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THE IMPACT OF DIFFERENT PREPARATION DESIGNS ON MARGINAL ADAPTATION OF PRESSABLE CERAMICS (AN IN-VITRO STUDY)

Mohammed Deeb[*], Enas Fathelbab Abdelhalim[**] *and* Hanaa Saber Rabeae[***]

ABSTRACT

Purpose: This study aimed to evaluate the impact of various preparation designs on marginal adaption of pressable ceramic crowns.

Materials and Methods: Forty freshly extracted maxillary premolars were used. Premolars were prepared to receive crowns with two marginal designs. The samples were divided randomly into two equal groups based on the tested ceramic materials (n=20); Group E for IPS e-max press and Group C for Celtra press. Each group was subdivided into two subgroups according to the tested finish line (n = 10); Subgroups (EF) and (ES) representing deep chamfer and chisel finish line of E-max samples, respectively. Subgroups (CF) and (CS) representing deep chamfer and chisel finish line of Celtra samples, respectively. Using a stereomicroscope, each sample's marginal gap was assessed microscopically before cementation. After Cementation, specimens were subjected to thermocycling to mimic intraoral conditions and then marginal gap was assessed microscopically.

Results: Subgroup (ES) recorded the highest marginal gap mean (62.96±6.48) and subgroup (CF) recorded the lowest one (51.9±4.95). Gp (E) recoded higher marginal gap mean value (63.23± 5.38 μm) than Gp (C) (57.42± 5.07 μm). The chisel margin subgroup recoded a statistically significant higher marginal gap mean value (62.65± 5.7 μm) than the chamfer margin subgroup (57.99± 4.75 μm).

Conclusion: Celtra press group (C) showed better marginal adaptation compared to IPS e-max press group (E) before/after cementation. Deep chamfer subgroups (EF) & (CF) showed better marginal adaptation compared to chisel finish line subgroups (ES) & (CS). The results were within the clinically accepted range (120 μm).

KEYWORDS: IPS E-max press, Celtra press, Marginal adaptation, Deep Chamfer finish line, Chisel finish line

* Masters' Studies, Fixed Prosthodontics Department, Faculty of Dentistry, Minia University, Egypt
** Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Minia University, Minia, Egypt
*** Lecturer of Fixed Prosthodontics Department, Faculty of Dentistry, Minia University, Minia, Egypt.

INTRODUCTION

All-ceramic restorations have gained popularity as a treatment choice for durable functional indirect restorations because of their excellent aesthetic and biocompatibility with delicate tissues and gums than porcelain fused to metal crowns and need less tooth reduction [1-3]. Despite the fact that they use a variety of ceramic materials and innovative processing procedures, not all these systems have undergone rigorous examinations of their clinical effectiveness, marginal fit, and the effect of varied preparation designs [4,5].

Pressable ceramic restorations have long been made with the help of a popular processing method called heat pressing. Glass ceramic ingots are heated to allow the ceramic material to be pressurized and flow into a lost wax mold [6-11].

Since the development of lithium disilicate glass-ceramics, which can be manufactured to achieve full-contour monolithic restorations and cemented with adhesive resin cement, it has been shown to be a suitable choice in situations involving higher stress. Zirconia reinforced lithium silicates is a new development in glass ceramics reinforced with polycrystalline ceramics. The fracture interruption of lithium silicate ceramic is strengthened by adding 10% weight of zirconia allowing the fabrication of single restorations, veneers, inlays, onlays, and multi-unit bridges [12-15].

Preparation designs can be divided into two categories: preparation with finish lines known as horizontal preparation and preparation without finish lines known as vertical preparation [15-17]. Shoulder and chamfer have been widely used as horizontal finish lines for preparation as they have the advantage of preventing overhangs and over-contouring of the restorations. Besides, they improved workflow and lab-clinician communication [16,18]. Previously, in certain clinical circumstances, vertical preparation; a feather edge (knife edge) or shoulder-less margin design was typically recommended for fixed prostheses of periodontally affected abutments as they offer a more conservative approach than horizontal preparation [14,15,16,18].

