenty from CAD/CAM zirconia milling group and twenty from 3D-printed permanent resin group. The internal fit test is done for the crowns both before and after thermocycle aging using silicone replica technique. Measurements were taken at marginal, axial, axio-occlusal, and centro-occlusal points under stereomicroscope of 20x magnification. Data analyzed on SPSS software using multiple comparison test.

Result: There were no differences that is statistically significant in most of the points measured for both types of CAD/CAM milled zirconia and 3D-printed permanent resin crown. Thermocycling aging did not result in statistically significant differences for the internal fit of both types of crowns.

Conclusion: Clinically acceptable internal fit values were shown by both 3D-printed permanent resin crowns and CAD/CAM milled zirconia crowns. In some cases of greater adaptation, 3D-printed crowns performed similarly to milled crowns. Thermocycling had no significant impact on internal fit, indicating the materials' and fabrication techniques' long-term clinical practicality.

Keywords: Internal fit, adaptation, CAD/CAM milled zirconia crown, 3D printed permanent resin crown

Article Information

Submission Date: 2/7/2025
Revision date: 24/8/2025
Acceptance date: 30/9/2025
Publishing date: June 2026

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INTRODUCTION

There are several reasons why dentists advise single-unit crowns. Large fillings, fractures, or carious lesions can all place a tooth at risk for additional deterioration. A tooth may be painful, indicating that it has cracked or has undergone endodontic therapy with significant missing tooth structure. In these circumstances, a dentist could suggest a crown to prolong the tooth's life and improve the patient's oral health.¹

In the restorative dentistry field, digital technology has become increasingly prevalent in recent years. Digital fabrication technologies use computer-aided design/computer-aided manufacturing (CAD/CAM) techniques in either 3D printing (additive) or milling (subtractive) manufacturing. In prosthodontics, zirconia, is a ceramic substance that is widely desired due to its exceptional transformation toughening mechanical capabilities, the greatest ever recorded for any dental ceramic—and its more natural appearance when compared to metal-ceramics. Its excellent chemical characteristics, dimensional stability, high mechanical strength, toughness, and Young's modulus (210 GPa), which is comparable to that of stainless steel alloy (193 GPa), make it a popular material for prosthetic appliance assembly.²

There are numerous applications for three-dimensional (3D) printing in dentistry and dental technology. While the mid-2000s saw a paradigm shift for new materials and treatment approaches due to CAD-CAM technology, more and more 3D-printed applications have emerged recently, including metal frameworks, surgical templates, individual impression trays, models, and occlusal splints. When compared to subtractive milling technologies, one major benefit is the manufacturing process's efficiency, which lowers material waste. Furthermore, by modifying the substrate's composition—for example, by adding color particles—the mechanical and aesthetic properties of the 3D workpiece can be precisely fabricated.³

Resin materials can be utilized for a variety of dental applications, including temporary crowns, cast models, denture bases, and occlusal splints. They are utilized in vat photo-polymerization techniques including digital light processing (DLP) and stereolithography (STL). More recent resin-composite materials for 3D printing have been shown to have great durability under occlusal loading and to disperse occlusal stress. These resin-composite materials may offer greater di-

mensional precision and high physical durability when used to fabricate permanent dental prostheses. The internal and marginal fit of milled resin-composite crowns and 3D-printed crowns have often been compared.⁴

There are numerous factors that affect the long-term prognosis of dental crowns, but one of the most significant ones that could result in clinical failure is adaptation in the terms of marginal adaptation and internal fit. The distance measured perpendicularly between the internal surface of the crown and the surface of the axial wall of a preparation is known as the internal gap.⁵ There are multiple methods to measure the internal fit of a crown, silicone replica technique is one of the most precisely methods to be used for this test. Plaque buildup, microleakage, recurrent cavities, and periodontal disease can result from poor adaptation. Furthermore, the dental crowns' internal fit is crucial to their success, as a decline in internal fit will result in decreased retention, instability during rotation, and fracture toughness. There is not much data on the internal fit and marginal gap of zirconia and 3D printed permanent resin crowns.⁶

Aim of the study

This study aims to assess the internal adaptation of CAD/CAM-milled zirconia crowns and 3D-printed permanent resin crowns.

