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Marginal Accuracy and Fracture Resistance of Cement Retained, Screw Retained and Combined Cement Screw Retained Implant Supported Zirconia and PEEK Crowns

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Abstract

Purpose: This study aimed to evaluate the marginal accuracy and fracture resistance of the implant-supported by cement, screwed type, or a combination of both cemented and screwed Zirconia and polyetheretherketone (PEEK) crowns. **Patients and methods:** All 36 implants supported molar crowns were chosen in this study then divided into three groups ($n = 12$) group I: cement-retained, group II: screw-retained, and group III: combined cement-screw retained, then each group was further subdivided into two subgroups ($n = 6$) according to superstructure material. Subgroup A: Zirconia crowns and subgroup B: PEEK. After cementation or screwing of the crowns, they were subjected to thermo cycling. Then the marginal gap, fracture resistance, and failure mode were evaluated for all the tested crowns. **Results:** The results of the current study recorded that the marginal gap for PEEK crowns was higher than that for the Zirconia one moreover; it was increased after cementation for both materials. Regarding the fracture resistance the highest values were recorded in group III for both materials followed by group I Zirconia and the lowest value was recorded in group I PEEK. Regarding the failure modes they were either cracks, chipping of veneer, crown fracture and fixture failure. **Conclusion:** For all tested crowns, the marginal gap distance was within the acceptable ranges. The fracture resistance of Zirconia crowns was greater than PEEK crowns.

Keywords: Cement-screw retained, Fracture resistance, Polyetheretherketone, Zirconia

1. Introduction

A surgical implant is a part placed into the jaw bone to provide support for the superstructure materials which may be fixed or removable prosthesis. It is considered the best treatment option for restoration of missing tooth or teeth. It becomes more popular because of its superiorities of restoring the masticatory function, satisfying aesthetics, and being permanently fixed [1].

The superstructure materials can be attached to the dental implant by screwing them on the implant through castable restorations using ULCA abutment or one-piece computer-aided design/computer-aided manufacturing (CAD/CAM) restorations, or on a screwing onto implant abutment using multiunit abutment. Another method of attachment is to cement the crown onto CAD/CAM or prefabricated abutments [2,3].

Another technique has been suggested which is screw-retrievable cement retained restorations that combines cement and screw retained implant prosthesis, combination prosthesis or hybrid restorations. In this technique the superstructure crowns should contain occlusal openings because these crowns are cemented on the abutment extra orally. After setting of the cement, the abutment crown interface is polished then the abutment-crown assembly is screwed into the patient's mouth [4].

The superstructure materials used in dental implants play a crucial role since the forces acting on the implant and bone interface can be passed

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through it, causing marginal bone changes or catastrophic failures. The development of novel materials is also influenced by patients' growing need for materials that appear beautiful and have good mechanical characteristics [5].

The excellent mechanical and aesthetic qualities of Zirconia ceramics have made it a popular material for dental applications. These restorations are available in a monolithic or full-contour Zirconia restoration and Zirconia veneered restorations [6].

A metal-ceramic and all-ceramic repair substitute, known as polyetheretherketone (PEEK), has been proposed as an implant-supported replacement. It is a biomaterial utilized in orthopedics for many years. Its lower elastic modulus which is comparable to human bone is what makes this material unique and allows it to absorb masticatory cycle energy and provide a cushioning effect [7].

The strength and marginal fitness for any restoration are important factors for its clinical success. Marginal inaccuracy may expose the luting material to the oral atmosphere, resulting in cement degeneration, caries, marginal discoloration, and biologic complications in the case of implant-supported prostheses. Since the clinical performance of any material depends on its capacity to sustain the occlusal forces without breaking, restorations with greater strength have been developed for withstanding functional pressures in the mouth [8].

Accordingly, the goal of the current study was to assess the fracture resistance and marginal accuracy of cement, screw, and cement-screw retained implant-supported Zirconia and PEEK crowns.

2. Patients and methods

2.1. Ethical approval

The Research Ethic Committee (REC), Faculty of Dental Medicine for Girls, Al-Azhar University, Egypt, has approved and confirmed the current study, with code REC-CR-23-10.

