Journal of Genetic and Environmental Resources Conservation, 2015, 3(3):205-211.
www.jgerc.com

The effect of porcelain veneering on marginal fitness of zirconia copings compared to full contour zirconia crown using three different CAD/CAM systems (An *In vitro* study)

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Abstract

This study aimed to determine the effect of veneering porcelain on the marginal fit of the zirconia-based crown designed and milled by three CAD/CAM systems. An ideal prepared dentoform model of a single posterior full-crown preparation with chamfer finish line design was used as a master die. The model was duplicated 48 times and poured in type IV dental stone for the fabrication of working dies that randomly divided into three major groups (A, B and C) (n=16) according to the CAD/CAM system being used. Each group further subdivided into two subgroups (n=8) full-contoured and traditionally veneered zirconia crowns. The working stone models were scanned, designed and milled with CAD/CAM system. Marginal gaps were evaluated on the master model in relation to four defined points on each aspect (Buccal, Mesial, Lingual and Distal). Using the direct view technique with the aid of Stereomicroscope at a magnification of (140X) and (image J). The measurement was done once for each full contoured sample and twice for the coping; before and after veneering. The data were statistically analyzed, using One-way ANOVA and LSD tests which revealed highly significant differences ($p<0.001$) among groups. Student t-tests revealed that the veneered zirconia crowns produced significantly greater marginal gap compared to that of both copings and full contoured crowns for each system correspondingly. The addition of veneering porcelain increases the vertical marginal discrepancy. The zirconia crowns that milled to full anatomy have better marginal fit than the traditionally veneered crowns. Sirona system showed the best marginal fit than the others. All systems have an acceptable marginal fit clinically.

Keywords: Marginal fitness, Zirconia, CAD/CAM, Porcelain.

Introduction

Marginal fitness is an important characteristic that can contribute to clinical long-term success of FPDs (Coli and Karlsson, 2004). The vertical marginalgap defined as the distance between the restoration and the preparation when measured parallel to the long axis of the abutment. Poor marginal adaptation negatively affects the restoration, which may lead to cement dissolution allowing the seepage of fluids, debris, and microorganisms along the interface between the restoration and the walls of the preparation, thus increase the risk of recurrent caries and periodontal illness (Holmes *et al*., 1989; Wolfart*et al*., 2003).

Dental ceramic restorations have been of increasing interest among dentists and patients, as expectations for more natural looking materials have increased. The development of advanced dental ceramics has led to the application of partially stabilized zirconia in restorative dentistry. Zirconium oxide–based materials, especially yttria-tetragonal zirconia polycrystals (Y-TZP) gaining popularity due to its superior mechanical properties, such as high strength and fracture toughness to be a substructure for dental crowns. The zirconia ceramics have no glassy matrix, relatively opaque, and need more esthetic feldspathic veneering porcelain on their surfaces (Aboushelib *et al*., 2006).

When fabricating dental crowns and fixed partial dentures, zirconia undergoes a heat treatment cycles as part of the veneering porcelain firing process. The feldspathic veneering porcelain is fired at a temperature ranged from 700– 900°C (Oilo *et al*., 2008).

Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) is a three-dimensional scanning technology being utilized in dentistry to increase productivity and patient satisfaction. CAD/CAM systems 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 (Denry and Kelly, 2008). Although all zirconia is chemically similar, the ultimate product can vary from manufacturer to other. Today, there is a range of options in zirconia ceramics, including monolithic full-contour type and conventional veneered type zirconia (Serkan *et al*., 2013).

The adaptation of ceramic restorations may be affected by the fabrication procedure, firing cycles, scanning technique, milling process, size of milling burs and material condition during milling procedure (Comlekoglu *et al*., 2009).

This study was performed to determine the effect of porcelain firing process on the marginal fitness of zirconia coping produced by three different CAD/CAM systems andto compare the fitness of full contour zirconia crowns with traditionally veneered crowns.

