

Original Article

Vertical Marginal Gap Distance of CAD/CAM Milled BioHPP PEEK Coping Veneered by HIPC Compared to Zirconia Coping Veneered by CAD-On Lithium Disilicate “In-Vitro Study”

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Abstract

Statement of problem: marginal inaccuracy causes a space between restoration and prepared tooth, which accelerates cement dissolution, leading to secondary caries, pulpal lesions, postoperative sensitivity, periodontal disease and marginal discoloration. Marginal gap should be less than 120µm. **Aim:** to evaluate vertical marginal gap of PEEK (Bio-HPP) veneered with CAD/CAM composite veneer (HIPC) as compared to zirconia veneered with CAD-On lithium disilicate glass ceramic. And the effect of ageing on the gap of both restorations. **Material and methods:** 40 extracted molars were prepared, divided into two groups, control group (ZR) (n=20), teeth restored with IPS e.max ZirCAD copings veneered with IPS e.max CAD and intervention group (PEEK) (n=20), teeth restored with breCAM BioHPP copings veneered with BreCAM.HIPC. Each specimen was photographed using Leica S8 APO stereomicroscope under magnification 32X and image analysis was done. Measurements were taken twice before and after thermo-mechanical cycling. **Results:** PEEK group recorded higher gap mean values (49.88±7.97µm) than zirconia (18.39±3.1µm). This was significantly (p < 0.05) as confirmed by Mann-Whitney test, but all measurements were clinically acceptable. And Thermo-mechanical cycling had no effect on both groups. **Conclusion:** PEEK veneered with composite can be used intra orally for single crown restorations.

Keywords: PEEK, Zirconia, Marginal gap, multilayering, CAD-on

Introduction:

Metal free restorations have been developed for better esthetic outcome to meet the patient's

expectations. All-ceramic fixed dental prostheses include lithium-disilicate reinforced glass ceramics and oxide ceramics such as alumina and zirconia, from which single-units and multiple-unit FDP

reconstructions have been made and placed at both anterior and posterior sites. (Nejatidanesh, Moradpoor and Savabi, 2016)

Zirconia is characterized by having high shear strength. Its mechanical properties are similar to stainless steel in which it has compression resistance (2000 MPa); therefore zirconia was nicknamed ceramic steel. Also its modulus of elasticity is 210 GPa. Zirconia is considered to be chemically stable that withstand different environmental changes in the oral cavity. Also it has low thermal conductivity, protecting the teeth from pulpal form temperature changes. In addition, zirconium is extremely biocompatible, and does not cause allergic reactions, thereby it is used as an implant (Piconi and Maccauro, 1999)

Zirconia can be manufactured in two methods by (CAD/CAM) technology: First, an enlarged coping/framework can be designed and milled from a homogenous ceramic soft green body blank of zirconia. Then the framework is sintered and linear shrinkage of 20-25% occurs in which the desired final dimension is reached. The soft presintered zirconia offers shorter milling time and reduces the wear on the milling burs. this may negatively affect the fit of a dental prosthesis owing to shrinkage in pre-sintered blanks during the sintering process.

Second method is milling a fully sintered prefabricated blank to the desired dimension but this may affect the microstructure and decrease the material strength, but it is claimed that it has superior marginal fit because no shrinkage is involved in their manufacturing process. (Piwowarczyk *et al.*, 2005)

Veneering of zirconia frameworks can be done by CAD-on technology . a corresponding CAD/CAM fabricated lithium-disilicate glass-ceramic veneering material sintered with zirconia framework by means of a glass-ceramic powder in one bake. The new CAD/CAM-fabricated bilayered restorations were superior to conventional layering

and pressing technique in terms of fracture load and lower risk of veneer chippings. (Beuer *et al.*, 2009)

