

# An in vitro evaluation of fit of the crowns fabricated by zirconium oxide-based ceramic CAD/CAM systems, before and after porcelain firing cycles and after glaze cycles

Sattar J. A. Hmedat, B.D.S. <sup>(1)</sup>

Adel F. Ibraheem, B.D.S., M.Sc. <sup>(2)</sup>

## ABSTRACT

**Background:** The objective of this in vitro study was to evaluate the vertical marginal fit of crowns fabricated with ZrO<sub>2</sub> CAD/CAM, before and after porcelain firing cycles and after glaze cycles.

**Materials and Methods:** An acrylic resin model of a left maxillary first molar was prepared and duplicated to have Nickel-Chromium master die. Ten die stone dies were sent to the CAD/CAM (Amann Girrbach) for crowns fabrication. Marginal gaps along vertical planes were measured at four indentations at the (mid mesial, mid distal, mid buccal, mid palatal) before (Time 0) and after porcelain firing cycles (Time 1) and after glaze cycles (Time 2) using a light microscope at a magnification of ×100. One way ANOVA LSD tests were performed to determine whether the mean and standard deviation of sub group Time 2.

**Results:** The mean values of the ZrO<sub>2</sub> CAD/CAM Time 0 were (6.77µm), Time 1(8.75µm) and Time 2(10.62 µm). One way ANOVA test revealed highly statistical significance(P<0.01). LSD test results showed that there is highly significant difference between time (0) and time (2), while there is no any significant difference between time (0) and time (1), and between time (1) and time (2).

**Conclusions:** Within the limitations of this study, it was concluded that the ZrO<sub>2</sub> CAD/CAM demonstrated acceptable marginal fit; The porcelain firing and the glaze firing cycles affected the marginal gap.

**Key words:** Vertical marginal fit, CAD/CAM, and Zirconium oxide. (J Bagh Coll Dentistry 2013; 25(1):43-48).

## INTRODUCTION

With a growing awareness of esthetics and biocompatibility, patients increasingly request metal-free solutions<sup>(1)</sup>. Due to the successful use of all-ceramic crowns both in the anterior and posterior segments<sup>(2)</sup>, and with the introduction of advanced dental technology and high-strength ceramic materials, all-ceramic systems may become a viable treatment option even for extended fixed partial dentures (FPDs). Such restorative all-ceramic systems must fulfil biomechanical requirements and provide longevity similar to metal-ceramic restorations<sup>(3)</sup> while providing enhanced esthetics<sup>(4)</sup>.

Zirconia, which is a polycrystalline material without a glassy matrix and is partly stabilized by yttrium oxide (approximately 3 mol%), is an alternative for multiunit frameworks.

The use of zirconia ceramics for multiunit FPDs has been facilitated by the advent of computer aided design/computer aided manufacturing (CAD/CAM) systems<sup>(5)</sup>. These all-ceramic restorations must meet requirements for strength, color stability, and precision of fit for clinical success<sup>(6)</sup>.

Due to the solubility of luting agents<sup>(7)</sup>, minimizing marginal opening is paramount in decreasing prosthetic failure resulting from caries, plaque and food accumulation, and inflammation of the periodontal tissues<sup>(8)</sup>.

McLean and Von Fraunhofer in 1971<sup>(9)</sup> examined more than 1000 crowns after a 5-year period and concluded that a marginal opening of ≤120 µm was clinically acceptable.

Copy milling and CAD-CAM systems have gained popularity due to their ease of fabrication, good mechanical properties, and decreased porosity<sup>(10)</sup>.

The CAD-CAM technologies introduced to the dental profession in 1971<sup>(11)</sup>. The most common method to fabricate a zirconia substructure is by CAD/CAM milling from a solid block. The fully sintered zirconia is milled at a 1:1 ratio, while the partially sintered zirconia is milled 20% to 25% larger than the desired final size due to shrinkage caused by the sintering process. The development of CAD/CAM technology has focused on precise and consistent manufacturing of zirconia ceramics. CAD/ CAM technology relies on exact dimensional predictions to compensate for sintering shrinkage, is an economical and reproducible method and in addition, has demonstrated improved marginal fit<sup>(12)</sup>.