Materials and Methods

An ideally prepared dentoform right maxillary first molar (Nissin Dental products, Kyoto, Japan) with deep chamfer finishing line (0.8) all around with 6 degrees convergence and 2mm reduction (Occlusally), was used as a master die to receive all-ceramic crowns. A base of self-cure acrylic resin (Duracryl Plus, Italy)was constructed to hold the master die; dental surveyor was used for this purpose. A plastic container was selected to be as a special tray, and then a groove of 2mm depth was created in the upper surface of the acrylic base, so that the plastic container was guided and stopped during impression taking (Figure 1). Five holes were created in the container, one on the base of the container and the others were evenly distributed on its sides to create a passage for the excess impression material and for retention.

Figure (1): A: Master die, B: Plastic container fitted with the groove of acrylic base

Impression procedure: The plastic container was filled with heavy body (Vinyl poly siloxane) impression material (Zhermack, Italy); a spacer (polyethylene sheet of 2mmthickness,Egypt) was placed over the heavy body impression material to provide enough space for light body impression material and seated over the master die then removed after setting. To register fine details; light body viscosity (Vinyl poly siloxane) impression material (Elite P&P, Zhermack, Italy) was auto-mixed with impression gun (5cm discarded), and placed over the heavy body then re-seated over the die. Then the impressions were poured with type IV gypsum product (Die stone) (Elite Stone, Zhermack, Italy) and placed on the vibrator. This procedure was repeated forty-eight times to construct forty-eight stone working dies. The manufacture instructions were followed during all procedures.

Sample grouping: Forty-eight stone dies were divided into three groups according to the CAD/CAM system used for zirconia crown construction (Figure 2).

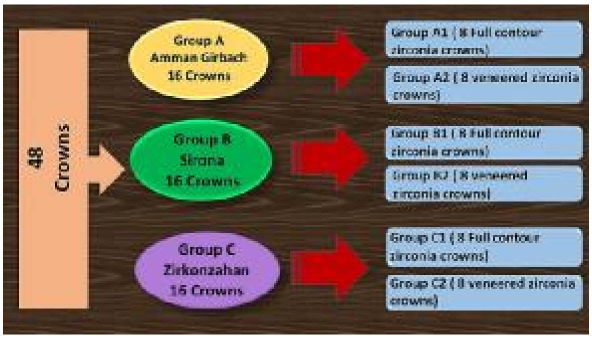


Figure (2): Sample grouping

For each system, the optical scanner scanned the die model and a three-dimensional image was displayed on the computer monitor with the aid of the 3D In Lab Software, so the finishing line and all the surfaces were appeared clearly. The full contour crowns (group $A_{1,}$ $B_1$and C_1) and copings (group A_2,B_2 andC_2) were designed through the software with the following parameters: the type of restoration and cement gap, the finishing line was automatically drown, the undercut and the path of insertion was determined.

After applying the information of the final design to the milling center in the software. A suitable zirconium block was selected and placed in the blank holder inside the milling machine and fixed with the screwdriver, and then the milling process was started.

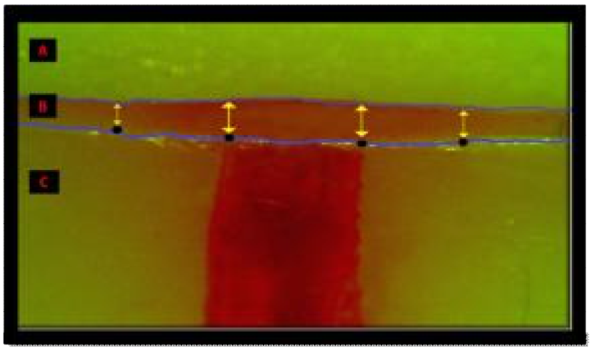
After the completion of milling procedure, the zirconia blank was removed from the holder and the crowns or the copy frame were separated from the blank by a laboratory hand piece with a disk bur. The crowns were placed in sintering jar and the sintering was carried out in the furnace according to the suitable sintering program of each system.

