

Marginal and Internal Crown Fit Evaluation of CAD/CAM versus Press-Laboratory All-Ceramic Crown

Mohammed M. Beyari

Department of Oral Maxillofacial, Oral Rehabilitation and Prosthetic Dentistry, Umm Alqura University, Faculty of Dentistry, Makkah, 21955, Saudi Arabia

Abstract The aim of this article is to evaluate marginal and internal fit between the all-ceramic crowns manufactured by the conventional press-dental laboratory and CAD/CAM systems. **Methods:** Tooth #14 was prepared per standard specification to receive an all-ceramic crown restoration. Forty-five prep tooth #14 were duplicated and randomly divided into three groups (n=15). All-ceramic CAD/CAM system (Group 1) was fabricated with the E4D CAD/CAM system according to the manufacturer's instructions. For press-dental laboratory made crowns, impressions were taken on the region area with two-step impression techniques with light and putty consistency VPS. Impressions were sent to two independent dental laboratories (Groups 2 and 3) for fabricating the monolithic press lithium disilicate crown. All crowns were cemented using Multilink® Automix (Ivoclar Vivadent) under constant pressure of 100N. Samples were embedded in acrylic and sectioned buccolingually. Sections were evaluated under digital stereo microscope and measured on three locations per buccal and lingual side of section: marginal-edge, mid-axial wall, and cusp-tip. One measurement was made on the occlusal table. Statistical analysis was accomplished with Kruskal-Wallis one-way ANOVA and significance was predetermined at $p < .05$. **Results:** No significant difference was found at the buccal and lingual margins in all groups. However, there was significance difference found for cement thickness in midaxial, cusp, and occlusal locations within the group. **Conclusions:** Based on the statistical results there was no statistical difference in marginal fit of all-ceramic crowns made by CAD/CAM system or dental laboratory press ceramic.

Keywords CAD/CAM, Dental crown, Dental laboratory, Dental cement, Marginal adaptation

1. Introduction

Digital Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) is a 3-dimensional scanning technology being utilized in dentistry to increase productivity and patient satisfaction. CAD/CAM technology in dentistry is quickly rising in popularity. It has been developed to eliminate the need for the traditional impression-taking, model-pouring, and laboratory-shipping steps of fabricating crowns. Optical imaging of the dentition replaces the use of conventional impression materials, and in-office mills are capable of milling an all-ceramic crown within a half-hour.

CAD/CAM technology has become increasingly popular as an in-office procedure as the amount of time and money saved appeals to clinicians while the idea of fewer office visits appeals to patients. Dental clinicians strive for techniques that will take a minimum amount of time, be financially sound, and, most importantly, produce restorations with minimal marginal gaps [1]. In the past,

there has been criticism of the CAD/CAM technology and its ability to create an acceptable marginal fit with restorations [2]. Since that time, however, the technology has rapidly evolved and chairside restorations have become a clinical reality [3] in which clinicians feel more confident placing an office milled crown.

CAD/CAM technology has advanced greatly in recent years, which has led to its use in many dental offices, and CAD/CAM techniques can be used in conjunction with either laboratory or chairside manufacturing [4]. CAD/CAM techniques offer the benefit of intraoral data acquisition with "optical impressions" [5] which can help reduce errors associated with conventional impression techniques [4]. Though chairside CAD/CAM technology has advanced, there are still questions regarding the marginal accuracy and internal fit of crowns produced with this technology when compared to conventional impression and laboratory produced crowns. The advantages of rapid in-office crown production are clear for both patient and provider, but the accuracy of CAD/CAM crowns has not been well documented.

One of the main criticisms of office based CAD/CAM crowns is the concern that they do not fit as well as crowns manufactured in a dental laboratory. Acceptable adaptation of a crown can determine the longevity of the crown [6].

* Corresponding author:

mmbeyari@uqu.edu.sa (Mohammed M. Beyari)

Published online at <http://journal.sapub.org/cmd>

Copyright © 2014 Scientific & Academic Publishing. All Rights Reserved

Poor marginal fit has been associated with marginal discoloration, dissolution of cement, microleakage, increased plaque retention, and secondary decay [7, 8].