Objectives of the study

The objective of this study is to evaluate and compare the clinical performance of CAD/CAM-milled zirconia crowns and 3-D printed permanent crowns made of resin in terms of adaptation, through conducting detailed analyses of these key properties, this study aims to establish the relative strengths and limitations of each crown material and fabrication method.

METHODS

Study Design

This study employs a two-group experimental design to assess the adaptation in terms of internal fitting of CAD/CAM milled zirconia and 3D-printed permanent resin crowns, and to assess the effect of thermocycle aging on the adaptation of the crowns.

There are forty crowns that are measured for the internal fit, ten crowns are among the group 1A of zirconia material before thermocycle aging, ten crowns are on the group of 1B of 3D printed permanent resin crown before aging. Group 2A have

ten crowns of zirconia and tested after aging and group 2B has ten crowns of 3D printed permanent resin crown after aging.

Sample preparation of the crowns

Plastic jaw typodont teeth (Dental Hard Gingiva, China) with all sound tooth models in the mandibular arch is scanned using dental oral scanner (Panda P3, China). The scanned data is exported to designing software in STL file, the preparation design is made using software (exocad web view, version 1.6.4, Darmstadt, Germany) with anatomical occlusal reduction of 1.5-2mm, cement gap of 60 μ m, axial reduction of 0.8-1.2mm, finish line of shoulder with internal line angle of 0.8mm and total occlusal convergence of 8-10° as shown in the figure 1.⁷

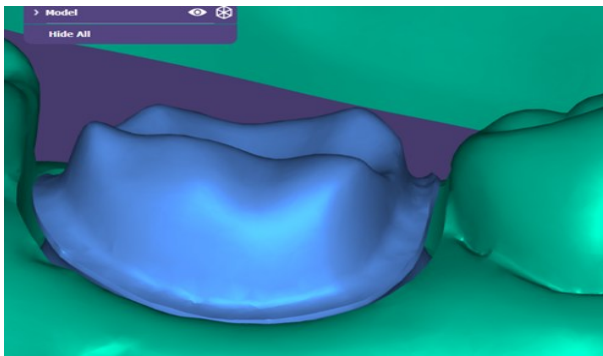


Figure 1. Design of preparation model on exocad software

The resin cast is printed (IMPRIMO LC Model 385nm, Germany) with the tooth number #46 being prepared on the cast with the given design using 3D printer (Asiga Ultra, Australia). After that ten impressions of the printed mandibular resin cast with prepared model is registered using heavy body consistency impression material (Bisico, S1 Suhy, Germany) followed by light body consistency impression material (Bisico, S4 Suhy, Germany) for further details to be recorded. The impression then poured with stone (Hera moldastone cn, Germany) for having stone cast model. The internal fit test is done on the stone cast model with prepared tooth no. #46. The cast is scanned using laboratory cast scanner (S600 ARTI SCANNER, Zirkozahn, Italy) to have the data of the cast on STL file in order for the crowns to be designed. The crowns are designed using software (Zirkozahn 300t designing software, Italy); same design is given for both types of 3D printed permanent resin crown and CAD/CAM milled zirconia crowns. Resin crown (Saremco print CROWN-

TEC, Switzerland) have been printed using digital light processing machine (Asiga Ultra, Australia). Then the printed crown inserted into the device for complete light curing (Dentacolor'XS, Kulzer, Germany). After that polishing of the resin crown and samples are done using brush and sandpaper burs (TOPDENT Pinselbürstchen, Ivoclar, Germany) (Filzpolierer, Ivoclar, Germany) and using clear liquid resin (Universalpolierpaste weiß, Ivoclar, Germany) for final polishing applied on the crowns and samples and light cured. Zircohnzahn 95mm ST white zirconia blocks (Zirkozahn Zirconia Blocks-3D Multi-Layer, Italy) used for milling zirconia crowns through milling machine (Zirkozahn compact line M1 Milling unit, Italy). After milling of the crowns, the specimens are glazed (Optiglaze, GC, Japan). Then inserting the zirconia crowns into ceramic furnace (InCeram furnace, Vita Zahnfabrik, Germany). The laboratory procedure all done in local laboratory German lab (German Zenter, Iraq).