Porcelain veneering of zirconia copings: For all the three groups (A_2, B_2 and C_2) the zirconia copings were placed on their working stone dies and then the porcelain veneering procedure was performed by the same technician. GC initial dentin and enamel porcelain (GC product, Japan) were used, by mixing their powder and liquid and then applied to the ZrO_2 CAD/CAM copings with bristle brush. All porcelain-layering steps were performed following the GC initial porcelain manufacturing instructions.

Marginal gap measurement: The measurement were made perpendicular to the die axis. This was achieved by holding the crown-die assembly with a (specimen holding device) composed of screw holding part with a load sensor attached to a digital scalar (sf-400, China) which specially designed for this purpose; in order to maintain seating pressure of (50N) nearly equal to (5Kg) (Dittmer *et al*., 2009) (Figure 3). Both the specimen holding device and the die were placed under the stereo microscope (ST 60 SERIES, Germany).

Figure (3): The sample scurried to the specimen holding device attached to a digital scalar

The stereomicroscope provided with microscopical camera placed in the eye lens and connected to the computer. The calibration was 0.001mm (1µm) at magnification of 140X. When the clear image of the marginal area appeared on the computer screen, the marginal gap was measured (Gonzalo *et al*., 2009) (Figure 4). The measurements were made on four points determined on each surfaces of the master die, (two at the edge of the line which was drawn on the mid of the surface by permanent marker, while the other were at a distance of (1mm) from the previous one, on both left and right sides (Holden *et al*., 2009).



Figure(4): Digital image was captured and represented marginal gab measurement, A: Crown, B: Marginal gap, C: Master die

All the digital readings were recorded in pixels and converted to (µm) with the same program (Image J). Sixteen measurements were obtained from each sample and the marginal discrepancy value of each crown was the arithmetic mean of these 16 measurements on four surfaces.

Results and Discussion

A total of (1152) measurements of vertical marginal gap from the major three groups (A, B and C) and their subgroups were recorded, with 16 measurements for each crown sample.

The full contour crowns were measured once, while the veneered crowns from each group were measured twice; before and after veneering.

A_1, B_1, C_1 (Full contoured crown).

A_2,B_2,C_2 (Copying before veneering).

A_3, B_3, C_3 (Copying after veneering).

The means and standard deviations of vertical marginal gaps with minimum and maximum values were calculated for all groups are shown in (Table 1) (Figure 5).

One-way ANOVA test was used to know if there was any statistically significant difference among the different groups as presented in the (Table 2).

The result showed that Sirona system zirconia coping before veneering (Group B2) presented the lowest mean of vertical marginal gap (58.39 µm), while the highest value was scored by Zirkonzahan system zirconia coping after veneering (Group C3) (107.69 µm).

From Table (2) it has been found that the difference in the vertical marginal gap among the three different CAD/CAM systems was statistically highly significant. Paired samples t-test was used to compare the marginal gap of copings before and after veneering (Table 3). Independent samples t-test was used to compare between the full contour zirconia crowns and veneered zirconia crowns (Table 4).

Table (1): Descriptive statistics of the marginal gap (μm) in each group

Systems	Groups	Descriptive statistics				
		N	Mean	±S.D.	Min.	Max.
Amman Girbach system	A1	8	91.49	3.02	86.43	95.96
	A2	8	90.05	6.12	83.35	98.96
	A3	8	103.80	7.16	92.39	113.63
Sirona System	B1	8	64.41	3.35	59.38	69.76
	B2	8	58.39	2.83	55.61	62.84
	B3	8	77.27	4.37	71.19	84.42
Zirkonzahan System	C1	8	85.04	3.93	79.86	88.99
	C2	8	89.90	6.35	82.6	97.6
	C3	8	107.69	7.11	97.79	116.69

