Mustansiria Dental Journal
MDJ

Vol.21, No.01, 06/2025
P- ISSN: 2618-0944
E- ISSN: 1813-8500

Evaluation of Marginal Fitness of CAD/CAM Monolithic Zirconia Crowns Fabricated using Different Parameter of CBCT and laboratory Scanner

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Received 18/09/2023 ***Accepted in revised form 21/12/2024*** ***Published 30/06/2025***

Abstract

Aim: to compare the marginal fitness of zirconia crowns made using laboratory scanners and various cone beam computed tomography (CBCT) parameter.

Methods: An extracted premolar tooth was prepared for a crown by zirconia crown preparation criteria. The scanning of the prepared tooth using Medit T710 extraoral scanner (group A), and CBCT scans were made with (planmeca promax) CBCT at different setting parameters: (group B) with the field of view 80x50mm and 150um voxel size and (group C) in which tooth scanned by another CBCT parameters with a field of view 50x50 mm and 75um voxel size. The 3D pictures from the CBCT scans and laboratory scanner were then imported into Exocad software, and a crown design was finished. The crowns are milled from computer-aided design/computer-aided manufacturing CAD/CAM zirconia by a 5-axis milling machine. A stereo-zoom microscope was used to assess the vertical marginal gap. A total of 120 points were measured throughout three groups (4 sites per crown). Vertical marginal gap mean values were obtained by averaging the readings for each specimen. The data was analysed using one-way ANOVA, and the Post hoc Tukey's test was performed to compare the significance of the difference between groups.

Result: one-way ANOVA indicated that there was a significant difference in marginal gaps among the experimented groups (p-value = 0.001). The results of the Post hoc HSD Tukey's test showed that there was no significant difference between the laboratory scanner (group A) and CBCT scan (group C) with the field of view (FOV) 50x50mm and 75um voxel size (p value=0.052). However, there was a significant difference between the laboratory scanner and CBCT scan group with (FOV) 80x50mm and 150um voxel size (group B), and also between CBCT scan groups (B and C) with different parameters(p-value=0.001).

Conclusion: Crowns made with the laboratory scanner exhibited smaller marginal gaps than crowns made using CBCT images with various settings parameters. All three groups were able to fabricate monolithic zirconia crowns with a marginal gap of less than 120um.

Keyword: Cone beam computed tomography CBCT, laboratory scanner, marginal fit**,** zirconia crown.

Introduction:

Long-term clinical success relies on maintaining the fixed dental prosthesis FDPs' marginal integrity **(1,2).** The condition of the surrounding periodontal area and the abutment teeth may suffer from an excessive marginal discrepancy of FDPs **(3).** Although an acceptable marginal fit has yet to be identified, a five-year clinical study of one thousand restorations revealed that the FDPs' misfit of margin should be below one hundred twenty micrometers **(4)**.

Using a laboratory scanner to scan a gypsum cast is one way to create a digital model **(5).** However, dentists will potentially face difficulties similar to those seen with impression procedures, and the precision of the digitized model is limited by the quality of the dental impression and cast **(6)**.

Intraoral scanner IOS of the patient is another method to create a 3D virtual model **(7)**. Despite the various advantages of digital impression-taking by IOS, there are drawbacks, such as a learning curve since optical impression-taking is difficult for beginners because precise measurement needs adherence to a complicated scan path **(8).** One of the most common complications with IOS is difficulties in recognizing deep finish lines on prepared teeth or in instances of bleeding. It might be more challenging for the light to find the whole marginal finish line correctly. Because light cannot physically separate the gum, it cannot capture 'non-visible' regions. Similar issues might arise in case of bleeding **(9, 10, 11)**.

To manufacture implant-supported FDPs, surgical guides particular to the patient for inserting implants, and casts of the oral arches without taking conventional impressions, virtual 3D models can also be made from computed tomography with cone beams (CBCT) pictures that are transformed toward standard tessellation language documents via a Computer Aided Design (CAD) software program **(12)**. In addition, crown production on a natural tooth is derived from CBCT data **(13)**.

The benefit of using CBCT is that it eliminates the requirement for gingival retraction and the removal of interim restorations that may obscure margins. Additionally, CBCT removes the necessity for intraoral impressions **(13; 14)**. CBCT is also economical and time efficient, with high patient acceptability **(15; 16).**

The accuracy of the virtual models can be significantly influenced by the CBCT scanning settings. Reducing the field of view (FOV), which is defined as the area of interest to be examined during the scanning operation, may improve accuracy by resulting in sharper beam angles in the upper and lower volumetric areas and a higher contrast-to-noise proportion. Voxel size, which refers to an image's capacity to disclose fine information, also influences precision by affecting the spatial precision of orthogonal slices: the lower the voxel size, the more accurate it is **(14)**. Limiting CBCT's field of view to the important areas helps limit radiation exposure **(17)**. Thus, it is critical to understand the scanning settings that must be used. Additional investigation is necessary.