Adaptation Test (Internal Fit)

For measuring the adaptation of the crowns, silicone replica technique is used for testing of all ten specimens of both types of crowns before aging and after aging. The interior surface of crowns was cleaned using ethylene alcohol 70% (Bechtozid sensitive, Becht, Germany) and dried with air. The low viscosity impression material (Bisico, S4 Suhy, Germany) is injected into the fitting surface of the crown, the crown was seated over the abutment, placed with finger to ensure it is in its place as shown in figure 2.



Figure 2. Light body injected into crown and placed on prepared model

then using the surveyor device and a tapered bur on the device (Amman Girbach AF350, Germany)

to apply steady pressure of 10 N for 5 minutes on the central groove of the crown until the impression material has completely set as it is shown in the following figure.

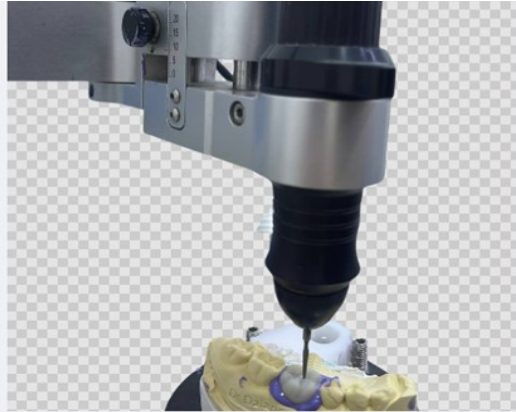


Figure 3. Steady pressure of Amman Girbach AF350 surveyor device on the crown sample

The crown was subsequently removed off, leaving the abutment with a slight silicone impression material that showed how thick the cement gap was. To get over the challenges of handling and cutting the tiny thickness of the light body, a putty silicone material (Bisico, S1 Suhy, Germany) was subsequently coated over the remaining light impression on the abutment and left until sets completely. The heavy body silicone removed from the cast holding the light body impression material with itself. Then Surgical blade number 11 (greetmed number 11, China) was used to cut the silicone replica buccopalatally in cross section after it had set.



Figure 4. Cross-section from the heavy body impression holding the light body material

Following this step the silicon replica is placed under stereomicroscope with 20x magnification (Motic ST-39 Series Stereomicroscope, China) as Amalorpavam et al used 12x magnification stereomicroscope in their research,⁸ Doan et al used

20x stereomicroscope magnification in their study,⁹ and Nizaroglu and Küçük used silicone replica to measure internal fit of veneered zirconia crown and monolithic zirconia crowns under 20x magnification light microscope.¹⁰ A digital cell-phone device (Iphone 12 ProMax, USA) attached to the microscope through a holder to capture the photos of the samples. For measuring the thickness of the light body material in some circumferential points for each of the sections that has been cut. The points checked were from the marginal gap (MG) which is distance measured perpendicularly between the prepared tooth and the internal surface at the coping's edge. The axial wall (AW) which is the disparity between the mid-axial wall's internal coping surface and the prepared tooth. The axio-occlusal (AO) disparity between the prepared tooth and the coping's internal surface in the axial-occlusal edge region, where two straight lines—one parallel to the axial wall and the other to the occlusal plane—intersect, and centro-occlusal (CO) which is discrepancy between the prepared tooth and internal surface of the coping in the center of the occlusal region.¹¹ Under same magnification of the microscope a picture of a ruler with the marking millimeters is captured for calibration of the images in micrometer. For the measurement AutoCad software (AutoCad 2025, Version 2025 Autodesk Inc. California, USA) is used to determine the thickness of the light body material in the selected points in calibration with the photo of the ruler. For each aspect four points were taken, total for each sample sixteen points of measurements are taken, four from each aspects of mesiobuccal, mesiolingual, distobuccal and distolingual. All the points were measured in micrometer measurement unit.

