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The Influence of Thermocycling on the Marginal Adaptation of Different Glass Ceramic Sectional Veneers

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Abstract

Background: Sectional veneers constructed from different glass ceramic can show variations in the marginal adaptation before and after thermocycling.

Methodology: 20 human central incisors were used to fabricate sectional laminate veneers SLV with preparation depth 0.5mm cervically and 0.7mm incisally. Samples were divided equally into groups according to material Group 1: Lithium disilicate Glass-Ceramic (IPS e-max press, Ivoclar, Schaan Liechtenstein) (n=10) and Group 2: zirconia reinforced lithium silicate Glass-Ceramic (Celtra Press, Dentsply Sirona) (n=10). SLV were bonded to the teeth using lightcure resin cement (Relyx veneer) (3M ESPE, Seefeld, Bayern, Germany). The samples were then subjected to 10,000 thermal cycles, the marginal adaptation was measured before and after thermocycling using stereomicroscope under magnification 40X using 8 measurement points for each margin (incisal, proximal, cervical and mid labial in two different positions) with total of 40 point per sample.

Results: The results of ANOVA showed a significant interaction between material and thermocycling. Before thermocycling, e.max samples showed statistically significant higher gap values with ($p<0.001$) Mean and standard deviation (SD) values (34.80±0.71) than Celtra samples with ($p<0.001$) (26.33±2.28). While after thermocyling, Celtra samples had significantly higher gap values (53.77±6.67) than e.max samples (42.81±1.67).

Conclusions: IPS e.max Press SLV showed better marginal adaptation compared to that of Celtra Press after thermocycling. Insufficient sealing between restoration and tooth may lead to leakage and marginal discoloration in sectional veneers after years of service.

1 Introduction

Nowadays, modern dentistry's main focus nowadays is dental aesthetics. This can be seen by the increased demand for cosmetic restorations and the shifting away from

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metal-based restorations. (1) All ceramic restorations are highly esthetic materials. Laminate veneers are a minimally invasive treatment option (2) because they require less tooth reduction with minimal porcelain thickness.

Porcelain laminate veneers PLVs are used to cover discolored teeth caused by a variety of reasons such as tetracycline staining, fluorosis, and amelogenesis imperfecta. They are also utilized to repair fractured and worn teeth, as well as abnormal tooth morphology and mild malposition. (3) The advantages of minimally invasive PLV include minimum or no tooth preparation. Furthermore, no local anesthetic is required prior to tooth preparation, and no interim restoration is required in some clinical situations. (4) Minimally invasive veneers have been documented with thicknesses of 0.3 mm, although traditional porcelain veneers are typically 0.3 to 1.0 mm thick. (5)

The ideal ceramic material for laminate veneer production is lithium-disilicate pressed glass ceramic, which combines both strength and outstanding optical qualities. When compared to other ceramic materials, it has also demonstrated a high level of long-term clinical performance. (6,7)

Celta press is a novel heat-pressed zirconia-reinforced lithium silicate developed to improve the mechanical and aesthetic qualities of ceramics by incorporating ten percent dissolved zirconia into a silica-based glass matrix. (8,9) its manufacturer claims that it is the most stable high-strength glass ceramic on the market.(10)

In comparison to machinable ceramic veneers, press-able glass ceramic laminate veneers provide higher marginal adaptability, homogeneous and thinner cement film thickness, and superior resistance to microleakage.(11) The porcelain sectional (PSV) veneer has been proposed as a ground-breaking ultra- conservative approach that covers only a portion of the tooth surface without the need of any preparation of the remaining tooth and has the aesthetic look of a ceramic laminate veneer. (12) Because marginal adaptation is the cornerstone for long-term clinical success,(13) porcelain sectional veneers produced using recently recommended ceramic materials marginal adaptation following thermocycling are assessed in this research study. (13) Simulation of the clinical situation have been widely used to evaluate the outcome of many recent studies and thermocycling is one of the main aging methods that provide satisfactory fatigue to the material.(14) The null hypothesis of this research study is that there will be no significant difference regarding the marginal adaptation of sectional laminate veneer made of different glass ceramic materials before and after thermocycling. Therefore, the aim of the current study is to evaluate the effect of thermocycling of different glass ceramic sectional laminate veneers marginal adaptation.

