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Evaluation of Marginal and Internal Adaptation of CAD/CAM and Pressable Ceramic Veneers of Different Preparation Designs Using Silicone Replica Technique: (A Comparative in Vitro Study)

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Abstract: ***Background**: Accurate marginal and internal adaptation is a significant considerations for the clinical success of all ceramic restorations. The purpose of this study was to evaluate the marginal and internal adaptation of IPS e.max CAD and IPS e.max press ceramic veneers with two different preparation designs by using silicon replica technique. **Materials and method**: A typodont maxillary central incisor was used for veneer preparation. Metal die was fabricated for each preparation deign, then each metal die was used to make twenty stone dies. The forty stone dies divided into four groups (n=10)according to the preparation design and the technique of veneer fabrication as follow: Group I: butt joint incisal reduction restored with IPS e.max CAD. Group II: overlapped incisal reduction with palatal chamfer restored with IPS e.max CAD. Group III: butt joint incisal reduction restored with IPS e.max press. Group IV: overlapped incisal reduction with palatal chamfer restored with IPS e.max press.A silicone replica was obtained to measure marginal and internal adaptation of each ceramic veneer. A silicone replica was sectioned vertically and horizontally, Marginal and internal adaptations were evaluated by measuring the thickness of the light body silicone material at different points using digital microscope. **Results**: Replica scores were analyzed with Two- way ANOVA and Independent sample t-test. The highest marginal gap was recorded for Group IV with highly significant differences when compared with other groups, followed by Group III, II, and I respectively. The fabrication technique and the preparation design showed significant effect on marginal gap values. There is no significant difference in internal gap between these four ceramic groups. **Conclusion**: The pressable ceramic veneers with overlapped incisal reduction design produced higher marginal gap. There is no significant difference in internal gap between these four ceramic groups. Only CAD/CAM Groups (Group I and II) showed a clinically acceptable total gap.***

Keywords: Laminate veneer, Marginal adaptation, internal adaptation, Silicone Replica technique

1. Introduction

Ceramic laminate veneers are considered as a successful treatment modalities for patients requiring improvement of the color, shape, or position of their anterior teeth **(Cehreli and Iplikçioglu, 2000; Ghaffari et al., 2016).** It became the treatment of choice in minimally invasive aesthetic dentistry (**Lin et al., 2012).**

Many ceramic systems are available, which may differ in composition or fabrication technique. Most laminate veneers are made from lithium disilicateceramic. Lithium disilicate is a glassy ceramic with a high flexural strength up to 440 MPa. IPS E.max lithium disilicate, introduced in 2005 by Ivoclar Vivadent (AG, Schaan, Liechtenstein), It is a glass ceramic material that has a needle-like crystal structure that give it an excellent strength, optimal durability and superior optical properties. IPSE.max lithium disilicate restorations can be fabricated either by lost-wax hot pressing techniques (IPS E.max Press) or computer-aided-designed/computer aided manufactured (CAD/CAM) milling procedures (IPS E.max CAD) (**Mounajjed et al., 2016).** The crystals of both the IPS e.max Press and IPS e.max CAD are the same in composition, the microstructures of both of them are 70% crystalline lithium disilicate, but these crystals are different in length and size, so the properties of these materials such as chemical solubility, CTE, and modulus of elasticity are the same, while the flexural strength and fracture toughness are slightly higher for the IPS e.max Press material (**IPS e.max CAD Scientific Documentation, 2009).**

Long term clinical performance of porcelain veneer depends on several factors; the marginal and internal adaptation of veneer to the tooth surface are of significant interest (**Ghaffari et al., 2016)**.Close proximity between the margin of the restorations and the tooth structure prevent the excessive exposure of the adhesive resin cement to the oral fluid which lead to gradual disintegration of its physical, chemical, and mechanical properties resulting in microleakage, recurrent carries, and periodontal desiese (**Felton et al., 1991).** On the other hand, the internal adaptation is defined as the perpendicular measurement from the axial wall of the tooth to the internal surface of the restoration, it has an important role in the retention of the restoration **(Svanborg et al., 2014).**