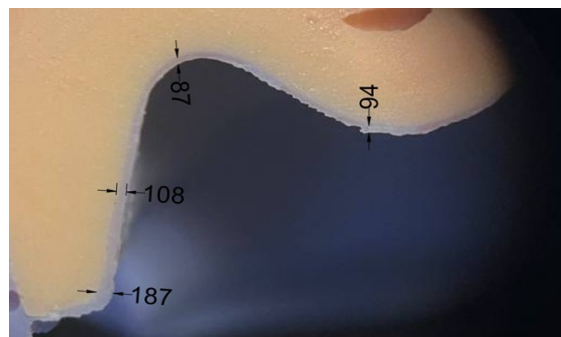


Figure 5. Internal fit measurement of zirconia sample under stereomicroscope

Thermocycle Aging

Thermocycle aging was performed on the crown

specimens to simulate the thermal stresses encountered under intraoral conditions. A total of 2500 thermocycling cycles was selected, corresponding to approximately three months of clinical service, based on commonly accepted equivalence models in dental materials research.

Thermocycling was carried out using a thermocycling device consisting of two temperature-controlled water baths. The hot bath was equipped with a boiler and a thermostat, maintaining the water temperature at 55 ± 2 °C, while the cold bath was 44 connected to a refrigeration compressor with a thermostat regulating the temperature at 5 ± 2 °C. The crown specimens were placed in a basket attached to a mechanical transfer arm, which allowed automatic movement of the samples between the two baths. Each thermocycling cycle consisted of 30 seconds of immersion in the hot bath followed by 30 seconds in the cold bath, with a 5-second transfer interval between immersions to allow drainage and movement of the specimens.

Temperature stability within both baths was continuously monitored using a thermocouple thermometer (HT-9815 Thermocouple Thermometer). One probe was placed in the hot bath and a second probe in the cold bath to verify that the target temperatures were consistently maintained throughout

the thermocycling process. After completion of the thermocycling protocol, the aged crown specimens were removed and prepared for subsequent testing procedures.

Statistical Analysis

All data were analyzed using the latest version of SPSS software (IBM, Armonk, NY, USA). For the evaluation of internal fit, analysis of variance (ANOVA) followed by multiple comparison post hoc tests was used to identify differences among the studied groups. A p-value less than 0.05 was considered statistically significant.¹²

RESULTS

This chapter presents the statistical analysis and results obtained from the experimental evaluation of CAD/CAM-milled zirconia and 3D-printed resin restorations. The independent variables investigated in this study were the type of restorative material (CAD/CAM-milled zirconia and 3D-printed resin) and the aging condition (pre-aging and post-aging). The dependent variable was internal fit. For all analyses, the level of statistical significance was set at $p < 0.05$, and results with p-values below this threshold were considered statistically significant. The detailed numerical results are presented in the following tables.

Table 1. Post-hoc Multiple Comparisons Test Following One-Way ANOVA of Internal Fit Between Zirconia & Resin Pre-Aging

Multiple Comparison Zirconia and Resin Pre-Aging						
Region	Points	Mean Zirconia	Mean Resin	Mean Difference	Std. Error	Sig.
DB	M	207	162.54	44.460	26.058	0.092
	A	203.46	159	44.460	26.058	0.092
	AO	39.46	21	18.460	26.058	0.481
	CO	158	126.36	31.640	26.058	0.228
DL	M	65.105	59	6.105	22.993	0.079
	A	79.105	73	6.105	22.993	0.079
	AO	142	75.105	66.895	22.993	0.005
	CO	146.195	68	78.195	22.993	0.001
MB	M	95	46.8	48.200	27.708	0.086
	A	86.2	38	48.200	27.708	0.086
	AO	45.1	41	4.100	27.708	0.883
	CO	124	76.5	47.500	27.708	0.091
ML	M	25.65	12	13.650	22.575	0.055
	A	89	75.35	13.650	22.575	0.055
	AO	100.35	50	50.35	22.575	0.029
	CO	158	99.35	58.65	22.575	0.011

Internal fit of Zirconia and Resin Pre-Aging

This table presents the results of multiple comparisons between two materials (Zirconia and Resin before aging) across different regions and points, focusing on the mean differences, statistical significance. There are no statistically significant differences in most of the points measured (DB, MB, at M, A, AO, and MB at all points) except the points of AO (p=0.005) and CO (p=0.001) in DL region, and ML region in the points of AO

(p=0.55) and CO (p=0.01).

Internal fit of Zirconia and Resin Post-Aging

Table 2 presents the results of multiple comparisons between two groups " Zirconia and Resin After Aging across different regions and sub-regions of a dental or biomedical study. There are no statistically significant differences in most of the points measured apart from DL region in the points of A (p=0.038) and CO (p=0.001).