2.2. Sample size estimation and statistical power

Analysis of variance test or an equivalent nonparametric test was used to study the effect of retention mode (cement, screw, or combined) and crown material type (Zirconia, PEEK) on fracture load and to compare between groups. According to a previous study [9], the mean fracture load ranged from 2125.1 ± 293.82 to 2508 ± 153.6 and 2718 ± 266.25 using different retention modes. A previous study [10] reported that the fracture load ranging from 950.75 ± 34.6 to 2070.5 ± 100.24 in different crown types. A total sample size of 36 (12 in each group, to be further subdivided into equal subgroups six in each subgroup was determined using G power statistical power Analysis program (version 3.1.9.7) for sample size determination [11].

2.3. Sample preparation

A 36 implants (Implant Direct, Sybron Manufacturing LIC, Thousand Oak, CA, USA) with dimensions of 4.2 mm in diameter and 11.5 mm in length were embedded in an auto-polymerizing polyester resin (KEMAPOXY150, Giza, Egypt) with high mechanical and chemical resistance and a solvent-free transparent epoxy with an elastic modulus that is comparable to that of the human body. The implants were centralized in the resin using a dental surveyor [8,9].

They were divided into three groups. Group I: cement-retained, group II: screw-retained, and group III: combined cement-screw retained according to mode of retention. Then, each group was subdivided according to material into: subgroup A: Zirconia crowns and subgroup B: PEEK crowns. In this study all the implant-supported Zirconia or PEEK crowns were constructed representing the mandibular first molar according to previous studies [9,12].

(I) Group I Crown fabrication steps:

(a) Scanning of implant abutment

The implant abutment (Implant Direct, Sybron Manufacturing LIC, Thousand Oak, CA, USA) was fixed to the dental implant and then sprayed with a light-reflecting spray (Occlutec spray -Renfert, GmbH, UntereGiesswiesen, Germany) and secured on the scanner on scan box (Smart optics scan Box Pro, Germany) for taking optical impression.

(b) Designing and milling of the crowns

Full contoured crowns of mandibular first molar in case of Zirconia crowns and coping for PEEK crowns were designed using in-lab three dimensional (3D) software (DentalCad, Exocad, Germany). Zirconia discs (Kuraray Noritake Dental Inc. Japan) were fixed in the milling machine (Roland DWX-51D, Japan) and milled with 25 % enlargement in size to compensate for the sintering shrinkage. After that, the crowns were separated from the zirconia disc by using a bur. For PEEK coping, PEEK disc (bre-CAM BioHpp, Bredent GmbH and Co.KG, Senden, Germany) was fixed in the milling machine (Roland DWX-51D, Japan) to be milled.

(c) Sintering and finishing of Zirconia crowns

The crowns were placed in high-temperature speed furnace (HTC, Sirona, Germany) and sintered as recommended by the manufacturer. All the crowns were then ultrasonically cleaned. Then Glaze paste (Ivoclar Vivadent AG, Schaan/ Liechtenstein, Germany) was applied evenly on the entire crown using a brush. Glaze firing was done according to the instruction of manufacturer (Fig. 1, A1 and B1).

(d) Veneering and finishing of PEEK crowns

The PEEK copings were then veneered using a veneering composite by the guide of silicon index that have the same dimensions and shape of full contoured crowns to recreate the shape precisely. Then adhesive (Visiolink, Bredent GmbH and Co.KG, Senden, Germany) was painted above the frame work to facilitate bonding of composite veneers (Visiolign, Bredent GmbH and Co.KG, Senden, Germany). A calibrated caliper was used to measure the mesiodistal and buccolingual diameter of the crowns after veneering confirming that the dimensions were the same for each of them. Then samples were finished using polishing paste (Bredent GmbH and Co.KG, Senden, Germany) and silicon polisher then cleaned on ultrasonic path for 5 min (Fig. 2, A1 and B1).

