Vertical marginal gap evaluation of PEEK and Zirconia crowns using extra-oral scanner and CAD/CAM systems (An Invitro study)

Raz Ali Aula[(1)]; Jawad Mohammed Mikaeel[(2)]

Background and objective: Selecting a material with lower marginal gap is the key factor for a successful dental prosthesis. With less marginal gap of the crown the aggregation of bacterial plaque at the gingival margins, that result in periodontal diseases and secondary caries could be limited.

Methods: A mandibular right first molar of a sound tooth was prepared for the reference model according to the tooth preparations guideline with a heavy chamfer finishing line for full zirconia and Polyetheretherketone (PEEK) coverage. Digital impression technique with extraoral scanner was used for scanning and taking impression of the reference model, ten crowns in each group were designed and milled using CAD/CAM systems. The vertical marginal gap between the crown's margin and the finishing line was measured for each crown on the reference model with the aid of a stereomicroscope in 160x.

Results: The average (mean) for the marginal gap of proximal, buccal and lingual surfaces of both PEEK, and zirconia materials were: 409.097 µm, 112.869 µm, 198.563 µm, for PEEK and, 105.085 µm, 27.659 µm, 45.135 µm for zirconia respectively. Statistical analysis using t -test for two independent samples revealed that PEEK material showed a significantly higher marginal gap than z. irconia material.

Conclusion: PEEK crowns had a higher marginal gap than clinically acceptable limit, while zirconia crowns exhibited much lower measurements.

Keywords: PEEK, Zirconia, Crown, Marginal adaptation, Vertical marginal gap.

[(1)]Ministry of Health in Kurdistan Government, Erbil, Iraq.
[(2)]Department of Prosthodontics, College of Dentistry, Hawler Medical University .
Corresponding author: Raz Ali Aula
Email: raz.helan@gmail.com

Introduction

Marginal adaptation is one of the important factors necessary for long-term success of a crown, which is possible through accurate reproduction of the finishing line,[1,2] and proper material selection. Material selection is an important key point for success of the prosthesis, by understanding features of materials patients and dentist will have better results, and communication with dental lab will be easier and more applicable.[3] "Holmes et al1 defined the internal gap as the measurement between the axial wall of the prepared tooth and the internal surface of the casting, while the same measurement at the margin is called "marginal gap".

Another definition is an angular merging of marginal gap and extension error is an "absolute marginal discrepancy," which precisely defines the linear distance from the surface finish line of the preparation to the margin of the restoration. Inadequate marginal adaptation consequence in aggregation of bacterial plaque at the gingival margins, resulting in periodontal diseases and secondary caries.[4] Beside, a major marginal gap increases the thickness of the cement exposed to the oral fluids, leading to dissolution of cement and marginal leakage.[5] Fransson et al.[6] and McLean and von Fraunhofer[7] claimed that the clinically adequate marginal gap after cementation should be less than 150 µm and 120 µm. Marginal values of 34-

78µm computer-aided design/computer-aided manufacture (CAD/CAM) generated partially sintered zirconia could be produced.[8] A clinically acceptable marginal gap 60 to 120 µm has been reported.[9] CAD/CAM all-ceramic crowns reported less than 90 µm as acceptable marginal gap.[10] Generally, materials that are used for dental crown restoration are all metal, ceramics, metal-ceramics and resin composites.[3] Many new alterations and innovations have been taken place in material science and it has seen an extensive transformation in the types of materials being utilized such as precious metals, all ceramic like zirconia and polyetheretherketone (PEEK).[11] Zirconia proved itself as one of the most successful restorative materials because it offers a very favorable mechanical characteristics and sufficient aesthetic. However, failures related to both biologic complications like secondary caries and technical problems such as fracture of the bridge or chipping of the veneering ceramic have been reported.[12] This led to the introduction of PEEK into dentistry.[11] High-strength resins have been introduced as a promising alternative to ceramic materials, including polyaryletherketone (PAEK), polyetheretherketone (PEEK), and polyetherketoneketone (PEKK) materials.[13] Polyetheretherketone (PEEK), a thermoplastic semi - crystalline polymer with outstanding mechanical properties, chemical stability, and high biocompatibility, is one of these new choices of material.[14] The null hypothesis was that there is no statistically significant difference in the vertical marginal gap between PEEK and zirconia crowns.