Table 2. Post-hoc Multiple Comparisons Test Following One-Way ANOVA of Internal Fit Between Zirconia and Resin Post-Aging

Multiple Comparisons						
Zirconia and Resin Post-Aging						
Region	Points	Mean Zirconia	Mean Resin	Mean Difference	Std. Error	Sig.
DB	M	104.893	83	21.893	21.772	0.318
	A	108.893	87	21.893	21.772	0.318
	AO	74	52.093	21.907	21.772	0.317
	CO	152.957	111	41.957	21.772	0.058
DL	M	25.1	6.479	18.621	21.502	0.389
	A	52.145	33.9	18.245	21.502	0.038
	AO	132	54.71	77.279	21.502	0.331
	CO	148	73.221	74.779	21.502	0.001
MB	M	65	27.4	37.600	22.791	0.103
	A	87	49.4	37.600	22.791	0.103
	AO	34	17	17.000	22.791	0.458
	CO	142	101.85	40.150	22.791	0.082
ML	M	75	42.65	32.350	23.826	0.179
	A	41	8.65	32.350	23.826	0.179
	AO	66	8.4	57.6	23.826	0.518
	CO	158	133.05	24.950	23.826	0.298

Internal fit of Zirconia Pre-Aging and Post-Aging

Table 3 compares between Zirconia before aging and after aging conditions across different regions and points. The goal is to determine whether there

are statistically significant changes in those 16 measurements from the pre-aging to post-aging phases, the only statistically significant differences in three points of A in DL and MB regions, and AO in ML region.

Table 3. Post-Hoc Multiple Comparisons Test Following One-Way ANOVA of Internal Fit Between Zirconia Pre-Aging and Post-Aging

Multiple Comparisons						
Zirconia Pre-Aging and Post-Aging						
Region	Points	Mean Zirconia before aging	Mean Zirconia after aging	Mean Difference	Std. Error	Sig.
DB	M	5.64	3.99	1.650	18.455	0.929
	A	45.23	21.432	23.798	18.479	0.200
	AO	74	35.242	38.758	18.234	0.300
	CO	157	106.592	50.408	18.234	0.400
DL	M	46.35	32.225	14.125	12.351	0.255
	A	52.145	21.495	30.650	12.351	0.014
	AO	142	125.475	16.525	12.351	0.183
	CO	112	73.625	38.375	12.351	0.522
MB	M	57	33.125	23.875	17.565	0.785
	A	87	43.625	43.375	17.565	0.015
	AO	147	109.5	37.500	17.565	0.064
	CO	19	12	7.000	17.565	0.691
ML	M	74	42.75	31.250	11.463	0.856
	A	31	18.8	12.200	11.463	0.289
	AO	47	17.95	29.050	11.463	0.056
	CO	128	84.425	43.575	11.463	0.074

Internal fit of Resin Pre-Aging and Post-aging
 Table 4 compares between Resin before aging and after aging across various regions and points, aiming to identify significant changes after aging. There is only one point of CO in DB region that

shows statistically significant difference between the materials in pre-aging and post-aging phase, there are no statistically significant differences between all other measured points whose values are larger than 0.05 ($p > 0.05$).

Table 4. Post-Hoc Multiple Comparisons Test Following One-Way ANOVA of Internal Fit Between Resin Pre-Aging and Post-Aging

Multiple Comparisons						
Resin Pre-Aging and Post-Aging						
Region	Points	Mean Resin before aging	Mean Resin after aging	Mean Difference	Std. Error	Sig.
DB	M	57	35.802	21.198	17.802	0.255
	A	44.21	21.332	22.878	17.595	0.116
	AO	78	39.18	38.820	17.362	0.227
	CO	145	136.68	8.320	17.362	0.032
DL	M	142.65	117.296	25.354	11.462	0.254
	A	52.145	39.945	12.200	11.462	0.209
	AO	111.65	92.6	19.050	11.462	0.234
	CO	147.23	113.655	33.575	11.462	0.412
MB	M	74	44.302	29.698	16.167	0.052
	A	48	12.151	35.849	16.070	0.067
	AO	169	155.152	13.848	15.966	0.387
	CO	85	62.027	22.973	15.966	0.152
ML	M	85	26.986	58.014	18.804	0.102
	A	37	16.557	20.443	18.691	0.276
	AO	58	20.429	37.571	18.571	0.065
	CO	112	87.004	24.996	18.571	0.070