(II) Group II Crown fabrication steps:

(a) For Zirconia crown fabrication:

Screw retained one piece Zirconia crowns were constructed using the press-on veneering technique for the prefabricated Zirconia abutment. In this group, the crown dimensions were standardized using the same dimensions previously mentioned in group I. The procedures were summarized as follows:

(i) Scanning of the implant abutment

Prefabricated Zirconia abutment (Implant Direct, Sybron Manufacturing LIC, Thousand Oak, CA, USA)was scanned as that of group I.

(ii) Designing and milling process

Full contoured crowns of mandibular first molar were designed on the scanned Zirconia abutment, using in-lab 3D software (DentalCad, Exocad, Germany) with an occlusal surface of 2 mm screw channel and the same dimension of the crowns on the cement-retained Zirconia subgroup. The wax disc (Ymahach, wax disc, Japan) was fixed in its place in the milling machine (Roland DWX-51D, Japan) and used the same milling preview design that was saved in the software, the milling procedure was carried out to create identical restorations.

(iii) Veneering process

After milling of the wax pattern, it was attached to the abutment then sprue. The sprue pattern was invested using Press Vest special investment material (IPS, Ivoclar Vivadent, Liechtenstein Germany). After setting of the investment preheating and wax elimination process was done. Once the investment ring was preheated, the pressing process was done using an ingot of the IPS e.max ZIR Press (Ivoclar Vivadent, Liechtenstein Germany) and the pressing program was selected and activated according to the instructions of manufacturer. The crowns were then divested and sprue separated then cleaned in ultrasonic path for 5 min. Crystal/glaze paste (Ivoclar Vivadent AG, FL-9494 Schaan/Liechtenstein Germany) was applied evenly on the entire crown using a brush and fired (Fig. 1, A2 and B2).

(b) For PEEK crowns fabrication:

(i) Scanning of the implant abutment

Ti-base (Ritter implants GmbH and Co.KG, Boberach, Germany) was scanned as that of Group I.

(ii) Designing of the crowns

PEEK coping of mandibular first molar were designed on the scanned Ti-base using in-lab 3D software (Dental Cad, Exocad, Germany) with 2 mm hole on the occlusal surface and the same dimension of the copings on the cement-retained PEEK sup-group. The steps of milling, spruing and investing of the wax pattern were the same as for Zirconia crowns.

(iii) Preheating and pressing procedure

The muffle and press plunger were placed in 850 °C preheating furnace for 60 min which was cooled down afterwards with 8°/min to 400 °C. After 20 min of waiting at this temperature, PEEK pellets (Bredent GmbH and Co.KG, Senden, Germany) were filled into the muffle's melt reservoir and the melting period accounted for 20 min. The molten PEEK with muffle and press plunger were placed into the pressing table of the pressing device (For 2 Press, Bredent, Germany). The pressing process was then run automatically. Then veneering was done with the same procedure as group I (Fig. 2, A2 and B2).

(III) Group III Crown fabrication

The scanning procedures were done for Ti-base (Ritter implants GmbH and Co.KG, Boberach, Germany) in the same manner as PEEK group II. The designing procedures for both Zirconia and PEEK crowns were the same as that of group II. The milling of both materials, sintering, and finishing of Zirconia crowns, and veneering and finishing of PEEK crowns were done with the same procedures as that of group I (Figs. 1 and 2 (A3 and B3)).

2.4. Cementation of the crowns

In group I and III Before cementation surface treatment for the abutment and crowns was performed as illustrated in (Table 1).

Rely X Unicom resin cement (3 M ESPE, Germany) was applied to the interior surface of the crowns after that the crowns were positioned directly onto the abutments for the cement retained group or Ti-base for the combined cement-screw

