

The Influence of Different Fabrication Techniques and Preparation Designs on the Marginal Adaptation of Ceramic Veneers (An *In vitro* Comparative Study)

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ABSTRACT

Background: Ceramic veneers represent the treatment of choice in minimally invasive esthetic dentistry; one of the critical factors in their long term success is marginal adaptation. The aim of the present study is to evaluate the marginal gap of ceramic veneers by using two different fabrication techniques and two different designs of preparation.

Material and methods: A typodont maxillary central incisor used in the preparation from which metal dies were fabricated, which were in turn used to make forty stone dies. The dies divided into four experimental groups, each group had ten samples: A1: prepared with butt-joint incisal reduction and restored with IPS e.max CAD, A2: prepared with overlapped incisal reduction and restored with IPS e.max CAD. B1: prepared with butt-joint incisal reduction restored with IPS e.max press. B2: prepared with overlapped incisal reduction and restored with IPS e.max press. The marginal gap was measured with direct view technique using digital microscope at a magnification of 230x. Measurements were recorded for four surfaces for each sample and the maximum value was taken to represent that sample.

Results: The data were analyzed with two-way ANOVA and independent samples t-tests. These tests revealed highly significant effects of both the preparation design and the technique of fabrication on the marginal gap ($p=0.00$), with CAD/CAM veneers, group A1 recorded the least marginal gap and pressing group, B2 showed the highest gap values. There was no significant effect of the interaction between the two parameters on the marginal gap.

Conclusion: the CAD/CAM veneers with butt joint incisal reduction produced the most accurate margins while the least favorable combination was the pressable ceramic veneers with overlapped incisal reduction.

Key words: Marginal adaptation, CAD/CAM veneers, Pressable veneers, IPS e.max system. (J Bagh Coll Dentistry 2015; 27(4):8-14).

INTRODUCTION

Advances in all-ceramic systems, adhesive materials, and clinical techniques have enabled the porcelain laminate veneer to evolve into highly esthetic restorations with excellent resistance to staining, abrasion and good marginal fit. It became treatment of choice in minimally invasive aesthetic dentistry⁽¹⁾.

Long term clinical success of porcelain veneers depends on number of critical factors; one of them is the marginal adaptation of the restoration of the tooth surface. No material has the ability to provide complete seal of the restoration-tooth interface, so it is crucial to at least minimizing the marginal gap to prevent the exposure of the adhesive resin cement to the oral cavity that would lead to eventual disintegration resulting in microleakage, recurrent caries, discoloration of the tooth structure, and fracture of the cemented veneers⁽²⁾.

Past clinical experiences and about 30 years of data show that porcelain laminate veneers are very predictable and successful when bonded to enamel.

Current best practices in use of porcelain laminate veneers are to use a minimal, or noninvasive, tooth preparation that is restored with a thin porcelain veneer⁽³⁾.

Most thin veneers are made of lithium disilicate ceramic, this material, compared with other materials, for example, ceramics reinforced by leucite, has greater biaxial strength and fracture toughness⁽⁴⁾.

MATERIALS AND METHODS

A right maxillary central incisor typodont used for veneer preparation. First, a primary impression was taken for the typodont using alginate impression material (Tropicalgin, Italy) which was then poured immediately with type IV dental stone (Zhermack, Italy), according to manufacturers' instructions to form the primary model that served later as a biocopy in order to restore the shape and form of the original tooth during the fabrication of the CAD/CAM veneers groups.

A silicone index was made for the tooth in the student typodont using a putty polyvinyl siloxane material (Zeta plus/soft, Zhermack/clinical, Italy) (Fig.1) to use it after sectioning as a guide for evaluating the amount of reduction⁽⁵⁾.

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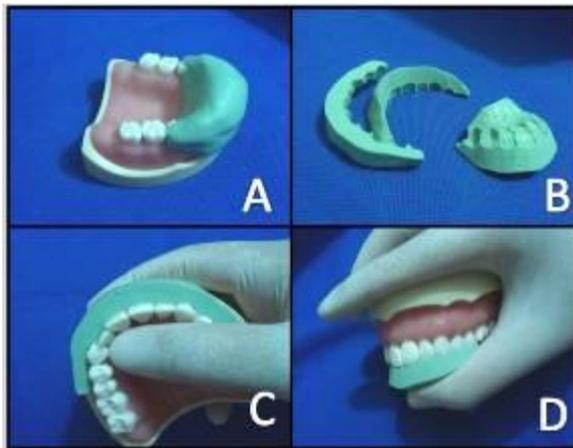