PEEK is white, radiolucent, rigid material with great thermal stability up to 335.8° C. It is non-allergic and has low plaque affinity with Flexural modulus 140-170 MPa, density – 1300 kg/m³ and thermal conductivity 0.29 W/mK. PEEK's mechanical properties do not change during sterilization process, using steam, gamma and ethylene oxide. Young's (elastic) modulus of PEEK is 3-4 GPa, which is close to human bone, enamel and dentin. An in vitro study done by Lieberman *et al.* comparing PEEK with polymethyl methacrylate and composite resin, PEEK has the lowest solubility and water absorption values. PEEK is more aesthetic, stable, biocompatible, lighter and has and resist discoloration in comparison with metals used in dentistry. But unfortunately it has a grayish brown color therefore it is not suitable for monolithic aesthetic restorations. (Monich *et al.*, 2017)

Composite used as an esthetic material for veneering of PEEK. But because of the Low energy of PEEK surface which creates resistance to chemical processing for the bonding to composite. Therefore many surface treatment options are done to PEEK. Air abrasion with and without silica coating creates wettable surface or by etching with sulfuric acid makes rough and chemically processed surface. (Zhou *et al.*, 2014)

PEEK can be pressed by special vacuum-pressing device. For this purpose, PEEK is used either as industrially pre-pressed pellets or in granular form. For the pressing process, the preheated muffle (with the press plunger) is placed into the vacuum-pressing device and pressed. Another option is the milling using CAD/CAM technologies where PEEK blanks are pressed industrially under standardized parameters. A study done by **Stawarczyk, B.** to compare between CAD/CAM and pressed PEEK, showed that three-unit PEEK fixed partial dentures manufactured via CAD-CAM

have a higher fracture resistance. (Stawarczyk *et al.*, 2015)

The aim of this study is to evaluate vertical marginal gap of PEEK (Bio-HPP) as a framework material to be veneered with CAD/CAM composite veneer (HIPC) as compared to zirconia framework veneered with CAD-On lithium disilicate glass ceramic.

The first null hypothesis is that there will be no difference in vertical marginal gaps between PEEK group veneered with CAD/CAM HIPC composite and zirconia group veneered with IPS e-max CAD

Second null hypothesis that there will be no effect of ageing on the vertical marginal gap of both groups.

Materials and methods:

Forty freshly extracted upper molars free from caries, attrition, cracks and fractures were selected and mounted in epoxy blocks. A putty index was made before teeth reduction to be used as a reference and was cut bucco-lingually.

All teeth were prepared by NOUVAG AF 30 milling machine, using the same tapered stone to standardize a uniform preparation for all teeth. Diameter of the tapered stone was checked by a digital caliper (2mm) to control finish line thickness during reduction. A circular deep chamfer finish line of a width 1.0 mm was made. Walls were prepared with a taper of 10° following the manufacturer's instructions and uniform axial reduction of 1.5 mm. Uniform anatomical occlusal anatomical reduction of 2.0 mm was made (Figure 1).

Teeth were randomly allocated into two groups according to the type of restoration received. Group A: n= 20 where Teeth are restored by ZirCAD veneered by e.max CAD and Group B: n=20 where Teeth are restored by PEEK BioHPP veneered by HIPC.

For the zirconia group teeth were scanned by CEREC Omnicam intra oral scanner and CEREC software 4.4 was used to design IPS e.max CAD-on restorations. Minimum thickness for ZirCAD is 0.5 mm and for e.max CAD is 0.7 mm, and a spacer of 120μ between the framework and the prepared tooth.

The IPS ZirCAD block (size C15, shade MO1) and IPS e.max CAD blocks (size 14, shade A2) were milled using a 4 axis milling machine in accordance with the approved design.

Sintering of zirconia frameworks was done in Sirona infire HTC speed furnace, accompanied by average 25% shrinkage which is accurately compensated for in the milling process.

IPS e.max ZirCAD framework and the IPS e.max CAD veneering structure were fused together using IPS e.max Crystall./ Connect low fusing special glass.