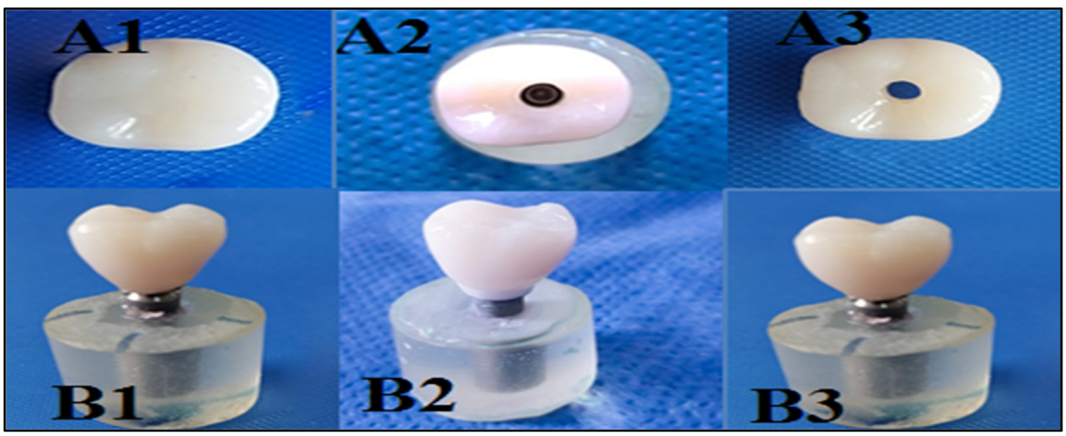

Fig. 1. Finished Zirconia crowns A1 and B1cement retained group, A2 and B2 screw retained group, and A3 and B3 combined cement-screw retained group (A: occlusal view, B: crown seated on the implant).

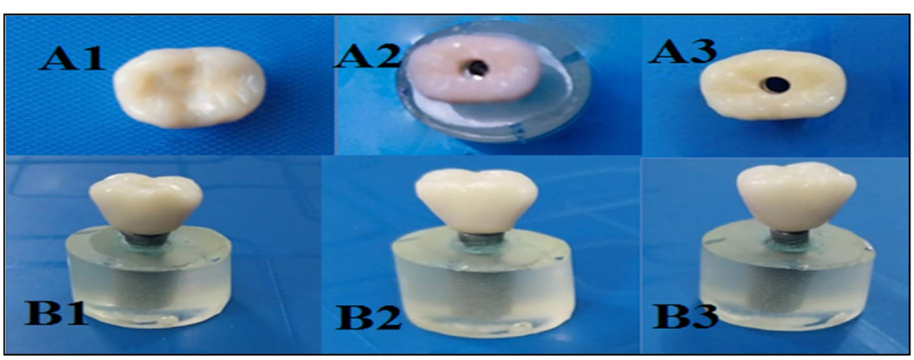

Fig. 2. Finished PEEK crowns (A: occlusal view, B: crown seated on the implant) (A1 and B1: cement retained group I, A2 and B2: screw retained group. A3 and B3: combined cement-screw retained group).

Table 1. Surface treatment procedures for abutments and supra structures.

Components	Surface treatments
Implant abutments and Ti-bases [13,14]	Using 110-μm aluminum oxide and 2-bar pressure for 10 s, they were blasted with airborne particles and then cleaned ultrasonically.
Zirconia crowns [13,14]	The crown 'sinner surface was sandblasted with 50 μm Al_2O_3 at 2.0 bar then ultrasonically cleaned for 10 min and primed with Zirconia primer
Peek crowns [14]	The inner surface of the crowns were air abraded using 110-μm aluminum oxide and 2-bar pressure for 10 s then ultrasonically cleaned and Visio-Link Primer was then applied

retained group. It was then light-cured after excess cement removal.

2.5. Thermo cycling procedure

Using an automated thermal cycling apparatus (Robota automated thermal cycle; BILGE, Turkey), all samples underwent a thermal aging procedure for 5000 cycles [13]. Each water bath had a dwell period of 25 s and a lag time of 10 s, 5 °C was the low temperature and 55 °C was the maximum temperature.

2.6. Testing procedures

2.6.1. Marginal and internal gap measurements

The vertical and horizontal marginal gap between the abutment finishing line and the crown margin was measured using a digital microscope (U500× Digital Microscope, Guangdong, and China) at 35× magnification. At five random points on each axial surface, the assessment was recorded before and after cementation in group I, and group III while it was recorded once in group II.

2.6.2. Fracture resistance testing

A computer software program (Blue Hill Lite Software, Instron, USA)was used to record the data from each sample that was mounted on computer-controlled testing equipment (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a 5 KN load cell. Tighten the screws were secured in each sample to the testing machine's lower immovable part. Utilizing a metallic rod with a 5 mm diameter round tip attached to the testing machine's top compartment, a compressive load was applied occlusally to perform the fracture test. The load applicator and the sample are separated by a tin foil sheet to ensure uniform stress distribution (Fig. 3).