2 Materials and Methods

2.1 Teeth collecting and preparation

This study used twenty intact, sound, freshly extracted human central incisor teeth which have been approved by the Research Ethics Committee of the Faculty of Dentistry of October University for Modern Sciences and Arts with approval number: ETH20. To fulfill the inclusion criteria, the teeth were cleansed, scaled with an ultrasonic scaler to remove blood and calculus, and then inspected under a 10x microscope to check the absence of any cracks or cavities. To achieve standardization by a digital caliber, the teeth in this study were chosen to be as close in dimension as possible (Mesiodistally= 8.5mm and Inciso-gingival= 10mm). During the study, teeth were kept separate in a container with saline that was replaced every three days.

To establish a consistent thickness of 0.5 mm for the whole planned labial area of reduction, a 0.5mm depth cutter (Tiefenmarkierer depth marker) was used as a guide. A pencil was used to mark the depth incisions made on the labial surface. The reduction was increased to 0.7mm incisally using a round-ended tapered diamond cutting stone and to join the depth cuts. To eliminate any sharp angles, the reduced area was smoothed. To aid in verifying the amount of reduction accomplished, a putty index is constructed form each individual tooth using putty impression material (Elite H-D Putty) as shown in F**igure (1)**.

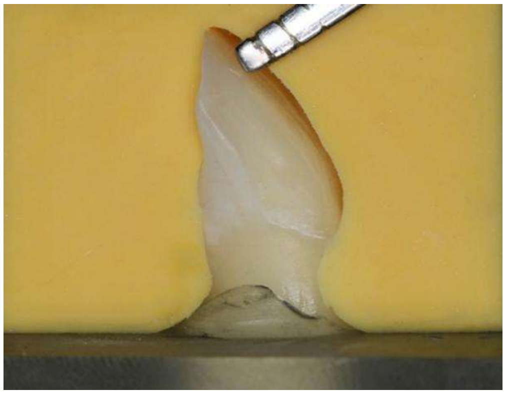


Figure 1. Verifying the preparation with putty index and periodontal probe.

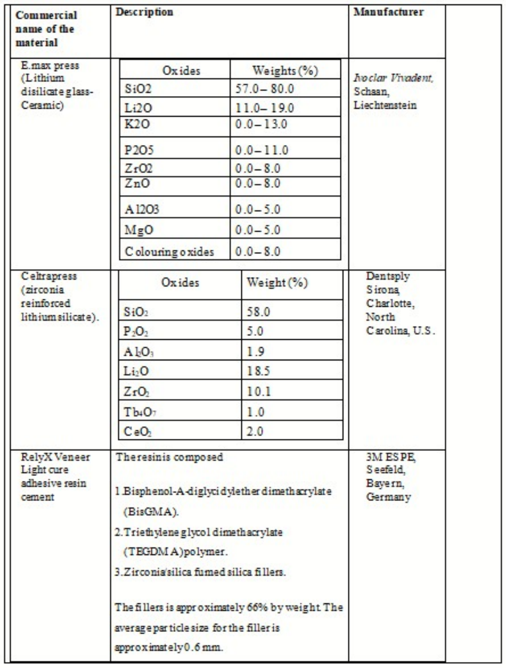
2.2 Epoxy fabrication and samples grouping

Total of twenty epoxy blocks (n=20) were fabricated using custom made blocks made by mixing (CMB Kemapoxy Clear epoxy resin) and pouring to produce prefabricated epoxy discs for milling the blocks. Roots of all teeth were then scanned using a dental lab scanner (Medit Identica Hybrid 3D) and their dimensions were uniformly enlarged by 0.21 mm using (Exocad software) to accommodate uniform thickness of Polyether impression material (Elite H-D Putty) 2mm away from (CEJ).

The milling computer-aided design/computer-aided manufacturing (CAD/CAM) machine (imesicore 250i) with provided Standard Tri-angle Language (STL) file was used to produce the final prepared block. After injecting polyether material, each block was numbered, and each tooth was placed inside its intended block and then to be divided to two groups (n=10) group I will receive Lithium disilicate glass ceramic (e.max press) restoration and group II will receive zirconia reinforced lithium silicate (Celtra press) restoration as shown in table (1) and the chemical composition in table (2).