## MATERIALS AND METHODS

### Preparation of Master Die:

A dentoform left maxillary first molar was prepared to receive all ceramic crown using a high speed hand piece with air-water coolant, that was adapted to the suspending arm of the modified surveyor in such a way so that the long axis of the bur was paralleled to the long axis of the ivory tooth, the horizontal arm of the surveyor

(1)M.Sc. Student in department of Conservative, College of Dentistry, University of Baghdad.

(2) Professor/Chairmen of department of Conservative, College of Dentistry, University of Baghdad, Baghdad, Iraq.

permitted vertical as well as rotational movement around the tooth.

The left maxillary first molar was prepared to receive a complete ceramic crown, with the following preparation features; a 90° radial shoulder finish line all around the tooth with (1 mm) depth determined by a digital vernier, a total circumferential axial reduction was about 1.5 mm, and axial taper of 6° using a diamond bur No.(G846R). This bur was selected because it provides a shoulder finishing line; occlusal reduction of about 2mm was performed using a diamond disk bur No.(G818)<sup>(13)</sup>. The prepared dentoform tooth was used as a pattern for construction of the metal master die. The dentoform tooth was then sprued, invested, burned out and casted using Nickel-Chromium alloy (Figure 1).



**Figure 1: Finished master die with its acrylic base having seating groove at each corner**

A block of acrylic resin was then constructed to hold the master die in such a way so that the long axis of the master die lied vertical to the horizontal plane of the acrylic block, and a dental surveyor was used for this purpose. Four seating grooves (5mm depth and 3mm base) at each corner of the upper surface of the block were made to be used later as a guide and stopper for the special tray during Impression making. A surveyor was used to construct the special tray for the master die.

#### **Impression procedures:**

A surveyor was used during the process of Impression taking, the master die was fixed to the horizontal table of the surveyor in such a way so that the long axis of the tooth was kept parallel to the long axis of the analyzing rod of the surveyor, the special tray was fixed to the suspending arm of the surveyor through the analyzing rod (previously attached to the tray during its

construction) so that a standardized path of insertion and removal of the special tray was obtained. The special tray was coated with poly (vinyl siloxane) adhesive for one hour prior to Impression making. The Impression was done using heavy and light viscosity poly vinyl siloxane. The special tray was used to obtain 30 Impressions. Both the heavy and light body Impression materials and catalysts were mixed using auto mixing gun. Type IV die stone was mixed in a vacuum auto mixer, the Impression was poured on the vibrator in accordance with the manufacturer's instructions, Thirty die stones were constructed from thirty Impressions. All laboratory procedures were performed by the same operator.

#### **Zirconia core manufacturing by CAD/CAM system(Group III):**

Ten zirconia crowns were constructed in the following manner:

##### Scanning of the die:

Scannable liquid (compatible with the scanning device of Ceramill InLab), was applied to the die stone to obtain precise scanning picture (Figure 2).



**Figure 2: The scanning machine (Ceramill, AmanGirbach, Germany).**

The optical scanner scanned the die models with the help of the Ceramill 3D InLab Software; Three-dimensional images were displayed on the computer monitor, so that all the surfaces and finishing lines were shown clearly (Figure 3).



**Figure 3: Scanning die in the monitor**

Core design:

Core designing procedure through the software was done with the following features, a minimum wall thickness of the core (1mm), and cement gap should have 0.05 mm thickness, starting at 0.25mm from the margin<sup>(14)</sup> (Figure 4).



**Figure 4: Selection of treatment for tooth**

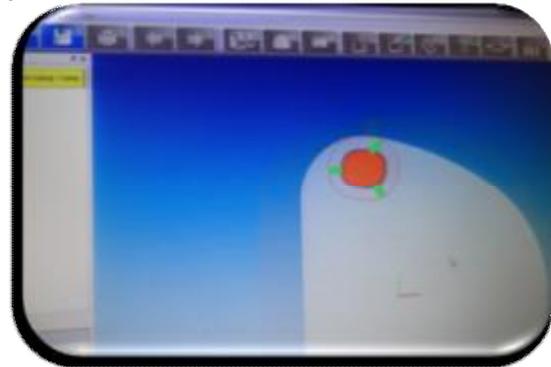
The copy seen in the final design in the monitor (Figure 5).