Methods

Fabrication of the reference model: The reference model was constructed from an intact, nonserious, unrestored human mandibular right first premolar, that was extracted for orthodontic reason selected among the collected teeth in a labeled jar containing a liquid consisted 0.5% sodium hypochlorite (Shoof, Iraq) with 1:4 concentration ratio to distilled water. The selected tooth was cleaned of surface debris and stains with an ultrasonic scaler (Cavitron GEN- 119; Dentsply, York, PA). A base for the tooth was fabricated using light curing acrylic resin (Dental Wunder tray, Plaque Photo Light Cure) and, cured with a light cure unit (Enquire light cure, china) for five minutes according to manufacture instruction, the tooth was imbedded in the acrylic for easy grasping and handling. It was mounted 1 mm shorter than the cementoenamel junction. The mounted tooth was prepared as followed: 1.5 mm axial reduction, 2 mm occlusal reduction, and a 360° chamfer finish line. Tooth preparations were carried out under water spray using a high-speed turbine (Pana-Max PLUS turbine, NSK, Japan) and a coarse diamond-tapered rotary cutting instrument (450K Max: Brasseler, Savannah, GA) for the initial gross reduction, then a chamfer bure (Blue Medium Diamond Bur FG, China), followed by a fine bur (KD7W6; Brasseler) to smooth the preparation surface, a heavy 1mm chamfer finishing line was produced Figure 1: Prepared tooth with marked dots on finishing line, the final shape was checked and evaluated using dental loupe (Dental Loupe 2.5′ magnification, NDL-025N,Hong Kong, china).

Impression making: Instead of taking impression of the prepared tooth a digital impression technique using extra oral scanner (FREEDOM extraoral Dental Scanner, Dof Inc., South Korea)was used for scanning the reference model, starting from occlusal surface to axial surfaces and finishing line then the digital impression was transferred to a personal computer (Macbook pro-Apple pc) for making a STL file. The files were transferred into the dental CAD Software (Exocad Dental CAD software, GmbH; Fraunhofer IGD, Darmstadt, Germany), for designing and fabrication. Crowns fabrication. Ten Zirconia (SIRONA, inCoris TZIC, Germany) crowns with a flat occlusal surface and 35µm cement space were fabricated starting 1mm from margins. Beside zirconia crowns ten PEEK (discs of DD Peek MED, Dental Direct GmbH, Germany) crowns were also fabricated with the same dimensions and specifications. Then the designed crowns were all sent to CAD/CAM machine (Roland Milling Machine – 52DC DWX, Japan). The zirconia crowns were sintered in 1500°C for about 12 hours in the sintering furnace (tegra SPEED, Teknik Dental, Turkey) according to the

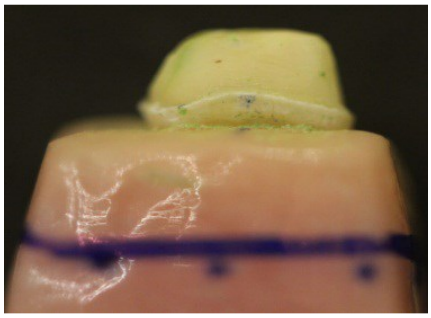
manufacturer's instructions, and all the dusts were removed prior to putting them in the furnace.