Aim

To evaluate and compare the marginal fitness of crowns made of monolithic zirconia that will be produced using different parameters of CBCT and extraoral laboratory scanner.

Null Hypothesis

there would be no difference found in the marginal fit of CAD/CAM crowns fabricated with data obtained from two different parameters of CBCT images and laboratory scanners.

Materials and Methods

This study utilized a maxillary first premolar tooth that was extracted according to ethical approval (MUo Pr 14). This tooth must be absent of caries, restorations, and cracks (18). It was kept in deionized distilled water to avoid dehydration during all steps of the study, it was immersed in a specifically constructed custom-made rubber mould that contained a cold cure acrylic mixture. The tooth was prepared for monolithic zirconia crowns with:360-degree 1-mm-rounded shoulder margin in depth and 1 mm coronal to cementoenamel junction, planner occlusal reduction, axial cutting around 1.5 mm, 4 mm occlusal-gingival length measured from the tip of the cusp to the intended finishing line level as shown in figure (1). After preparation, the tooth was scanned by using two machines; the powder-free laboratory scanner (Medit T710, Korea) and labeled as a group (A) seen in figure (2), and the CBCT machine (Planmeca ProMax, Finland) was used to scan the prepared tooth with two different parameters:

(1) field of view (80×50-mm) and voxel size (150 µm)
labeled as group (B)

(2) field of view (50×50 mm) and voxel size (75 µm) labelled as group (C)

The data obtained from CBCT was saved in the digital imaging and communications in medicine (DICOM) format. The Planmeca Promax CBCT software was utilized to automatically convert DICOM data into STL format as shown in Figure (3).

The three-dimensional STL images, acquired from the CBCT and laboratory scanner in STL formats, were transmitted to CAD design software (Exocad software V3.1) then, the crown design of the maxillary first premolar was completed.

Cement space of 20 um around the margin of preparation for all groups and 50um beginning 1mm occlusal to the finish line for groups (A, B) while 130um for group (C). The zirconia disc (IPS e.max ZirCAD disc, Ivoclar Digital, Germany) is milled into crowns using a milling machine (5X-300 Pro, South Korea). The crowns after milling using the same crown design (n=10 for laboratory scanner and 20 for CBCT scans).

Vertical marginal gap values were measured using a stereo microscope (MEIJI, Germany) under 20x magnification provided with a microscopical camera and connected to the computer. The permanent marking pen was used to mark four indentations on the margin area at the middle of the mesial, buccal, distal, and palatal aspects of the tooth and the measurements were taken at three distinct points on each side of the crown as seen in figure (4). To ensure uniform seating pressure between the tooth and crown during Marginal gap measurement, a specimen-holding device was utilized as seen in Figure (5). This device was specifically designed to maintain a constant pressure of approximately 50 Newtons, which is equivalent to 5 kilograms. The specimen was then placed under a stereo-microscope for further analysis.

Twelve measurements were obtained from each crown achieved by the same observer to avoid errors. The average of each three points of one surface was taken and then the average of the four surfaces was selected to represent the marginal gap of that sample.

The statistical analysis of the marginal gap in this study has been performed. The data were subjected to a One-way ANOVA test for analysis. The Post hoc HSD Tukey's test was utilized to evaluate and compare the significance of differences among groups at the significance level.
(0.05).

Result:

Shapiro-Wilk test was used to determine the normality of data distribution. This test revealed the data were normally distributed ($P>0.05$).

In this study, the mean marginal gap measurement for the laboratory scanner group (group A) was (39±3.29 um), and CBCT group with setting parameters of 80x50-mm FOV and voxel 150-µm (group B) has been presented with a mean value (51±4.96um), while group C (CBCT scanned group with 50x50-mm and voxel 75-µm) was (43± 2.88um) as shown in table (1).

The study's results show that decreasing the voxel size and field of view lowered the marginal gap. The measurement of a marginal gap for the laboratory scanner group was 39um, which was less than the marginal gap for the other groups (CBCT-scanned groups).

Results of 1-way ANOVA indicated that there were significant differences in marginal gaps among the experienced groups (p-value less than 0,001) as shown in Table (2).

The results of the Post hoc HSD Tukey's test show that for the laboratory scanner (group A) and CBCT-scanned group with FOV=50x50mm/Voxel=75um (group C), no statistically significant differences were found ($P<.062$) with a lower marginal gap measured in group A, whereas the laboratory scanner (group A) showed significantly lower marginal gaps than CBCT-scanned group with FOV=80x50mm /Voxel=150um (group B) ($P<.001$).