Type of restorative material Number	Group I E.max press	Group II Celtra press
Number of samples(n) Total	10	10
Total number of samples	20	

Table 1. Samples grouping.



Commercial name of the material	Description		Manufacturer
E.max press (Lithium disilicate glass-Ceramic)	Oxides	Weights (%)	*Ivoclar Vivadent*, Schaan, Liechtenstein
	SiO2	57.0– 80.0	
	Li2O	11.0– 19.0	
	K2O	0.0–13.0	
	P2O5	0.0–11.0	
	ZrO2	0.0–8.0	
	ZnO	0.0–8.0	
	Al2O3	0.0–5.0	
	MgO	0.0–5.0	
	Colouring oxides	0.0–8.0	
Celtrapress (zirconia reinforced lithium silicate).	Oxides	Weight (%)	Dentsply Sirona, Charlotte, North Carolina, U.S.
	SiO_2	58.0	
	P_2O_2	5.0	
	Al_2O_3	1.9	
	Li_2O	18.5	
	ZrO_2	10.1	
	Tb_4O_7	1.0	
	CeO_2	2.0	
RelyX Veneer Light cure adhesive resin cement	The resin is composed 1.Bisphenol-A-diglycidylether dimethacrylate (BisGMA). 2.Triethylene glycol dimethacrylate (TEGDMA)polymer. 3.Zirconia/silica fumed silica fillers. The fillers is approximately 66% by weight. The average particle size for the filler is approximately 0.6 mm.		3M ESPE, Seefeld, Bayern, Germany

Table 2. Main materials used and their chemical composition

2.3 Veneers fabrication

The 20 Sectional veneers were fabricated from digital wax patterns using white CAD/CAM wax, sprued, invested, burnt out and then pressed in glass ceramics according to their assigned groups following the manufactures recommendations for each material. The preparations were scanned after spraying them with scanning spray using inlab dental scanner. The acquired STL files were exported to a professional dental laboratory. The wax patterns for sectional veneer (SV) were created using exocad software (dentalDB 3.0 Galway). The restoration thickness for all groups was set to 0.5mm at the cervical and 0.7mm at the incisal extending 1mm proximally, the spacer thickness was set to 40µm, 1mm away from the preparation margins, and the SV was semi-anatomically shaped in the software to achieve a standardized ceramic thickness for all veneers. To begin milling the dental wax (Aidite), the STL file of the design was transferred to a CAM machine (Ceramill motion 2, Amann Girrbach). Following the prior directions, the same experienced dental laboratory technician digitally created all wax designs.

For the construction of each material group (e.max press and Celtra press), the manufacturer's instructions were followed. The wax pattern weight was used to determine the size of the ingot by weighing the sprue base (0.0-0.70g wax weight/one 3g ingot) for ingot size selection for each material, for Celtra press and (0.0-0.75g wax weight one small ingot) for e.max press. The IPS Press VEST premium investment and its specific liquid for the e.max group were used to invest. Celtra Vest and its specific liquid investment were used for the Celtra group. For investment, a 100g silicone ring with a matching ring gauge and ring base was used.

The investment ring was preheated in a preheating furnace (Neytech Vulcan Benchtop Furnace) before being immediately placed in the pressing furnace (Programat EP 3010 Ivoclar Vivadent). This phase took no more than 30 seconds.

The length of the Alox plunger was marked on the investment ring after it had cooled to room temperature (60 minutes), and the investment ring was separated using a separating disc (EVE, Diasynt plus Di- apro). Rough divestment was done with glass beads, followed by fine divestment (50m, two cm distances) at two bar pressure. To avoid harm to the veneer mar- gins during divestment, the blasting direction and distance were carefully chosen.

The reaction layer was removed from the e.max repair by soaking it in Invex liquid (Ivoclar Vivadent) and washing it in an ultrasonic cleaner for ten minutes before fine sandblasting. To minimize overheating, all specimens were polished with a ceramic diamond polishing kit at moderate speed and low pressure. Glazing material was uniformly placed to the restoration, and it was fired for six minutes at 770 °C on a honey-comb tray firing tray in the pressing furnace. After the fire cycle was completed, the restorations were withdrawn from the furnace and allowed to cool at room temperature in a draft-free environment.

