EGYPTIAN
DENTAL JOURNAL

Vol. 63, 3767:3781, October, 2017

I.S.S.N 0070-9484

EDJ
EGYPTIAN DENTAL JOURNAL

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 147/1710

ASSESSMENT OF ACCURACY OF DIFFERENT CAD/CAM FABRICATED PORCELAIN LAMINATE VENEERS

Rasha Ramadan Basheer *, Shereen M Elsayed ** *and* Sherif Fayez Ahmed Bahgat ***

ABSTRACT

Objectives: The aim of the current study was to compare the accuracy of different restorative materials currently used in porcelain laminate veneers (PLV) fabrication, in terms of external and internal adaptation, and to evaluate the longevity of the PLV seal in response to thermocycling, in terms of microleakage.

Methods: 30 (PLV) preparations were performed on maxillary central incisor to be restored with restorations fabricated by milling ceramic blocks using a CAD/CAM system. Samples were divided randomly into three groups (n=10) according to the restorative material ([Prettau, Zirkonzahn, Pustertal, Italy], [IPS e.max CAD, Ivoclar, Schaan, Liechtenstein] and VITA SUPRINITY, VITA Zahnfabrik, Bad Sackingen, Germany]). The veneers were cemented using total-etch resin cement according to manufacturer instructions, then subjected to artificial aging program after which they were immersed in basic fuchsine dye for 24 hours. All specimens were sectioned in labio-lingual direction using a precision cutting machine, and vertical gap distance, internal adaptation, and dye penetration were measured using stereomicroscope. Data were statistically-analyzed using one-way ANOVA, two-way ANOVA, Tukey's post-hoc and Student t-tests ($P \leq 0.05$).

Results: The highest statistically significant marginal gap distance and lowest internal adaptation values were recorded with Prettau group followed by IPS e.max CAD group while the lowest statistically significant marginal gap distance and highest internal adaptation values were for VITA SUPRINITY group. For the microleakage, the highest statistically significant leakage values were recorded with IPS e.max CAD group followed by Prettau group. The lowest statistically significant leakage values were for VITA SUPRINITY group. Irrespective of material's group, it was found that incisal margin recorded statistically significant higher marginal gap distance mean values than cervical one. For the microleakage, the reverse was found.

Conclusions: Under the test conditions, the following could be concluded: 1. All ceramic materials used in this study were within the clinically acceptable range of marginal accuracy. 2. CAD/CAM technology does not necessarily present highly accurate restorations, in terms of external and internal adaptation. 3. Lithium disilicate-based restorations showed better external and internal adaptation, and microleakage than monolithic Zirconia-based restorations. 4. The correlation between external and internal adaptation and microleakage is still questionable.

Keywords: Monolithic Zirconia, Lithium Disilicate, marginal accuracy, microleage, internal adaptation.

* Operative Dentistry Department, Modern Science and Arts University, Faculty of Dentistry, Cairo, Egypt.
** Fixed Prosthodontics Department, Cairo University, Faculty of Dentistry, Cairo, Egypt.
*** Fixed Prosthodontics Department, Modern Science and Arts University, Faculty of Dentistry, Cairo, Egypt.

INTRODUCTION

For decades, porcelain fused to metal restorations (PFM), has been considered the standard procedure for fixed dental prosthetic restorations, due to their combined strength and esthetic. Unfortunately, prevention of light transmission by the metal substructure diminishes the possibility of fully mimicking natural teeth optical properties.[1]

To overcome this esthetic restraint, a diversity of metal-free materials and techniques have been developed, including the introduction of CAD/CAM technology, with evidence-based clinically adequate performance.[2-5]

Accordingly, there is increased usage of ceramic and composite materials and also growth of the CAD/CAM market.[6] This together with advances in dental bonding technology has led to the evolution of porcelain laminate veneers (PLV).[7-11]

PLVs are thin ceramic shells that are bonded to the anterior teeth labial surface,[12] and are considered as conservative solution for restoring anterior teeth shape, color, or position improvement.[13,14] Once adhesively bonded, PLVs become an integral part of the tooth structure, thus sharing part of loading stresses applied during chewing cycle.[15]

Presently, there are many contemporary ceramic materials reinforced with leucite, lithium disilicate, zirconium dioxide, and aluminum oxide, which can be used to produce minimally invasive restorations,[8,16,17] with thicknesses ranging from 0.1 to 0.7 mm, thus requiring minimum or no tooth structure preparation.[16]

Owing to those varieties, material selection is considered to be one of the most substantial determinants for extra-coronal as well as intra-coronal restorations success. Some dentists are still less than inspired by dental materials science, although, most of their clinical concerns with restorations are based on material properties, such as strength, fitness, and aesthetics.[18,19]

The IPS e.max CAD is considered one of the most commonly used materials in fabrication of PLVs is which is based on a lithium disilicate glass-ceramic system ($Li_2O.2SiO_2$), and was introduced in 2007 by (Ivoclar, Schaan, Liechtenstein) company, using (CAD/CAM) technology in its fabrication.[19] The blocks are produced by grand casting of transparent glass ingots, prevention of formation of defects (pores and pigments accumulation) in the ingot bulk is achieved through a continuous glass technology-based manufacturing process. The process of partial crystallization results in formation of lithium metasilicate (Li_2SiO_3) crystal, which is responsible for the material's optimal processing features, edge stability, and comparatively high strength.[20,21]

Recently, in 2013, zirconia-reinforced lithium silicates (ZLSs) (e.g., VITA SUPRINITY) were introduced by (VITA Zahnfabrik, Bad Sackingen, Germany). ZLS materials are lithium silicate glass ceramics that are strengthened with nearly 10% zirconia crystals by weight.[21] Although these materials are recently introduced, preliminary in vitro testing demonstrated that they owe superior optical and physical features similar to lithium disilicates due to their special fine-grained and homogeneous structure.[21,22]

However, due to the high hardness, one of the main disadvantages of current ceramic restorations is excessive wear of the opposing teeth.[6,23] Recently, full contour (monolithic) zirconia, (e.g., Prettau), which was introduced by (Zirkonzahn, Pustertal, Italy), have become popular material for esthetic restoration fabrication because of its color matching with natural teeth, flexural strength, minimal abrasion of opposing dentition, and minimal tooth preparation requirements, which will all contribute to the increased longevity of such restorations.[24]

One of the main determinants of success of PLV is the external marginal adaptation, which is the vertical distance between its margin and the prepared tooth finish line.[25] Proximity between the restoration margin and the tooth structure assure the insulation of the adhesive resin cement from exaggerated exposure to the oral environment which can lead to its progressive disintegration resulting in microleakage, recurrent decay, tooth structure discoloration, and even fracture of the PLV.[15] However, internal marginal adaptation is considered as the direct measurement of the cement film thickness underneath the restoration, which is markedly affected by the precision of fabrication process used.[26,27] Also for many years, microleakage was considered an indicative measure for the longevity of bonded restorations.[28,29]

So, while patients are primarily concerned with improved aesthetics, dentists' main interest remains the longevity of restorations in terms of fitness and strength.[19] unfortunately, as long-term clinical trials are impractical due to the constant evolution of restorative materials, in vitro simulation of thermocycling is necessary to study the aging effect on microleakage. Moreover, according to our knowledge, there is no enough data concerning the accuracy and longevity of these new aforementioned restorative materials. Therefore this study aimed to compare the accuracy of these materials, in terms of external and internal adaptation, and to evaluate the longevity of the PLV seal in response to thermocycling, in terms of microleakage. The null hypothesis to be experienced was that the restorative material type and the measurement site would not affect the marginal accuracy, internal adaptation and microleakage of ceramic veneers.