Many techniques have been used to measure the internal and marginal fitness of restorations such as direct measurement, sectioning method, profilometry, micro-CT technique and silicone replica technique. Each one has advantages and disadvantages. The silicone replica technique offers the advantages of being a non-destructive method which rely on measuring the thickness of low viscosity impression silicon material used in place of the resin cement (**Reich et al., 2011).**

Up to the authors knowledge's, there are no investigations in the literature evaluating the marginal and internal adaptation of ceramic laminate veneers by using replica technique, Therefore, it was the objective of this in vitro study to investigate these parameters of pressable and machinable ceramics with two preparation designs by using replica technique.

2. Materials and Methods

A typodont maxillary right central incisor was used for veneer preparation. A primary impression was taken for the typodont using alginate impression material (Tropicalgin, Italy), then poured immediately with type IV dental stone (Zhermack, Italy) to produce the primary model that served later as a biocopy to restore the shape of the original tooth during the fabrication of the CAD/CAM veneers groups **(Abdul Khaliq AGH; Najim and Al-Rawi, 2015)**. A silicone index was made for the tooth in the student typodont using a putty polyvinyl siloxane material (Zeta plus/soft, Zhermack/clinical, Italy) to use it after sectioning as a guide for evaluating the amount of reduction **(Herbert et al., 1997).**

Veneer Preparation with Butt-Joint Incisal Reduction Design:

The preparation was doneby using a ceramic veneers burs system kit (komet, Germany) with a high speed handpiece. Labial reduction was 0.3 mm cervically and 0.5 mm in the middle and the incisal third (**Touati et al., 1999).**The final cervical margin had chamfer profile with 0.3 mm (**McLaren, 2006;Hekimog et al., 2004)** and positioned 1 mm away from cervical line (**Gresnigt et al, 2007)**. The preparation was extended proximally without destroying the contact areas which represent the areas of highest contour.

Incisal reduction was 1.5mm **(McLaren, 2006; Hekimog et al., 2004)**; the bur was held parallel to the incisal edge inclination to create butt joint incisally. All the line angles were rounded with white stone bur using slow speed hand piece. Finally the preparation was checked with previously prepared silicone indices to ensure that the necessary reduction of the labial surface and incisal edge was done properly (**Najim and Al-Rawi, 2015)**.

Final impression was taken for the prepared typodont tooth using Additional silicone impression materials (elite P&P/putty soft, Zhermack/clinical, Italy) which was then poured with blue inlay casting wax to form wax pattern for the first preparation design **(Aboushelib et al., 2012).**

Veneer Preparation with (Overlapped Incisal Reduction with Palatal Chamfer) design:

The same typodont was modified for Preparation of the second design.1.5 mm of incisal edge was reduced, chamfer finishing line was prepared on the palatal surface of the tooth with round end tapered diamond bur which was held parallel to the palatal surface of the tooth with its end forming a chamfer 0.5 mmin depth and 1mm in height (i.e. 1 mm from reduced incisal edge), and extended it through the interproximal areas. Mesial and distal corners were rounded. Impression for the second preparation was taken and poured with blue inlay wax to form the wax pattern for the second design (**Najim and Al-Rawi, 2015)**.

The two wax patterns were taken to the laboratory where the metal dies were fabricated using the standard protocol of lost wax technique.

Twenty impressions were taken for each metal die using modified tray which was loaded with putty additional silicone impression materials (elite P&P/hydrophilic, Zhermack, Italy) and light body addition silicone impression materials (elite HD plus/hydrophilic, Zhermack, Italy) was injected on the metal die and the tray was then placed on the tooth while maintaining finger pressure until setting. These impressions were poured with type IV dental stone (Zhermack, Italy) to form stone dies (i.e. ten stone dies for each experimental group).

Samples Grouping

The Forty stone dies were divided into four groups (n=10) according to the preparation design and the technique used for veneer fabrication:

- **Group I:** prepared with butt joint incisal reduction design and restored with IPS e.max CAD.
- **Group II:** overlapped incisal reduction with palatal chamfer design restored with IPS e.max CAD.
- **Group III:** butt joint incisal reduction design restored with IPS e.max press.
- **Group IV:** overlapped incisal reduction with palatal chamfer design restored with IPS e.max press.

