A Comparison of Vertical Marginal Fit of different Brands of Translucent Zirconia Crown Restorations

Sattar J. Abdul-Zahra Al Hmedat, B.D.S., M.Sc. (1)

ABSTRACT

Background: As the development of zirconia crown using CAD/CAM technology, the usage of full zirconia crown is gradually increased. The aim of this in-vitro study was to evaluate and contrast the vertical marginal fit of single all-ceramic translucent zirconia crowns constructed from different brands translucent zirconia blanks.

Materials and Methods: An acrylic resin model of a left maxillary premolar was prepared all around the tooth with (1 mm) depth and 3D scanning to get fifteen STL files, then distributed into three groups (Imes-icor, Whitepeaks and Dental direct), 3D scanning and milling machine by Imes-icor CAD/CAM devise. Marginal gaps along vertical planes were measured at four indentations at the (mid mesial, mid distal, mid buccal, mid palatal) using a light microscope at a magnification of x100. One-way ANOVA, LSD tests were performed to determine the mean and standard deviation of the three blanks groups.

Results: Statistically high significant difference ($p < 0.00$) was found between the groups. The marginal gap value of the groups varied Whitepeaks crowns was (105.42 ± 7) μm, which was significantly higher than the two overall mean marginal gap measured for the Imes-icor crowns (59.3 ± 4) μm and Dental direct crowns (54.5 ± 4.9) μm, the Dental direct which was lowers overall mean vertical gap measurement.

Conclusions: The marginal gap values of Dental direct crowns is considerably lower than that of Whitepeaks crown, The marginal gap values of all the groups made of monolithic high translucent Y-TZP demonstrated acceptable marginal gaps values.

Key words: Vertical marginal fit, crown, zirconia. . **(J Bagh Coll Dentistry 2017; 29(2):33-41)**

INTRODUCTION

At the last decay the all-ceramic restorations rapidly improved combined with the use of computer-aided design (CAD)/computer-aided manufacturing (CAM), have been continuously developed and upgraded in prosthetic dentistry in association with zirconium oxide, used primarily for the restoration of single crowns and fixed partial dentures (FPDs) in both the anterior and posterior regions.

Metal free, high esthetics; excellent biocompatibility and high flexural strength have fueled public demand for all ceramic instead of porcelain-fused to metal crowns

Since all-ceramic crowns are associated with some disadvantages. Ceramic is brittle and has low tensile strength and fracture toughness due to unavoidable inherent imperfection as they potentiate cracks when subjected to stress. The most common complication with all-ceramic crowns is fracture (1).

Veneering a CAD/CAM designed core provides high strength with high optical quality, which is commonly being used in the recent dentistry. However, veneering material is usually weaker than the core material, which leads to the typical failure pattern, chipping of the veneer layer (2).

Some manufacturers have introduced a new approach by designing a full contour crown (no veneering) from a CAD/CAM ingot to avoid the problem from veneer chipping.

IPS e-max CAD (lithium disilicate glass-ceramic) and IPS Empress CAD (leucite) are examples of these crowns. The flexural strength of lithium disilicate glass-ceramic and leucite glass ceramic are around 350 MPa and 160 MPa respectively (3).

These materials are suitable for anterior and premolars restorations only because the strength is not sufficient to withstand occlusal forces generated by posterior teeth.

This led to development of dental zirconia, which is currently one of the toughest ceramic materials. Garvie (4) described it as ceramic steelas it has a flexural strength of 1000 MPa (3)

Zirconia was first used in dentistry in 1990s although first application in Orthopedics occurred much earlier in 1969 (4).

Zirconia is a polycrystalline (directly sintering crystals together without the glass phase to form a dense Yttria (Y_2O_3), magnesia (MgO), and ceria (CeO_2) are common oxides added to zirconia for a toughening mechanism (5). It has flexural strength of approximately 900 MPa to 1100 MPa, and fracture toughness of 8-10 MPa m1/2 (6).

Zirconia is the toughest dental ceramic available in dentistry. The particle size is 0.1 μm to 0.5 μm (7), White in color and possessing relatively great strength, it has been used to fabricate crowns and FPDs frameworks as an alternative to metal.