Statistically significant differences were found between CBCT-scanned groups that had different parameters (CBCT with FOV=80x50mm/
Voxel=150um/ CBCT with FOV=50x50 mm/Voxel=75um) with higher marginal

gaps for group B (P<.001) as shown in table (3).

Discussion:

From the data obtained in this study, it was observed that using laboratory scanners and different parameters of CBCT, produced a statistically significant difference in the marginal gap areas, thus it was partially rejected. The mean marginal gap of the laboratory scanner (group A) was 39 um and CBCT scanned group of parameters (FOV=50x50 mm /Voxel=75um) (group C) with (43 um) had a better marginal fit, and the mean vertical marginal gap showed no statistically significant variations. The CBCT scanning group with (FOV =8ox50mm/voxel = 150um) (group B) exhibited the lowest marginal fit, with a mean vertical gap significantly higher than the other groups.

According to Mclean,Von Fraunhofer and Fransson et al., the acceptable clinical marginal gap is between 100-120 µm. (19, 20). According to Assif and colleagues, it is recommended that the average marginal gap should be in proximity to 140 µm. Conversely, Hung and colleagues established a range of values between 50-75 µm. According to Aman et al's. (2018) study, the marginal gap of all groups in this study was found to be within the clinically acceptable range based on previous studies.

The findings of this study indicate significantly lower vertical marginal gap measurements obtained from the laboratory scanner group. It is worth mentioning that no single factor could be considered responsible for these differences. This could be attributed to the use of an automatically adjusted threshold during the process of converting CBCT data from DICOM to STL format (21) or may be explained by the significant accuracy (<4µm) of the laboratory scanner (Medit, Seoul, Korea), which is the most recent version of in lab scanner introduced by media company according to ISO 12836 (22).

Interestingly, no statistically significant difference in the mean of the vertical marginal gap was recorded between group A and subgroup C. This may be related to the CBCT's usage of a reduced voxel size setting (75um) (23).

Another finding of this study was that group C has a significantly lower marginal gap than group B. It might be explained by CBCT scanning settings, which could have a significant effect on the precision of the virtual models. Adjustments to the field of view (FOV) may result in improved accuracy due to greater contrast-to-noise ratio and sharper angulations of the beam in the upper and lower volume regions. Additionally, by affecting the level of spatial resolution of orthogonal slices, voxel size can have an impact on accuracy. A decrease in the size of the voxel tends to result in higher accuracy. This outcome was consistent with prior research results by Hassan et al. (2010), Al Rawi et al. (2010), Seker et al. (2016), Kale et al. (2020), and Belgin et al. (2022) (24,25,13,14).

Other explanations of that significant difference were that small scan field selection provided the best visibility of the teeth and the interproximal space, and small voxel size selection provided best visibility of the occlusal surfaces (24). However, the result is in disagreement with Sang et al who studied the accuracy of 3D reconstructions from CBCT using different voxel sizes and CBCT systems, and they reported increasing voxel resolution does not result in increased accuracy of 3D tooth reconstruction while different CBCT systems can affect the accuracy (26).

The results of this study are by previous in vitro study, Seker et al. in 2016 reported that voxel size had a significant effect on the marginal integrity of CAD/ CAM fabricated crowns on virtual 3D tooth models generated from CBCT scans but the VMDs determined in this investigation were less than those that Seker et al. reported. Polymethyl methacrylate (PMMA) crowns were produced via an identical adjusted workflow and utilizing CAD-CAM and CBCT equipment of a different manufacturer plus model using identical imaging settings as that of the group CBCT scan was found to have a larger mean vertical marginal gap value in that study.

Before examining the marginal integrity, Seker et al. indefinitely adhered the specimens to the abutment tooth using silicone impression material. It has been claimed that using low-viscosity silicone to temporarily attach crowns can mimic clinical cementation. Research indicates that higher VMD will occur from the presence of any luting film thickness between crowns and their corresponding abutments (13).

Kale et al also evaluated the Vertical marginal gap of monolithic zirconia crowns fabricated by using CBCT and laboratory scanner that resulted in a mean marginal gap of laboratory scanner groups and CBCT scan group showed enhanced fit accuracy and no statistically significant variations in the mean vertical marginal discrepancy in between that result. This finding agrees with the results of the present study (14).

Also, Elkersh et al. studied the accuracy of Models Obtained from Digital Impressions Versus Scanning of Conventional Impressions and they found no significant differences in most linear measurements between them the findings of this study came in agreement with Elkersh et al. in 2021(27).