MATERIALS AND METHODS

I. Teeth preparation

In the present study, maxillary central incisor was selected as it is the most commonly indicated tooth requiring a PLV.[15,30] A silicon index (Virtual Putty fastset, Ivoclar Vivadent, Schaan, Liechtenstein) was made for a defect-free maxillary left central incisor in a student typodent (Frasaco, Tettnang, Germany) with transposable hard resin teeth to ensure even tooth reduction. Overlay preparation for PLV was performed with 1.5 mm incisal edge reduction and 0.7 mm labial reduction extended to proximal contact regions with 0.5mm chamfer finish line cervically. Depth orientation grooves were cut followed by tapered diamond point and finishing stones.[31-33] After which, the preparation was polished using a nylon bristle brush and polishing paste at 5000 rpm in a slow speed handpiece. A heavy and light body full arch impression (Virtual Putty fastset, Ivoclar Vivadent) was taken and then poured into epoxy resin material (Chema poxy150, CMB chemicals, Egypt) to obtain thirty epoxy resin dies. Epoxy resin dies were left for 24 hours to ensure complete setting and then separated from the silicon impression material, and checked for any imperfections using magnification loupes (Zeiss EyeMagPro, 5X-300, Carl Zeiss Meditec AG, Germany).

II. Grouping of the specimens

Epoxy resin dies were divided randomly into three equal groups (n=10) according to the tested restorative materials, Group I: Full contour monolithic zirconia (Prettau), Group II: Lithium disilicate glass ceramics (IPS e.max CAD), Group III: Zirconia reinforced lithium silicate (VITA SUPRINITY). (table 1)

TABLE (1) Samples grouping.

Type of restorative material	Group I Prettau	Group II IPS e.max CAD	Group III VITA SUPRINITY
Number of samples(n)	10	10	10
Total number of samples	30		

III. Machining fabrication technique

Impression of the previously prepared acrylic typodont tooth was done using polyvinyl siloxane impression material (Imprint II, 3M ESPE, Germany). An extra hard type IV special stone material (special stone CAM base VITA dentonapicodent) was poured inside the impression according to manufacturer instructions to obtain special stone model ready for scanning. Prettau, IPS e.max CAD, and VITA SUPRINITY blocks (shade A3) were used to mill 30 PLVs. After application of powder imaging spray on the surface of the prepared tooth gypsum die, 3D camera (Charge-Coupled Device) was positioned over the powdered die, and the 3D image was captured for each specimen in labial, palatal and incisal directions and then transferred into the CAD software. The preparation finish line was marked on the digital model. After selection of the required anatomy, labeling of the curvature lines was done to adjust the contours, and the design of the laminate veneers was done using the CAD software. Machinning of the laminate veneers was done using CAD/CAM milling machine (CEREC 3D1 3.0, CEREC Mc XL, Sirona dental system, Charrlotte, USA). After milling, Prettau veneers were sintered in zirconia furnace (Zirkonfen 600, ZirkonZahn, Gais, Italy) according to manufacturer's instructions. the IPS e.max CAD veneers were crystallized in an Ivoclar Vivadent ceramic furnace (Programat P500) according to manufacturer instructions. The VITA SUPRINITY veneers were crystallized at 840°C for eight minutes in the Vita Vacumat furnace (Vita Zahnfabrik, Bad Sackingen, Germany) then the veneers were finished and polished according to manufacturer´s instructions.

IV. Cementation procedure

IPS e.max CAD, and VITA SUPRINITY veneers were etched using 9.6% hydrofluoric acid gel for 30s (Porcelain Etch Gel, Pulpdent Corp., Watertown, MA, USA), washed, dried, and then coated with a silane primer (Variolink S bond primer; Ivoclar Vivadent) which was left to dry for 3 min. As for Prettau veneers, the fitting surfaces of the veneers were blasted with aluminum oxide ≤ 40μm, then the blasted surfaces were cleaned with alcohol and dried with water- and oil-free air. A freshly mixed resin cement (Variolink A3) was applied on fitting surface which was then seated in an inciso-gingival direction on the prepared tooth using firm finger pressure both incisally and labially. Excess cement was wiped off and the resin cement was light polymerized for 60 s using Bluephase G2 (Ivoclar Vivadent) first from the lingual surface then from the Labial surface.[34]

V. Thermocycling

The specimens were stored at 37°C for one month in distilled water, thermocycled for 1500 cycles between 5° and 55°C with a 30 second immersion time and a transfer time of 3 seconds. The end of root portions of the specimens were sealed with sticky wax; All external surfaces were covered with two layers of nail varnish staying away from the margins of the PLVs for 1.0 mm and then immersed in a 0.5% basic fuchsin dye solution for 24 hours, then the specimens were rinsed in running water and then dried.

VI. Specimen sectioning technique

The root portion of each epoxy resin die was sectioned 2 mm below the cervical line. All the specimens were vertically sectioned in a labio-lingual

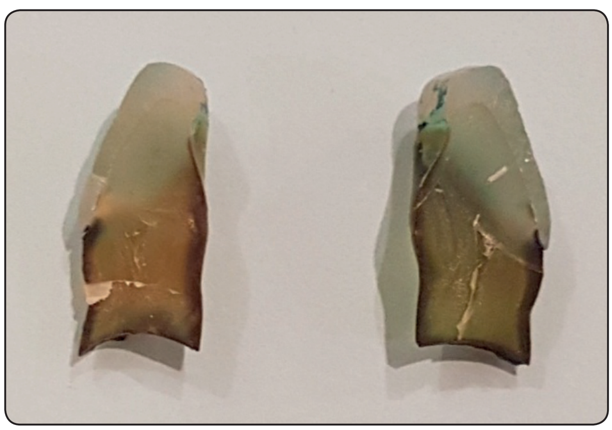

Fig. (1): Specimens sectioning labiolingually.

direction Figure (1) using a diamond coated disc and a precision cutting machine (Mikracut 120, Metkon, Germany). To remove surface contaminants, the obtained sections were ultrasonically cleaned in distilled water for 60 seconds.