Zirconia framework is usually veneered with porcelain, leucite reinforced glass ceramic. Because of the possibility of chipping the veneer layer, the idea of fabricating a crown made entirely from zirconia was proposed. That would

(1) Assistant Lecturer. Department of Conservative Dentistry, College of Dentistry, University of Kufa.

merge the strength and the esthetics of the zirconia material, for fabrication of full contour crowns.

Several companies have been working on different processing techniques to improve the esthetic result of zirconia. That has resulted in a new generation of zirconia with a higher translucency than the traditional zirconia used for core fabrication only. In this paper, we referred to zirconia with higher translucency as “translucent zirconia,” and to the zirconia for core fabrication as “non-translucent traditional zirconia.” translucent zirconia is proposed that less tooth reduction is needed to achieve the same or greater overall strength in the crown when compared with the reduction needed for lithium disilicate crowns.

Many companies have been working of manufacturing translucent zirconia blanks therefore the objective of this study to comparison the vertical marginal fit among these brands.

Optical quality of translucency zirconia and its impact on strength

The processing techniques mentioned by researchers, which led to increased translucency in the processed zirconia. Adding titanium oxide to yttrium-stabilized zirconia, and it was reported to be effective in densifying yttrium-stabilized zirconia [(8)].

Tsukuma [(9)] studied the effect of TiO2 on the transparency of zirconia, instead of translucency. He added 10 mol% TiO2 to 8 mol% yttria-zirconia powder and sintered it to 1430 °C for 12 hrs and 1630 °C for 7 hrs.[10]The x-ray diffraction showed that TiO2 dissolved in ZrO and formed a solid solution, but the grain size in TiO2-doped zirconia was larger than in TiO2 un-doped. That indicates that TiO2 stimulates grain growth during sintering. It was found that the addition of TiO2 provides a fairly high transmittance to the zirconia. Moreover, the pressure associated with TiO2-adding technique led to pore migration, which is thought to increase the transparency and the strength as well.

Clinical acceptable vertical marginal gap

Several authors have estimated maximal marginal gap (MG) values [(10)]. After a clinical examination of more than 1000 crowns at 5-years, McLean et al [(11)] concluded that a marginal opening of no more than 120 µm was clinically acceptable. However, several authors of in vitro studies reported a 100µm value. There is limited literature on the precision of fit of zirconia-based crowns. Previous studies have found marginal discrepancies in the range of 40-160 µm [(12)].

Marginal fit is a key criteria used in the clinical evaluation of fixed restorations. The importance of marginal fit for clinical success of ceramic complete coverage restorations inaccurate marginal fit is responsible for plaque retention, micro leakage and cement breakdown [(13)]. The presence of large marginal discrepancies in the restoration exposes the luting agent to the oral environment. Clinical studies of zirconia CAD/CAM fixed dental prostheses luted with resin cement have shown 10.9% and 21.7% of the FDPs having secondary caries after a period of 3 and 5 years, respectively [(14,15)]. The high rate of secondary caries has been attributed to marginal deficiencies. The larger the marginal discrepancy, the more rapid is the rate of cement dissolution. Subsequently, if the cement seal fails and permits percolation of the bacteria, it could be one of the causes of pulpal inflammation and even pulpal necrosis [(16)].

The risk of carious lesions, periodontal disease and endodontic inflammation is thus increased, and adverse consequences affecting the health of underlying abutments and optical properties may result [(13,17)].

Various studies have reported different values for precision of fit of zirconia restorations, which is attributed to differences in experimental designs and evaluation procedures. The marginal gaps ranged between 9.0 and 148.8 µm, with an average value of 73.8 µm [(18)]. Higher discrepancies have been detected at the internal gap (i.e. the internal distance measured between the coping and the abutment), ranging between 68.8 and 215 µm in the occlusal direction and between 52.3 and 192 µm in the axial direction [(19)].

Research Hypotheses

(1) There is no difference in vertical marginal fit between the three different brands of translucent zirconia crown restorations.

(2) All the different brands of translucent zirconia crown restorations have acceptable vertical marginal gap values.

H. Alternative

(1) There is a difference in vertical marginal fit between the three different brands of translucent zirconia crown restorations.

MATERIALS AND METHODS

A dentoform left maxillary first premolar was prepared to receive all ceramic crown (figure 1) using a high speed handpiece 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 ivorine tooth, the horizontal arm of the surveyor permitted vertical as well as rotational movement around the tooth.