Fig. 3. Sample fixed on the universal testing machine.

2.6.3. Failure mode analysis

Each sample from the test groups was examined using a digital microscope (U500× Digital Microscope, Guangdong, China) with a 35× magnification after the fracture resistance test to identify the failure mechanism.

2.7. Statistical analysis

One-way analysis of variance followed by Post Hoc test was applied for multiple comparisons between different groups and time intervals for parametric data analysis. The comparison of mode of failure results between the three studied groups was done using Kruskal—Wallis followed by the Mann—Whitney test for pairwise comparisons (Nonparametric test). *P* value less than or equal to 0.05 was considered statistically significant (*P* value ≤ 0.001 was considered highly statistically significant (99 % significance level).

3. Results

3.1. Results of marginal gap distance

Regarding the Cement-retained group, comparing the marginal gap between the two materials used, the mean marginal gap of the PEEK crown showed a statistically nonsignificantly higher than Zirconia crowns in the vertical and horizontal marginal while regarding the gap distance it was increased in both materials after cementation however; both were within the clinical range).

3.2. Regarding the screw-retained group

Zirconia crowns achieved the highest vertical marginal gap compared with PEEK one, while in the horizontal measurement, the PEEK crowns achieved the highest marginal gap over Zirconia as shown in (Table 2).

Table 2. Compare between the mean values of the vertical and horizontal gap for both materials before and after cementation in group II.

	Screw retained Zirconia crowns	Screw retained PEEK crowns	*P* value*
Vertical gap (μm)			
Buccal	42.63 ± 6.09	27.71 ± 2.59	0.078^{NS}
Mesial	51.32 ± 10.74	27.74 ± 7.39	0.001^{HS}
Lingual	48.78 ± 11.81	29.09 ± 2.93	0.007^{S}
Distal	40.71 ± 7.79	30.24 ± 7.64	0.416^{NS}
Horizontal gap (μm)			
Buccal	59.58 ± 6.53	88.09 ± 13.38	0.007^{S}
Mesial	65.61 ± 8.75	79.25 ± 12	0.539^{NS}
Lingual	63.49 ± 8.4	87.31 ± 12.65	0.036^{S}
Distal	64.11 ± 10.22	84.15 ± 14.73	0.120^{NS}

NS, nonsignificant *P* greater than 0.05; S, statistically significant; HS, highly significant.

3.3. Regarding the combined cement-screw retained group

The results of the current study revealed that the marginal gap for PEEK crowns was higher than that in the Zirconia crowns. However, both materials showed an increase in the marginal gap mean values after cementation (Table 3).

3.4. Results of fracture resistance

Regarding group I, the mean values of a load of failure was (1440.39 ± 143.25 N) in Zirconia subgroup, and (690.57 ± 153.96 N) in the PEEK. While for group II, the mean value of the load failure was (1364.56 ± 216.32 N) in the Zirconia, and (764.21 ± 78.31 N) in the PEEK. In the case of group III: the mean of the load at failure was (1565.94 ± 226.34 N) in the Zirconia, and (1061.33 ± 16.04 N) in the PEEK; obviously, the difference between the two types of materials was statistically highly significant. The highest mean load of failure was achieved with zircon material, and the difference between the two materials was highly significant. The differences between the three groups were not significant in the Zirconia material; however, it was significant in the PEEK material (Table 4).

3.5. Results of failure mode

For Zirconia crowns, 100 % of the samples failure mode were (fracture crown failure) in GI. Also, 100 % of samples achieved failure mode (chipped veneer failure) in GII. But in the GIII, 66.7 % of samples recorded fracture fixture failure, while 33.33 % of samples achieved bending of fixture failure.

For PEEK crowns, GI and GII, 33.3 % of samples have chipped veneer failure, 33.3 % of samples had fracture crown failure, and 33.3 % of samples have cracked veneer failure. While for GIII, 100 % of samples achieved chipped veneer failure (Table 5).