VII. Internal adaptation, marginal accuracy and microleakage

The cut sections were examined under stereomicroscope (Carl Zeiss stereomicroscope, Germany) using (Olympus Camedia C-5060 digital camera, Japan) under different magnifications. On these vertical sections, internal adaptation was measured at five fixed locations, Figure (2). Replicas of the gap between the inner surface of the PLV and tooth surface made with a silicone indicator paste to evaluate discrepancies was not the adopted method, as it suffers from shortcomings like the defects of the silicone material in the area of measurement and inaccuracies in the assessment of the film thickness with a microscope.[35] The marginal gap was measured on both the cervical and the incisal margins at 3 predetermined points. Microleakage was identified by the distance the dye was able to penetrate at both the cervical and the incisal margins separately along the axial wall, Figure (3).

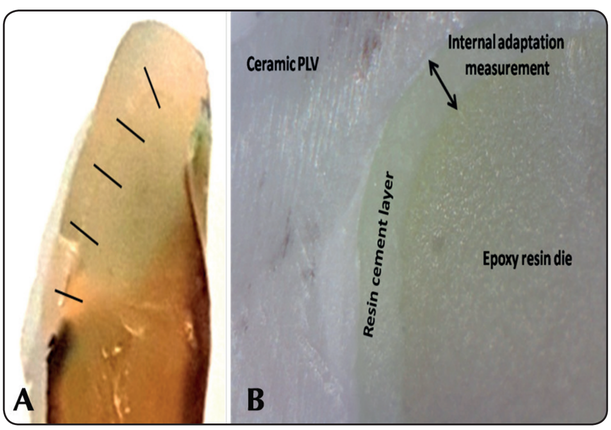

Fig. (2): Internal adaptation measurement: a) Fixed five points of measurements. b) One of the points under stereomicroscope.

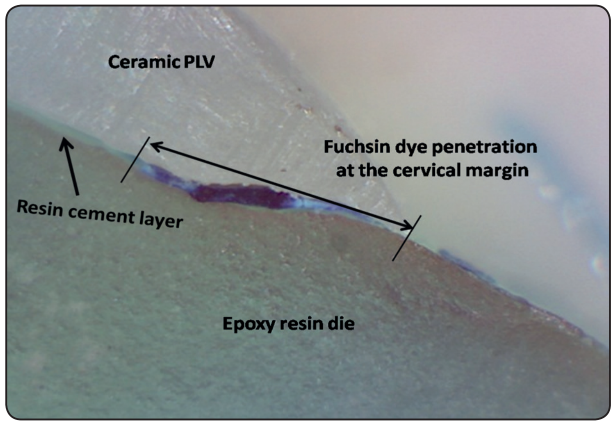

Fig. (3): Die penetration at the cervical margin under stereomicroscope.

VIII. Statistical analysis

Statistical analysis was performed by using ms excel 2013 and asistat 7.6 statistics software for windows (campina grande, paraiba state, brazil). Descriptive statistical data was introduced in the form of mean and standard deviation. Since a normal distribution was observed for all the values of all groups, the significance between the different groups was tested using one-way analysis of variance (ANOVA) followed by multiple group comparisons using Tukey's post hoc tests. For leakage and marginal gap two-way analysis of variance ANOVA test of significance was done for comparing variables (material and margin site) affecting mean values. Student t-test was performed to detect significance between margins with each material. P-values ≤ 0.05 considered being statistically significant in all tests.

RESULTS

Internal adaptation

Descriptive statistics showing mean values, standard deviations (SD) for internal gap distance measured in (um) recorded for all material groups summarized in table (2) and graphically represented in figure (4).

It was found that the highest internal gap distance mean±SD values were recorded with Prettau group followed by IPS e.max CAD group while the lowest internal gap distance mean±SD values were for VITA SUPRINITY group. Statistically significant difference between groups was found as indicated by one-way ANOVA followed by Tukey's post-hoc tests (F=19.82, p=0.0002<0.05) – table (2) and figure (4).

TABLE (2) Internal gap distance results (Mean values ±SD) for all material groups.

Variables		*Mean ±SD*	*95 %CI*	
			Low	*High*
Material groups	**Prettau**	***245^{A} ± 50.93***	181.77	308.23
	IPS e.max CAD	***159^{B} ± 51.16***	95.49	222.52
	VITA SUPRINITY	***78.5^{C} ± 6.02***	71.03	85.97
ANOVA	***P-value***	0.0002*		

Different letter in same column indicating significant (p<0.05) CI; confidence interval *; significant (p<0.05) ns; non-significant (p>0.05)

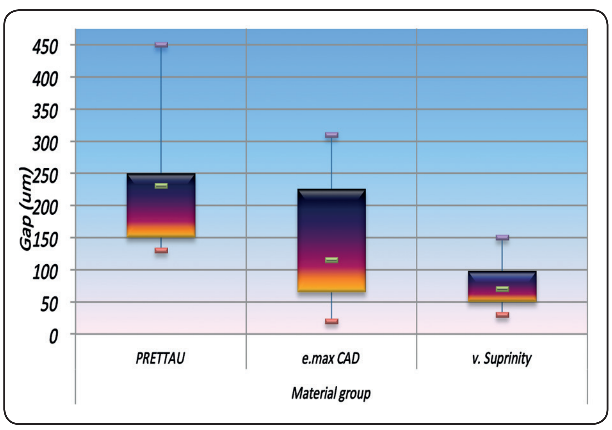

Fig. (4) Box plot showing internal gap distance mean values for all groups.

Marginal gap distance

Descriptive statistics showing mean values, standard deviations (SD) for marginal gap distance measured in (um) recorded for all material groups as function of measurement site summarized in table (3) and graphically represented in figure (5).

For cervical measurement site

It was found that the highest marginal gap distance mean ± SD values were recorded with ***IPS e.max CAD*** group followed by ***Prettau*** group while the lowest marginal gap distance mean±SD values were for ***VITA SUPRINITY*** group. The difference between groups was statistically significant as indicated by one-way ANOVA test (F=10.92, p=.0025<0.05). Pair-wise Tukey's post-hoc test showed non-significant (p>0.05) difference between ***Prettau*** group and ***VITA SUPRINITY*** table (3) and figure (5)

TABLE (3) Marginal gap distance results (Mean values ±SD) for all material groups at cervical margin.