Measurement of crown marginal gap: The 20 single-unit zirconia crowns and PEEK (2 groups, 10 specimens/ group) Figure 2: a. PEEK crowns b. zirconia crowns were checked and inspected on the reference model for complete seating prior to measuring, no modifications were made on the fixed dental prosthesis (FDP) specimens to fit the reference model. Six points of evaluation were permanently marked on the prepared tooth in the form of dots 2mm below the finish line with a permanent marker (Name Pen, MONAMI, Korea).[15] Each crown was held in place with a constant load on the reference model with aid of c- clamp (Tekton Branded Tool, C-clamp, Michigan Industrial Tools), each time the screw of the clamp was tightened in the same place for standardization of the load on each crown. 16 By direct visualization method under the stereomicroscope the marginal gap was measured. The vertical gap was measured from the most cervical external edge of the restoration to the most outer edge of the finishing line (Rayyan, 2019).[17] A computerized digital image analysis system was performed for evaluation.[10,15,18,19] This included an image gained throughout the stereomicroscope (Olympic, Tokyo, Japan) at 160x magnification power using a digital camera (Nikon, D7 100, Tokyo, Japan), that was secured on the stereomicroscope with a special lens adopter (NDPL 1(2X), Lucky Zoom, Biological Microscope Eyepiece Lens Adapter, China).

Images were taken by the camera in the same position and magnification for reproducible positions throughout the process of image taking. With image analyzing software (ImageJ, LOCI, University of Wisconsin) the images were measured. Photos were calipered with 300pixil. Each determined point was measured three times and the mean of the length was recorded by the same operator, the analyzed data were divided to proximal, buccal and lingual views to an excel file (Microsoft, version16.40).

Figure 1. Prepared tooth with marked dots on finishing line.

a



b

Figure 2. Fabricated specimens a. PEEK crowns, b. Zirconia crowns

Statistical analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS, version

25). The normality of data was tested using Kolmogorov Smirnov test and Shapiro-Wilk test. Student's t test of two independent samples was used to compare two means of the normally distributed data. Mann Whitney test was used to compare the mean ranks of non-normally distributed data. A p value of ≤ 0.05 was considered statistically significant.

Results

The vertical marginal gap for each crown was measured, three times at each surface, and the average was reported in micrometers (μm). Normality of data was tested by Kolmogorov Smirnov test and Shapiro-Wilk test. The data of the proximal measurements were not normally distributed, in addition to the data of the buccal measurement for PEEK material. The rest of the data were normally distributed (Table1). The mean vertical marginal gap for the PEEK crowns was higher a b than zirconia crowns in all tested surfaces. Table 2 shows that the mean and the mean rank of the proximal measurements of PEEK material (409.097, and 15.5 respectively) were significantly higher than the mean and mean rank (105.085 and 5.5 respectively) of the zirconia material (p = 0.008). The same pattern was observed for the buccal measurements, where it is evident that the mean and mean rank of the PEEK material was significantly higher than those of the zirconia material (p = 0.003). The mean of the lingual measurements of the PEEK (198.563) was significantly (p = 0.006) higher than that of the Zirconia (45.135).

Table 1. marginal gap measurement of different surfaces

		Kolmogorov Smirnov			Shapiro-Wilk		
	Material	**Statistic**	**df**	**p**	**Statistic**	**df**	**p**
Proximal measurements	Peek	0.296	10	0.013	0.827	10	0.031*
	Zirconia	0.240	10	0.107	0.839	10	0.043*
Buccal measurements	Peek	0.302	10	0.010	0.842	10	0.046*
	Zirconia	0.134	10	0.200	0.916	10	0.324†
Lingual measurements	Peek	0.206	10	0.200	0.905	10	0.247†
	Zirconia	0.153	10	0.200	0.919	10	0.350†

*Not normally distributed. †Normally distributed.

Table 2. marginal gap measurement of different materials

	Peek			Zirconia			
	Mean	**(±SD)**	**Mean rank**	**Mean**	**(±SD**	**Mean rank**	**p**
Proximal measurements	409.097	(±155.073)	15.50	105.085	(±46.081)	5.50	0.008*
Buccal measurements	112.869	(±98.357)	14.00	27.659	(±15.347)	7.00	0.003*
Lingual measurements	198.563	(±136.943)		45.135	(±20.799)		0.006†

*By Mann Whitney test. †By t test for two independent samples.