Figure 1: Prepared tooth

The die was prepared to receive a full crown of translucent zirconia, with the following preparation features: a 90°radial shoulder finish line all around the tooth with (1 mm) depth, a total circumferential axial reduction was about (1 mm), and axial taper of 6° using a diamond bur No. (G846R). This bur was selected because it provides a shoulder finishing line (figure 2); occlusal reduction of about 1mm was performed using a diamond disk bur No. (G818) (Figure 3) [20].

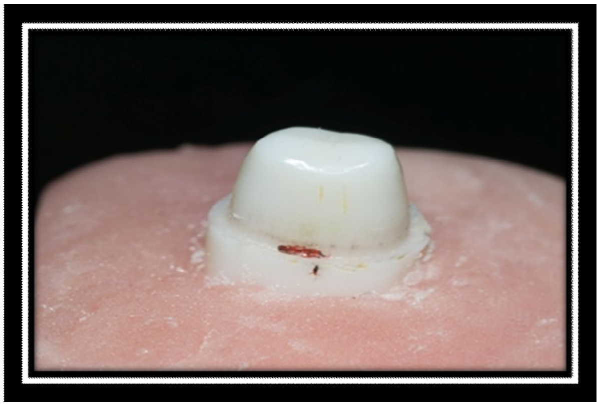

Figure 2: Master die

The prepared dentoform tooth was used as patterns of the master die for complete the construction of translucent zirconia crowns by the CAD/CAM imes-icon machine. After complete the master die preparation, remove it from the jaw base and construct acrylic base to the die to facilitate the procedure of the scanning.

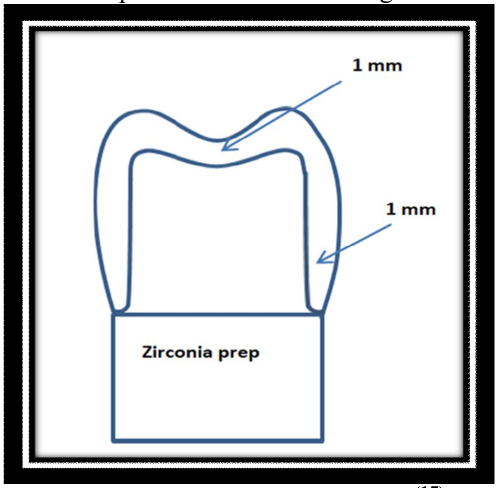

Figure 3: Zirconia preparation [17].

Adapt the master die at the scanning table with the gypsum base, the scanning table fixed with the 3Dscanner (figure 4) by magnetic and switch on the scanner and CAM computer to start the scanning as a following:

Figure 4: 3D scan of Imes-icor system.

1-insert the information of the case as: (patient name, technician name, address, and dentist name) and save the case, and name the type of the crown (full anatomy crown) with minimum thickness 0.6mm.

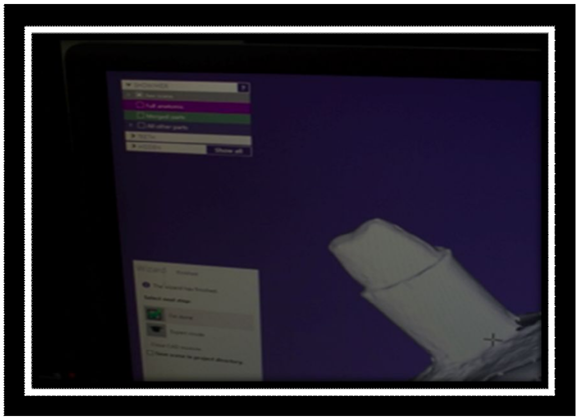

Figure 5: Full 3D scan of master die in monitor.

2- Use 3Dscan (imes-icor) press scanning icon to start the 2Dscanning to determine the position of the crown, and then continue with the 3Dscanning, the 3Dscanner will tack multipicture and then press match iconto get the 3D picture of the master die. Three-dimensional images were displayed on the computer monitor (figure 5).
3-Desgin of the crown by press the design icon to open the design window and start the designing of full zirconia crown, the first step determined the finishing line, the crown done with the following features a minimum wall thickness of the core (1mm) and cement gap should have 0.05um thickness, the cement space started at 0.25mm from the finishing line, after complete the design of the crown copy it as a STL file and send it to the CAM computer to amount the design crown in to the translucent zirconia blank (figure 6), the crown fixed in to the blank by three connector and than calculate the crown to the milling computer.