Marginal adaptation plays a critical role in the success of all ceramic restorations. It is predicted that a properly fitted margin will decrease accumulation of plaque, recurrent caries that harm the tooth and the periodontium that supports it, and possibly shorten the restoration's lifespan [13,14,17,19].

The success of the crown restoration can be impacted by tooth preparation. Besides, after completing all clinical and laboratory phases, cementation of an indirect dental restoration is the last stage and is thought to be equally significant because it can impact the restoration's longevity[11,13,15]. Resin cements offer proper retention of fixed restorations. Total etch, self-etch, and self-adhesive resin cements are the three categories of resin cements based on their adhesive properties. They can also be divided into light cure, dual cure, and self-cured resin cements based on the polymerization mode[13,20]. Dual cure (Duo-link universal TM) resin cement is a universal bond that ensures optimal curing and produces the best bonding to the ceramic material. The marginal fit of the crowns was improved with a cement space of 30-70μm according to manufacturer instructions[20-24]. 120μm is the recommended clinically accepted marginal gap by Mclean and Fraunhofer [25].

Laboratory simulations of clinical service are often performed because clinical trials are costly and time consuming. Thermal cycling is an in vivo process often represented in these simulations. Temperature regimens previously used for in vitro tests of thermal cycling is common in tracer penetration (leakage), shear bond strength and tensile bond strength tests of dental materials [8,15,,17,26,27]. The 1000 cycles correspond to two years of clinical survival, as stated in ISO/TS 11405 by the International Organization for Standardization [17,26,27].

There are numerous ways to measure marginal adaptation, including: direct microscopic inspection of the margin, microscopic inspection of cross-sectioned cemented specimens, measurement of light body silicone replica, x-ray microtomography, profilometry, and laser videography [28]. The amount of marginal discrepancy can be precisely measured using a stereomicroscope with an integrated camera, which is the high precision method [13,15,29,30].

This study was formulated to evaluate the impact of preparation design on marginal adaptation of two pressable ceramic crowns. A postulated hypothesis that marginal adaption would vary depending on the type of preparation design and ceramic type.

MATERIALS & METHODS:

Teeth collection:

According to the ethical protocol (no. 482/2021) for the Faculty of Dentistry, Minia University, forty freshly extracted maxillary premolar teeth for orthodontic purposes were collected and checked for being sound and free from caries. After being submerged in a 0.5% sodium hypochlorite solution for fifteen minutes, teeth were ultrasonically cleaned and disinfected before being kept in containers of distilled water in incubators at 37^{o}c.

Sample grouping:

Forty maxillary premolar teeth (n=40) were randomly divided into two groups, Group E for the IPS e-max press (Ivoclar Vivadent, Liechtenstein, USA) and Group C for the Celtra press (Dentsply Sirona, Norway), based on the type of ceramic material (n=20). Each was divided into two subgroups representing the type of finish line preparation, IPS e-max press samples for the deep chamfer finish line and chisel finish line are represented by subgroups (EF) and (ES), respectively. On the other hand, subgroups (CF) and (CS), stand for deep chamfer and chisel finish lines Celtra press samples, respectively (n = 10)

Construction of Silicon Index:

A split cylindrical copper mold and ring were used to allow mounting teeth in epoxy resin blocks (CMB international group Giza-Egypt). All blocks were numbered on their base (1-40), where 1- 20 were assigned for IPS e-max press samples and 21-40 for Celtra press samples.

Each premolar was fixed along its long axis in a properly mixed clear epoxy resin using parallelometer (United Instruments, New Jersey, United States). In order to guarantee a uniform, standard reduction of teeth, a specially designed cylindrical perforated metal tray was used to record the index for each tooth using addition silicone-based impression material (Zhermack S.p.A., Bovazecchino, Balida Polesine, Italy) prior to teeth preparation.