Ivoclar Vivadent Programat P510 was used for Fusion/Crystallization firing in the IPS e.max CAD-on technique. The sintering temperature of IPS e.max CAD Crystall./Connect fusion glass ceramic has been adjusted to the crystallization temperature of IPS e.max CAD so that the fusion process and the crystallization of IPS e.max CAD can be conducted in one firing cycle.

For the PEEK group, teeth were scanned by SHERA eco-scan 3 extra-oral scanner and Designing was done by Dental wings DWOS CAD/CAM Software. The material thickness was standardized according to the recommended values which are 0.7 mm PEEK and 0.7 mm HIPC, and a spacer of 120μ between the framework and the prepared tooth.

The breCAM.BioHPP blank (98.5 mm diameter and 12 mm fold) and breCAM.HIPC blank (98.4 mm diameter and 16 mm fold) (Shade A3) were milled using SHERA eco-mill 50 4-axis milling machine.

Frameworks and veneers were air abraded with 110 μm Al₂O₃ powder at 2.5 bar and conditioned using visio.link, and light cured using bre lux Power light curing Unit (intensity: 220 mW/cm² for 90 seconds)

Veneers were cemented to frameworks using combo.lign resin cement, using cementing device, a uniform load of 5 kg (49 N) for 10 minutes according to the ADA specification #96.

All crowns were air abraded at their fitting surface and zirconia was conditioned with Z-PRIME Plus and PEEK with Visio.link. and all crowns were cemented with Duo-link resin cement. (figure 2)

Thermo-Mechanical aging was performed using ROBOTTA chewing simulator, A weight of 5 kg, which is comparable to 49 N of chewing force was exerted. The test was repeated 75000 times to clinically simulate the 6 months chewing condition.

A stereomicroscope Leica S8 APO at magnification 32X used to determine the vertical marginal gap (figure 3) . A previously marked 5 points on each aspect of each crown are measured (with total 20 points). These measurements were taken before and after thermo-mechanical cycling.

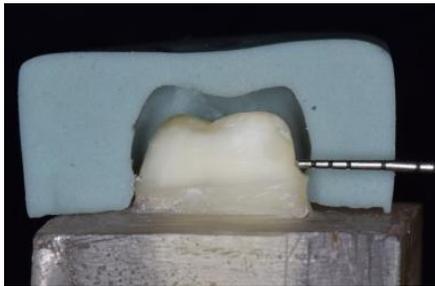


Figure 1. Teeth preparation.

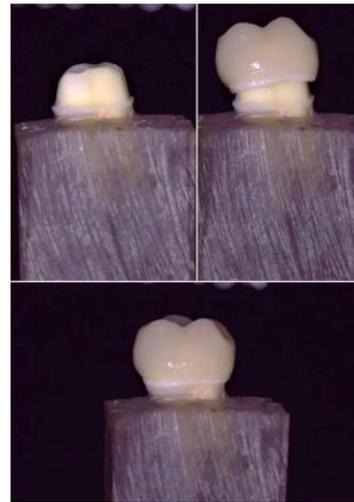


Figure 2. Cementation of final restorations

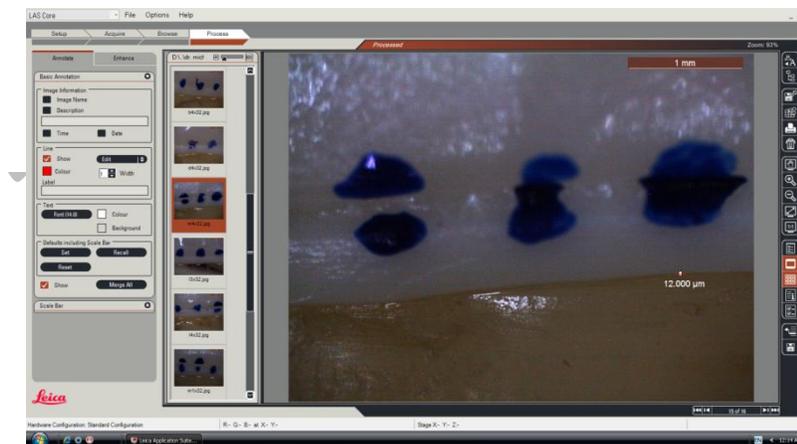


Figure 3. Leica Application suite (LAS) Version 4.0 software.