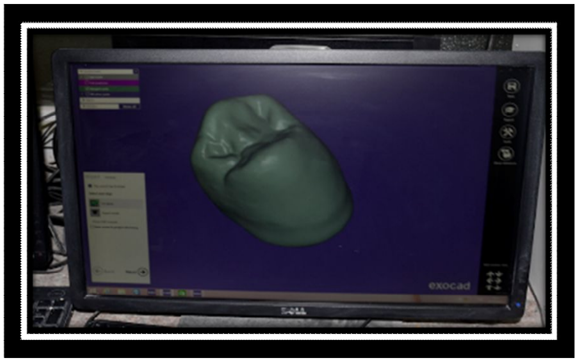

Figure 6: Full anatomy crown in CAD computer.

The milling computer that was connected to the milling machine will receive the calculated crown from the CAM computer for crown milling, at the same manner copy (15) STL files for three groups, (5) STL files for every group, at the end result will obtain five translucent zirconia crowns for each group.

Translucent zirconia crowns have a one 3D scanning and one design and then the complete designed crown STL file copied (15) STL files so we have a standardizes in 3D scanning, designing, and thickness of the crowns.

The crowns that were milled separated from the blank by grinned the connecter with micro motor machine by using fisher bur.

Coloring and Sintering

All the crowns apply color agent (Whitepeaks Monolith color paint on: Germany) to obtain the natural color to the crowns.

Sintering was carried out in the (HT-S MV mihmvogt-Germany) (figure 7) high temperature furnace the sintering temperature and sintering program according to the manufacture instruction.

Figure 7: Sintering oven (HT-S MV mihmvogt-Germany).

Measurement of the marginal gap

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

A screw loaded holding device following Thiab and Zakaria [21] was used during measurements in order to maintain a seating pressure of (13.4N) [22] between the all-ceramic crown and the master die during measurements calculation for this purpose (figure 8).

The marginal gap of the coping was determined by measuring the vertical marginal gap between the margin of the die and the margin of the coping, the measurements were made on indentation area that were done on the four surfaces of the die (Labial, Mesial, Palatal and Lingual) below the margin of the preparation in order that the measurement could be made at the same point on each aspect at each time (Lombardas) [23] This was achieved by using a light microscope provided with a digital camera in the eye lens and connected with the computer.

Figure 8: Master die with crown in the holding device.

The microscope was calibrated to 0.001mm (1um) at magnification 100x and the measurement 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, A millimeter calibration was used for each group session at the same magnification and referenced for calibration.

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. All digital readings were recorded and converted to (um) by a magnification factor (The length of a radiographic, photographic, or microscopic image divided by the object length) [24].

Forty measurements were continued for every group two measurements for all the four surfaces (mesial, palatal, distal, and buccal) of each sample, of each subgroup in the same manner.

The same investigator performed all measurements with the assistance of an engineer [23,25]

To be ensure the accuracy and to overcome any faulty in reading, measurements were done at 4 times repeatedly [27]. The marginal discrepancy value of each coping was the arithmetic mean of these 4 measurements on the four surfaces.

Statistical Analyses

The SPSS software package was used to perform the statistical analysis. Descriptive statistics were computed for marginal gaps. Statistical methods were used in order to analyze and assess the results which include:

A- Descriptive statistics:

1- Statistical tables.
2- Standard deviation "SD".
3- Standard errors "SE".
4- Maximum value.
5- Minimum value.
6- Arithmetic mean.
7- Graphical presentation by (Bar-Charts).

B-Inferential statistics:

1-One-way ANOVA (analysis of variance) test was carried out to see if there were any significant differences among the means of groups.

2-LSD (least significant difference) test was carried out to examine the source of differences.

Samples grouping: -

The (30) copies of STL files were divided into three groups according to the grand zirconia blanks (figure 9):

1- Group (1) Imes-icor.
2- Group (2) Whitepeaks.
3- Group (3) Dentaldirect.

Figure 9: Groups distribution of translucent zirconia blanks.

RESULTS

A total of 60 images (3 groups, 5 crowns per group, 8 sites per crown) were measured. The results of the measurements, along with the results of the statistical analysis, are summarized in (Table 1) and graphically presented in (Figure 10).