Conclusions

Within the limitation of this in-vitro study and based on results, it
can be concluded that:

1. The vertical marginal gap of the monolithic zirconia crown fabricated by the laboratory scanner was smaller than that fabricated by CBCT data.
2. When CBCT data were used with the setting parameter (FOV=50x50mm/Voxel=75µm) produced a smaller marginal gap compared with the setting parameter (FOV=80x50mm /Voxel=150µm).
3. All monolithic zirconia crowns fabricated from laboratory scanners and CBCT data within clinically acceptable limits.

Conflict of interest

The authors reported that they have no conflicts of interest.

Acknowledgements

The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq), Baghdad, Iraq, for their support in the present work.

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Table (1): Values of Mean, standard deviation, maximum and minimum of marginal gaps of all groups.

	N	Mean	Std. Dev.	Minimum	Maximum
Group A	10	39.16	3.296	34.16	45.00
Group B	10	51.12	4.960	43.31	60.65
Group C	10	43.36	2.884	36.82	46.55

Table (2): One-way ANOVA test for comparison of the marginal gap among the different groups.

ANOVA					
Sum of squares		Df	Mean square	F	Sig
Between groups	736.462	2	368.231	25.229	0.001
Within groups	394.083	27	14.596		
Total	1130.546	29			

Table (3): Post hoc HSD Tukey's test for comparison of statically significant differences in vertical marginal gap means

Tukey HSD						
(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-11.96100-*	1.70855	.001	-16.1972-	-7.7248-
	C	-4.20000-	1.70855	.052	-8.4362-	.0362
B	C	7.76100*	1.70855	.001	3.5248	11.9972
	A	11.96100*	1.70855	.001	7.7248	16.1972

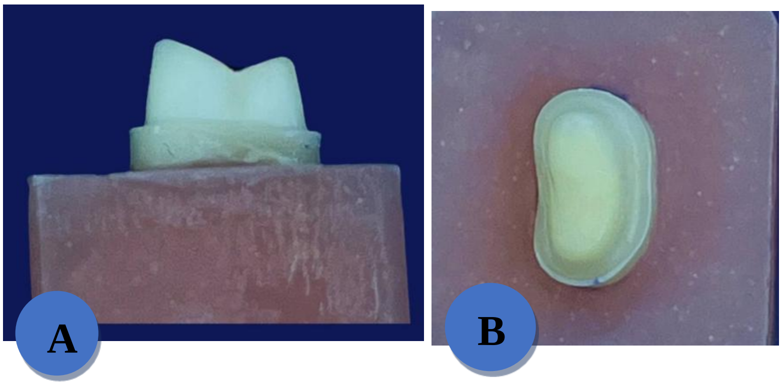

Figure (1): finished prepared tooth. A: lateral view. B: occlusal view

Figure (2): Scanning of the tooth by Medit T710 in-lab scanner

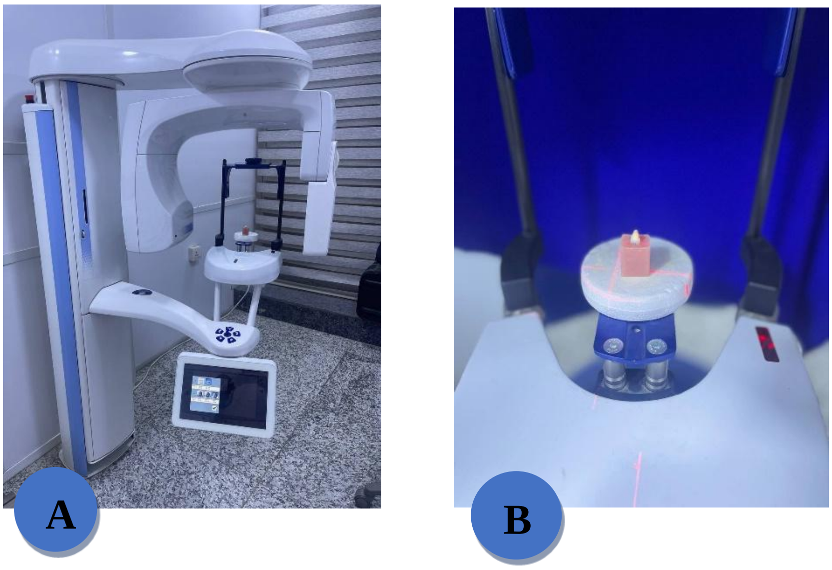

Figure (3) A: Planmeca Promax CBCT machine, B: Tooth with the acrylic base on the table of CBCT.

Figure (4): Three points for marginal gap measurement

Figure (5): Stereo-zoom microscope with specimen holding device that was particularly constructed to maintain a constant pressure of (5N)