Table (2): Systems' difference using ANOVA test

ANOVA	Sum of Squares	d.f.	Mean Square	F-test	p-value
Between Groups	3202.193	2	1601.097	134.047	0.000 (HS)
Within Groups	250.830	21	11.944		
Total	3453.023	23			
Between Groups	5319.849	2	2659.925	92.966	0.000 (HS)
Within Groups	600.846	21	28.612		
Total	5920.696	23			
Between Groups	4384.474	2	2192.237	54.372	0.000 (HS)
Within Groups	846.702	21	40.319		
Total	5231.176	23			

Table (3): Descriptive statistics and effect of veneering on the marginal gap

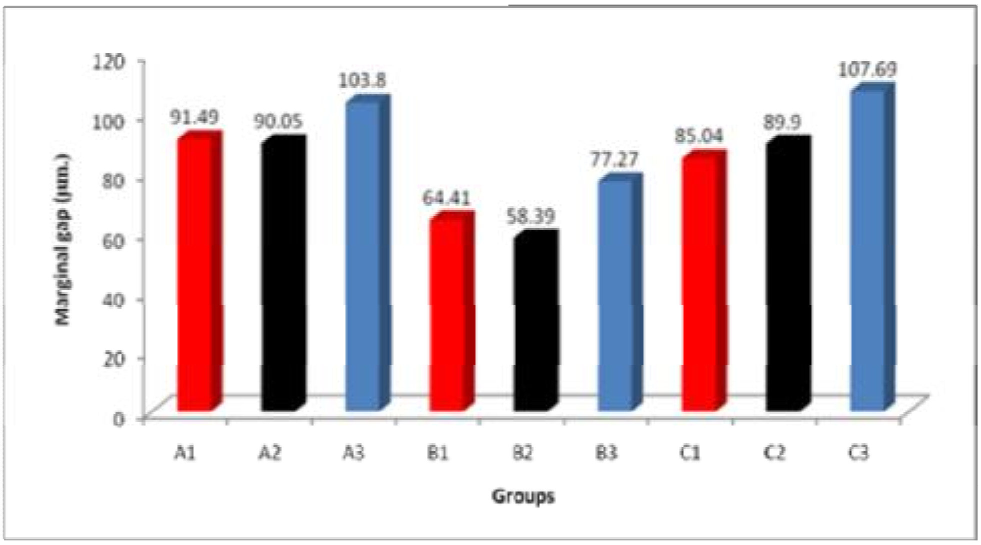
Groups	Descriptive statistics				Veneering effect (d.f.=7)		
	Before veneering		After veneering				
	Mean	±S.D.	Mean	±S.D.	Mean difference	t-test*	p-value
A2 vs. A3	90.05	6.12	103.80	7.16	-13.75	-11.608	0.000 (HS)
B2 vs. B3	58.39	2.83	77.27	4.37	-18.88	-26.623	0.000 (HS)
C2 vs. C3	89.90	6.35	107.69	7.11	-17.79	-13.802	0.000 (HS)

**t-test used here is Paired samples t-test*

Table (4): Descriptive statistics and comparison between full contoured crown and copings after veneering

Groups	Descriptive statistics				Comparison (d.f.=14)		
	Full contoured crown		Copying after veneering				
	Mean	±S.D.	Mean	±S.D.	Mean difference	t-test*	p-value
A1 vs. A3	91.49	3.02	103.80	7.16	-12.31	-4.479	0.001 (HS)
B1 vs. B3	64.41	3.35	77.27	4.37	-12.86	-6.605	0.000 (HS)
C1 vs. C3	85.04	3.93	107.69	7.11	-22.64	-7.881	0.000 (HS)

**t-test used here is Independent samples t-test*



Figure(5): Mean values of the vertical marginal gap of all groups

The results in (Table 4 and 5) showed that the effect of veneering on the marginal gap and the comparison between full contour crowns and veneered zirconia was statistically highly significant for the three different CAD/CAM systems

In this study, ideal prepared dentoform tooth#16 was used per standard specifications to receive an all-ceramic crown restoration (Beyari, 2014). Deep chamfer finishing line of the master die with (0.8mm) depth was selected because it has more round angle between the axial wall and gingival seat, which enable more accurate seating for the crown (Reich *et al.,* 2005).