The overall mean vertical gap measurement for the Whitepeaks crowns was (105.42 ± 7) µm, which was significantly higher than the two overall mean gap measured for the Imes-icor crowns (59.3 ± 4) µm and Dental direct crowns (54.5 ± 4.9) µm, the Dental direct crowns which was lowers overall mean vertical gap measurement.

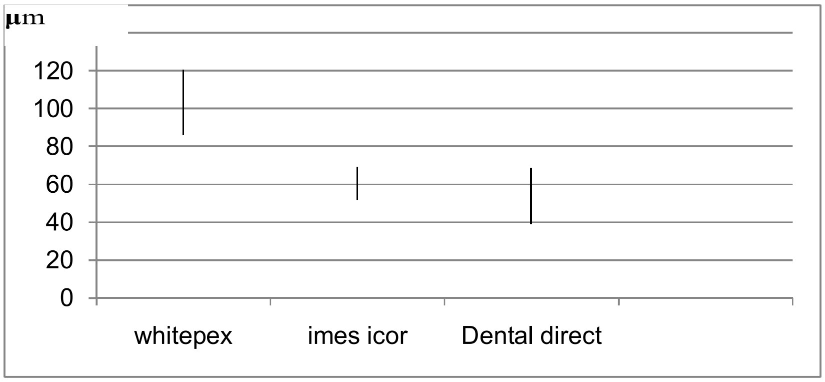

Figure 10: Charts of the results of marginal gap measurements

Table 1: Descriptive statistics of vertical marginal gap measurements (µm)

Groups	N	Mean (µm)	S.D.	S.E.	Min.	Max.
Whitepeaks	5	105.4250	15.78384	7.05875	86.00	120.63
Imes icor	5	59.3000	8.97636	4.01435	51.38	69.25
Dental direct	5	54.5000	11.05526	4.94406	38.88	68.88
Total	15	73.0750	26.34146	6.80133	38.88	120.63

To spot whether the variation in the mean value at three groups, was statistically significant or not, one way (ANOVA) test was functional in (table 2). One-way ANOVA for translucent crowns milling machine groups (white peaks, Imes-icor and dental direct).

Table 2: One way- ANOVA for translucent crowns milling machine groups (whitepeaks, Imes icor and dental direct)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7906.519	2	3953.259	26.243	.000
Within Groups	1807.694	12	150.641		
Total	9714.213	14			

HS: P<0.01(highly significant)

In table (2), it was revealed that the difference in marginal gap mean values among three groups (whitepeaks, Imes-icor and dental direct) was statistically highly significant.

Additional analysis among three groups was performed using LSD test to examine the resource of the difference between the groups (whitepeaks, Imes-icor and dental direct).

This LSD test results show that there is highly significant difference between (whitepeaks) and (Imes-icor), while there is no significant difference between (Imes-icor) and (Dental direct), and between (whitepeaks) and (dental direct) there is highly significant difference as shown in (Table 3) and (Figure 11).

Table 3: LSD test between the three groups (Whitepeaks, Imes-icor and Dental direct)

Groups		Mean Difference	Sig.
Whitepeaks	Imes-icor	46.12500*	.000
	Dental direct	50.92500*	.000
Imes-icor	Whitepeaks	-46.12500-*	.000
	Dental direct	4.80000	.548
Dental direct	Whitepeaks	-50.92500-*	.000
	Imes icor	-4.80000-	.548

This LSD test showed highly significant differences in the marginal gap values between the Whitepeaks and the (Imes icor, Dental direct), showed non-significant differences in the marginal gap values between the Imes icor and Dental direct and this was clearly shown in (figure 12-14).

Figure 11: LSD test between (whitepeaks, Imes-icor and dental direct)

Whitepeaks	Imes-icor	Dental direct
*-----------Highly significant--------------------		*
---------------------Highly significant------------------------		
	---------Non significant----------	