Figure 1: Silicone Index: A. Impression Adapted on the Teeth Surfaces. B. Sectioning of the Impression. C. Labial Index. D. Incisal index

Preparation of the First Design (Butt-Joint Incisal Reduction)

The preparation conducted by using a high speed handpiece and ceramic veneers burs system kit (komet, Germany). The preparation ended 1 mm from the cervical line^(6,7). All the preparations were made 0.1 mm less than the proposed final reduction which was later removed in final finishing stage. Labial reduction was 0.3 mm cervically and 0.5 mm in the middle and the incisal third⁽⁸⁾.

The final cervical margin had chamfer profile with 0.3 mm^(10,11). Incisal reduction was 1.5mm^(10,11). The bur was held parallel to the incisal edge inclination to create butt joint incisally (Fig.2).

All the line angles were rounded with white stone bur using slow speed hand piece. Final impression was taken for the prepared typodont tooth with 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⁽¹²⁾.

Preparation of the Second Design (Overlapped Incisal Reduction with Palatal Chamfer)

The same typodont was modified for the overlapped incisal reduction preparation⁽¹⁾ by forming 0.5mm palatal chamfer that extend 1mm palatally, and extended it through the interproximal areas. Mesial and distal corners were rounded⁽⁹⁾ (Fig.2).

Impression for the second preparation was taken and poured with blue inlay wax to form the wax pattern for the second design The two wax patterns were taken to the laboratory were they

were sprued, invested, burned out and cast with Nickel-Chromium alloy to form the master metal dies.

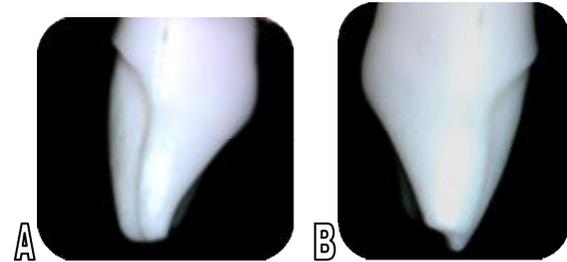


Figure 2: A. Butt Joint Incisal Reduction, B. Overlapped incisal reduction

Impression was taken for each metal die 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) and forty impressions were taken, twenty impressions for each preparation design. 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 (40) stone dies were divided into four groups according to the preparation design and the technique used:

- Group A1: butt joint incisal reduction restored with IPS e.max CAD.
- Group A2: overlapped incisal reduction with palatal chamfer restored with IPS e.max CAD.
- Group B1: butt joint incisal reduction restored with IPS e.max press.
- Group B2: overlapped incisal reduction with palatal chamfer restored with IPS e.max press.

Pressing Fabrication Technique

Twenty ceramic laminate veneers were fabricated using IPS e.max press (MO 1, Ivoclar Vivadent). A die spacer was applied 1mm from the preparation margin of the die. A wax pattern was manually built on each stone die to restore the anatomical features of the unprepared tooth.

A silicone index fabricated on the primary model previously formed was used and a wax gauge (caliper) was used to check the thickness of wax pattern. Wax patterns were attached to a 200g investment ring base using a 3mm wax sprue and a freshly vacuum mixed investment material was cast.

Following chemical setting of the investment, the ring was transferred to a preheated burn out oven (800 °C) after removal of the plastic base for 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 the room temperature, pressable ceramic laminate veneers were divested by gentle airborne particle abrasion by using gentle airborne particle abrasion using 50 μm Al_2O_3 particles and cutting and finishing the location of the sprue were done. The mixed glazing material (IPS e.max Ceram Glaze and Stain Liquids longlife) was applied on the external surfaces of the restoration and glazing is conducted according to the glaze firing parameters.

CAD/CAM Technique of Fabrication:

The primary model fabricated previously scanned by InEos Blue scanner (Sirona Dental Systems, Bensheim, Germany) to form a biocopy of the tooth before preparation in order to build a restoration to the original dimensions of unprepared tooth.

Then each dying stone was scanned with a 3D image. Digital images of both of the primary models and the stone dies automatically analyzed and correlated with each other by a system which allow alignment of the 3-dimensional image of the primary models on top of the 3-dimensional image of dies correctly.