Teeth preparation:

Each epoxy resin block was mounted on a dental surveyor (Marathon-103 surveyor, Microtech co., Saeyang, Korea) that was powered by an electric micromotor (Strong 204, Korea) rotating at a speed of 15000 rpm and a low-speed handpiece (NSK, Japan). Teeth were typically prepared to receive full veneer crowns with a 12^{O} total occlusal convergence. For deep chamfer finish line, a taper stone with a round end (Bur No. (8856) (Komet, Germany)) (diameter 1.6 mm) was used to achieve 0.8 mm finish line. For preparing Chisel finish line, a 0.12mm diamond bur with a non-cutting tip and round end (Bur No. (851314012) (Komet, Germany)) was used. The prepared finish lines were 0.5 mm higher than CEJ and then a finishing stone was used for smoothing and finishing the preparations. Secondary plans and a functional cusp bevel were completed with the same finishing stone (Bur No. (8851314012) (Komet, Germany)) [13].

Digital impression and computer aided designing

To create a three-dimensional image of each tooth on the computer screen of the computer aided design/

computer aided manufacturer CAD/CAM software system (omnicam AC Scanner,sirona,Germany), the prepared premolars were scanned after being sprayed with occlutec scanning optical spray (Renfert, Giesswiesen, Hilzingen, Germany). White CAD/CAM wax patterns (Crowax - Renfert, Saint Charles, USA) were produced. The STL files of the designs were transferred to a CAM machine (Dental DB 3.0 Galway) for milling (Figs. 1 & 2).

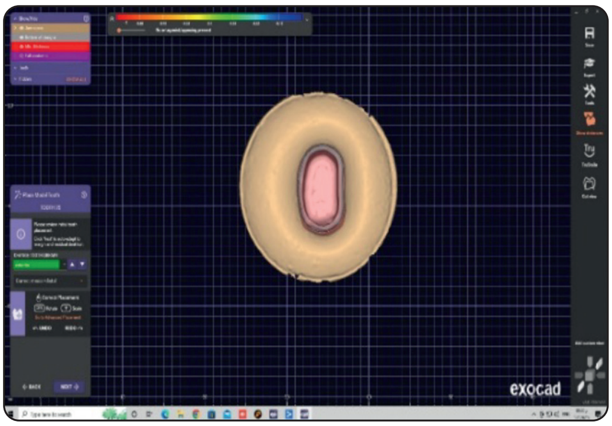

Fig. (1) Digital scan of tooth

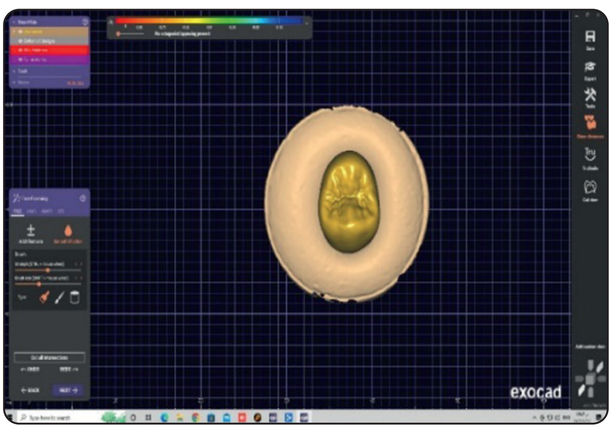

Fig. (2) Digital design of restoration

Ceramic pressing:

Forty digitally fabricated wax patterns using white CAD/CAM wax (Crowax - Renfert, Saint Charles, USA) were sprued (Vigodent, Rio de Janeiro, Brazil), invested (IPS-PressVEST Speed; Ivoclar Vivadent) , burnt out in a burnout furnace (EP 600; Ivoclar Vivadent) and then immediately pressed into an automated dental heat-pressing furnace (Programat EP 3010 Ivoclar Vivadent) that was already preheated into ceramic crowns according to their assigned groups following manufactures recommendations for each tested material.

Cementation:

The fitting surface of each crown was etched using 9% hydrofluoric acid (Bisco, Company, USA) for 20 seconds. Each etched surface was rinsed with water spray for 60 seconds and then air dried for 20 seconds. A layer of silane coupling agent (Bisco, Company, USA) was applied for 60 seconds to the etched surface, and then air thinned [31]. Each tooth was etched using 37% phosphoric acid (Meta Biomed, Korea) and then a universal bond (Bisco, Company, USA) was applied. Dual cured self-etch and self-adhesive resin cement (Bisco, Company, USA) was then loaded into the fitting surface of each treated crown [31]. Each crown was then cemented to its corresponding prepared abutment. A special device was constructed to standardize load application; a 2 kg static stress for 5 minutes [15] during cementation process.