Veneer Fabrication Techniques:

Twenty ceramic laminate veneers were fabricated using IPS e.max press (MO 1, IvoclarVivadent). Two layers of die spacer were applied on the master die with 1mm short of the margin. A wax pattern was manually built on each stone die to restore the anatomical features of the unprepared tooth. A sectioned silicone index was used as a reference and a wax gauge (caliper) was used to check the thickness of wax pattern. Wax patterns were attached to investment ring base using a 3mm wax sprue and a freshly vacuum mixed investment material was cast. After chemical setting of the investment, the ring was transferred to a preheated burn out oven at (800 ^{0}C) and remained for about 60 minutes. Ceramic ingots were placed inside the hot ring and transferred to the pressing furnace (programat EP3000; Ivoclar Vivadent) which was automatically programmed to complete the pressing cycle. After cooling, Pressable ceramic laminate veneers were divested by using 50 µm Al_2O_3particles, cutting and finishing the location of the sprue were done. The external surfaces of the restoration were glazed by using mixed glazing material (IPS e.max Ceram Glaze and Stain Liquids long life) and glazing is conducted according to the glaze firing parameters.

Twenty ceramic laminate veneers were fabricated using IPS e.max CAD (IvoclarVivadent).The fabrication was done following the standard protocol of Sirona CAD/CAM system. In "SCAN" phase, In Eos Blue scanner (Sirona Dental Systems, Bensheim, Germany) was used to scan the previously fabricated primary model to form a biocopy of the tooth before preparation in order to build a restoration to the original dimensions of unprepared tooth. Then each stone die was scanned and a 3D image was obtained. Digital images of both of the primary model and the stone dies automatically analyzed and correlated with each other by a system which allow alignment of the 3D image of the primary model on top of the 3D image of stone dies correctly. The designing of veneer was determined in "MODEL" phase, the margin of preparation was drawn automatically by the system, then in copyline section, and the area to be copied from the biocopy was drawn in order to design the veneer identical to the original tooth form. The preparation of finishing line was marked on the digital model. In "DESIGN" phase, veneer parameter in this study was set such as minimum veneer thickness (0.4mm), spacer (0.08mm). IPS e.max CAD blocks (IvoclarVivadent) used to mill 20 veneers, 10 veneers for each preparation design. From the "MILL" phase screen, the type, the size of the block (C14) and its position were determined, the milling process was done by the CEREC in-lab machine**.** After complete the milling process, the restoration was fired for 30 minutes in a ceramic furnace (IvoclarVivadent, Liechtenstein, Germany) according to manufacturer's instructions. This process gives the glass-ceramic with its final strength and esthetic properties.

Silicone replica technique: For silicone replica technique, Low viscosity addition silicone impression material (Express™, regular set, light body, 3M ESPE, Germany) was used for the cementation of each veneer on the master die. The light body was injected into the inner surface of veneer then the veneer was seated on the metal die using fixed pressure of 250 g for one min, then a heavy body silicone impression material (Express™ XT Penta™ H, 3M ESPE, Germany) with a contrasting color was used to support this thin film of the light body. The silicone replica was then sectioned vertically and horizontally using cutting knife in a specially designed sectioning base. Measurement of the marginal and the internal gaps was done by measuring the thickness of the light body silicone material at prdetermined points, Measurements were done using Dinolite digital microscope connected to PC and at a magnification of 230x. For each specimen, a total of ten different measurements were done at predetermined points for the vertical and horizontal sections. These measuring points represented different areas of measurement: margins (gingival, mesial, distal, incisal margin), chamfer, axial, and incisal area. Image analysis software (Image J) was used for measurement of the gap at these predetermined points. All measurements were done by one operator, as recommended by Holmes et al. (**Holmes et al., 1989).**

3. Results

Descriptive statistics of the marginal, internal, and total gaps (means, standard deviations, minimum and maximum gap values) are presented in Table 1.The highest mean value of marginal, internal, and total gap showed in group IV followed by Group III, Group II, and group I respectively.