Then the designing of veneer starts in "model" phase were the margin of preparation was drawn automatically by the system, after that in copyline section, the area to be copied from the biocopy was drawn in order to design a laminate veneer identical to the original tooth form. The preparation of finishing line was marked on the digital model. After selection of the required anatomy, the veneer parameter defined as "design" phase such as minimum veneer thickness (0.4mm), spacer (0.08mm) according to Sirona's instructions, the restoration was designed according to them. IPS e.max CAD blocks (Ivoclar Vivadent) 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 of the 20 samples was done by the CEREC in-lab machine and. After completion of milling process, the restoration was separated automatically, fired in a short 30 minutes firing cycle in a ceramic furnace according to manufacturer's instructions. This process gives the glass-ceramic with its final strength and esthetic properties.

Evaluation of Marginal Gap:

Measurements conducted by using Dinolite digital microscope that connected to PC and at a

magnification of 230x. Six reference points were marked on each metal die using indelible marker. These points were two gingivally: mesially, distally and two incisally (Fig.3 A).

Each veneer seated on its corresponding metal die with finger pressure and stabilized with sticky wax at both the mesioincisal and distocervical points⁽¹⁾. The dying metal placed on the stand of the microscope at a marked point so that each sample would be measured from that position and the digital microscope was directed on the sample in such a way that its horizontal plane (long axis) was perpendicular on the long axis of the metal die (Fig.3 B).

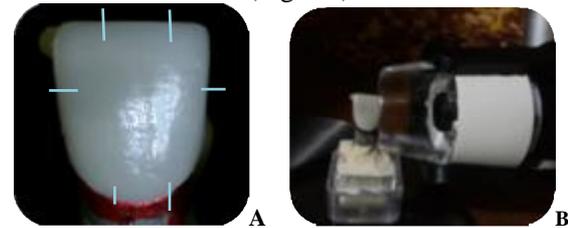


Figure 3: A. Ceramic Veneer on the Metal Die with Marked Points. B. Metal Die Positioned on the Stand of the Microscope

The images were captured and processed by Dinocapture software, the captured images opened in (Image J) software which was used to measure the marginal gap and it gave the measurements in pixels and then converted to micrometers (Fig.4).

After recording sixth measurements for each veneer sample, the highest one selected to represent the maximum marginal gap of that sample.

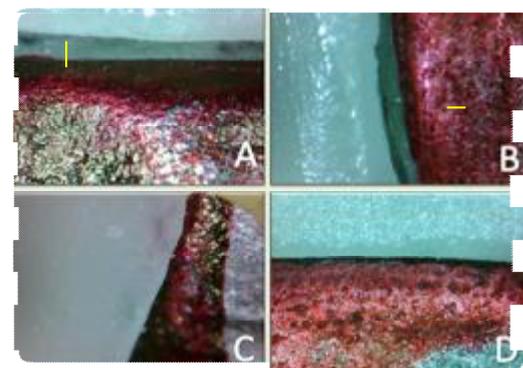


Figure 4: A. Incisal Marginal Gap, B. Distal Marginal Gap C. Fit Restoration Margin Distally, D. Restoration Margin is fit Incisally.

RESULTS

Results showed that the means and standard deviations of marginal gap with minimum and maximum values performed for each group and are indicated in Table 1.

The highest mean value of marginal gap measured was that of group B2 (overlapped incisal reduction restored with IPS e,max Press veneers) followed by group B1(butt-joint incisal reduction restored with IPS e,max Press veneers) while the least mean value was of group A1 (butt- joint incisal reduction restored with IPS e.max CAD veneers) (Fig.5).

Table 1: Descriptive Statistics of Marginal Gap for Each Group

Groups		Min.	Max.	Mean	S.D.
CAD/ CAM technique	A1	30.26	115.73	68.03	±23.50
	A2	35.73	338.29	172.49	±98.65
Pressing technique	B1	97.92	305.64	239.57	±63.52
	B2	220.15	519.32	366.25	±116.75

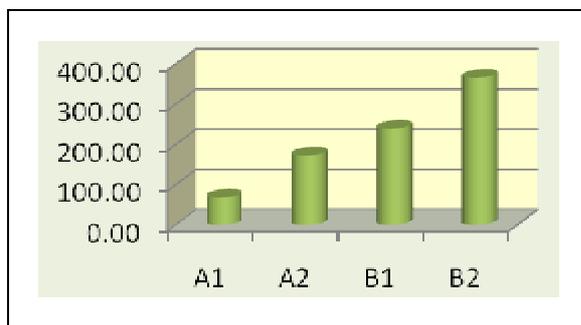


Figure 5: The Mean Values of Marginal Gap

Two-way ANOVA test was used to detect whether there were significant effects of the technique of fabrication of veneers and the preparation design used and their interaction on the marginal gap for the four experimental groups (Table 2).