This study compared the accuracy of the marginal and internal fit between laboratory produced and office produced monolithic ceramic crowns. Information regarding the comparison of these measurements is scarce [9] but is of interest to clinicians when determining the success of CAD/CAM generated crowns.

The purpose of the study was to compare the in vitro marginal fit of all-ceramic crowns produced using the in-office CAD/CAM system with the fits of all-ceramic crowns produced by two independent dental laboratories. The null hypothesis was that there would be no difference in marginal fit between the methods of manufacturing.

2. Methods and Materials

2.1. Preparation of the Master Model

Tooth #14 was prepared per standard specifications to receive an all-ceramic crown restoration on a Dentofrom Typodont (Model type: D85SDP-200 Kilgore international Inc, MI). The preparation had a well-defined 360° circumferential shoulder gingival margin, a 2 mm occlusal reduction, rounded internal angles, and 13° total occlusal convergence (Figure 1).

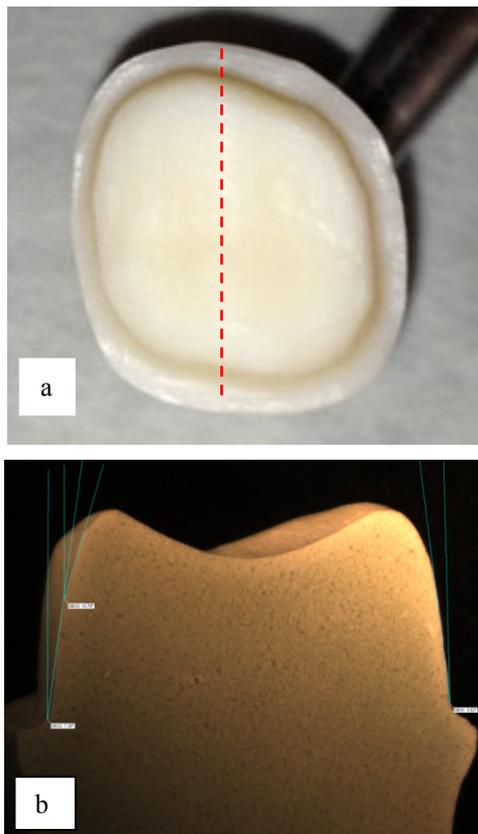


Figure 1. a. Images of the tooth #14 preparation. b. The replicated tooth was sectioned in buccolingually direction. The total occlusal convergence was measured using the analysis software

The prepared typodont tooth was then duplicated as a replicated model made of type V dental stone (Die-Keen™ Green, Heraeus Kulzer). A total of 45 individual impressions were taken with two-step impression techniques on custom tray using light and putty consistency Vinyl Polysiloxane Hydrophilic Silicones (VPS) impression material (Imprint™ 3, 3M ESPE). Six small indentations were made on the root of the die tooth as a plane of sectioning. A line was drawn from the indentation for guidance as a plane of sectioning. The duplicated teeth were randomly divided into three groups (n=15) and placed in full-dentate typodont as follow:

Group 1: CAD/CAM Fabricated crown

Group 2 and 3: Conventional dental laboratory crown

2.2. Fabrication of All-ceramic Crown

2.2.1. CAD/CAM System

Each duplicated tooth was placed in a full-dentate typodont and scanned with E4D handheld digital laser scanner according to the E4D software's specifications. The operator was trained at the learning facility provided by the D4D company (Richardson, Texas). The 3D crown design was calculated and generated from the database's software based on the images captured during a scanning procedure. Additionally, any adjustments made to the design within the software were noted to ensure consistency. The completed crown design data was transmitted wirelessly to the E4D milling unit which was loaded with IPSe.max® CAD LT A1/C14 all-ceramic block (Ivoclar Vivadent).