Two-way ANOVA test was used to detect if there is a significant effect of the fabrication technique and the preparation design used and their interaction on the marginal, internal, and total gaps for the four experimental veneer groups (Tables 2, 3, 4). The results of the present study showed that the fabrication technique had a highly significant effect on marginal gap (p=0.00), no significant effect on internal gap (p=0.30), and had significant effect on total gap (p=0.02). On the other hand, the preparation design showed significant effect on marginal gap (p=0.02), and no significant effect on internal and total gaps (P>0.05).The effect of the interaction between those two factors was significant on the marginal gap measurements (p=0.03) and insignificant on the internal and total gap (P>0.05).

Table 1: Descriptive statistics of the marginal, internal, and total gaps of the four different groups measured in micrometer

	Groups	N	Min	Max	Mean	±SD
Marginal gap*	Group I	10	122	207	150.6	±26.95
	Group II	10	118	240	151.8	±41.9
	Group III	10	111	219	161.7	±30.49
	Group IV	10	175	301	211.6	±35.87
Internal gap**	Group I	10	113.5	177	147.92	±22.56
	Group II	10	128.5	167.25	148.15	±13.14
	Group III	10	102	216.25	149.67	±29.41
	Group IV	10	106.5	274	168.52	±54.24
Total gap***	Group I	10	126.9	194.9	149.8	±23.76
	Group II	10	123.1	194.7	150.23	±23.04
	Group III	10	107.2	191.4	156.01	±26.37
	Group IV	10	146.6	241.7	185.82	±35.15

* Marginal gap was measured by calculating the mean values of the gingival, mesial, distal, and incisal marginal gaps.
**Internal gaps were measured by calculating the mean values of the chamfer, axial, and incisal area gaps.
***Total gaps were measured by calculating the mean values of the internal gap and the marginal gap.

Table 2: Two-Way ANOVA for the marginal gap measurements

Source of Variation	SS	df	MS	F	P-value
Design	6528.024	1	6528.024	5.556	0.02
Technique	12567.025	1	12567.025	10.697	0.00
Interaction	5929.225	1	5929.225	5.047	0.03
within	42292.5	36	1174.791		
total	67316.775	39			

Table 3: Two-Way ANOVA for the internal gap measurements

Source of Variation	SS	df	MS	F	P-value
Design	909.639	1	909.639	0.8104	0.37
Technique	1223.789	1	1223.789	1.090	0.30
Interaction	867.226	1	867.226	0.772	0.39
within	40405.468	36	1122.374		
total	43406.123	39			

Table 4: Two-Way ANOVA for the total gap measurements

Source of Variation	SS	df	MS	F	P-value
Design	2286.144	1	2286.144	3.021	0.09
Technique	4368.1	1	4368.1	5.772	0.02
Interaction	2157.960	1	2157.960	2.851	0.10
within	27242.526	36	756.736		
Total	36054.731	39			

Two-Independent Samples T-Test was used to determine the difference in (marginal, internal, and total gaps) between the two preparation designs within each type of technique or between the two fabrication techniques within each type of design, the result presented in (Table 5) showed that there is no significant difference in marginal, internal, and total gaps between the two designs of the CAD/CAM veneer groups (P>0.05). For the pressable groups, the comparison between the two preparation designs showed a highly significant differences in marginal gap between the two preparation designs (p=0.00), no significant difference in internal gap (p=0.3), and significant difference in total gap (p=0.04) between the two preparation designs.

On the other hand, the comparison between the two fabrication techniques within each type of design showed that there is no significant difference in marginal, internal, and total gaps (P>0.05) between group I and group III, and when compare between pressing group IV and CAD/CAM group II with the same preparation design found that there is highly significant difference in marginal gap (0.00), no significant difference in internal gap (0.2), and significant difference in total gap between these two groups.