The technique of fabrication has a high significant effect on marginal gap (p=0.00), the design of the preparation has a highly significant factor (p=0.00).

On the contrary, the effect of the interaction between those two factors was non-significant on the gap measurements (p=0.68).

Table 2: Two-Way ANOVA for the Marginal Gap Measurements

Source	Type III Sum of Squares	df	Mean Square	F-test	Sig.
Technique	333628.673	1	333628.67	47.75	0.00
Design	133561.129	1	133561.13	19.11	0.00
Technique * design	1233.799	1	1233.80	0.18	0.68
Error	251545.259	36	6987.37		
Total	2510706.235	40			

Further analyses conducted and two independent samples of t-test used to detect the difference in marginal gap between the two designs types within each type of technique or

between two techniques within each type of preparation design (Table 3).

Ceramic veneer groups restored with IPS e.max CAD (A1 and A2) showed high significant effects for the design used (p=0.00), while the preparation design has a highly significant effect on pressing technique groups too (B1 and B2) (p=0.00).

On the other hand, fabrication method has highly significant influence on means of ceramic veneers groups with butt joint incisal reduction making the means difference between group B1 and A1 (171.54 µm), while pressing Group B2 has significantly higher mean gap than CAD/CAM group A2 with the same design(p=0.00).

Table 3: Two-Independent Samples T-Test.

Groups comparison	Mean difference	t	P value
A1xA2	-104.46	-3.258	0.00
B1xB2	-126.67	-3.014	0.00
A1xB1	-171.54	-8.01	0.00
A2xB2	-193.76	-4.009	0.00

DISCUSSION

This in vitro study evaluated the influence of different fabrication techniques and preparation designs on the marginal fitness of ceramic veneers.

In order to overcome the variations that are shown in natural teeth and to make the preparation more standardized, a typodont resin tooth used from the working dies of all the samples were fabricated. Maxillary central incisor selected because of it is the most common tooth restored with a laminate veneer⁽²⁾.

Primary impression was taken for the typodont to form a primary model that served as a biocopy for group A1 and A2 to create ceramic veneers of the original form and shape of the teeth⁽¹³⁻¹⁵⁾.

The preparation of the tooth guided by the use of silicone indices which helped the technician in wax pattern build up to restore the original shape and form of the tooth^(2,16). Two preparation designs involving incisal reduction used in this study: (overlapped incisal reduction and butt joint incisal reduction), because the esthetic characteristics of the porcelain veneer are more easily handled and controlled by the dental technician with such types of preparation⁽¹⁷⁾.

The depth of reduction was 0.5mm at the middle while the incisal third of the labial surface reduced to 0.3mm of cervical to keep the preparation depth confined within the enamel as stated by Shillingburg and Grace⁽¹⁸⁾. Preparations were done by using depth cutter burs (komet) to

guide the reduction and avoid the excessive removal of tooth structure. Incisal reduction was 1.5 mm to provide adequate support and fracture resistance and required thickness of ceramic material to impart the restoration esthetics and natural translucency incisally. The second preparation was done by modifying the same tooth incisally for more standardization of the preparation depth labially and proximally⁽¹⁾.

The IPS e.max lithium disilicate glass ceramic was used in the present study for veneer fabrication, as it can be traditionally pressed or processed via CAD/CAM technology. It is a material that has a needle-like crystal structure providing an excellent strength and optimal durability and, superior optical properties. 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, $\text{Li}_2\text{Si}_2\text{O}_5$, but the size and length of these crystals are different. This is why material properties such as CTE, modulus of elasticity, and chemical solubility are the same, yet the flexural strength and fracture toughness are slightly higher for the IPS e.max Press material⁽¹⁹⁾.

Measurement of marginal discrepancy was done by direct viewing method which has the advantage of being non-invasive so there was no need for any procedures on the tooth-restoration such as sectioning and it was less time-consuming. Measurements carried out by using digital microscope and with no cementation which eliminated the factor of overlapping some of the margins with excess cement⁽¹⁾. The marginal gap was measured at each surface of the sample then the maximum gap value was selected to represent the gap for that sample as we need to demonstrate the highest possible gap that could be measured. Hence, the results of the current study appeared to be relatively higher than that of previous studies.