Marginal Gap measurements:

Before and after cementation, stereomicroscope (Image J 1.43U, National Institute of Health, USA) was used to measure the marginal gap. To ensure the marginal gap measurement accuracy for each specimen, four locations at the center of the buccal, lingual, mesial, and distal surfaces of the copings were marked. Two additional marks were added and marked 2 mm to the right and left of the center points on each surface [12]. A total of twelve measuring points (three on each surface) were obtained. Data obtained were collected and tabulated.

Thermocycling:

Cemented specimens were stored in distilled water at 37° c for 24 hours and then subjected to thermal strains (Thermocycler THE-1100, SD sd-mechatronik, Germany) at bonding interface by thermal changes in water baths 5-55°C to mimic intraoral conditions. Marginal gap measurements were made. Data obtained were collected, tabulated and then subjected to statistical analysis [32]. In this study the number of cycles used were 5000 cycles to simulate ten years of clinical use. Dwell times were 25 s. in each water bath (Robota automated thermal cycle; BILGE, Turkey) with a lag time 10 s.

RESULTS

Marginal Gap measurements (μm):

Subgroup (ES) recorded the highest marginal gap mean value (62.96±6.48 & 56.06±5.23) and subgroup (CF) recorded the lowest marginal gap mean value (51.9±4.95 & 40.82±2.49) before and after cementation, respectively. While after thermocycling, Subgroup (CS) recorded the highest marginal gap mean value (72.09±2.89) and Subgroup (CF) recorded the lowest marginal gap mean value (55.09±7.47) (Table 1).

TABLE (1) The effect of finish line type on marginal gap of both tested materials before/after cementation and thermocycling

Variable		Cementation		Thermocycled
		Before	After	
IPS e.max press Gp. E	Chamfer	62.74 ±9.05	50.41 ±4.31	65.49 ±2.24
	Chisel	62.96 ±6.48	56.06 ±5.23	63.75 ±6.90
Celtra press Gp.C	Chamfer	51.9 ±4.95	40.82 ±2.49	55.09 ±7.47
	Chisel	57.68 ±7.19	52.14 ±6.31	72.09 ±2.89

Marginal Gap results according to ceramic type:

E-max press group (Gp. E) recoded statistically significant higher marginal gap mean value (63.23± 5.38 μm) than Celtra press group (Gp. C) mean value (57.42± 5.07 μm). (Table 2, Figure 3)

TABLE (2) The effect of the tested materials on marginal gap (μm)

Variables		Mean ± SD	95% CI	
			Low	High
Material	IPS e.max press (E)	63.23±5.38	60.87	65.59
	Celtra press (C)	57.42±5.07	55.19	59.64
Statistics	P value	0.0012*		

*; significant ($p<0.05$) ns; non-significant ($p>0.05$)

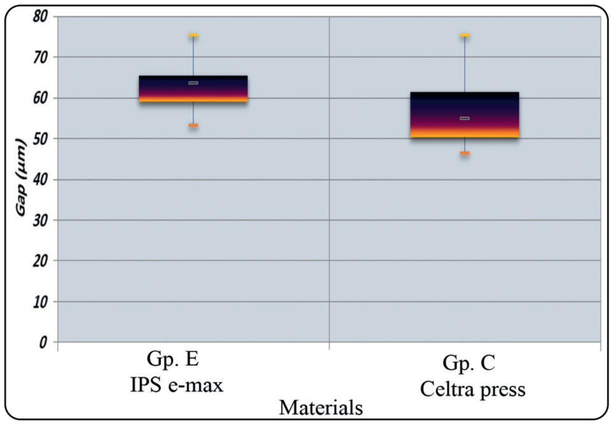

Fig. (3) Marginal gap mean values of the tested materials

Marginal Gap results according to preparation design

Chisel margin group recoded statistically significant higher vertical marginal gap mean value (62.65± 5.7 μm) than chamfer margin group mean value (57.99± 4.75 μm). (Table 3, Figure 4)