Table 5: Two-Independent Samples T-Test

	Groups comparison	Mean difference	t	p-value
Marginal gap	I x II	1.2	2.13	0.9
	III x IV	49.4	2.1009	0.00
	I x III	11.1	2.1009	0.3
	II x IV	59.8	2.1009	0.00
Internal gap	I x II	0.23	2.144	0.9
	III x IV	18.85	2.144	0.3
	I x III	1.75	2.109	0.8
	II x IV	20.37	2.228	0.2
Total gap	I x II	0.43	2.1009	0.96
	III x IV	29.81	2.109	0.04
	I x III	6.21	2.1009	0.58
	II x IV	35.59	2.119	0.01

4. Discussion

In the present study, atypodont resin tooth was used for veneer preparation to overcome the variations that may show in natural teeth. Maxillary central incisor was selected in this study because it is the most common tooth restored with a laminate veneer (**Aboushelib et al., 2012; Najim and Al-Rawi, 2015).**

Primary impression was taken for the typodont to produce the primary model that served later as a bioscopy to restore form and shape of the original tooth during the fabrication of the CAD/CAM veneers groups (**Abdul Khaliq AGH, Al-Rawi, 2014, Najim and Al-Rawi, 2015**).

Silicone indices were used to evaluate the amount of tooth reduction, and assisted the technician in buildup of wax pattern to restore the original form and shape of the tooth **(Aboushelib et al., 2012).** Two preparation designs were used in this study: (butt joint incisal reduction and overlapped incisal reduction), to evaluate the effect of different preparation designs on the marginal and internal adaptation of laminate veneer.

The preparation was done by using depth cutter burs (komet) to avoid the excessive reduction of tooth structure. The preparation was 0.3 mm cervically and 0.5 mm in the middle and the incisal third to keep the preparation depth confined within the enamel as stated by Shillingburg and Grace (**LeSage, 2013).** The incisal reduction was 1.5 mm to ensure adequate thickness of ceramic material that give the restoration adequate fracture resistance and natural translucency incisally. The second preparation design (Overlapped Incisal Reduction with Palatal Chamfer) was made by modifying the same tooth incisally for more standardization of the preparation depth labially and proximally (**Lin et al., 2012).**

In the present study, the replica technique was used for quantitative analysis of the marginal and internal adaptation of veneer, this technique is a non-destructive and reliable method to determine the marginal and internal adaptation of indirect restorations, because it is easy, relatively inexpensive and not time consuming to perform **(Pedroche et al., 2016).** This technique was used in several in vivo and in vitro studies and in comparisons of clinical and laboratory results, and can therefore be considered as a well-documented procedure (**Denissen et al, 2000; Stappertet al, 2008;Stappert et al, 2005; Frankenberger et al, 2007; Bindl and Mormann, 2003; Majeed and Al-Adel, 2016).**

The fitness of indirect restorations is related to a minimal marginal gap between the restoration and the prepared tooth. The importance of marginal adaptation lies in the fact that the major reasons of indirect restoration failure are recurrent carries and loss of retention due to the dissolution of the luting cement. As important as marginal fitness, a minimum and uniform internal gap is also a desirable aspect of indirect restorations, as large and inhomogeneous internal gaps may adversely affect the retention or the resistance of the restoration (**Pedroche et al., 2016).**

Different levels of adaptation were evaluated In the present study, (gingival margin, chamfer, axial, incisal) to obtain a complete picture about veneer seating.

According to the results of the present study, the highest gap values recorded for the pressable ceramic groups; with a higher mean values for Group IV followed by Group III, Group II, and Group I respectively. The technique of fabrication showed a highly significant effects on the marginal gap (p=0.00), this finding is in agreement with the study of Jha et al. (**Jha et al., 2013)**in which they found the highest marginal gap in the pressing group, but it disagrees with a study done by Aboushelib et al. **(Aboushelib et al., 2012)** they found that the pressable ceramic veneers demonstrated significantly lower marginal and internal gap values compared to machinable ceramic veneers. In the present study, the higher gap values of pressable ceramic veneers may be attributed to many factors such as the sensitive nature of the pressing technique; as it is depending largely on technician skills and experience, and wax has many inherent limitations include delicacy, elastic memory, thermal sensitivity, and a high coefficient of thermal expansion (**Song et al., 2013),** the shrinkage of the porcelain material toward the region of greater bulk (**Khatib et al., 2009)**, The grit blasting during divestment can produce microcracks and chipped margins that may be another causes of marginal discrepancy (**Santos et al., 2013**). Eliminating laboratory steps like waxing and investing reduces the human errors and increases the accuracy in the CAD/CAM technology (**Prasanth et al., 2013)** that can explain the result of present study. The technique of fabrication showed no significant effect on internal gap (p=0.30), this in agreement with the study of Bindl and Mormann (**Bindl and Mormann, 2005)** in which they found that there is no significant difference in the internal fit of all ceramic crown between the CAD/CAM fabrication technique and the conventional techniques.