**Figure 5: Completing the core design.**

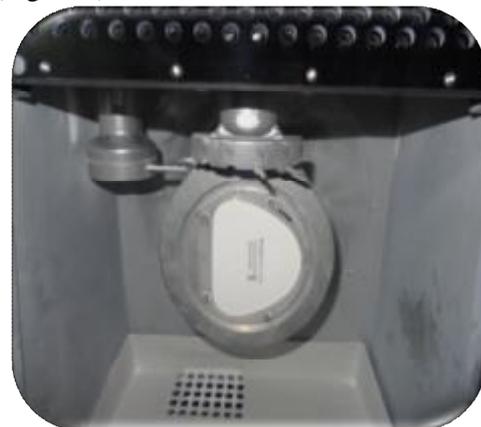
After applying the information for the design to the milling centre in software (Figure 6), a suitable blank (height and size) was selected from

the blank loaded library of the CAD-CAM system.



**Figure 6: Set and adjust the core in the Y-TZP blank.**

The Y-TZP blank (zirconium block) was placed in the blank holder and fixed with the screws by the screw key, and the milling process was then started. All those steps were done following the manufacturer instructions of Ceramill InLab CAD/CAM system (AmannGirrbach Dental Systems, Germany) (Figure 7).



**Figure 7: The blank in the milling machine**

After the milling procedure had ended the blank was removed from the milling machine and the copy frame separated from the blank by a labrotary hand peice with a fissure bur (Figure 8).



**Figure 8: Complete milling and the copy removed it from the blank**

Colouring and Sintering:

The copy was given its individual colour by immersing it in the dye solution. Sintering was carried out in the Ceramill Therm high-temperature furnace 1500°C for 9 hours to complete sintering.

Porcelain veneering cycling:

For all three groups, the closing margins were made with a core structure. The veneer started (0.5 mm) thickness at the margin, occlusally 1mm and at middle third about 0.75mm.

Measurement of the marginal gap:

Marginal gaps along vertical planes were measured at four indentations on the margin at the midpoint of mesial, distal, buccal and palatal surfaces of the die using a light microscope.

The measurements were done at three interval times:

- 1-(Time 0): Before porcelain firing.
- 2-(Time 1): After porcelain firing.
- 3-(Time 2): After glazing cycle.

A screw loaded holding device following Thiab and Zakaria, 2007<sup>(15)</sup> was used during measurements in order to maintain a seating pressure of (13.4N) <sup>(16)</sup> between the all-ceramic crown and the master metal die during measurements calculation for this purpose.

The microscope was calibrated to 0.001mm (1µm) at magnification 100x. and the measurements were done by placing the sample on the microscope stage, which was adjusted until the image of the marginal area was display clearly on the computer monitor, and the digital image of the gaps were then captured. The image was treated with program (Image J) which was used to measure the vertical marginal gap between the copy and master die, the program (Image J) was used to measure the value in a pixels mark by drawing a line between the finishing line on the die and the copy margin line (Figure 9). All digital readings were recorded and converted to (µm) by a magnification factor.



**Figure 9: Digital images were captured during the measurement**

**RESULTS**

A total of 480 measurements from CAD/CAM were recorded at three intervals, Time 0 (before) and Time 1 (after) porcelain firing cycles and Time 2 (after glaze cycles) with 16 measurements per crown at each interval time. On the other hand comparing the results recorded in table (1) showed that the lowest mean value was recorded 6.775 µm in (time 0) subgroup followed by 8.750 µm (time 1) and with height vertical marginal gap value recorded 10.625 µm(time 2).

**Table 1: Descriptive statistics of the three groups or three times.**

Sub group	N	Min	Max	Mean	SD
Time (0)	10	4.25	10.75	6.775	1.8388
Time (1)	10	6.25	11.75	8.750	1.9257
Time (2)	10	7.25	14.25	10.625	2.6621

The ANOVA test results showed highly significant differences among the different time subgroups (as shown in Table 3).