Discussion

Fixed dental prostheses are the standard treatment plan for replacing missing teeth, its impact not only influence the mastication ability and patients overall good wellbeing but has an impact on psychological aspect as well.[20] Crown adaptation is the most crucial factor that affect the quality and success of any dental prosthesis. If the marginal fit is not appropriate, it leads to increased plaque accumulation, , bone loss, occurring of microleakage, gingival sulcular fluid flow followed by recurrent caries, periodontal disease and ultimately influencing the permanency of prosthetic restorations.[21]

Therefore, this study was designed to measure the vertical marginal gap to give an idea of how close the zirconia and PEEK crown margins are adapted to the finishing line. In a -vivo longitudinal pilot study conducted by Sulaya and Guttal,[11] PEEK crowns were able to be considered as a qualified prosthesis, when they were evaluated by Ryge's Criteria at a time interval of one week, one month, three months, six months, one year. Direct viewing with external measurements using stereomicroscope was applied in this study; same operator made all measurements for standardization. This method has advantage of being non-invasive. The technique is conducted by measuring the gap between the crown and tooth structure margin. Before measuring the gap there was no need for sectioning or replications of the cement space, which in turn make it less expensive and time consuming than other techniques and decreasing the chance of error.[22] All restorations were analyzed outside actual clinical environment of a dental crown, without cementation. This had a positive effect on the recording the exact marginal gaps of the crowns in this study since, cementation results in increasing marginal and internal gap of restoration, which impacts seating of the crowns.[23]

In this study, the mean marginal gap values of PEEK crowns exhibited statistically significant higher marginal gap than zirconia crowns. Thus, the null hypothesis of the study was rejected. Proximal marginal gap of PEEK crowns showed highest measurements (409.097µu) of marginal gap, while buccal measurements were (112.869µu) and lingual measurements were (198.563µu), lingual and proximal measurements are much larger than acceptable range of 120µu according to McLean and von Fraunhofer,[7] all measurements of zirconia were even lower than mentioned acceptable range this means that zirconia crowns showed better marginal fit than PEEK material, these outcomes can be linked to the semi crystalline structure of PEEK which incorporate an amount of fillers embedded in resin matrix that can lead to larger marginal gap during fabrication than zirconia which is polycrystalline.[24] The nature of selected material for crown fabrication has a significant impact on the fitting marginal gap. Our results were in agreement with a study conducted by Emad et al.[25] which also showed a higher marginal gap in PEEK crowns group than zirconia crowns, this study was accomplished using direct marginal vision with stereomicroscope as well. In a vivo study done by Roy et al.[26] the same results were obtained but the comparison of the PEEK crowns were with porcelain fused to metal (PFM) crowns, a higher marginal gap of PEEK crowns were observed with stereomicroscope, while in the same study when the method of measuring was changed to Cone beam computed tomography (CBCT) the results were opposite, PFM had a very larger marginal gap, we can conclude that method of measuring marginal gap has an effect on the ranges of readings. According to Byrne G,[27] the cemented or uncemented crowns have an influence on the marginal gap measurement. The discrepancy in result beside method of measurements, type of material, also the cemented or uncemented crowns affect the marginal gap in the time of analyzing.[27] When zirconia crowns were used as a control group to compare its marginal adaptation with PEEK crown that were fabricated by different techniques, the zirconia group had lower marginal gap, but the difference were not extensive, which also support the results of this study.[13]

Type of material might has a crucial role in reducing the marginal gap, in both studies done by Hossam et al.,[28] and, Park et al.,[29] biologically high performance polymer (Bio - HPP) type of PEEK was used, which confirming this fact, they concluded that the marginal gap of Bio-HPP prosthesis was less than Zirconia but the