DISCUSSION

Dental crown success depends heavily on the internal fit, since a decline in this fit will result in reduced retention, reduced rotational stability, and reduced fracture toughness.⁶ For dental crowns to avoid microleakage and periodontal problems, as well as secondary caries around abutment teeth, internal fit is essential. A restoration's lifespan and efficacy are guaranteed by proper adaptation, which also improves patient happiness and general oral health.¹³ The clinically acceptable range for internal fit, according to McLean and von Fraunhofer, was 120 µm, even though the internal discrepancies may be well over 200–300 µm.¹⁴ Zirconia material has been used since a long time for dental crowns and it has a long-term clinical success as a restorative material.^{15,16,17,18} Specially designed 3D-printed "permanent" crown resins

(ceramic-filled permanent crown resins and resin-composite printable materials) have been introduced in recent years. Promising mechanical qualities, an acceptable marginal fit, and short-term clinical effectiveness are demonstrated by laboratory data and early clinical reports/reviews, establishing them as a novel substitute for conventional materials, prefabricated zirconia, and milled composites.¹⁹ The possibility of permanent use is supported by in vitro research that demonstrates 3D-printed resin composites can reach mechanical performance on level with milled resin composites when adhesively bonded.²⁰ This study compares zirconia, a long-established material for dental restorations, with novel 3D-printed permanent resin crowns to determine how closely their performances are related. Silicone replica technique is used to test the internal fit of the speci-

mens as it is a dependable, trustworthy and non-destructive method.²¹

From this study, the null hypothesis is accepted that there will be no significant difference between the printed group and the milled group in the point of internal fit of the crowns. The current investigation found that although some occlusal/axio-occlusal points (such as AO, CO in the DL area; A in DL/MB; and CO in DB) showed statistically significant variations, the magnitude of these differences stayed below or close to clinically acceptable levels per McLean & von Fraunhofer (120–300 μm). This indicates that the basic internal adaptation for both materials is still dependable, despite occasional inconsistency at non-marginal points. Abualsaud and Alalawa have reported similar results. Both 3D-printed and milled zirconia crowns did not significantly differ in terms of internal fit.⁷ Similarly, despite slight variations in accuracy and trueness, Al-Ramadan et al. showed that resin crowns can achieve internal fit and marginal adaptation that are comparable to milled crowns.²² There is no agreement with the results of Refaei et al. who compared the internal fit of zirconia crowns fabricated in two different techniques of milled and printed groups, in their study the milled group showed better fit in the point of internal fit comparison to the printed group of zirconia.⁶ Marouki et al. compared the internal fit of two types of zirconia material one fabricated through subtractive and other is fabricated through additive manufacturing technique, there is an agreement in their study with this investigation in which it is mentioned that both of them are within clinically acceptable limit, while the printed group have higher accuracy of internal fit.²³ Abualsaud and Alalawi did a study about the internal fit and precision between zirconia crowns manufactured in two different techniques of milled and printed groups, there is an agreement of their study with this research that there is no statistically significant difference between the two groups and the printed group is more accurate in the measured number in comparison to the milled group.⁷ There is an agreement with the results of the study of da Silva et al. study in which they contrasted the internal fit and precision of the zirconia material through techniques of subtractive and additive manufacturing methods, in their study there was no statistically significant difference between the groups and both of them were within clinically acceptable margin in their study for the marginal point milling group