Variables		*Cervical*		
		Mean ±SD	*95 %CI*	
			Low	*High*
Material groups	*Prettau*	***110^{B} ± 7.07***	101.22	118.78
	IPS e.max CAD	***150^{A} ± 15.81***	130.37	169.63
	VITA SUPRINITY	***104^{B} ± 31.29***	73.29	134.71
ANOVA	***P-value***	.0025*		

Different letter in same column indicating significant (p<0.05) CI; confidence interval *; significant (p<0.05) ns; non-significant (p>0.05)

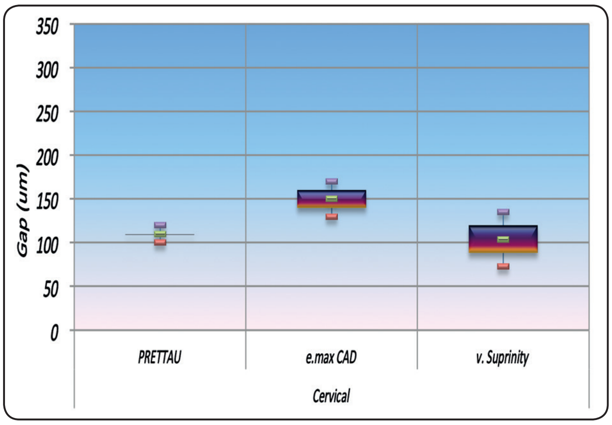

Fig. (5) Box plot showing marginal gap distance mean values for all groups - cervical margin.

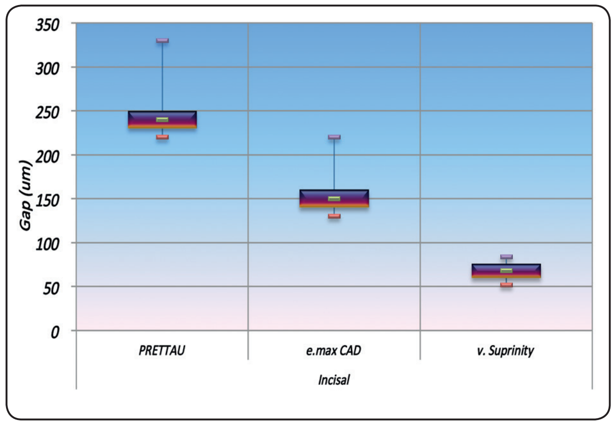

Fig. (6) Box plot showing marginal gap distance mean values for all groups – incisal margin.

For incisal measurement site

It was found that the highest marginal gap distance mean±SD values were recorded with ***Prettau*** group followed by ***IPS e.max CAD*** group while the lowest marginal gap distance mean±SD values were for ***VITA SUPRINITY*** group. The difference between groups was statistically significant as indicated by one-way ANOVA followed by Tukey's post-hoc tests (F=38.79, p=<0.0001<0.05) – table (4) and figure (6)

TABLE (4) Marginal gap distance results (Mean values ±SD) for all material groups at incisal margin.

Variables		*Incisal*		
		Mean ±SD	*95 %CI*	
			Low	*High*
Material groups	*Prettau*	*254^{A} ± 43.93*	199.46	308.54
	IPS e.max CAD	*160^{B} ± 35.36*	116.11	203.89
	VITA SUPRINITY	*68^{C} ± 12.85*	52.05	83.95
ANOVA	*P-value*	<0.0001*		

Different letter in same column indicating significant (p<0.05) CI; confidence interval *; significant (p>0.05)

Cervical vs. incisal margin (Table 5 and Figure7)

For the ***Prettau group;*** it was found that ***incisal margin*** recorded statistically significant higher marginal gap distance mean value than ***cervical margin*** as indicated by t-test (t=7.24, p=<0.0001<0.05)

Regarding ***IPS e.max CAD;*** it was found that ***incisal margin*** recorded statistically non-significant higher marginal gap distance mean value than ***cervical margin*** as indicated by t-test (t=0.5774, p=0.5796<0.05)

While for the ***VITA SUPRINITY;*** it was found that ***cervical margin*** recorded statistically significant higher marginal gap distance mean value than ***incisal margin*** as indicated by t-test (t=2.89, p=0.0203<0.05)

Totally, regardless to measurement site, it was found that the highest statistically significant marginal gap distance mean±SD values were recorded with Prettau group followed by IPS e.max CAD group while the lowest statistically significant marginal gap distance mean±SD values were for VITA SUPRINITY group as indicated by two way ANOVA test (F=34.55, p= <0.0001<0.05).

Totally, irrespective of material group, it was found that incisal margin recorded statistically significant higher marginal gap distance mean values than cervical one as indicated by two way ANOVA test (F=16.35, p= 0.0004<0.05).

TABLE (5) Marginal gap distance results (Mean values ±SD) for all material groups as function of measurement site.

Variables		Cervical	Incisal	t-test
		Mean ±SD	Mean ±SD	P value
Material groups	Prettau	110^{B} ± 7.07	254^{A} ± 43.93	<0.0001*
	IPS e.max CAD	150^{A} ± 15.81	160^{B} ± 35.36	0.5796 ns
	VITA SUPRINITY	104^{B} ± 31.29	68^{C} ± 12.85	0.0203*
ANOVA	P-value	0.0025*	<0.0001*	

Different letter in same column indicating significant (p<0.05) *; significant (p<0.05) ns; non-significant (p>0.05)

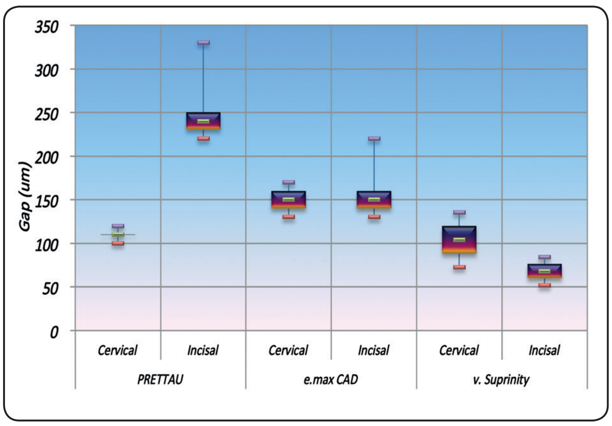

Fig. (7) Box plot showing marginal gap distance mean values for all groups as function of measurement site.

Microleakage

Descriptive statistics showing mean values, standard deviations (SD) for leakage through die penetration measured in (um) recorded for all material groups as function of measurement site summarized in table (6) and graphically represented in figure (8).

For cervical measurement site

It was found that the highest leakage mean±SD values were recorded with ***IPS e.max CAD*** group followed by ***Prettau*** group while the lowest leakage mean±SD values were for ***VITA SUPRINITY*** group. The difference between groups was statistically significant as indicated by one-way ANOVA followed by Tukey's post-hoc tests (F=94.58, p=<0.0001<0.05) – table (6) and figure (8)

TABLE (6) Leakage results (Mean values ±SD) for all material groups at cervical margin.