difference was not statistically significant to place Bio-HPP in a better position, the outcome of these studies was returned to the fact that zirconia ceramic material fabricated by CAD/CAM technique have volume shrinkage rates of 22 - 25% of its size, during sintering, it negatively affect the fit of a dental prosthesis, because of shrinkage in presintered blanks during the sintering process. Bio- HPP does not exhibit shrinkage because of the absence of a sintering process that perhaps eliminate the shrinkage and contraction that zirconia undergoes,[29] although these outcomes are opposing this study. Implant supported PEEK crowns showed a non-significant better marginal gap than zirconia and porcelain PFM when they were evaluated in a comparative in vitro study, which takes the same side as the current study.[30]
In accordance with this study PEEK crowns were compared to zirconia and composite, and same result of higher marginal gap was recorded.[31]
Marginal fit values of 19 ± µm for PEEK three unit implant- supported framework found, which is lower than our study, when the frameworks were constructed from Bio-HPP type of PEEK material.[32]

Conclusion

PEEK crowns had a higher marginal gap measurement than clinically acceptable limit compared to zirconia. Considering the limitations of this study further investigations are required regarding evaluation of the of PEEK material for being a substitution to zirconia crowns.

Conflict of interest

The author reported no conflict of interests.

References

1. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent. 1989;62(4):405–8. https://doi.org/10.1016/0022-3913(89)90170-4
2. Alfadda S. Vertical Marginal Gap Evaluation of Conventional Cast and Computer Numeric Controlled–Milled Titanium Full-Arch Implant-Supported Frameworks. J Prosthodont. 2014;27 (6):517–22. https://doi.org/10.11607/ijp.4134
3. Wassell RW, Walls G, Steele JG. Crowns and extra-coronal restorations: Materials selection. BDJ. 2002;192(4):199–211. https://doi.org/10.1038/sj.bdj.4801334
4. Kokubo Y, Ohkubo C, Tsumita M, Miyashita A, Vult von steyern P, Fukushims S. Clinical marginal and internal gaps of Procera AllCeram crowns. Oral Rehabil. 2005;32(7):526–30. https://doi.org/10.1111/j.1365-2842.2005.01458.x
5. Nakamura T, Tanaka H, Kinuta S, Akao T, Okamoto K, Wakabyashi K, Yatani H. In Vitro Study on Marginal and Internal Fit of CAD/CAM All-ceramic Crowns. Dent Mater J. 2005;24(3):456–9. https://doi.org/10.4012/dmj.24.456
6. Fransson B, Oilo G, Gjeitanger R. The fit of metal-ceramic crowns, a clinical study. Dent Mater. 19851;5:197–9. https://doi.org/10.1016/s0109-5641(85)80019-1
7. McLean JW, Von F. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131(3):107–11. https://doi.org/10.1038 sj.bdj.4802708.0.1038/sj.bdj.4802708
8. Parmar S. An In–Vitro Comparative Study on the Marginal Adaptation of Metal Ceramic Crowns and Zirconium Dioxide Crowns with Rounded Shoulder Finish Line Preparation. IOSRJDMS. 2020;19(6):13–7. https://doi.org/10.9790/0853-1906041317
9. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig. 2015;20(7):1495–1504. https://doi.org/10.1007/s00784-015-1641-y
10. Ng J, Ruse D, Wyatt C. A comparison of the marginal fit of crowns fabricated with digital
and conventional methods. J Prosthet Dent. 2014;112(3):555–60. https://doi.org/10.1016/j.prosdent.2013.12.002
11. Sulaya K, Guttal SS. Clinical evaluation of performance of single unit polyetheretherketone crown restoration-a pilot study. J Indian Prosthodont Soc. 2020;20:38–44.
12. Zarone F, Russo S, Sorrentino R. From porcelain-fused-to-metal to zirconia: Clinical and experimental considerations. Dent Mater. 2011;27:83–96.