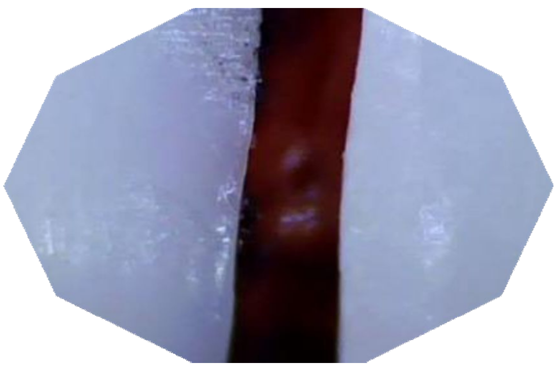

Figure 12: Enlarged photo of marginal gap of the Whitepeaks

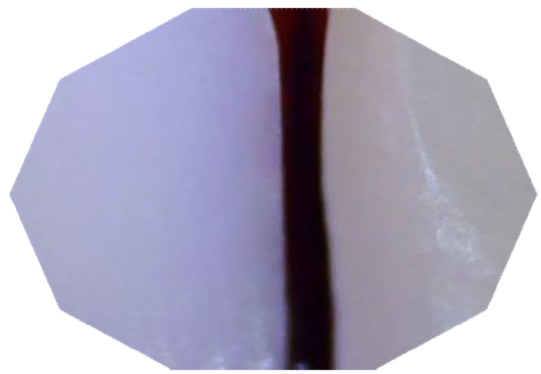

Figure 13: Enlarged photo of marginal gap of the Imes icor

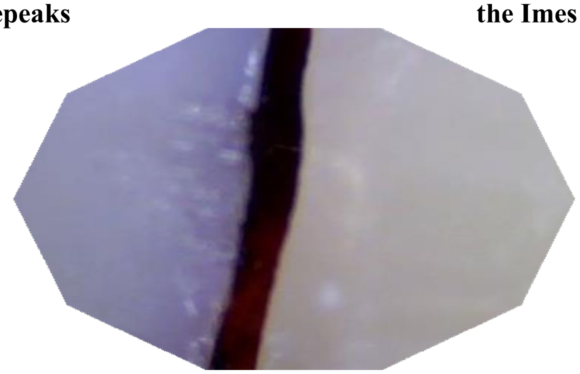

Figure 14: Enlarged photo of marginal gap of the Dental direct

DISCUSSION

Crown marginal fit is critical for success of the restoration; crowns with poor fit (marginal gap) are prone to failure due to micro-leakage, cement dissolution, and dental caries. In this study, the fit of crowns was assessed based on the vertical gap measurement that was selected as the most critical factor of marginal gap (MG) while being the least susceptible to manipulation post-fabrication, as indicated by Holmes et al [27] in this in vitro study.

An in vitro study was conducted to examine marginal adaptation and fracture strength of single crowns made of different materials, the three groups of translucent yttrium oxide-stabilized zirconium dioxide that was milled with the CAD/CAM imes-icor systems that show significant difference between Groups, the whitepeaks crowns show mean marginal gap (105.4 µm) was followed by the Imes-icor crowns mean marginal gap (59.3 µm) and than the Dental direct crowns mean marginal gap (54.5 µm) which all demonstrated acceptable marginal gaps according to many findings [28-35] who suggested that 120 µm should be the highest limit for clinically acceptable marginal discrepancies.

The justifying of the present findings of the study, the methods in all the steps and measurements has a perfect standardized in between the groups, due to throughout methods steps have one master die, one 3D scanning, one designing of the crown, and the end result to have the STL file this file copied 15 time equal the crowns groups, so the non effect of the fabrication procedure of the three brands of zirconia blanks showed a large variation in marginal gap values among them due to difference in their procedures of manufacture, partial sintering, and measuring of thermal shrinkage therefore the standardized fabrication technique of methods could be obtained.

The most critical factors that effect in the vertical marginal gap is the thermal dimensional changes pre-sintering and post-sintering, The pre-sintered zirconia blank have a number that was set in the software during designing of the crown that represent the volume of sintering shrinkage, so that the balance between the enlarged machining of the pre sintered zirconia block and the shrinkage occurring during the sintering process is highly effect in the fitting of the crowns.

For example when the zirconia blank has number (1,224) this number indicate that the pre-sintering crown larger than the sintering crown in 1,224 times.

The enlarged machining of the pre sintered Y-TZP blank may be inadequate to compensate for the shrinkage occurring after sintering of the Y-TZP blank milling procedure such as the accuracy in the CAD-CAM system. 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 [36].

This clinical study demonstrated that it was possible to fabricate CAD-CAM zirconia single crowns with satisfactory accuracy.

(1) There is difference in Vertical Marginal Fit between the three different brands of translucent zirconia crown restorations.
(2) All the different brands of translucent zirconia crown restorations have acceptable vertical marginal gap values.

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