Variables		Cervical		
		Mean ±SD	95 %CI	
			Low	High
Material groups	Prettau	160^{B} ± 15.81	140.37	179.63
	IPS e.max CAD	284^{A} ± 30.49	246.14	321.86
	VITA SUPRINITY	117.80^{C} ± 1.92	115.41	120.19
ANOVA	P-value	<0.0001*		

Different letter in same column indicating significant (p<0.05) CI; confidence interval *; significant (p>0.05) ns; non-significant (p>0.05)

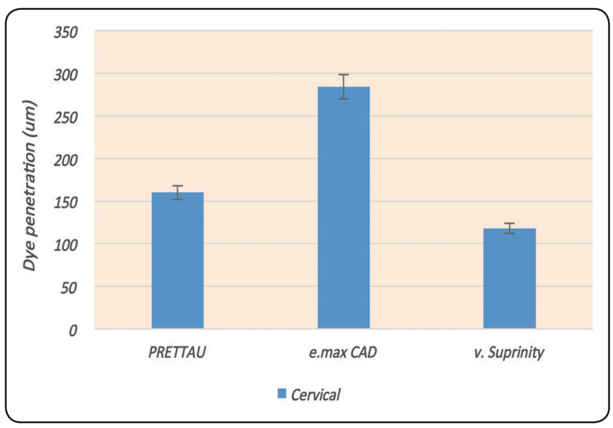

Fig. (8) Column chart showing leakage mean values for all groups - cervical margin

For incisal measurement site

It was found that the highest leakage mean±SD values were recorded with ***Prettau*** group followed by ***IPS e.max CAD*** group while the lowest leakage mean±SD values were for ***VITA SUPRINITY*** group. The difference between groups was statistically significant as indicated by one-way ANOVA followed by Tukey's post-hoc tests (F=357.98, p=<0.0001<0.05) – table (7) and figure (9)

TABLE (7) Leakage results (Mean values ±SD) for all material groups at incisal margin.

Variables		Incisal		
		Mean ±SD	95 %CI	
			Low	High
Material groups	Prettau	$238^{A} \pm 10.24$	214.12	261.88
	IPS e.max CAD	$120^{B} \pm 7.07$	111.22	128.78
	VITA SUPRINITY	$37.20^{C} \pm 2.59$	33.99	40.41
ANOVA	P-value	<0.0001*		

Different letter in same column indicating significant (p<0.05) CI; confidence interval *; significant (p>0.05) ns; non-significant (p>0.05)

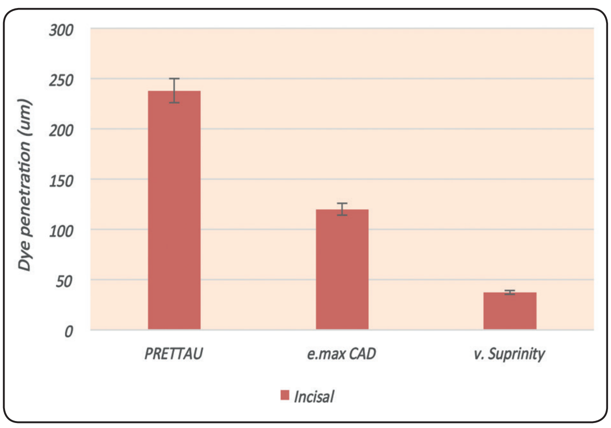

Fig. (9) Column chart showing leakage mean values for all groups – incisal margin

Cervical vs. incisal margin (Table 8 and Figure 10)

Regarding the ***Prettau group;*** it was found that ***incisal margin sub***group recorded statistically significant higher leakage mean value than ***cervical margin sub***group as indicated by t-test (t=7.01, p=0.0001<0.05)

While for the ***IPS e.max CAD;*** it was found that ***cervical margin*** recorded statistically significant higher leakage mean value than ***incisal margin sub***group as indicated by t-test (t=11.71, p=<0.0001<0.05)

As for the ***VITA SUPRINITY;*** it was found that ***cervical margin*** recorded statistically significant higher leakage mean value than ***incisal margin*** as indicated by t-test (t=55.89, p=<0.0001<0.05)

Totally, regardless to measurement site, it was found that the highest statistically significant leakage mean±SD values were recorded with IPS e.max CAD group followed by Prettau group while the lowest statistically significant leakage mean±SD values were for VITA SUPRINITY group as indicated by two way ANOVA test (F=187.97, p= <0.0001<0.05).

Totally, irrespective of material group, it was found that cervical margin recorded statistically significant higher leakage mean values than incisal one as indicated by two way ANOVA test (F=86.18, p= <0.0001<0.05).

TABLE (8) Leakage results (Mean values ±SD) for all material groups as function of measurement site.

Variables		Cervical	Incisal	t-test
		Mean ±SD	Mean ±SD	P value
Material groups	Prettau	$160^{B} \pm 15.81$	$238^{A} \pm 10.24$	0.0001*
	IPS e.max CAD	$284^{A} \pm 30.49$	$120^{B} \pm 7.07$	<0.0001*
	VITA SUPRINITY	$117.80^{C} \pm 1.92$	$37.20^{C} \pm 2.59$	<0.0001*
ANOVA	P-value	<0.0001*	<0.0001*	

Different letter in same column indicating significant (p<0.05) *; significant (p<0.05) ns; non-significant (p>0.05)

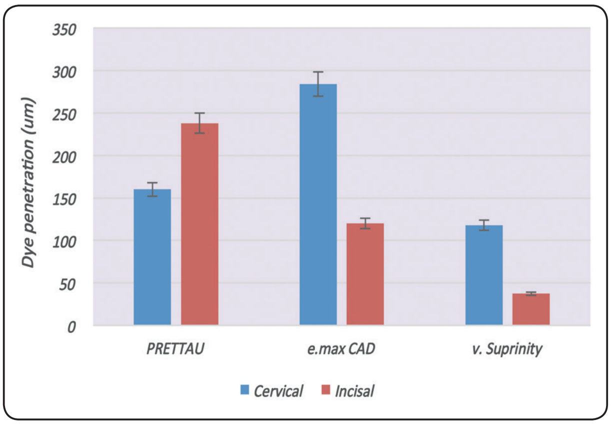

Fig. (10) Column chart showing leakage mean values for all groups as function of measurement site.

DISCUSSION

The in-vitro investigations can always help in estimation of in-vivo usability of new dental materials and products.[36] Clinical parameters like the preparation design and dimensions were included in the present investigation to obtain a more realistic data.[19] For example, preparation finish line has to be maintained in enamel to reduce probability of fracture under functional stresses.[8] Also, Thermocycling was used in this study to simulate thermal degradation of the restoration and the cement under clinical conditions.[37,38]

Minimal marginal and internal discrepancies and hence leakage are essential for clinical success of restorations.[39] Also, the mechanical integrity of restoration is directly affected by the thickness of the cement film in bonded veneers, in addition to increased polymerization pre-stresses or influence final shade and translucency. The effect of thermo-cycling and dynamic fatigue is seen in the form of bulk cracks that are related to lack of rigid support underneath the veneers or the surface flows extension.[40]

The results of the present investigation justify rejection of the null hypothesis as there was significant influence of the restorative material type and the measurement site on the marginal accuracy, internal adaptation and microleakage of ceramic veneers.