2.2.2. Conventional Dental Laboratory System

The prepared typodont tooth was placed in full-dentate typodont. A total of thirty impressions were taken on the posterior left region area utilizing double arch impression techniques and a triple-bite tray with light and putty consistency VPS impression material (Imprint™ 3, 3M ESPE). This impression technique has been well described in literature [10, 11]. The impressions were sent to two dental laboratories to fabricate the monolithic press ceramic crowns.

Initial laboratory procedures for the crown followed traditional methods for cast crowns, including sterilization, model fabrication, trimming, sealing, marking of the margin, and waxing up of the tooth. The investing procedure for lithium disilicate crowns differs from traditional casting methods and manufacturer's instructions were followed. Ivoclar IPS e.max Press LT ingots (Low Translucency) were utilized and natural glaze was used with no additional staining or layering procedures.

2.3. Crown Cementation and Analysis

The crowns were cemented using Multilink®Automix (Ivoclar Vivadent) under constant pressure of 100N and all of the remaining cement was cleaned prior to the curing. All samples were then stored in distilled water for 24 hours at 37°C. For sectioning, samples were embedded in clear

acrylic resin and sectioned buccolingually in a consistent plane using the root indentations as guidance (Isomet 1000, Buehler). Sections were measured under digital stereo microscope with 0.8X objective (Olympus SZX16) using OmniMet software (Buehler) on three different points per buccal and lingual side of section: marginal-edge, mid-axial wall, and cusp-tip. One measurement was made on the occlusal table.

2.3.1. Measurement Landmark

The measurement landmarks were defined in the following way (Figure. 2):

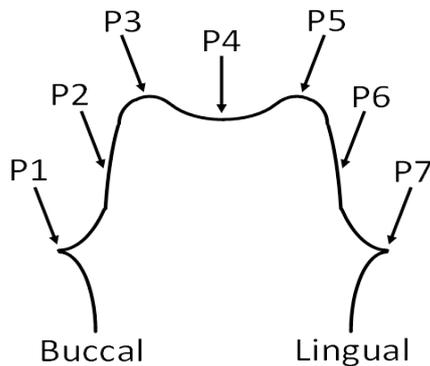


Figure 2. Illustration images of the measurement landmarks: P1 and P7: Margin, P2 and P6: Mid-axial, P3 and P5: The junction of the axio-occlusal walls, and P4: Occlusal Plateau

P1: The marginal discrepancy that represented the cement thickness as first described by Holmes et al. [12]. The cement or replica cement was measured as the perpendicular distance from the internal surface at the margin of the crown to the preparation.

P2: The mid-axial discrepancy that represented the distance between the inner surface of the crown and the replicate model measured at the middle of the axial wall.

P3: The junction of the axial and occlusal walls. It is specified as the bisector of the angle defined between a straight line applied to the axial wall and a straight line attached to the occlusal plateau.

P4: The mid occlusal discrepancy on the occlusal plateau.

The measurement landmarks of P1, P2, and P3 were on the buccal side of the section while the P7, P6 and P5 landmarks were on the lingual side section (Fig. 2).

All of the data were analyzed with non-parametric Mann-Whitney U tests to compare the different analysis techniques in all landmarks and significance was predetermined at $p < 0.05$.

2.4. RESULTS

Table 1 shows the means and standard deviations of marginal discrepancies and internal gaps in each group measured at all landmarks. The lingual (P7) and buccal (P1) marginal discrepancy width showed no significant differences between the in-office CAD/CAM systems with all-ceramic crowns produced by two independent dental laboratories. There were no significant differences in internal gap width (P2, P4 and P6) between in-office CAD/CAM system with all-ceramic crowns produced by two independent dental laboratories was significantly different. However, the internal gap width at P3 and P5 of CAD/CAM crowns showed significantly smaller gaps than all-ceramic crowns produced by two independent dental laboratories.