2.4 Thermocycling

All samples were thermocycled (Thermocycler THE- 1100, SD sd-mechatronik, Germany) **Figure (2)** for 10,000 cycles in tap water between 5 and 55 °C with a 30 second dwell time at each temperature and a 20 second transfer time to simulate one year of clinical service. Before and after thermocycling, the epoxy block location was standardized during the capture of the restoration margin. The block was positioned with the labial surface outward to capture the tooth's incisal border. The block was positioned with the labial surface facing the microscope lens to capture the cervical margin and the mid labial margin, but due to the length of the margin and the magnification, the surface was captured using two images (incisal capture and cervical capture). The block was positioned on its proximal surface with the margin towards the microscope lens to capture the proximal margin. One week following cementation, marginal adaptation was assessed again, but this time 24 hours after thermocycling the same way as before cementation.

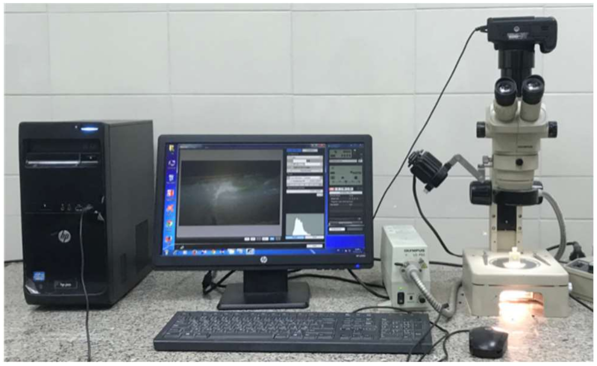


Figure 2. Thermocycling machine.

2.5 Margins examination

Marginal gap distance was measured using a measuring stereomicroscope (OLYMPUS) at 40X magnification, with the image of the restoration acquired using a digital camera (Canon EDS 650D) **Figure (3)** mounted to the stereomicroscope and downloaded to a computer running image processing software. The gap width was measured and evaluated using a computerized image analysis system (Image J). A known- size item was used to calibrate the system (a ruler in this study). Image J software generated the scale. Each specimen had its margins photographed. Then, for each photo, morphometric measures were taken (eight equidistant landmarks throughout the circle of each surface). After thermocycling, each point was measured a second time at the same locations as shown in **Figure (4,5)**.

Figure 3. Marginal adaptation measuring with steriomicroscope

Figure 4. Measurement of the incisal external margin adaptation before thermocycling of e.max sample using image j software.

Figure 5. Measurement of the incisal external margin adaptation after thermocycling of e.max sample using image j software.

2.6 Statistical analysis

Numerical data were explored for normality by checking the data distribution using Shapiro-Wilk test. Data showed parametric distribution so; they were represented by means and standard deviation (SD) values. Three-way mixed model ANOVA was used to study the effect of different tested variables and their interaction. Comparison of main and simple effects was done utilizing multiple t-tests with Boenferroni correction. The significance level was set at p 0.05 within all tests. Statistical analysis was performed with IBM SPSS Statistics Version 26 for Windows.

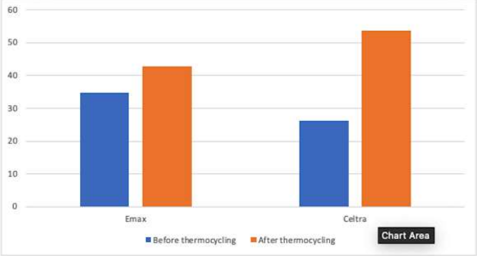


Figure 6. Bar chart showing average marginal adaptation (µm) for different materials.

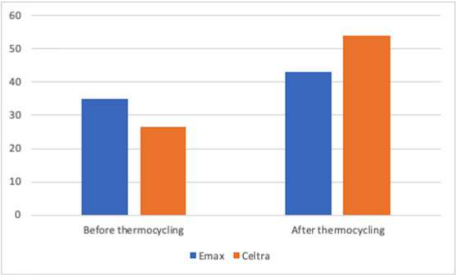


Figure 7. Bar chart showing average marginal adaptation (µm) before and after thermocycling.