Internal adaptation

The internal adaptation plays an important role in the retention and hence the longevity of indirect restorations,[41] but, unluckily, the internal adaptation has not been studied to the same extent as the marginal fitness. Accordingly, the acceptable clinical range of the internal adaptation of dental restorations varies in the literature, and up till now, there is no standard procedure to assess such important criteria. This inconsistency may lead to misinterpretation and limits the comparisons between results from different studies.[42]

It was suggested that internal gap of all-ceramic restorations should fall between 49 -136 μm.[43,44] According to the aforementioned internal gap range of all-ceramic restorations,[43,44] only VITA SUPRINITY (78.5±6.02 μm) falls within. This was in agreement with Aboushelib et al., 2012,[15] who claimed that adequate internal adaptation was not necessarily demonstrated with restorations fabricated with CAD/CAM milling technology. Also it was in agreement with Manhal and Samar, 2016,[41] who proved that although the cement space was digitally adjusted, the CAD/CAM technology was unable to create a homogenous gap width even within the same specimen, which may be attributed to the quality of capturing and processing of the digital data and the thickness, form and inadequate ability of the milling instruments in the reproduction of fine details.[45,46]

When comparing the internal adaptation of each restorative material used, it was found that the highest internal gap distance values were recorded with Prettau group followed by IPS e.max CAD group while the lowest internal gap distance values were for VITA SUPRINITY group. The difference between groups was statistically significant. This was found in agreement with Yildirim et al., 2017,[39] who found that the VITA SUPRINITY showed lower internal gap than IPS e.max CAD. However, this was not in accordance with Majeed and

Al-Adel, 2016,[41] whom results showed that there was no significant difference between IPS e.max CAD and VITA SUPRINITY which both showed less internal adaptation than the monolithic Zirconia group. They attributed this to the like hood of chemical composition and identical fabrication method from milling to firing process, of the first two groups. Also the crystallization firing process proved to affect negatively (0.2% associated shrinkage) the dimensional accuracy of glass ceramic.[47,48]

However the statistically significant differences among all groups which could be accredited to the chemical composition dissimilarity of the material used for PLV fabrication and the differences in the post-milling treatment needed.[49]

Marginal gap distance

For the restorations to be clinically acceptable, they should possess minimal marginal and internal gaps.[39] Poor marginal fitness negatively affects the restoration strength, increases the risk of recurrent caries and periodontal disease and accordingly reduces its longevity.[41,49] Maximum clinically acceptable marginal gap distance values have been reported to be between 100-150 μm.[50-53] Accordingly, all groups within incisal and cervical measurements fall within this range except for the incisal margin of Prettau group (254 ± 43.93 μm).

Regardless of measurement site, it was found that the highest statistically significant marginal gap distance values were recorded with Prettau group followed by IPS e.max CAD group while the lowest statistically significant marginal gap distance values were for VITA SUPRINITY group. This was in accordance with Güngör et al., 2015,[54] who claimed that the excessive marginal gap might be attributed to sinterization shrinkage of zirconia material of the full contour monolithic zirconia restoration. This was also in agreement with Michael Gödiker and Jens Fischer, 2013,[55] who stated that VITA SUPRINITY exhibits higher marginal accuracy than the lithium disilicate ceramic, while using the default milling programs. Also, it agrees with Christian Brenes and Ibrahim Duqum, 2014,[56] who proved that zirconia restorations exhibit less accurate and standardized marginal adaptation when compared to lithium disilicate ones. This also was proven by Papadiochou and Pissiotis, 2017,[57] who proved that the restorative material type affects the performance of a CAD-CAM system relative to marginal adaptation. However, the results were not in accordance with Majeed and Al-Adel, 2016,[41] whom results showed that there was no significant difference between IPS e.max CAD and VITA SUPRINITY which both showed less marginal adaptation than the monolithic Zirconia group, claiming that the internal and marginal adaptation of Zirconia-based restorations was not greatly affected although they were sintered, owing to their high strength.[58]

The differences in marginal and internal adaptation results in the literature may be due to the difference between each CAD/CAM system resulting in various shrinkage rates depending on the manufacturer, scanning procedure, thickness of milling bur used, and the milling axis number.[59] However, according to the literature, the benefit of using CAD/CAM technology is not to attain the most accurate level of adaptation, but instead to achieve a standardized high level of trustworthiness; especially when high production levels are anticipated.[60]

Irrespective of material group, it was found that incisal margin recorded statistically significant higher marginal gap distance mean values than cervical one. This was in agreement with Aboushelib et al., 2012,[15] who assumed that this was because of CAD/CAM software limitations in restorations' designing, and hardware limitations of the scanner, and milling equipments resulting in errors, particularly during manual tracing and fine milling of the finish line area.[61] Additionally, the cutting tool may be thicker than the inner surface of the incisal edge causing misfits, resulting in a inferior marginal properties.[62] This was also assured by White et al., 1997,[63] and Majeed and Al-Adel, 2016,[41] who correlated the misfit at the incisal edges to its limited access which may restrict full access of the milling tool in these areas.

Leakage

Remake of esthetic restoration as laminate veneers is indicated in case of microleakage as it is considered as direct failure.[40] The adhesive type, polymerization method,[64] margin location,[34,65] preparation design and finish line configuration and preparation design,[66] are among many factors that affect microleakage.

Regardless of measurement site, it was found that the highest statistically significant leakage values were recorded with IPS e.max CAD group followed by Prettau group while the lowest statistically significant leakage values were for VITA SUPRINITY group. Also, irrespective of material group, it was found that cervical margin recorded statistically significant higher leakage mean values than incisal one. While correlating the areas and material of lower marginal accuracy with that of higher microleakage, there is some inconsistency. This was in accordance with many studies that questioned this correlation.[67,68] However, this is not in accordance with Aboushelib et al., 2012,[15] whom results showed increased dye penetration with inferior marginal accuracy and higher internal gap of CAD/CAM milled ceramic veneers, as this leads to exposure of more area of the resin cement to hydrolytic effect of water under the influence of thermo-cycling which might be the cause of cement degradation and hence microleakage.

Finally, a limitation of this study is that it was carried out in-vitro on resin teeth, without being sure that similar microleakage pattern would happen if natural teeth were used instead.

CONCLUSIONS

Under the test conditions, the following could be concluded:

1. All used ceramic materials fall within the clinically acceptable range of marginal accuracy.
2. CAD/CAM technology does not necessarily present highly accurate restorations, in terms of external and internal adaptation.
3. Lithium disilicate-based restorations showed better external and internal adaptation and microleakage than monolithic Zirconia-based restorations.
4. The correlation between external and internal adaptation and microleakage is still questionable.

DISCLOSURE

The authors report no conflicts of interest in this work.