**Table 2: One way- ANOVA for CAD-CAM group (Time 0, Time 1 and Time 2)**

	Sum of Squares	Mean Square	F	Sig.
Between Groups	74.129	37.065	7.844	0.002
Within Groups	127.588	4.725		H.S.
Total	201.717			

HS:P<0.01(highly significant)

The LSD test of results showed that there is highly significant difference between time (0) and time (2), while there is no any significant difference between time (0) and time (1), and between time (1) and time (2) (as shown in Table 3).

**Table 3: LSD test between the time subgroups of the CAD-CAM.**

(I) VAR0000	(J) VAR0000	Mean Difference (I-J)	Std. Error	Sig.
Time (0)	Time (1)	-1.90000-	.97032	.061
Time (0)	Time (2)	-3.82500*	.97032	.001
Time (1)	Time (2)	-1.92500-	.97032	.058

**DISCUSSION**

In this in vitro study, the zirconium oxide-based ceramic CAD/CAM systems mean marginal gap (10.62µm) was demonstrated acceptable marginal gaps according to Christensen <sup>(17)</sup>; McLean and von Fraunhofer <sup>(9)</sup>; Suarez et al <sup>(18)</sup>; Wolfart et al <sup>(19)</sup>; Quintas et al <sup>(20)</sup>; Bindl and

Mörmann<sup>(21)</sup>; Sailer et al<sup>(22)</sup>; Iwai et al<sup>(23)</sup> who suggested that 120 µm should be the highest limit for clinically acceptable marginal discrepancies.

The results showed that glazing produced greater marginal gap differences that are statistically highly significant. These results are in agreement with the results of Balkaya et al<sup>(24)</sup> and Pak et al<sup>(25)</sup>.

Marginal gap values reported in the present study also in agreement with those of Gonzalo et al<sup>(14)</sup> who reported that the CAD-CAM Zirconia restoration showed the lowest marginal gap (9- 12 µm).

However, these results disagree with the results of Pera et al<sup>(26)</sup>; Probst et al<sup>(27)</sup>; Shearer et al<sup>(28)</sup>; Song et al<sup>(29)</sup>; Vigolo and Fonzi<sup>(30)</sup> which could be attributed to:

The increase in the marginal gap in veneered coping after the body porcelain firing cycles may also be a result of porcelain contamination on the inner surfaces of copings, and reduction in the resilience of the core material and rigidity of the porcelain<sup>(31)</sup>.

The difference in thermal expansion coefficient (TEC) of the veneering ceramic and the core material leads to pressure tensions during cooling at room temperature which lead to enhancement in bonding strength between the two materials. This bonding strength might affect the marginal fitness, so the marginal fit changes in the veneering stages of the firing cycle could be attributed to (TEC) incompatibility of the veneering ceramic used and the core material which lead to stress effect on the marginal fit<sup>(32)</sup>.

Another explanation of the difference in marginal gap may be explained by the fact that during the porcelain veneering procedure, particles of porcelain melt and gather to fill up voids and the resulting contraction of the porcelain mass causes a compressive force on the coping<sup>(33)</sup>.

The deformation of the coping under the stress of contracting porcelain is spread around the whole circumference of the margin. So the literature has suggested certain causes that may be responsible for the distortion such as: porcelain contraction, design and thickness of the core substructure and inadequate support of the core framework during firing<sup>(34)</sup>.

The small value of vertical marginal gap attributed to:

The creating of an enlarged during designing of the framework before sintering Y-TZP blank and milling, to compensate the account shrinkage that associated with sintering to achieve the definitive fit of restoration with its final strength<sup>(35)</sup>.

The presintered Y-TZP blank have a number that was set in the software during designing of the core that represent the volume of sintering shrinkage, so that the balance between the enlarged machining of the pre sintered Y-TZP block and the shrinkage occurring during the sintering process is highly precise, thus creating frameworks with an overall improved marginal gap and high significantly smaller than other system.

The CAD-CAM Ceramill system is the supra fine milling of the inner surface that will improve the seating of the coping to the die.

#### Effect of die spacer:

Some authors (Grajower, Lewinstein<sup>(36)</sup>; Hunter, Hunter<sup>(37)</sup>, and Adriana et al<sup>(38)</sup>) stated that "adequate die spacing is a more important factor than margin configuration for the accuracy of crown margins". The greater the internal relief, the less time interval is required for definitive seating, leading to less force required and potentially less strain to all-ceramic margins<sup>(39)</sup>.