TABLE (3) Marginal gap mean values (μm) of the tested margin design

Variables		*Mean* ± SD	*95% CI*	
			Low	*High*
Margin design	*Chamfer*	57.99± 4.75	55.92	60.08
	Chisel	62.65±5.7	60.15	65.14
Statistics	*P value*	0.008*		

*; significant ($p<0.05$) ns; non-significant ($p>0.05$)

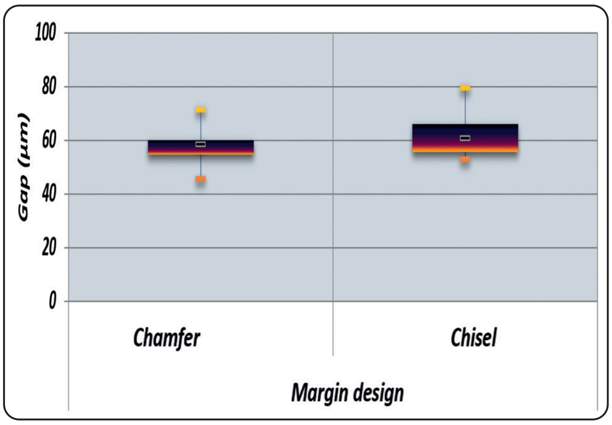

Fig. (4) Marginal gap mean values of the tested margin designs

The effect of cementation on marginal gap:

Marginal gaps were statistically significant higher after cementation than before (59.63±4.73µm) and (51.58± 4.38) µm, respectively. (Table 4, Figure 5)

TABLE (4) Effect of cementation on marginal gap mean values (µm)

Variables		*Mean* ± SD	*95% CI*	
			Low	*High*
Cementation	*After*	59.63±4.73	57.55	61.70
	Before	51.58±4.38	49.66	53.49
Statistics	*P value*	<0.0001*		

; significant (p<0.05)** ***ns; non-significant (p>0.05)

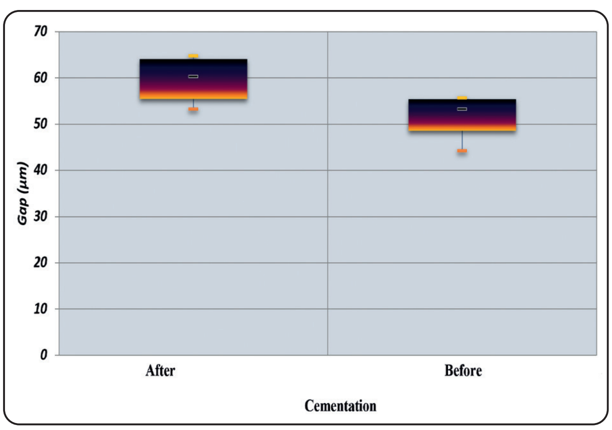

Fig. (5) marginal gap mean values of cemented samples

After Before Cementation

The effect of thermocycling on Marginal gap:

There was a statistically significant difference in the marginal gap mean values between the thermocycled samples (69.76±3.41µm) and the non- thermocycled samples (55.6± 4.51 µm). (Table 5, Figure 6)

TABLE (5)The effect of thermocycling on marginal gap mean values (µm)

Variables		*Mean* ± SD	*95% CI*	
			Low	*High*
Thermal aging	*Non-aged*	55.60 ± 4.51	53.62	57.58
	Aged	69.76 ± 3.41	68.27	71.26
Statistics	*P value*	<0.0001*		

;significant (p<0.05)** ***ns; non-significant (p>0.05)