3 Results

There was significant interaction between both glass ceramic material (p<0.001). Mean and standard deviation (SD) values of marginal gap (µm) for both ceramic materials were presented in **Table (3)** and **Figure (6)**. Before thermocycling, e.max samples showed statistically significant higher gap values than Celtra samples (p<0.001). After thermocyling, Celtra samples had significantly higher gap values than e.max samples (p<0.001) Mean and standard deviation (SD) values of marginal gap (µm) before and after thermo-cycling are presented in **Table (4)** and **Figure (7)**. For both materials, samples had significantly higher gap values after aging (p<0.001).

Thermocycling	Marginal gap (µm) (mean±SD)		Mean Difference [95%CI]	p-value
	e.max	Celtra		
Before	34.80±0.71	26.33±2.28	8.47[6.80:10.14]	<0.001*
After	42.81±1.67	53.77±6.67	-10.96[-15.80:-6.12]	<0.001*

*; significant (p ≤ 0.05) ; non-significant (p>0.05)

Table 3.Mean ± standard deviation (SD) of marginal gap (µm) for different materials before and after thermocycling.

Material	Marginal gap (µm) (mean±SD)		Mean Difference [95%CI]	p-value
	Before Thermocycling	After Thermocycling		
E.max	34.80±0.71	42.81±1.67	-8.10[-9.62:-6.76]	<0.001*
Celtra	26.33±2.28	53.77±6.67	-27.44[-32.34:-22.54]	<0.001*

*; significant (p ≤ 0.05) ; non-significant (p>0.05)

Table 4. Mean ± standard deviation (SD) of marginal gap (µm)before and after thermocycling within other variables.

4 Discussion

This study aimed to evaluate the effect of thermocycling on the marginal adaptation of glass ceramics sectional veneers in an in-vitro study. The study's hypothesis is that there will be no significant difference regarding the marginal adaptation of sectional laminate veneer made of different glass ceramic materials before and following thermocycling was rejected.

Human natural teeth were chosen for this investigation in an attempt to simulate the clinical situation. They offer the ability to reproduce their esthetic properties, bonding ability, and strength, which provide closer simulation of the clinical situation. (15) All teeth were stored in normal saline during the study, which was proven to have no effect on dentinal permeability (16), while preventing them from drying out and becoming brittle. The saline was changed every week throughout the duration of the study.

A new method to construct epoxy block embedding the teeth within designed and milled epoxy blocks was implemented to simulate the physiological tooth supporting system. (17) This method allowed standardization of the position of the teeth during measuringthe marginal gap.

Sectional laminate veneers were suggested through some studies as a treatment solution for misalignment and diastema closure. (2, 12) Cervical 0.5 reduction was chosen as the thickness of enamel is less than incisally. (13, 18–21) Three-wheel depth cutter was used to standardize the preparation depth along with an index and checking with a periodontal probe was an effective method adopted by many studies. (20) The reduction was increased incisally by 0.2mm to increase the cement space and provide bulk for the un-supported part of the veneer proximally (10,19) while maintaining the reduction within enamel as bonding to enamel provides optimum bonding. (22) CAD wax was used in this study for the pressing process. It is synthetic containing acrylic polymer that burns out completely leaving no residue, thus allowing pore free surface, and higher dimensional stability than conventional wax pattern while allowing better standardization and production of high quality restoration. Two extra-oral scanners were used Medit Identica Hybrid 3D for the preoperative scan that was used to fabricate the epoxy blocks and Ceramill map 600 for scanning the preparation that was used to fabricate the digital wax patterns Both extra-oral scanners had provided satisfactory accuracy and discrepancies that are clinically acceptable in prosthodontics. (23) The heat pressing technique was chosen for sectional veneer fabrication as it has proven to provide decreased porosity, increased flexural strength, and superior marginal fit. (24) Lithium disilicate ceramics (e.max) and the recently modified material identified as zirconia reinforced lithium silicate (Celtra) gained comparable popularity as a result of combining both high fracture resistance and great esthetic properties.

In recent years, the sectional/partial/fragment laminate veneer approach has emerged, as a treatment modality in different case reports in conservative dentistry, combined with the advances in material sciences. (5,12,25,26) In the present laboratory study, sectional laminate veneers with conservative preparation were used with lateral one mm extension, as an attempt to provide a conservative approach for diastema management.