Table 1. Comparison of CAD/CAM vs. Two Dental Laboratories Press All-Ceramic Crown

	Landmark	Mean	SD	minimum	Q25	Median	Q75	Maximum
CAD/CAM (n=15)	P1	39.069	32.444	5.880	12.380	24.760	76.880	102.560
	P2	154.605	57.944	88.740	100.600	134.880	204.180	260.280
	P3	94.999	34.533	34.840	62.330	102.640	116.490	164.440
	P4	161.049	29.113	123.230	128.690	156.870	181.300	206.230
	P5	95.473	59.991	22.140	48.510	74.640	143.980	238.210
	P6	120.453	45.947	52.480	92.540	118.360	134.130	219.240
	P7	44.879	32.055	8.870	17.730	34.690	71.810	118.920
Lab A (n=15)	P1	36.091	38.470	0.000	0.000	29.620	53.590	133.820
	P2	178.895	77.203	60.880	139.890	152.400	211.100	378.550
	P3	167.987	45.121	45.180	158.900	168.470	199.910	229.950
	P4	215.714	35.799	137.710	188.060	217.680	242.850	269.510
	P5	178.148	56.327	103.340	144.230	165.850	203.030	337.970
	P6	183.949	43.162	111.900	141.960	183.250	217.990	258.430
	P7	33.465	38.766	0.000	0.000	28.470	36.630	119.770
Lab B (n=15)	P1	62.023	49.962	0.000	0.000	62.320	103.630	157.660
	P2	117.508	50.132	60.600	78.450	110.000	130.890	228.670
	P3	238.972	81.135	97.680	166.230	233.870	311.910	399.820
	P4	221.893	111.030	91.320	145.120	217.680	266.870	545.860
	P5	249.416	54.673	153.400	215.130	254.590	289.250	344.920
	P6	150.515	57.963	63.190	107.050	139.590	210.140	268.980
	P7	45.221	41.871	0.000	11.930	39.080	54.150	165.460

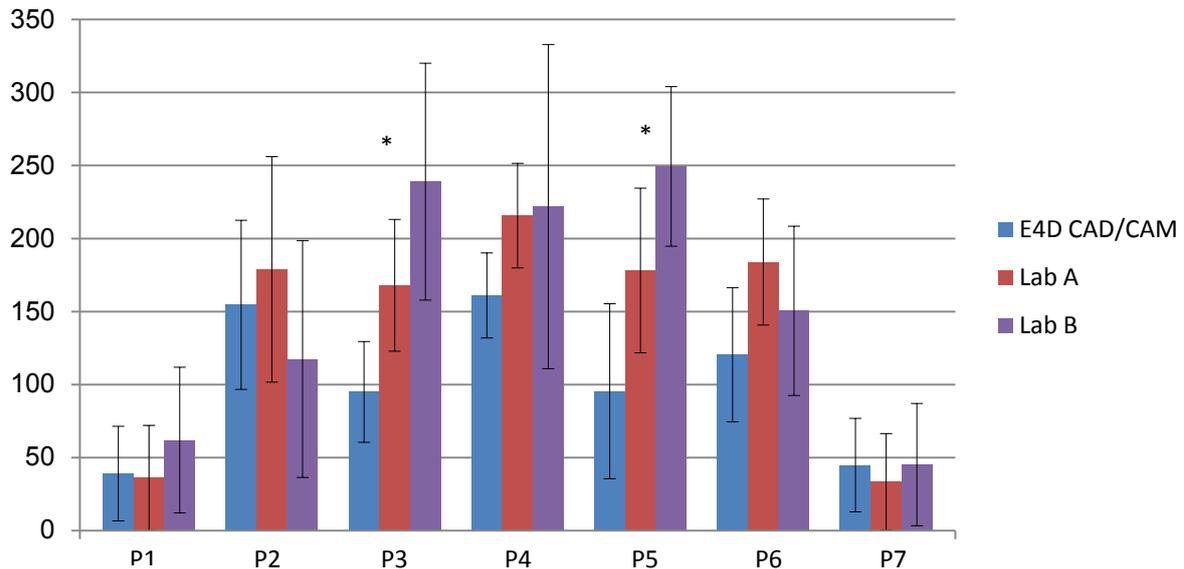


Figure 3. The mean values and standard deviations of the marginal and internal widths measured at all landmarks.* $P < 0.05$