It has been demonstrated an improvement of the marginal fit of (In-Ceram) ceramic system for crowns fabricated on chamfer compared with shoulder finish line, also the chamfer finishing line preferred because the observation of that increasing in the finishing line depth of preparation would lead to increased marginal gap (Pera *et al*., 1994; Azar *et al*., 2011).

In addition to the standardized preparation of the selected model, it made from unchangeable; hard plastic that resist wear during the manufacturing processes and measurements (Beyari, 2014).

The specimen holding device was specially designed to have a screw that secured the zirconia crowns on the master model, while holding the specimens on the stage of the microscope during measurement. Furthermore, the device designated to have a load sensor attached to a digital scalar, in order to ensure the application of a uniform standard load of 50 N over each sample during measurement (Al-Hariri and Dimashkieh, 2010).

In the present study, the direct view of the crown placed on the master die with the aid of stereomicroscope, microscopical camera and (image J) software was used, this method was preferred because it not involved any procedures on the crown-die assembly, such as sectioning or replications of the cement space before measuring the gap. Thus, it is a non-destructive in nature and reduced the chance of errors that may be accumulate from multiple process, which may affect the accuracy of results.

There is a lot of controversy in the dental literature, regarding the clinical acceptable value of the marginal fitness. Many investigators stated that a marginal gap of 120 µm should be the extreme limit of the clinical acceptability (Bindl and Mormann, 2005; McLean and Vonfraunhofer, 1971; Tinschert*et al*., 2001; Iwai *et al*., 2008).

The marginal gap of all groups of the study were within the clinically acceptable range and the comparison between the present study and the previous studies is difficult, due to the differences in the method of measurements (cemented or non-cemented crowns), different finishing line, using of different CAD/CAM systems and zirconia blanks material.

In the present study, the result revealed that the veneering process for all the three groups (A, B and C) had a high-significant effect on the vertical marginal gap. This may be attributed to the differences in the coefficient of thermal expansion of zirconia (10.2×10^{-6} K^{-1}) and that of the porcelain veneering (9.4×10^{-6} K^{-1}) used in this study. In addition, high-significant differences may be attributed to the fact that during the procedure of veneering, the porcelain mass contracts as the particles melt and fill up voids. Thus, compressive forces applied on the coping, that lead to displacement of the axial wall of the coping medially, which could produce tighter fit and incomplete seating of the crown on the die. The distortion of the coping under the stress of contracting porcelain is expanded to the whole circumference of the margin.

Because the firing shrinkage of porcelain occurs mostly in the bulked area, the marginal fit of the coping changes due to uneven distortion during the porcelain firing cycles, thus causing asymmetric form of coping margin and this may be the primary reason for variations in the marginal discrepancies (Al-Saady *et al.,* 2015).

Furthermore, the increased values of marginal gap that obtained after veneering may be due to distortion of the core and inadequate support during firing cycles of porcelain, since the heat treatment of the veneering process reduced the strength of the underling zirconia material (Oilo *et al.,* 2008).

This results came in agreement with Balkaya *et al*. (2005); Pak *et al*. (2010); Euan *et al*. (2012) who found that the veneering porcelain firing cycle can affect the marginal and internal fit of zirconia-based crowns and fixed partial dentures.