4. Discussion

Dental implants are considered as the treatment option with high chance of success for restoration of function and esthetic in completely or partially edentulous patients [15]. The material chosen for a dental restoration has a significant impact on its long-term success since it affects how stress is transferred to the implant or underlying abutment tooth during function [16].

Zirconia ceramics have great interest in the biomedical field because of its excellent physical, mechanical, and biological properties. It has been used in fixed or removable prosthesis, root canal posts, implant-supported crowns, implant abutments, and dental implants [16]. It is a heterogeneous highly-resistant polycrystalline ceramic with good mechanical and optical characteristics. Additionally, it is not soluble in water, has good radiopacity, excellent biocompatibility. These restorations were machined using CAD/CAM technology by either soft or hard machining [17].

Table 3. Compare between the mean values of vertical and horizontal gap for both materials before and after cementation in group III.

	Combined cement-screw retained Zirconia crowns			Combined cement-screw retained PEEK crowns		
	Before	After	*P* value*	Before	After	*P* value*
Vertical gap (μm)						
Buccal	27.7 ± 3.59	59.15 ± 9.54	0.000^{HS}	52.34 ± 14.38	79.02 ± 7.21	0.005^{S}
Mesial	24.54 ± 4.13	53.26 ± 7.26	0.000^{HS}	45.51 ± 7.5	63.04 ± 14.31	0.123^{NS}
Lingual	23.41 ± 4.45	63.28 ± 8.38	0.000^{HS}	62.31 ± 10.15	72.38 ± 6.44	0.526^{NS}
Distal	26.19 ± 4.62	63.08 ± 14.27	0.000^{HS}	61.63 ± 19.55	60.69 ± 10.2	1.000^{NS}
Horizontal gap (μm)						
Buccal	50.5 ± 5.95	110.31 ± 9.74	0.001^{HS}	75.19 ± 12.7	108.7 ± 5.16	0.001^{HS}
Mesial	53.2 ± 13.82	105.01 ± 1.78	0.000^{HS}	72.61 ± 16.8	124.29 ± 1.63	0.000^{HS}
Lingual	49 ± 14.26	105.34 ± 8.53	0.002^{S}	54.3 ± 19.36	101.03 ± 3.13	0.000^{HS}
Distal	59.67 ± 13.74	109.97 ± 6.44	0.000^{HS}	66.1 ± 17.07	107.35 ± 8.22	0.002^{S}

Overall *P* value intra-group comparison (before vs. after).
S = statistically significant at *P* less than or equal to 0.05, HS = highly significant at *P* less than or equal to 0.001, NS = nonsignificant greater than 0.05.

Table 4. Comparison of fracture resistance (N) of the two materials in the three groups.

	GI	GII	GIII	*P*-value[a]
Zirconia	1440.39 ± 143.25[a]	1364.56 ± 216.32[a]	1565.94 ± 226.34[a]	**0.240^{NS}**
PEEK	690.57 ± 153.96[b]	764.21 ± 78.31[b]	1061.33 ± 16.04[a]	**0.000^{HS}**
P value[b]	**0.000^{HS}**	**0.000^{HS}**	**0.000^{HS}**	

[a] Overall *P* value for inter-group comparison between the three groups (ANOVA Test).
[b] Overall *P* value for Intragroup comparison between the two materials (Zirconia vs. PEEK). Small letters for intergroup comparison.

Table 5. Comparison of the failure mode distribution between all groups for both materials.

	Zircon			Peek		
	GI	GII	GIII	GI	GII	GIII
Chipped veneer failure, *n* (%)	0	100	0	33.3	33.3	100
Fracture crown failure, *n* (%)	100	0	0	33.3	33.3	0
Cracked veneer failure, *n* (%)	0	0	0	33.3	33.3	0
Fracture fixture failure, *n* (%)	0	0	66.7	0	0	0 %
Bending of fixture failure, *n* (%)	0	0	33.3	0	0	0
Mean Rank	9.5	3.5	15.5	11.5	11.5	5.5
P value*	0.000^{HS}			0.044^{S}		

HS = highly significant at *P* less than or equal to 0.001- S = statistically significant at *P* less than or equal to 0.05.