The Effect of the Fabrication Technique, Preparation Design and Their Interaction on the Marginal Gap of the Experimental Ceramic Veneers

Two-way ANOVA test used in the present study so that we can examine the interaction effect of the main factors, the technique and the design, in addition to their individual effects on the measured gap values.

According to the results of the present study, a highly significant effect found for the technique of fabrication on the marginal gap. CAD/CAM group (A1) with butt joint design had less gap in mean than the pressing group B1 with the same

design, the same finding noticed when comparing between group A2 and B2 with the highest gap recorded for pressable ceramic group. This finding is in agreement with Jha et, al.⁽²⁰⁾ who found the highest gap in the pressing group in their in vivo study but it disagrees with a study done by Aboushelib et, al.⁽²⁾ in which they found that CAD/CAM ceramic veneers were associated with significantly higher marginal gap values compared to pressable ceramic veneers, this could be explained by the latest improvements in the CEREC unit and software that makes it possible to produce more clinically acceptable marginal gap of about 50 μm . The designing and the milling processes involve optical scanning and formation of a digital image of the die of the prepared tooth, so the dimensions of the margins may be reproduced precisely⁽²⁾. On the other hand, higher marginal gap associated with pressable ceramic veneers may be attributed to factors include the sensitive nature of the pressing technique where the wax pattern was directly built on the die by the technician, depending largely on her/his skills and experience. Wax has several inherent limitations namely delicacy, thermal sensitivity, elastic memory and a high coefficient of thermal expansion⁽²³⁾. Another factor may be the tendency of porcelain material to shrink from the thin parts of the veneer toward the area of the greatest bulk during firing process of the pressing technique⁽¹²⁾ that leads to marginal discrepancy that could be noticed clearly with high gap mean recorded cervically for the pressing group B2 (207.98 μm). The grit blasting during divestment could also be one of the causes of marginal discrepancy by producing microcracks and chipped margins⁽²¹⁾.

Eliminating laboratory steps like waxing and investing reduces the human errors and enhances the accuracy in the CAD/CAM technology⁽²⁴⁾.

The present study showed a highly significant effect of the preparation design on the gap. It was found that group A1 involving butt joint incisal reduction preparation had significantly more accurate margins than group A2 of overlapped incisal reduction (p value=0.00). Also, group B1 showed superior marginal fit to B2 with mean difference (126.67 μm), this can be explained that in the overlapped design, the margin is thin incisopalatally and could shrink toward the incisal edge, causing gap formation, in addition, those thin margins are more liable to chipping than the thick margin in butt joint design. The butt joint design had another advantage of providing an easy path of insertion and positive seating leading to a better fit⁽²⁴⁾. That agree with

Çelik and Gemalmaz⁽²⁵⁾ while disagree with the study of Lin et, al.⁽¹⁾ in which the effect of the design on the gap shows no significant differences.

The highest gap means found incisally, in pressable group B2 that had the overlapped incisal reduction (349.5 µm). In the pressing technique steps, several errors could leading to defective margins in the incisal surface, such as shrinkage during wax build up, failure to be reproduced during the investment and liability to chipping of the divestment, In addition to the technique factor, overlapped incisal reduction design produced thinner margins incisally than in butt-joint reduction, which is more difficult to be produced in the laboratory.

As shown by the two-way ANOVA test, the effect of the interaction between the technique and the design on the gap means values was not significant which means that the technique and the design were independent on each other. When comparing between IPS e.max CAD group and IPS e.max press group that had the butt joint design, a highly significant effect was found, however, the same influence was seen when the overlapped incisal reduction design was used, also, the means difference between butt-joint incisal reduction design group and overlapped incisal reduction group remained significantly high regardless of the technique used.

The range of the mean values of marginal gap recorded mesially was (5.6-90.11 µm) and distally between (6.9-61.1 µm) which are considered within the acceptable clinical range that was determined by McLean and von Fraunhofer to be within 120 µm. However, the vertical marginal gap could be rated as good for group A1 (68 µm) and acceptable for groups (A2 =172 µm and B1=239 µm), but for group B2 it was considered as unacceptable (366 µm) according to criteria established by Moldovan et,al.,⁽²²⁾.

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