In this study, the full-contour zirconia crowns from all groups (A_1, B_1 and C_1) had the lowest marginal gap value when compared with that of the conventional veneered zirconia crowns, since they milled directly to the full anatomical crown without need to porcelain veneering, thus not undergo additional firing cycle. These results could be related to the unique composition of the anatomical blanks zirconia material. That required less amount of heat for sintering; compared to that need for zirconia core, or it may be due to the fact that the conventionally layered zirconia usually requires more laboratory steps for fabrication and processing, which might increase the possibility for distortion and errors (Bindl and Mormann, 2005). This coincide with (Atta and Sabea, 2013) who conclude that the full contour crowns showed the best marginal adaptation, internal fitness and less microleakage compared to the veneered zirconia crowns.

The significant result regarding the effect of porcelain veneering on the vertical marginal gap of the current study was came in disagreement with Sulaiman *et al*. (1997); Vigolo and Fonzi (2008); who found that the addition of veneering porcelain not cause any significant changes in the marginal fitness. This may be because different materials been used, different die shape and finishing line and different firing cycles.

In the current study, the results showed that Sirona system (group B) had the lowest mean of vertical marginal gap. This may be attributed to the difference on the type of milling (wet milling) and the higher degree of pre-sintering zirconium blanks (InCorisZi, TZI), which results in a reduction of shrinkage and sinter distortion (Beuer *et al*., 2009). However, the adaptation of ceramic restorations may be affected by fabrication procedure, scanning technique, milling process, size of milling burs and material condition during milling procedure (Comlekoglu *et al*., 2009).

Conclusion

Within the limitations of this *In vitro* study, the following conclusions can be derived:

1. The mean marginal gaps of the three CAD/CAM systems were within the clinically acceptable marginal fit.
2. Highly significant differences were present in the marginal gap before and after veneering of all the three CAD/CAM systems.
3. The full-contoured zirconia crowns showed better marginal adaptation compared to conventionally veneered zirconia crowns of each group.
4. Sirona system showed statistically lower marginal gaps than the other two systems.

References

Aboushelib, M.N.; Kleverlaan, CJ, Feilzer, AJ. 2006. Microtensile bond strength of different components of core veneered all-ceramic restorations. Part II: Zirconia veneering ceramics. Dent. Mater., 22(9): 857-63.

Al-Hariri, M. and Dimashkieh, M. 2010. The effect of veneering porcelain on the marginal fit of cercon zirconia copings. Master thesis. College of Dentistry, King Saud University.

Al-Saady, A.; Ittihad, E. and Al-Obaidy, A. 2015. Marginal discrepancy of cobalt chromium metal copings fabricated with three different techniques. J. American Sci., 11(5): 12-4.

Atta, A. and Sabea, N. 2013. Comparison of marginal adaptation, internal fitness and microleakage of zolid, zirconia and empress 2 all-ceramic crown materials. Mustansiriyah Dental J., 10(2): 1-6.

Azar, M.S.; Lehmann, K.M.; Dietrich, H.; Weibrich, G.; Schmidtmann, I. and Scheller, H. 2011. Effect of preparation depth differences on the marginal fit of zirconia crown copings: an *In vitro* study. Int. J. Prosthodont, 24(3): 264-266.

Balkaya, M.C.; Cinar, A. and Pamuk, S. 2005. Influence of firing cycles on the margin distortion of three all-ceramic crown systems. J. Prosthet. Dent., 93: 346-355.

Beuer, F.;, Aggstaller, H.; Edelhoff, D.; Gernet, W.

and Sorensen, J. 2009. Marginal and internal fits of fixed dental prostheses zirconia retainers. Dent. Mater., 25: 94–102.

Beyari, M. 2014. Marginal and internalr crown fit evaluation of CAD/CAM versus press-laboratory all-ceramic crown. J. Clin. Med. Diagn., 4(1A): 21-26.

Bindl, A. and Mormann, W.H. 2005. Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. J. Oral Rehab., 32:441-447.

Coli, P. and Karlsson, S. 2004. Fit of a new pressure-sintered zirconium dioxide coping. Int. J. Prosthodont, 17: 59-64.