2.5. Discussion

In this study, no significant difference was found in marginal gap measurements between the chair side CAD/CAM manufactured crowns and the dental laboratory manufactured crowns. The literature is scarce in studies that have compared the gap measurements of laboratory processed lithium disilicate crowns and chair side processed crowns. This study compared these processes by comparing crowns manufactured in two different laboratories and chair side. Both laboratories were unaware of the fact that their crowns were part of a study and the CAD/CAM operator was experienced with using the technology. This study used a digital stereo microscope to measure the marginal gaps, as has been done in previous studies [13, 14]. Additionally, a shoulder preparation was used for the crown preparation, although many studies show that either a chamfer or a shoulder finish line can accomplish clinically acceptable margins [15, 16].

The main measurement of interest for this study was marginal fit. Good adaptation has been found to be critical for the longevity of a crown [6]. Poor marginal fit can lead to secondary caries, microleakage, marginal discoloration, and dissolution of cement [7, 8]. Because marginal fit plays such an important role in the clinical outcome of a crown, clinicians will reject crowns that they do not feel are well adapted. Studying this parameter is important in determining whether or not CAD/CAM chair side crowns are an acceptable alternative to laboratory processed crowns.

In the literature the clinically acceptable size of marginal gap varies. Some studies have found $<120\mu\text{m}$ acceptable [17], while others found anywhere from 50-100 μm to be acceptable [18, 19]. In this study each of the investigated crown manufacturing procedures had an average of $<63\mu\text{m}$ at the marginal measurements and no statistically significant difference in marginal fit was found between crowns manufactured at the two laboratories and the CAD/CAM

generated crowns. The average measurements were well below the maximum clinically acceptable 120 μm , and the majority of the measurements were beneath 50 μm with only the marginal fit on the lingual of Lab B being above 50 μm .

The internal fit of the crowns was also studied. While internal fit has not been found to be as clinically relevant as marginal fit [20-24], it is still of interest as it may affect the durability of the crown [25]. Proper internal adaptation is also important as it facilitates the seating of the crown while allowing for both retention and resistance [26]. In the majority of the measurements, with the mid-axial measurement of the lingual (P2) as the exception, the CAD/CAM group had smaller internal fit measurements. The p-values for the P3 and P5 measurements were highly significant ($P < .0001$) with the CAD/CAM technique producing significantly smaller average measurements than either of the laboratory processed crowns. This is most likely due to the spacer that was placed during the laboratory process in these areas to prevent sharp internal angles of the crown, especially at P3 and P5, which could potentially lead to fractures or cracks of the lithium disilicate material.

While the literature is somewhat sparse in comparing laboratory processed pressed ceramics to CAD/CAM crowns [9], there is literature supporting the finding of clinically acceptable marginal fit of CAD/CAM restorations of various types. In one study which compared laboratory made CAD/CAM crowns the marginal gap for each experimental crown met the clinically acceptable level [27]. Some studies have been done on composite crowns manufactured with a CAD/CAM system that have found that the marginal accuracy was clinically acceptable [16, 28]. Studies have also compared in-office CAD/CAM generated copings and those generated in a private laboratory and found that the accuracy of fit of the CAD/CAM copings was acceptable [8]. One study that compared laboratory processed pressed ceramic onlays to chairside CAD/CAM onlays found that both systems exhibited a clinically acceptable gap width of

less than 100 μm [9]. Clinical studies are also of interest and one such study found that CAD/CAM chair side produced lithium disilicate crowns performed well after two years of clinical service [29].

The results of this study add to the literature concerning the clinical acceptability of the marginal fit of chairside manufactured CAD/CAM crowns. If CAD/CAM technology is utilized correctly, as it was in this controlled study with an experienced operator, it is clinically accurate with adequate marginal fit.

One limitation of this study was that by sectioning the samples and using a digital stereo microscope only a limited amount of data points could be observed. In future studies, with the advantage of better technology, 3-D scanning could allow for better measurements. Our department is moving forward in this direction. Another potential study could look at the longevity of the crowns under masticatory type function, comparing the difference in longevity of the crowns that may potentially arise due to the difference in internal fit, especially at the P3 and P5 measurements.