13. Attia MA, Shokry TE. Effect of different fabrication techniques on the marginal precision of polyetheretherketone single-crown copings. J Prosthet Dent. 2020; 124(5):565.e1–e7.
14. Hahnel S, Scherl C, Rosentritt M. Interim rehabilitation of occlusal vertical dimension using a double-crown-retained removable dental prosthesis with polyetheretherketone framework. J Prosthet Dent. 2018;119:315–8.
15. Baig MR, Tan KBC, Nicholls JI. Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system. J Prosthet Dent. 2010; 104(4):216–27.
16. Euan R, Figueras-Alvarez O, Cabratosa-Termes J, Brufau-de Barbera M, Gomes-Azevedo S. Comparison of the Marginal Adaptation of Zirconium Dioxide Crowns in Preparations with Two Different Finish Lines. Journal of Prosthodontics. 2012; 21 (4):291–295.
17. Rayyan M. Marginal Adaptation of Monolithic High-Translucency Versus Porcelain-Veneered Zirconia Crowns. Int J Prosthodont. 2019;32 (4):364–6.
18.Hamza TA, Ezzat HA, El-Hossary MMK, El Megid Katamish HA, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/ CAM systems. J Prosthet Dent. 2013;109(2):83–7.
19.Romeo E, Iorio M, Storelli S, Camandona M, Abati S. Marginal adaptation of full-coverage CAD/CAM restorations: in vitro study using a non - destructive method. Minerva Stomatol. 2009;58 (3):61–72.
20. Harish V, Ali SAM, Jagadesan N. Evaluation of internal and marginal fit of two metal ceramic system – in vitro study. J Clin Diagn Res. 2014;8 (12):ZC53–6.
21. Buso L, Higert E, Neisser MP. Marginal fit of electroformed copings before and after the coction of the porcelain. Braz J Oral Sci. 2004;3(8):409–13.
22. Gassino G, Barone Monfrin S, Scanu M, Spina G, Preti G. Marginal adaptation of fixed prosthodontics: a new in vitro 360-degree external examination procedure. Int J Prosthodont. 2004;17(2):218 –23.
23. Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and Reliability of Metods to Measure Marginal Adaptation of Crowns and FDPs: A Literature Review. Journal of Prosthodontics. 2013;22:419–28.
24. Rodiger M, Schneider L, Rinke S. Influence of material selection on the marginal accuracy of CAD/ CAMfabricated metal- and all-ceramic single crown copings. Article ID 2143906. Biomed Res Int. 2018;2018:1–8
25. Meshreky M, Halim C, Katamish H. 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". Advanced Dental Journal. 2020;2(2):43–50. https://10.21608/adjc.2020.21032.1043
26. Roy MS, Tewary S, Sanyal P, et al. An in vivo study to compare the marginal fit accuracy of crowns prepared using two different materials. J. Evolution Med. Dent. Sci. 2019;8(24):1930–4. https://10.14260/jemds/2019/424
27. Byrne G. Influence of finish-line form on crown cementation. Int J Prosthodont. 1992;5:137–144.
28. Hossam M, Elshahawy W, Masoud GE. Evaluation of Marginal Adaptation and Fracture Resistance of Bio HPP and Zirconia. EDJ. 2018; 64:1489–501.
29. Park JY, Bae S-Y, Lee JJ, Kim JH, Kim HY, Kim WC. Evaluation of the marginal and internal gaps of three different dental prostheses: comparison of the silicone replica technique and three-dimensional superimposition analysis. Journal of Advanced Prosthodontics. 2017;9(3):159–69.
30. K. Amin B. Comparative Study of Marginal Gap Among Zirconium Dioxide, Poly Ethyl Ethyl Ketone and Porcelain Fused to Metal Implant Supported Crowns. Sulaimani Dent J. 2019;6(1):29–32.
31. Zeighami S, Ghodsi S, Sahebi M, Yazarloo S. Comparison of Marginal Adaptation of Different Implant-Supported Metal-Free Frameworks Before and After Cementation. International Journal of Prosthodontics. 2019;32(4):361–3.
32. Jin H, Teng M, Wang Z, Li X, Liang J, Wang W. Comparative evaluation of Bio-HPP and titanium as a framework veneered with composite resin for implant-supported fixed dental prostheses. The Journal of Prosthetic Dentistry. 2019;122(4):383–8. https://10.1016/j.prosdent.2019.03.003