is preferred and for the axial point printed method is preferred, while in this study from all the points printed group shows more accuracy of the fit.²⁴ Al-Ramadan et al. did a study close to this investigation in comparison of internal fit between multiple types of 3D printed permanent resin crowns with the milled crown, there is an agreement between this study and their research that there is no significant difference in between printed and milled groups, while in their study the milled group has more precise fitting.²² Mosaddad et al. compared the internal fit between two groups of crowns, the milled zirconia and printed zirconia, in which there is an agreement with this study that there is no significant difference between the groups.²⁵ Kakinuma et al. did a study to measure the internal fit between resin crowns fabricated through printing and milling. In their result, there is agreement with this study that the printed group showed better fit numerically, but with no significant difference.⁴ This study agrees with the measured result of the study from Kumar et al., in which they compared the internal fit of 3D printed crowns with milled crowns; there is no significant difference between the groups, while the printed group shows better accuracy in close fitting.²⁶ This study is supported by the results obtained from the study of Clark et al., which demonstrates the internal fit of multiple 3D printed crowns, and like this study, they are all in the clinically acceptable range.²⁷ There is no statistically significant difference between the milled group of crowns with the printed group in the study of Kang et al., which is also in agreement with this study.²⁸ In terms of aging, our study's minimal thermocycling effect is in line with previous research of Vasiliu et al., which indicates that zirconia and some resin materials both retain dimensional stability under thermal stress. certain results support the hypothesis that, although combining thermal and mechanical stress in the future may show more subtle effects, thermocycling alone may not significantly impair internal fit in certain crown types.²⁹ There is another study done by Nassar and Abo El-Mal that shows no significant effect of thermocycle aging on internal fit of crowns that is in agreement with this study.³⁰ There is an agreement with Sadeqi et al. as well that thermocycle aging will not have a significantly effect on the crowns' internal fit.³¹ Although most differences were not statistically significant, the size of the differences varied across regions. Before aging, zirconia showed higher internal gaps

than resin in some areas, especially at DL-CO ($\approx 78 \mu\text{m}$) and DL-AO ($\approx 67 \mu\text{m}$), with moderate differences also seen at ML-CO ($\approx 59 \mu\text{m}$). After aging, the largest difference remained at DL-CO ($\approx 75 \mu\text{m}$), while other areas showed smaller differences (around 20–40 μm). Despite this variation, all values for both materials were within clinically acceptable limits, suggesting that these differences are not likely to have a meaningful clinical impact. There are limitations in this study, for further investigation in the future different aging procedure can be done for the comparison in between both materials like thermo-mechanical aging for evaluation of clinical durability of the materials and fracture resistance test can also be evaluated.

Recommendations

- Further studies are recommended to evaluate the physical and mechanical properties of restorations in the presence of a luting cement layer between the tooth structure and the prosthesis.
- Combining the silicone replica technique with advanced digital methods such as micro-CT or three-dimensional scanning is suggested to achieve higher accuracy in internal fit evaluation.
- Future research should include optical evaluations to assess shade matching, translucency, and color stability of CAD/CAM-milled and 3D-printed restorations.
- Long-term clinical studies are required to investigate the in vivo performance and biocompatibility of the tested materials under functional oral conditions.
- Additional investigations are suggested to assess the bonding effectiveness and durability of different luting cements with both CAD/CAM-milled zirconia and 3D-printed resin restorations.

CONCLUSION

In this study, internal fit is evaluated between CAD/CAM milled zirconia and 3D printed permanent resin crown across four regions (MB, ML, DB, and DL) and four reference points for each region (Margin, Axial, Axio-occlusal, Centro-occlusal). Aside for a few distinctive sites in the DL area (AO and CO before ageing; A and CO after ageing), the multiple comparison analyses (Tables 1 and 2) demonstrated no statistically significant changes between zirconia and resin crowns

at most measurement points before and after aging. Likewise, intra-material comparisons (Tables 3 and 4) showed that aging caused relatively minor changes, with resin exhibiting alterations at a single point (CO in DB) and zirconia at three points (A in DL and MB, AO in ML). These slight differences show that the internal fit of both materials was only slightly impacted by thermocycling. All things considered, the data show that both zirconia and resin crowns retained clinically satisfactory adaptation, and the resin crown's similar performance supports their usage as a good alternative for milled zirconia in permanent restorations.

Acknowledgment

I would like to express my sincere gratitude to Hawler Medical University/College of Dentistry, the Department of Prosthodontics, my supervisor Asst. Prof. Dr. Fahd Sudad Ikram, Prof. Dr. Omer Naqshbandi, Asst. Prof. Dr. Khurshid A. Kheder Khrwatany, Eng. Sarkawt Nzar, Dt. Kawan Saleh, Mr. Ari Hameed (German Laboratory), and all those who supported and contributed to this study.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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