Regarding the preparation design, The result found that the preparation design used had significant effect on marginal gap (p=0.02), and no significant effect on internal and total gaps (P>0.05).

In the four experimental groups, The higher gap value recorded incisally (incisal margin and incisal area internaly) when compared with other areas, this result is in agreement with the study of Suh et al. (**Suh et al., 1997)**, they found that the least adaptation was incisally. In pressable groups, several errors may occur in the pressing technique that may lead to misfit incisally, such as shrinkage during wax build up, failure to be reproduced during the investment and liability to chipping of the divestment, and the tendency of the porcelain material to shrink toward the region of greater bulk. When compare between the two designs of pressable groups (Group III and IV), it is found that Group IV (with overlapped incisal reduction)had significantly higher mean values of marginal gap than Group III (with butt-joint incisal reduction), this can be explained that in the overlapped incisal reduction design, the margin is thinner incisally than in butt-joint design and could shrink toward the incisal edge, causing gap formation, in addition, this thin margin is more liable to chipping than the thick margin in butt joint design **(Prasanth et al., 2013).**In the CAD/CAM groups the higher values of gap incisaly may related to the diameter of cutting tool that may be larger in diameter than some parts of the tooth preparation, such as the inner surface of the incisal edge causing misfits incisally **(Aboushelib et al., 2012)**, there is no statistical differences between the two designs of CAD/CAM groups (Group I and II) in mean values of marginal, internal, and total gaps (P>0.05).

The total gap was measured by calculating the mean values of the internal gap and the marginal gap, the result showed that Group IV (pressable with overlapped incisal reduction) had significantly higher mean values of total gap than other groups followed by Group III, II, and I respectively. The fabrication technique had significant effect on the total gap (p= 0.02), while the preparation design showed no significant effect on the total gap (0.09).

The two-way ANOVA test showed that the effect of the interaction between the fabrication technique and the design on the marginal gap mean values was significant so the technique and the design were dependent on each other. While for internal and total adaptation, the interaction between these two factors was insignificant.

Previous studies reported a wide range of marginal gap in laminate veneer systems, but many literatures stated that a marginal gap of 120 µm is considered as clinically acceptable (**Beuer et al., 2009, Borba et al., 2013; Al-Zubaidi and Al-Shamma, 2015; Majeed MA, Al-Adel, 2016).** Regarding the internal gap it has been suggested that internal gap of all ceramic restorations it should be ranged from (49 -136 µm) **(May et al., 1998; Bindl and Mormann, 2005)**. Concerning the total gap, it has been suggested that the acceptable range of total gap should be from (50-150 µm) (**Yeo et al., 2003; Quintaset al., 2004)** accordingly, only CAD/CAM Groups (Group Iand II) showed a clinically acceptable total gap (149.8µm, 150µm respectively). Nevertheless, marginal and internal gap values reported in the present study were higher than these acceptable ranges, different measuring instruments different equipment, sample sizes, materials, methods, number of measurements per specimen may be account for these differences.

5. Conclusion

Under the conditions of this study the following conclusion could be drawn: The pressable ceramic veneers with overlapped incisal reduction design produced significantly higher marginal gap. The fabrication technique and the preparation design showed significant effect on marginal gap values,

Regarding the internal adaptation, there is no significant difference in the internal gap between these four groups. the fabrication technique and the design used showed no significant effect on the internal gap.

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