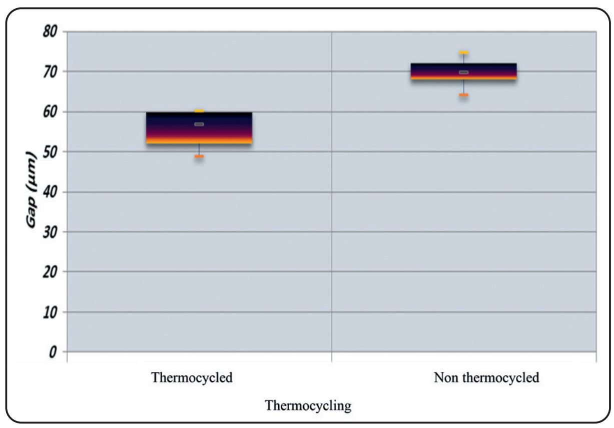

Fig. (6) Marginal gap mean values as function of thermocycling

DISCUSSION

The most important technical factor for long-term restoration success and enhanced prosthesis retention is marginal adaptation of fixed prosthodontics [(31)]. Marginally, the tissues surrounding restorations and their long-term durability are affected by design of the finish line and materials used [(34)].

Lithium disilicate (IPS e-max) is a glass-ceramic that has been precerammed and contains a high concentration of crystals that serve as reinforcement. Zirconia-reinforced lithium silicates, a recent development in glass ceramics reinforced with polycrystalline ceramics which is strengthened by a 10% weight addition of zirconia [34]. Pressable ceramics produce higher marginal adaptation, homogenous and thinner cement film thickness, and improved resistance to microleakage compared to machinable ceramics [6]. Glass ceramic materials, specifically lithium disilicate (IPS e-max press) and zirconia-reinforced lithium silicate (Celtra press), were employed in the current study.

The goal of minimally invasive dentistry is to achieve outstanding cosmetic outcomes without compromising the preservation of biological structures, especially in the cervical region where maintaining the strength of the restoration and vitality of the pulp depends critically on the preparation distance off pulp. A vertical preparation strategy, in contrast to a horizontal finish line, protects tooth structure [36,37].

Conservative tooth preparation; chisel finish line which overcame the typical FPD preparation drawback; substantial tooth tissue removal from the abutment teeth is necessary for retention and resistance form. Deep chamfer finish line is a more suitable in marginal adaptation than a 90° shoulder because of variations in preparation depth, which are easily detected in deep chamfer marginal design, have an impact on the accuracy of digital scanner detection [13]. In this study deep chamfer finish line for horizontal preparation and chisel finish line for vertical preparation were used.

Marginal gap measurements are obtained by a variety of techniques including; direct microscopic inspection of the margin, microscopic inspection of cross-sectioned cemented specimens, and measurement of light body silicone replica, x-ray microtomography, profilometry, and laser videography. In the current study, a stereomicroscope microscope was used to assess marginal adaptation as it is a simple and convenient method [38].

This in vitro study examined the effect of finish line preparation design on the marginal gap of pressable all-ceramic crowns.

Standardization techniques are the most accurate approaches in any research studying variables. So, the results will exhibit high power and will be less biased due to sample preparation. Standardized reduction was ensured following tooth preparation by applying the index to every tooth that had been prepared. 0.8 mm Deep chamfer finish line was prepared using half the tip of a 1.6 mm round end taper stone and held parallel to the tooth's long axis. 0.12 mm Chisel finish line preparation was made by a taper stone with flat edge non-cutting tip held parallel to the long axis of the tooth, 0.5 mm above CEJ. The cement space was chosen to be 55 μ [20,24].

In this study the number of cycles used were 5000 cycles to simulate ten years of clinical use. Dwell times were 25 s. in each water bath with a lag time 10 s.

The results of the current study showed that regarding the effect of material type, the marginal gap mean values of Gp. E, which represented IPS e.max press samples, recoded statistically significant higher marginal gap mean values than those of Gp. C, which represented Celtra press samples (63.23± 5.38 μm) and (57.42± 5.07) μm, respectively. These results were in agreement with (Al-Zubaidy Z. & Al-Shamma AMW, 2015) [13] who claimed that this is due to the different microstructures of the two materials and the different fabrication processes.