Results:

Data were presented as mean, standard deviation (SD) for values. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Mann-Whitney test and ANOVA were used to study the effect of material and aging on mean values. The

significance level was set at $P = 0.05$ and 95% Confidence interval. Statistical analysis was performed using Graph Pad InStat (Graph Pad, Inc.) software for windows. And results were described in tables 1,2 and 3 and Figure 4

Table 1. Marginal gap results (Mean values \pm SDs) as function of group type and thermo-mechanical cycling (μm).

Variable		Mean \pm SDs	95% CI		
			Low	High	
Group	Zr group	Before	18.39 \pm 3.1	11.89	24.88
		After	19.29 \pm 3.56	11.84	26.75
	PEEK group	Before	49.88 \pm 7.97	33.19	66.57
		After	45.81 \pm 6.87	31.43	60.19

Table 2. Comparison between marginal gap results (Mean values \pm SDs) as function of group type and thermo-

Variable		thermo-mechanical cycling		Statistics
		Before	After	P value
Group	Zr	18.39 \pm 3.1	19.29 \pm 3.56	0.7353 ns
	PEEK	49.88 \pm 7.97	45.81 \pm 6.87	0.7868 ns
Statistics	P value	0.0001 *	0.0001 *	

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

Table 3. Comparison of total marginal gap results (Mean values \pm SDs) as function of material group (μm).

Variable		Mean values \pm SDs	Rank	P value
Group	Zr	18.84 \pm 2.55	B	<0.0001 *
	PEEK	47.85 \pm 7.09	A	

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

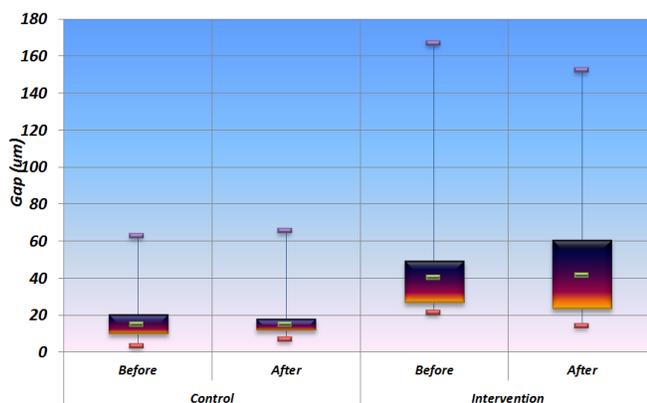


Figure 4. Box plot of marginal gap mean values for both groups before and after thermo-mechanical cycling (μm).

Discussion:

Extracted human molars were used because their modulus of elasticity, bonding characteristics, thermal conductivity and strength are closer to the clinical situation.(Att *et al.*, 2009)

The accuracy of the milling process is largely affected by the axis of the milling machine. 3-axis milling has a short production time and simple operation, while a 4-axis milling machine with three axis added to the rotation axis and a 5-axis milling machine with two rotation axes were developed. (Beuer *et al.*, 2008)

According to Bosch *et al.* the 5-axis milling machine has better accuracy than a 4-axis milling machine. However, using a 4-axis milling machine is cheaper. The number of the milling axis is not necessarily proportional to the level of accuracy.(Bosch, Ender and Mehl, 2014)

Cementation of the crowns in this study was done by a special loading device as recommended by Gorten and Probst in 1997 for proper seating over the corresponding prepared teeth. With a load of 5 kg directed parallel to the longitudinal access of the teeth.(Groten and Probst, 1997)

Artificial aging is an essential, as all specimens were subjected to dynamic loading and thermal cycling to investigate specimen behavior under clinical like conditions as materials would undergo subcritical cracks during mastication.(Bankoglu Gungor and Karakoca Nemli, 2018)