Recent dental applications have utilized PEEK a linear, semi-crystalline thermoplastic high-performance polymer, as a framework material for metal-free permanent prostheses. The main advantage of this material is its low modulus of elasticity of which is about 4 GPa, so it is elastic as bone, which lessen the stress placed on the underling abutment teeth [16]. The titanium dummy implant can be used for exraoral scientific research which is identical to an implant used in clinical procedures. The implants were set into epoxy resin with a Young's modulus that is comparable to that of the bone of the jaw [8,9].

A variety of techniques, including direct seeing, cross-sectional views, impression replica techniques, and clinical assessments can be used to assess the restoration's marginal adaptability. The direct viewing method which is quick, nondestructive, and most commonly used to measure marginal discrepancy so that it was chosen for marginal accuracy evaluation on the current investigation [18,19].

In the present study, the recorded marginal gap on each tooth surface was in the clinically accepted range and the difference between them may be related to laboratory procedures such as the milling process, sintering of Zirconia restorations, and veneering process of PEEK copings.

Regarding the effect of materials on the marginal accuracy, in the present study Zirconia restoration had better marginal adaptation in comparison to PEEK one however both were within the clinically acceptable range (Tables 2, 3 and 6). These results were in agreement with the previous study which reported that the greatest gap was found in PEEK material, whereas Zirconia crowns had the least marginal gap, followed by porcelain fused to the metal crown [20].

Also the marginal gaps of all restorations were in the clinically acceptable range. This was in accordance with previous studies who concluded that the marginal gap for both restorations was within the acceptable range, with Zirconia copings demonstrating a better marginal fit than PEEK copings [8,21].

This discrepancy could be explained by the fact that PEEK has a lower elastic modulus (4 Gpa) than Zirconia (210 Gpa), which leaves PEEK restorations vulnerable to distortion from the pressure of milling burs during the milling process. Moreover, the heat produced during the milling process may result in deformation and lessen PEEK restorations' marginal adaptability. Furthermore, the veneering composite's polymerization shrinkage may have an impact on the substructure [22].

Table 6. Compare between the mean values of the vertical and horizontal gap for both materials before and after cementation in group I.

	Cement retained Zirconia crowns			PEEK Cement retained crowns		
	Before	After	*P* value*	Before	After	*P*-value*
Vertical gap (μm)						
Buccal	29.65 ± 4.78	85.68 ± 6.67	0.000^{HS}	37.02 ± 6.38	62.37 ± 0.2	0.014^{S}
Mesial	28.87 ± 4.72	92.59 ± 6.45	0.000^{HS}	33.31 ± 5.14	69.91 ± 7.65	0.000^{HS}
Lingual	33.06 ± 5.7	87.04 ± 14.27	0.000^{HS}	36.87 ± 8.42	67.41 ± 4.97	0.003^{S}
Distal	27.97 ± 2.74	74.24 ± 14.17	0.000^{HS}	33.06 ± 6.62	68.45 ± 9.66	0.001^{HS}
Horizontal gap (μm)						
Buccal	63.75 ± 21.84	101.46 ± 7.39	0.001^{HS}	70.1 ± 7.9	117.64 ± 20.5	0.000^{HS}
Mesial	51.59 ± 12.66	106.15 ± 4.08	0.000^{HS}	72.89 ± 5.01	121.57 ± 10.28	0.000^{HS}
Lingual	63.33 ± 20	104.12 ± 14.2	0.002^{S}	67.08 ± 9.53	112.27 ± 18.06	0.000^{HS}
Distal	60.58 ± 20.77	106.32 ± 11.36	0.000^{HS}	68.19 ± 12.29	111.98 ± 16.68	0.000^{HS}

Overall *P*-value Intra-group comparison (before vs. after).
S = statistically significant at $P \leq 0.05$, SS = highly significant at $P \leq 0.001$ NS=Non significant <0.05.

The results of the present study were in contradiction with previous study who reported that the PEEK restorations had a better fit than the Zirconia one and both were within the clinically acceptable range [23]. Moreover, It was reported that both frameworks' marginal discrepancies were within the acceptable range, however, the Zirconia framework displayed a nonsignificantly greater one [19].