3. Conclusions

In this study, we evaluated the in vitro accuracy of marginal and internal fit of all-ceramic crowns produced using the E4D in-office CAD/CAM system and all-ceramic crowns produced by two independent dental laboratories. Within the limitations of this study, all-ceramic crowns produced using the E4D chair side CAD/CAM system had in vitro marginal fits that were not significantly different than marginal fits of all-ceramic crowns produced by two independent dental laboratories.

REFERENCES

- [1] Tan, P.L., Gratton, D.G., Diaz-Arnold, A.M., Holmes, D.C., 2008, An in vitro comparison of vertical marginal gaps of CAD/CAM titanium and conventional cast restorations. *Journal of Prosthodontics*. 17(5):378-83.
- [2] Bayne, S.H., 1996, CAD/CAM in Dentistry: Present and Future Applications. *Quintessence Int*. 27(6):431-3.
- [3] Miyazaki, T., Hotta, Y., Kunii, J., Kuriyama, S., Tamaki, Y., 2009, A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. *Dental materials journal*. 28(1):44-56. Epub 2009/03/14. PubMed PMID: 19280967.
- [4] Luthardt, R.G., Bornemann, G., Lemelson, S., Walter, M.H., Huls, A., 2004, An innovative method for evaluation of the 3-D internal fit of CAD/CAM crowns fabricated after direct optical versus indirect laser scan digitizing. *The International Journal of Prosthodontics*. 17(6):680-5. Epub 2005/02/03. PubMed PMID: 15686096.
- [5] Mormann, W.H., 2006, The evolution of the CEREC system. *J Am Dent Assoc*. 137 Suppl. 7S-13S. Epub 2006/09/05. PubMed PMID: 16950932.
- [6] Sjogren, G., 1995, Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. *Acta Odontologica Scandinavica*. 53(1):24-8. Epub 1995/02/01. PubMed PMID: 7740927.
- [7] Addi, S., Hedayati-Khams, A., Poya, A., Sjogren, G., 2002, Interface gap size of manually and CAD/CAM-manufactured ceramic inlays/onlays in vitro. *Journal of Dentistry*. 30(1): 53-8. Epub 2001/12/14. PubMed PMID: 11741736.
- [8] Bindl, A., Mormann, W.H., 2005, Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. *Journal of Oral Rehabilitation*. 32(6):441-7.
- [9] Reich, S., Gozdowski, S., Trentzsch, L., Frankenberger, R., Lohbauer, U., 2008, Marginal fit of heat-pressed vs. CAD/CAM processed all-ceramic onlays using a milling unit prototype. *Operative Dentistry*. 33(6):644-50.
- [10] Christensen, G.J., 2008, Ensuring accuracy and predictability with double-arch impressions. *J Am Dent Assoc*. 139(8):1123-5. Epub 2008/08/07. PubMed PMID: 18682627.
- [11] Wilson, E.G., Werrin, S.R., Groom, G.S., 1983, Temporary coverage using the double-arch impression technique. *General Dentistry*. 31(4):273-5. Epub 1983/07/01. PubMed PMID: 6352396.
- [12] Holmes, J.R., Bayne, S.C., Holland, G.A., Sulik, W.D., 1989, Considerations in measurement of marginal fit. *The Journal of Prosthetic Dentistry*. 62(4):405-8. Epub 1989/10/01. PubMed PMID: 2685240.
- [13] Rinke, S., Huls, A., Jahn, L., 1995, Marginal accuracy and fracture strength of conventional and copy-milled all-ceramic crowns. *The International Journal of Prosthodontics*. 8(4):303-10. Epub 1995/07/01. PubMed PMID: 7575971.
- [14] Sulaiman, F., Chai, J., Jameson, L.M., Wozniak, W.T., 1997, A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. *The International Journal of Prosthodontics*. 10(5):478-84. Epub 1998/03/12. PubMed PMID: 9495168.
- [15] Shearer, B., Gough, M.B., Setchell, D.J., 1996, Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. *Biomaterials*. 17(19):1891-5. Epub 1996/10/01. PubMed PMID: 8889069.
- [16] Akbar, J.H., Petrie, C.S., Walker, M.P., Williams, K., Eick, J.D., 2006, Marginal adaptation of Cerec 3 CAD/CAM composite crowns using two different finish line preparation designs. *Journal of Prosthodontics*. 15(3):155-63.
- [17] McLean, J.W., von Fraunhofer, J.A., 1971, The estimation of cement film thickness by an in vivo technique. *British Dental Journal*. 131(3):107-11. Epub 1971/08/03. PubMed PMID: 5283545.
- [18] Hung, S.H., Hung, K.S., Eick, J.D., Chappell, R.P., 1990, Marginal fit of porcelain-fused-to-metal and two types of ceramic crown. *Journal of Prosthetic Dentistry*. 63(1):26-31.
- [19] Holmes, J.R., Sulik, W.D., Holland, G.A., Bayne, S.C., 1992, Marginal fit of castable ceramic crowns. *Journal of Prosthetic Dentistry*. 67(5):594-9.
- [20] White, S.N., Sorensen, J.A., Kang, S.K., Caputo, A.A. 1992, Microleakage of new crown and fixed partial denture luting