Direct viewing with external measurements using stereomicroscope was used in this study; all measurements were made by the same operator for standardization. The method used in this study has the advantage of not being invasive. The technique measures the gap between the crown and tooth structure margin. No sectioning or replications of the cement space before measuring the gap, which make it cheaper and

less time consuming than other techniques and reducing the chance of error.(Gassino *et al.*, 2004)

In this study, 5 points in each crowns aspect were selected to measure the marginal gap, a total of 20 points for each crown. This was according to Groten *et al.* who suggested 50 measurements per crown but, at least 20 to 25 measurements. (Groten *et al.*, 2000)

In this study, the mean marginal gap values of PEEK crowns showed statistical significant higher marginal gap than Zirconia crowns. These results can be contributed to the semi crystalline structure of PEEK which contains an amount of fillers embedded in resin matrix which can result in higher marginal gap during fabrication than zirconia which is polycrystalline, or may be due to the use of different CAD/CAM machines for both groups.

Our results were in agreement with Park *et al.* who compared PEEK crowns with zirconia and lithium disilicate crowns using replica technique and three dimension analysis. Results showed that all marginal gaps were clinically acceptable.(Park *et al.*, 2017)

Also marginal gap measurements of PEEK were similar to Abdullah *et al.* who evaluated marginal gap of CAD/CAM fabricated PEEK temporary crowns. It was found that PEEK recorded 46.75 (± 8.26) μm which is considered to have a superior fit so as it can be used as a final restoration as it has a fracture strength 802.23 (± 111.29) N. where these measurements would indicate PEEK to be used as a final restoration. (S Abdullah and Ibraheem, 2017)

Therefore, the first null hypothesis was rejected as the zirconia group has statistically significant lower marginal gaps than PEEK. The results were in agreement with Wael *et al.* who assumed the

marginal discrepancies had no significant changes after artificial aging.(Att *et al.*, 2009)

On the contrary, a study done by El-Dessouky et. al showed that thermo-mechanical loading has significantly increased marginal gap measurements when done under temperatures between 5°C and 55°C. Although the critical temperature of zirconia aging suggested above 100°C. (El-Dessouky *et al.*, 2015)

Also a similar study done by Khaled et. Al to assess the effect of ageing on zirconia crowns using ROBOTA chewing simulator with 49 N chewing forces for 75000 cycles (6 months clinical condition), it was found that there is increase of marginal gap measurements after aging , from (31.41±5.9)µm to (95.28±9.2) µm of Bruxzir crowns.(Haggag, Abbas and Ramadan, 2018)

While Stappert et. al found that the marginal gap decreased after artificial aging. It was explained that some portions of the cement film are washed out during the aging procedure, making clearer image for more exact measurements of the marginal gap.(Stappert *et al.*, 2004) The second null hypothesis was accepted as there was no effect on aging on marginal gap of both groups as there was no statistical significance.

However, all results of vertical marginal gap in this study were within the acceptable range according to previous studies. Authors stated vertical marginal gaps under 120 to be clinically acceptable for fixed prostheses. Others have reported 160 - 172 µm to be clinically acceptable for conventional crowns. (Ha and Cho, 2016)

Conclusions:

Within limitations of this study, it can be concluded that:

1. The mean marginal gap distance of all tested specimens were within the acceptable clinical

standards which are less than 120µm. But zirconia showed lower mean marginal gap distance than PEEK.

2. Thermo-mechanical cycling had no effect on the mean marginal gap of both groups.
3. Due to the acceptable marginal gap measurements as shown in this study, PEEK veneered with HIPC composite can be used intra orally for single crown restorations.

Recommendations:

Further studies are required to:

1. Examine the effect of the technique of fabrication on the fracture resistance of both restorations.
2. Examine the effect of different milling machine axes on marginal accuracy.
3. Further investigation with larger samples and clinical trials needed to reinforce the results.

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