Comlekoglu, M.; Dundar, M.; Özcan, M.; Gungor, M.; Gokce, B. and Artunc, C. 2009. Influence of cervical finish line type on the marginal adaptation of zirconia ceramic crowns. Oper. Dent., 34: 586-592.

Denry, I. and Kelly, J.R. 2008. State of the art of zirconia for dental applications. Dent. Mater., 24(3): 299-307.

Dittmer, M.P.; Borchers, L.; Stiesch, M. and Kohorst, P. 2009. Stresses and distortions within zirconia-fixed dental prostheses due to the veneering process. Acta Biomater., 5: 3231-3239.

Euan, R.; Figueras-Álvarez, O.; Cabratosa-Termes, J.; Brufau-de Barberà, M. and Gomes-Azevedo, S. 2012. Comparison of the marginal adaptation of zirconium dioxide crowns in preparations with two different finish lines. Int. J. Prosthodont, 21(4): 291-295.

Gonzalo, E.; Suarez, M.J.; Serrano, B. and Lozano, J.F. 2009. A comparison of the marginal vertical discrepancies of zirconium and metal ceramic posterior fixed dental prostheses before and after cementation. J. Prosthet. Dent., 102: 378–384.

Holden, J.; Goldstein, G.; Hittelman, E. and Clark, E. 2009. Comparison of the marginal fit of pressable ceramic to metal ceramic restorations. J. Prosthodont ACP, 1-4.

Holmes, J.R.; Bayne, S.C.; Holland, G.A. and Sulik, WD. 1989. Considerations in measurement of marginal fit. J. Prosthet. Dent., 62(4): 405-408.

Iwai, T.; Komine, F.; Kobayashi, K. and Saito, A. 2008. Matsumura, H. Influence of convergence angle and cement space on adaptation of zirconium dioxide ceramic copings. Acta Odontol. Scand., 66: 214-218.

McLean, J.W. and Vonfraunhofer, J.A. 1971. The estimation of cement film thickness by an *In vivo* technique. British Dent. J., 131: 107-111.

Oilo, M.; Gjerdet, N.R. and Tvinnereim, H.M. 2008. The firing procedure influences properties of a zirconia core ceramic. Dent. Mater., 24: 471–475.

Pak, H.; Hand, S.; Lee, J., Kim, S. and Yang, J. 2010. Influence of porcelain veneering on the marginal Degudent and Lava CAD/CAM zirconia ceramic crowns. J. Adv. Prosthodont, 2: 33-38.

Pera, P.; Gilodi, S.; Bassi, F. and Carossa, S. 1994. *In vitro* marginal adaptation of alumina porcelain ceramic crowns. J. Prosthet. Dent., 72: 585-590.

Reich, S.; Wichmann, M.; Nkenke, E. and Proeschel, P. 2005. Clinical fit of all-ceramic three-unit fixed partial dentures, generated with three different CAD/CAM systems. European J. Oral Sci., 113:174-179.

Serkan, S.; Onjen, T. and Gamze, A. 2013. Basic properties and types of zirconia: An overview. World J. Stomatol., 2(3): 40-47.

Sulaiman, F.; Chai, J.; Jameson, L.M. and Wozniak, W.T. 1997. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. Int. J. Prosthodont, 10:478-484.

Tinschert, J.; Natt, G.; Mautsch, W.; Spiekermann, H. and Anusavice, K.J. 2001. Marginal fit of alumina-and zirconia-based fixed partial dentures produced by a CAD ⁄CAM system. Oper. Dent., 26: 367-374.

Vigolo, P. and Fonzi, F. 2008. An *In vitro* evaluation of fit of zirconiumoxide-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, 17: 621-626.

Wolfart, S.; Martin, S. and Kern, M. 2003. Clinical evaluation of marginal fit of a new experimental all–ceramic system before and after cementation. Int. J. Prosthodont, 2003; 6: 587–592.