- agents. *The Journal of Prosthetic Dentistry*. 67(2):156-61. Epub 1992/02/01. PubMed PMID: 1538320.
- [21] Hunter, A.J., Hunter, A.R., 1990, Gingival margins for crowns: a review and discussion. Part II: Discrepancies and configurations. *The Journal of Prosthetic Dentistry*. 64(6):636-42. Epub 1990/12/01. PubMed PMID: 2079668.
- [22] Sorensen, J.A., 1989, A rationale for comparison of plaque-retaining properties of crown systems. *The Journal of Prosthetic Dentistry*. 62(3):264-9. Epub 1989/09/01. PubMed PMID: 2681694.
- [23] Felton, D.A., Kanoy, B.E., Bayne, S.C., Wirthman, G.P., 1991, Effect of in vivo crown margin discrepancies on periodontal health. *The Journal of Prosthetic Dentistry*. 65(3):357-64. Epub 1991/03/01. PubMed PMID: 2056454.
- [24] Suarez, M.J., Gonzalez de Villaumbrosia, P., Pradies, G., Lozano, J.F., 2003, Comparison of the marginal fit of Procera AllCeram crowns with two finish lines. *The International Journal of Prosthodontics*. 16(3):229-32. Epub 2003/07/12. PubMed PMID: 12854783.
- [25] Rungruanganunt, P., Kelly, J.R., Adams, D.J., 2010, Two imaging techniques for 3D quantification of pre-cementation space for CAD/CAM crowns. *J Dent*. 38(12):995-1000. Epub 2010/08/31. doi: 10.1016/j.jdent.2010.08.015. PubMed PMID: 20801185.
- [26] Beuer, F., Edelhoff, D., Gernet, W., Naumann, M., 2008, Effect of preparation angles on the precision of zirconia crown copings fabricated by CAD/CAM system. *Dental Materials Journal*. 27(6):814-20. Epub 2009/02/27. PubMed PMID: 19241690.
- [27] Nakamura, T., Tanaka, H., Kinuta, S., Akao, T., Okamoto, K., Wakabayashi, K., et al., 2005, In vitro study on marginal and internal fit of CAD/CAM all-ceramic crowns. *Dental Materials Journal*. 24(3):456-9. Epub 2005/11/11. PubMed PMID: 16279739.
- [28] Tsitrou, E.A., Northeast, S.E., van Noort, R., 2007, Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM. *Journal of Dentistry*. 35(1):68-73.
- [29] Fasbinder, D.J., Dennison, J.B., Heys, D., Neiva, G., 2010 A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. *J Am Dent Assoc*. 141 Suppl 2:10S-4S. Epub 2010/06/11. PubMed PMID: 20516109.