According to (Tantawy A. et al., 2022) [8], IPS e.max Press showed better marginal adaptation compared to that of Celtra Press after thermocycling but before thermocycling the e-max recorded higher marginal gap than Celtra Press due to the stress generated at the cement-tooth and cement-porcelain interfaces due to the luting resin cement's polymerization shrinkage and the variations in the thermal expansion coefficients of the cement, tooth, and porcelain. These findings were also in agreement with those of (Comlekoglu M. et al., 2009) [39] who found that zirconia ceramic crowns exhibited the least marginal discrepancy.

However, the findings were against (Basheer R., 2017) [40], zirconia reinforced lithium silicate has higher marginal accuracy than lithium disilicate ceramic. The zirconia material of the complete contour monolithic zirconia repair may have shrunk during sintering, which could account for the variation in the marginal gap, and (Duqum S. et al., 2019) [41], different laboratories made the zirconia and lithium disilicate crowns as well as the different milling protocols of these two materials also account for the variations in marginal fits.

Regarding the effect of margin design on marginal gap, the marginal gap mean values of chisel margin subgroups (62.65± 5.7 μm) were larger than those of chamfer margin subgroups (57.99± 4.75 μm). This may be due to the difference in the depth of the preparation, the design of the finishing line, which had a more rounded angle between the axial and gingival seats for the chamfer finishing line, enabled a more accurate seat for the crown than with chisel finishing line, with a slight round angle, which led to an incomplete seat of the crown and increased the vertical marginal gap; and it is possible that the differences in depth preparation are affecting the accuracy of scanner detection [42-44]. Vertical preparations demonstrated procedural advantages of easier impression creation and increased marginal and internal adaption after cementation. The use of different materials and measuring techniques may have been a factor in the current study's finding that horizontal preparation performed much better in terms of marginal adaption than vertical preparation. There is little evidence in the literature about how feather edge finish lines affect marginal adaptation and internal fit. However, this was against the findings of (Cho L. R. et al., 2004) [45] ; who clarified that despite having slight lower marginal gap values, feather edge finish lines are not advised for usage in clinical settings because they might raise marginal bulk.

Regarding the effect of thermocycling on Celtra press group and IPS e.max group samples both showed statistically significant increase in marginal gap values. this was in agreement with (Hasaneen F.A. & Mogahed M. M, 2021) [46], the marginal gap widened during thermocycling due to the different rates of thermal expansion of the ceramic, luting agent, and tooth. The bond between the luting agent and the tooth dissolves as a result of repeatedly subjecting all ceramic materials too high and low temperatures. Percolation is promoted in the space between the luting agent and the tooth by temperature cycling.

It is important to mention that the results of the marginal gap distance for both ceramics used in this study are within the clinically acceptable standards of 120 μm even after thermocycling that was in accordance to the findings of (El Sayed S. M. & Emam Z. N, 2019) , (Asaad R. S. & Salem S. K, 2020) & (Mclean J. W. & Von Fraunhofer J. A, 1971) [9,26,47]. Stress can be caused at the tooth-cement and cement-porcelain interfaces due to polymerization shrinkage of the luting resin cement and differences in thermal expansion coefficients between cement, tooth, and porcelain. Because of the contraction stress, the adhesive forces of the two bonded interfaces compete.

Regarding the effect of cementation, it was found that, marginal gap mean value was statistically significant higher after cementation (59.63±4.73μm) than before mean value (51.58± 4.38 μm) which may be due to the increase in hydraulic pressure of the resin cement [48]. (Wolfart S. et al., 2003) [49], attributed this to the viscosity of the luting cement used that could affect restoration seating.

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. The natural teeth variation after preparation in terms of tooth composition, age and storage. Aging using only 5,000 cycles thermocycling, while other published literature using additional cyclic loading.

CONCLUSIONS

Based on the findings and with the limitations of this in-vitro study, the following was concluded:

1. Celtra press showed good marginal adaptation compared to IPS e-max before and after cementation.
2. Thermal aging affect vertical marginal adaptation negatively.
3. Deep chamfer finish line provides better marginal adaptation than chisel one.

RECOMMENDATION

1. Further investigations should be carried out for verification of different occlusal preparation designs on marginal adaptation.
2. Further in-vivo investigations for verification of the current study results.

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