The restorations were designed by the same dental technician using CAD software for standardization of the internal fit of the restoration. (27) The veneers were anatomically shaped in the software in order to produce a uniform ceramic thickness. (28, 29) Cement space of 40μm was chosen. (30–33) Reducing microleakage and improving the marginal adaptation of indirect restoration is of utmost importance for success of esthetic restorations. Different materials and techniques in the dental adhesive of veneer restoration have significant effects on marginal adaptation of the final restoration. The polymerization shrinkage of the luting resin cement and the different in thermal expansion coefficient between cement, tooth, and porcelain can cause stress at tooth-cement and cement-porcelain interfaces. Due to this contraction stress, there is a competition between the adhesive forces of the two bonded interfaces. The interface with the lower adhesive forces will fail and microleakage will occur at this interface leading to staining, post-operative sensitivity, plaque accumulation and recurrent caries. Minimal marginal gap of restorations is essential since increasing marginal gap results in increasing cement dissolution, which reduces the success rate of restoration. (34) Thus, the assessment of the marginal gap is an important parameter that affects the long-term service of ceramic restorations. (24,34) Therefore, in this study, different materials were tested before and after thermocycling to simulate one-year of clinical service.

To assure measurement accuracy of the marginal gap for all specimens, a digital image analysis system Image J was used to measure and evaluate the gap width. Within the Image J software, all limits, sizes, frames, and measured parameters were expressed in pixels.

Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (an endodontic ruler in this study) with a scale generated by the Image J software. Shots of the margins were taken for each specimen. Morphometric measurements were done for each shot at eight equidistant landmarks along the circumference for each surface. Measurement at each point was done after cementation and before thermocycling the repeated second time after thermocycling.

The null hypothesis that there will be no statistically significant difference regarding the marginal adaptation of sectional laminate veneer made of different glass ceramic materials before and following thermo-cycling was rejected as before thermocycling e.max press samples showed significantly higher gap values than Celtra press while after thermocycling Celtra press showed significantly higher gap values than e.max press group as shown in **Table (3,4)** and **Figure (6,7)**.

These results were in accordance with Basheer et al., 2017 (35), who stated that VITA SUPRINITY exhibits higher marginal accuracy than the lithium disilicate ceramic, while using the default milling programs. This result is also in agreement with Brenes and Duqum, 2019 (36), who proven 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 (37), who found that the restorative material type affects the performance of a CAD-CAM system relative to marginal adaptation.

The results were in disagreement with El sayed et al. (38); who found that Celtra group revealed a statistically non-significant higher marginal gap than the e.max but on the other hand regarding the e.max groups they revealed significant difference between the CAD and conventional wax pattern groups which may affect the results in addition to the aging method applied. Others reported no significant difference between e.max CAD and VITA SUPRINITY, claiming that the internal and marginal adaptation of Zirconia- based restorations was not greatly affected. The study reported results that were in disagreement may be because they tested Suprinity (CAD) which is not identical in composition to celtra press glass ceramic ingot. Regarding the effect of thermocycling on the Celtra press group and the e.max group samples both showed a statistically significant increases in marginal gap values. Our results agreed with Hasaneen et al. (14) who found that thermal aging result in statistically significant increases in marginal gap mean values across all ceramic systems. The difference in thermal expansion between the tooth, the luting agent, and the ceramic caused the marginal gap to widen during thermocycling. Cycling all ceramics between high and low temperatures causes the bond between the luting agent and the tooth to disintegrate. Temperature cycling promotes percolation in the gap between the luting agent and the tooth. (39) Studies claim that artificial aging results in significant increase in the marginal gap distance. (24,36)

It is important to mention that the results of the marginal gap distance for both ceramics sectional laminate veneers used in this study are within the clinically acceptable standards of 120 μm even afterthermocycling. (24,40)

Limitations

1) In this study we tried to reproduce the clinical situation as closely as possible, however, clinical studies remain the ultimate test to the success of any restoration. but they are time consuming and costly.

2) The natural teeth variation after preparation in terms of tooth composition, age and storage.

3) Aging using only 10,000 cycles thermocycling, while other published literature using additional cyclic loading.

5 Conclusion

Within the limitation of current study, the following conclusions maybe drawn:

1) Thermocycling affected marginal adaptation of sectional laminate veneers.

2) E.max press sectional laminate veneers showed higher marginal accuracy compared to Celtra press veneers following thermocycling.

3) The marginal adaptation values recorded for both tested materials were within the clinical acceptable values after thermocycling.

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