The other causes of lowest marginal gap of the CAD-CAM Ceramill system was attributed to fewer laboratory steps and predetermined die spacer designed in the software (50 µm thickness) According to some studies, if die spacer was applied to the entire prepared surface except a region of 0.25 µm above the finish line might cause improved marginal fitting of the core<sup>(38,40,41)</sup>.

## REFERENCES

- 1- Reich S, Wichmann M, Nkenke E, Proeschel P. Clinical fit of all-ceramic three-unit fixed partial dentures, generated with three different CAD/CAM systems. *Eur J Oral Sci* 2005;113:174-9.
- 2- Fradeani M, D'Amelio M, Redemagni M, Corrado M. Five-year follow-up with Procera all-ceramic crowns. *Quintess Int* 2005;36(2):105-13.
- 3- Denry IL, Holloway JA, Rosenstiel SF. Enhanced chemical strengthening of feldspathic dental porcelain. *J Dent Res* 1998; 77: 583.
- 4- Raigrodski AJ, Chiche GJ. The safety and efficacy of anterior ceramic fixed partial dentures: a review of the literature. *J Prosthet Dent* 2001;86:520-5.
- 5- Raigrodski AJ, Chiche GJ, Potiket N et al. The efficacy of posterior three-unit zirconium-oxide-based ceramic fixed partial dental prostheses: a prospective clinical pilot study. *J Prosthet Dent* 2006; 96: 237-44.
- 6- Schwartz NL, Whitsett LD, Berry TG et al. Unserviceable crowns and fixed partial dentures: life span and causes for loss of serviceability. *J Am Dent Assoc* 1970;81:1395-401.
- 7- Schwartz IS. A review of methods and techniques to improve the fit of cast restorations. *J Prosthet Dent* 1986; 56: 279-83.
- 8- Bergenholtz G, Cox CF, Loesche WJ et al. Bacterial leakage around dental restorations: its effect on the pulp. *J Oral Pathol* 1982; 11:439-50