REFERENCES

1. Li Q, Yu H, Wang YN. Spectrophotometric evaluation of the optical influence of core build-up composites on all-ceramic materials. Dent Mat. 2009; 25:158–165.
2. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc. 2008; 139(Suppl):8S–13S.
3. Fasbinder DJ. Computerized technology for restorative dentistry. Am J Dent. 2013; 26:115–120.
4. Vichi, A., Carrabba, M., Paravina, R., Ferrari, M. Translucency of Ceramic Materials for CEREC CAD/CAM System. Journal of Esthetic and Restorative Dentistry. 2.04 26: 224–231.
5. Karapetian VE, Sorg T, Jöckel M, Baumann MA. Comparison of different polishing systems for dental inlay ceramics. In: Mörmann WH, editor. CAD/CIM in aesthetic dentistry. Chicago: Quintessence Publishing Co., Inc.; 1996.
6. Li-Hong He, Michael Swain. A novel polymer infiltrated ceramic dental material. Dental materials. 2011; 27:527–534.
7. Hekimoğlu C, Anil N, Etikan I. Effect of accelerated aging on the color stability of cemented laminate veneers. Int J Prosthodont. 2000; 13 (1):29-33.

8. Chun YH, Raffelt C, Pfeiffer H, Bizhang M, Saul G, Blunck U, Roulet JF. Restoring strength of incisors with veneers and full ceramic crowns. J Adhes Dent. 2010; 12 (1):45-54.

9. Horn HR. Porcelain laminate veeners bonded to etched enamel. Dent Clin North Am. 1982; 27 (4):671-684.

10. Dozic A, Tsagkari M, Khashayar G, Aboushelib M. Color management of porcelain veneers: influence of dentin and resin cement colors. Quintessence Int. 2010; 41 (7):567-573.

11. Ana Paula R. Magalhães; Patrícia C.siqueira; Paula C. Cardoso; João B. Souza; Rodrigo B. Fonseca; Fernanda C. P. Pires Souza; Lawrence G. Lopes. Influence of the Resin Cement Color on the Shade of Porcelain Veneers after Accelerated Artificial Aging. Rev Odontol Bras Central. 2013; 21(60).

12. Douaa khatib, Hesham Katamish, Atef Shaker Ibrahim. Fracture Load of Two CAD/CAM Ceramic Veneers with Different Preparation Design. Cairo Dental Journal. 2009; 25 (3): 425:432.

13. Calamia JR, Calamia CHS. Ceramic laminate veneers: reasons for 25 years of success. Dental Clinics of North America. 2007; 51:399–417.

14. Chen JH, Shi CX, Wang M, Zhao SJ, Wang H. Clinical evaluation of 546 tetracycline-stained teeth treated with porcelain laminate veneers. Journal of Dentistry. 2005; 33:3–8.

15. Moustafa Nabil Aboushelib, Waleed AbdelMeguid Elmahy, Mohammed Hamed Ghazy. Internal adaptation, marginal accuracy and microleakage of a pressable versus a machinable ceramic laminate veneers. Journal of dentistry.2012; 40:670–677.

16. Archegas LR, Freire A, Vieira S, Caldas DB, Souza EM. Colour stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated aging. Journal of dentistry. 2011; Sep 3.

17. Charisis D, Koutayas SO, Kamposiora P, Doukoudakis A. Spectrophotometric Evaluation of the Influence of Different Backgrounds on the Color of Glass-Infiltrated Ceramic Veneers. Eur J Esthet Dent. 2006; 1 (2):142-56.

18. Wassell RW, Walls AW, Steele JG. Crowns and extra-coronal restorations: materials selection. Br Dent J. 2002; 23; 192(4):199-202, 205-211.

19. Cherif Fayez, Hisham katamish, Mona El-Agroudi. Cervical marginal accuracy and fatigue strength after dynamic loading of IPs empress 2 crowns using conventional and novel machinable (CAD/CAM) techniques. (In vitro study). Egyptian Dental Journal. 2009; 55:1-13.

20. Guess PC, Zavanelli RA, Silva NR, Bonfante EA, Coelho PG, Thompson VP. Monolithic CAD/CAM lithium disilicate versus veneered Y-TZP crowns: comparison of failure modes and reliability after fatigue. Int J Prosthodont. 2010; 23(5):434-442.

21. G. SANNINO, F. GERMANO, L. ARCURI, E. BIGELLI, C. ARCURI, A. BARLATTANI. CEREC CAD/CAM CHAIRSIDE SYSTEM. Oral & Implantology - anno VII. 2014; 3:57- 70.

22. Edward A. McLaren, Johan Figueira. Updating Classifications of Ceramic Dental Materials: A guide to material selection. Inside dentistry. 2015:48-53.

23. Heintze SD, Cavalleri A, Forjanic M, Zellweger G, Rousson V. Wear of ceramic and antagonist—a systematic evaluation of influencing factors in vitro. Dent Mater. 2008; 24:433–49.

24. Al-Baadani AH. Evaluation of internal adaptation of full contour zirconia crowns versus veneered zirconia crowns: In vitro study. Int Dent Med J Adv Res. 2016; 2:1-6.

25. Celik C, Gemalmaz D. Comparison of marginal integrity of ceramic and composite veneer restorations luted with two different resin agents: an in vitro study. International Journal of Prosthodontics. 2002; 15:59–64.

26. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. Journal of Dentistry. 2000; 28:163–177.

27. Toh G, Setcos J, Weinstein A. Indirect dental laminate veneers—an overview original research article. Journal of Dentistry. 1987; 15:117–124.

28. El-Badrawy W, Hafez RM, El Naga AI, Ahmed DR. Nanoleakage for Self-Adhesive Resin Cements used in Bonding CAD/CAD Ceramic Material to Dentin. Eur J Dent. 2011; 5(3):281–290.

29. Abeer Abo El Naga, Mohammed Yousef, Rasha Ramadan, Sherif Fayez Bahgat and Lana Alshawwa. Does the use of a novel self-adhesive flowable composite reduce nanoleakage? Clinical, Cosmetic and Investigational Dentistry. 2015:7; 55–64.

30. Calamia JR. Etched porcelain facial veneers: a new treatment modality based on scientific and clinical evidence. New York Journal of Dentistry. 1983; 53:255–259.

31. Shetty A, Kaiwar A, Shubhashini N, Ashwini P, Naveen DN, Adarsha MS, et al.. Survival rates of porcelain laminate restoration based on different incisal preparation designs: an analysis. Journal of Conservative Dentistry. 2011; 14:10–15.

32. Walls A, Steek J, Wassell R. Crowns and extra-coronal restorations; porcelain laminate veneers. Journal of Prosthetic Dentistry. 2002; 193:73–82.

33. Brunton PA, Aminian A, Wilson NH. Tooth preparation techniques for porcelain laminate veneers. British Dental Journal. 2000; 189:260–262.

34. Christensen G. Why use resin cements. Journal of American Dental Association. 2010; 141:204–206.

35. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil. 1999; 26:582–593.

36. Rosentritt M, Plein T, Kolbeck C, Behr M, and Handel G. In vitro fracture force and marginal adaptation of ceramic crowns fixed on natural and artificial teeth. Int J Prosthodont. 2000; 13:387-391.