The clinically acceptable maximum marginal opening has been reported to be at 120 μm [24]. The clinically appropriate range for long-lasting dental prosthesis is 100–200 μm reported by other studies [25]. Conversely, some noted a greater marginal divergence in 200–300 μm [26]. The marginal gap was increased after cementation as reported by the present study and this was in accordance with previous investigators who reported that cementation procedure increased the marginal gap [19,27]. It was reported that the cementation procedure increases the restoration marginal gap however it was within the clinically accepted range [28].

On the other hand, it was found that the marginal discrepancies were decreased after cementation and the marginal fit could be enhanced by cementation. It was reported that the marginal fit and small misalignments could be improved after cementation [29].

It was reported that the greatest masticatory forces detected in premolar teeth were in the range of 200–445 N while for molar teeth were about 900 N [30]. The maximum occlusal force for individuals with implant-supported prostheses was found to be 206.1 ± 87.6 N for first premolars, 209.8 ± 88.2 N for molars, and 293.2 ± 98.3 N for second premolars [31].

Regarding the fracture resistance, fracture resistance of Zirconia crowns were higher than that of PEEK one and group III that combined cement-screwed retained type on both materials reported the highest mean of the load of failure, but the results were significant in PEEK crowns and insignificant in Zirconia one as shown in (Table 4) and this is was in accordance with previous studies [10,14,32] who reported that Zirconia restorations had a higher fracture resistance than PEEK restorations.

The possible explanation for higher fracture resistance of Zirconia in comparison to PEEK restoration is that the used Zirconia restoration is monolithic while PEEK is bilayered and consists of coping material which is then veneered by composite veneer. It was reported that the monolithic Zirconia ceramics structure has the potential to enhance the performance of these restorations, because of its geometric and material characteristics, which seem to reduce the likelihood of fracture [33]. Another explanation is the lower Young's modulus (3–4 GPa) of PEEK in comparison to Zirconia (E-modulus 210 GPa) that are perceived to offer insufficient support that in turn increases the stress on the surrounding structure [34].

On the other hand, a previous study found that PEEK copings exhibited better resistance to fracture than Zirconia one. The difference in the results may be related to using core materials without veneering and the absence of thermal cycling fatigue in that study [8]. Also another study found that the resistance of fracture of PEEK crowns was higher than Zirconia and lithium disilicate crowns [35].

Regarding the failure mode of PEEK crowns, the fracture patterns were composite veneer failure or complete crown fracture (Table 5) and this with in agreement with a previous study that found both types of failure among the tested PEEK frameworks [36].

While in cement-retained and combined cement-screw retained Zirconia groups the fracture patterns were fracture crown or fracture abutment and screw bending (Table 5) and this was in agreement with that reported by other studies [13,37] which concluded that the significant stress accumulation on the screw head and abutment caused by the high elasticity modulus of Zirconia may be the cause of these catastrophic fractures.

The failure mode of screw-retained Zirconia was veneer fracture which was similar to that reported by other study [38]. It was reported that the most common technical failure in the coating of CAD/CAM Zirconia crowns is fracture of the porcelain veneer [39].

4.1. Conclusion

Within limitations of the present study the following were concluded:

(a) The marginal accuracy of all tested crowns is within the acceptable range however Zirconia crowns showed better marginal adaptation than PEEK crowns.
(b) The fracture resistances of Zirconia crowns are superior to peek crowns in all the tested groups.
(c) Combined cement-screw retained group showed the highest fracture resistance in comparison to the cement-retained or screw-retained.
(d) Cement retained PEEK group showed the least fracture resistance value.
(e) The failure modes of peek crowns were mainly repairable while in Zirconia crowns it ranges from repairable and irreparable form.

4.2. Recommendation

Further *in-vitro* study will be needed to compare the fracture resistance of monolithic and veneered PEEK restorations to know whether the veneering process affects their fracture. Also, *in-vivo* trials will be needed to evaluate the clinical success of the tested groups in the present *in-vitro* study.

Conflict of interest

There are no conflicts of interest.

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