- 9- McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. *Br Dent J* 1971;131:107-11.
- 10- Gorman CM, McDevitt WE, Hill RG. Comparison of two heat-pressed all-ceramic dental materials. *Dent Mater* 2000;16(6):389-95.
- 11- Duret F, Jean I, Bernard D. CAD-CAM in dentistry. *J Amer Dent Assoc* 1988; 117:715-20.
- 12- Tinschert J, Natt G, Hassenpflug S, Spiekermann H. Status of current CAD/CAM technology in dental medicine. *Int J Comput Dent* 2004;92:25-45.
- 13- Penwadee L, Edwin K, Gerard JCh, Markus BB. Comparison of marginal fit between all-porcelain margin versus alumina-supported margin on proceram R-Alumina Crowns, *J Prosthodont* 2009; 18: 162-6.
- 14- Gonzalo E, Sulrez M.G, Serrano B, Lozano JL. A comparison of the marginal vertical discrepancies of zirconium and metal ceramic posterior fixed dental prostheses before and after cementation. *J Prosthet Dent* 2009;102:378-84.
- 15- Subhy AG, Zakaria MR. Evaluation of the effects of an Iraqi phosphate bonded investment and two commercial types on the marginal fitness of porcelain-fused-to-metal copings. *Mostansiria Dent J* 2005;2(2):183-93.
- 16- Thiab SS, Zakaria MR. The evaluation of vertical marginal discrepancy induced by using as cast and as received base metal alloys with different mixing ratios for the construction of porcelain fused to metal copings. *Al-Rafidain Dent J* 2004; 4(1): 10-19.
- 17- Christensen GJ. Marginal fit of gold inlay castings. *J Prosthet Dent* 1966; 16(2):297-305.
- 18- Suarez MJ, Gonzalez de Villaumbrosia P, Pradies GL, Lozano JF. Comparison of the marginal fit of Proceram AllCeram crowns with two finish lines. *Int J Prosthodont* 2003;16:229-32.
- 19- Wolfart S, Wegner SM, Al-Halabi A, Kern M. Clinical evaluation of marginal fit of a new experimental all-ceramic system before and after cementation. *Int J Prosthodont* 2003;16:587-92.
- 20- Quintas AF, Oliveira F, Bottino MA. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: an in vitro evaluation. *J Prosthet Dent* 2004;92:250-7.
- 21- Bindl A, Mormann WH. An up to 5-year clinical evaluation of posterior in-ceram CAD/CAM core crowns. *Int J Prosthodont* 2002;15(5):451-6.
- 22- Sailer I, Feher A, Filser G, Gauckler LJ, Luthy H, Hammerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. *Int J Prosthodont* 2007;20:383-8.
- 23- Iwai T, Komine F, Kobayashi K, Saito A, Matsumura H. Influence of convergence angle and cement space on adaptation of zirconium dioxide ceramic copings. *Acta Odontol Scand* 2008,66:214-8.
- 24- Balkaya MC, Cinar A, Pamuk S. Influence of firing cycles on the margin distortion of 3 all-ceramic crown systems. *J Prosthet Dent* 2005;93:346-55.
- 25- Pak H S, Han J S, Lee J B, Kim S H, Yang J H. Influence of porcelain veneering on the marginal fit of Degudent and Lava CAD/CAM zirconia ceramic crowns, *J Adv Prosthodont* 2010;2:33-8.
- 26- Pera P, Gilodi S, Bassi F, Carossa S. In vitro marginal adaptation of alumina porcelain ceramic crowns. *J Prosthet Dent* 1994;72:585-90.
- 27- Probst L, Geis-Gerstorfer J, Kirchner E, Kanjantra P. In vitro evaluation of a glass-ceramic restorative material. *J Oral Rehabil* 1997;24:636-45.
- 28- Shearer B, Gough MB, Setchell DJ. Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. *Biomaterials* 1996;17:1891-5.
- 29- Song TJ. Marginal fit of the auro galvano crown system made using the electroforming technique. Master thesis, Seoul, Korea: Seoul National University, 2004.
- 30- Vigolo P and Fonzi F. An in vitro evaluation of fit of zirconium-oxide-based ceramic four-unit fixed partial dentures, generated with three different CAD/CAM systems, before and after porcelain firing cycles and after glaze cycles *J Prosthodont* 2008;17: 621-6.
- 31- Faucher R M, & Nicholls J I: Distortion related to marginal design in porcelain-fused to-metal restoration. *J Prosthet Dent* 1980; 43 (2): 149-55.
- 32- Luthardt RG, Sandkuhl O, Reitz B. Zirconia-TZP and alumina-advanced technologies for the manufacturing of single crowns. *Eur J Prosthodont Restor Dent* 1999; 7: 113-9.
- 33- Weaver JD, Johnson GH, Bales DJ. Marginal adaptation of castable ceramic crowns. *J Prosthet Dent* 1991;66:747-53.
- 34- Van Rensburg F, Strating H. Evaluation of the marginal integrity of ceramometal restorations: Part II. *J Prosthet Dent*, 1984;52(2):210-4.
- 35- Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. *J Am Dent Assoc* 2006;137:1289-96.
- 36- Grajower R, Lewinstein I. A mathematical treatise on the fit of crown castings. *J Prosthet Dent* 1983;49:663-74.
- 37- Hunter AJ, Hunter AR. Gingival margins for crowns: a review and discussion. Part II: Discrepancies and configurations. *J Prosthet Dent* 1990;64:636-42.
- 38- Adriana FQ, Fabiano Oliveira, Marco AB. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: An in vitro evaluation *J Prosthet Dent* 2004;92:250-7.
- 39- Wilson PR, Goodkind RJ, Delong R, Sakaguchi R. Deformation of crowns during cementation. *J Prosthet Dent* 1990;64:601-9.
- 40- Campagni WV, Preston JD, Reisbick MH. Measurement of paint-on die spacers used for casting relief. *J Prosthet Dent* 1982;47:606-11.
- 41- Campbell SD. Comparison of conventional paint-on die spacers and those used with the all-ceramic restorations. *J Prosthet Dent* 1990;63:151-5.