37. Bonfante F, Coelho P, Guess P, Thompson V, Silva N. Fatigue and damage accumulation of veneer porcelain pressed on Y-TZP. Journal of Dentistry. 2010; 38:318–324.

38. Sim C, Neo J, Chua EK, Tan BY. The effect of dentin bonding agents on the microleakage of porcelain veneers. Dental Materials. 1994; 10:278–281.

39. Güler Yildirim, DDS,a Ismail H. Uzun, DDS, PhD,b and Ali Keles, DDS, PhD. Evaluation of marginal and internal adaptation of hybrid and nanoceramic systems with microcomputed tomography: An in vitro study. J Prosthet Dent. 2017; 118(2):200-207.

40. Baig MR, Tan KB, Nicholls JI. Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system. Journal of Prosthetic Dentistry. 2010; 104:216–27.

41. Manhal A. Majeed, Samar K. Al-Adel. Evaluation of the marginal and internal fitness of full contour CAD/CAM crowns made from zirconia, lithium disilicate, zirconia-reinforced lithium silicate and hybrid dental ceramic by silicone replica technique. (A comparative In vitro study). Journal of Gene c and Environmental Resources Conservation. 2016; 4(1):10-20.

42. Svanborg, P., Skjerven, H., Carlsson, P., Eliasson, A., Karlsson, S., Ortorp, A. Marginal and internal fit of Cobalt-Chromium fixed dental prostheses generated from digital and conventional impressions. Int J Dent. 2014:1-9.

43. May, K.B, Russell, M.M., Razzoog M.E., Lang B.R. Precision of fit: the Procera All Ceram crown. J Prosthet Dent. 1998; 80(4):394-404.

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

45. Pfeiffer, J. Dental CAD/CAM technologies: the optical impression (II). J. Int Comput Dent. 1999; 2(1):65-72.

46. Luthardt, R., Weber, A., Rudolph, H., Schone, C., Quaas, S., Walter, M. Design and production of dental prosthetic restorations: basic research on dental CAD/CAM technology. J. Inter ComputerDent. 2002; 5:165–176.

47. Farid, F., Hajimiragha, H., Jelodar, R., Mostafavi, A.S. In Vitro Evaluation of the effect of core thickness and fabrication stages on the marginal accuracy of an All-Ceramic System. J. Dent TehranUniver Medi Sci. 2012; 9(3):188-194.

48. Shen, J., Kosmac, T. Advanced Ceramics for Dentistry. J El Savier. 2014:227-248.

49. Felton, D.A., Kanoy, B.E., Bayne, S.C., Wirthman. Effect of in vitro crown margin discrepancies on periodontal health. J.prosthet Dent. 1991; 65(3):357-364.

50. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD-CAM generated restorations. Br Dent J. 2008; 204: 505-511.

51. Re D, Cerutti F, Augusti G, Cerutti A, Augusti D. Comparison of marginal fit of Lava CAD-CAM crown-copings with two finish lines. Int J Esthet Dent. 2014; 9:426-35.

52. Song TJ, Kwon TK, Yang JH, Han JS, Lee JB, Kim SH, et al. Marginal fit of anterior 3-unit fixed partial zirconia restorations using different CAD-CAM systems. J Adv Prosthodont. 2013; 5:219-225.

53. Huang Z, Zhang L, Zhu J, Zhao Y, Zhang X. Clinical marginal and internal fit of crowns fabricated using different CAD-CAM technologies. J Prosthodont. 2015; 24:291-295.

54. Merve Bankoğlu Güngör, Aylin Doğan, Bilge Turhan Bal, Seçil Karakoca Nemli. Evaluation of marginal and internal adaptations of posterior all-ceramic crowns fabricated with chair-side CAD/CAM system: an in vitro

study. Poster presentation at the 39th Annual Conference of the European Prosthodontic Association, Prague, Czech Republic, September 3-5, 2015. This study was supported by grant no. 114S238 from The Scientific and Technological Research Council of Turkey (TÜBİTAK).

55. Michael Gödiker, Jens Fischer. Internal studies, VITA R&D: VITA Zahnfabrik H. Rauter GmbH & Co. KG Research and Development Inorganic Chemistry Spitalgasse 3 79713. Date of issue: 07.13.

56. Christian Brenes, Ibrahim Duqum. MICRO-CT EVALUATION OF THE MARGINAL FIT OF CAD/ CAM ALL-CERAMIC CROWNS. Master thesis in Prosthodontics, School of Dentistry, University of North Carolina, Chapel Hill. 2014.

57. Papadiochou S, Pissiotis AL. Marginal adaptation and CAD-CAM technology: A systematic review of restorative material and fabrication techniques. J Prosthet Dent. 2017 Sep 27.

58. Komine, F., Blatz, M.B., Matsumura, H. Current status of zirconia-based fixed restorations.J. Oral Science. 2010; 52(4):531-539.

59. Min-Kyung Ji, Ji-Hee Park1, Sang-Won Park, Kwi-Dug Yun, Gye-Jeong Oh, Hyun-Pil Lim. Evaluation of marginal fit of 2 CAD-CAM anatomic contour zirconia crown systems and lithium disilicate glass-ceramic crown. J Adv Prosthodont. 2015; 7:271-277.

60. Christian Brenes, Ibrahim Duqum, Gustavo Mendonza. Materials and systems for all-ceramic CAD/CAM restorations. CAD/CAM international magazine of digital dentistry. 2016; 3:10-15.

61. Martin N, Jedynakiewicz NM. Interface dimensions of CEREC-2 MOD inlays. Dental Materials. 2000; 16:68–74.

62. 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. European Journal of Oral Science. 2005; 113:174–183.

63. White SN, Suh PS, Yu Z, Johnson R. Effect of fit adjustment on CEREC CAD-CAM veneers. American Journal of Dentistry. 1997; 10:46–51.

64. Maleknejad F, Moosavi H, Shahriari R, Sarabi N, Shayankhah T. The effect of different adhesive types and curing methods on microleakage and the marginal adaptation of composite veneers. Journal of Contemporary Dental Practice. 2009; 10:18–26.

65. Hekimoglu C, Anil N, Yalc¸in E. A microleakage study of ceramic laminate veneers by autoradiography: effect of incisal edge preparation. Journal of Oral Rehabilitation. 2004; 31:265–9.

66. MOĞLU, L. KARAAĞAÇIOĞLU, ÜÇCTAŞLI. Influence of porcelain material and composite luting resin on microleakage of porcelain laminate veneers. Journal of Oral Rehabilitation. 1992; 19:319–327.

67. Christgau M, Friedl KH, Schmalz G, Resch U. Marginal adaptation of heat-pressed glass–ceramic veneers to dentin in vitro. Operative Dentistry. 1999; 24:137–146.

68. Christgau M, Friedl KH, Schmalz G, Edelmann K. Marginal adaptation of heat-pressed glass–ceramic veneers to class 3 composite restorations in vitro. Operative Dentistry. 1999; 24:233–244.