Clinical Evaluation of Internal Fit of Milled BioHPP Polyetheretherketone (PEEK)-Based Versus Zirconia-Based Single Crowns

(Randomized Clinical Trial)

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ABSTRACT

Objective: To evaluate the internal fit of milled BioHPP PEEK- copings veneered with Visio.lign composite resin in comparison with zirconia coping veneered by e-max as single posterior crown.

Material and Methods: Twenty full coverage posterior crowns were fabricated for endodontically treated molars divided into 2 groups according to the material used. Ten zirconia crowns (Group 1) and milled BioHPP PEEK-based crowns (Group 2). The preparations were standardized with an equi-gingival, deep chamfer finish line for all teeth. BioHPP PEEK and zirconia copings were fabricated by CAD/CAM technology. These coping were veneered according to manufactures instructions either by special composite resin or low fusing glass ceramic respectively. The internal fit of crowns were recorded using a replica technique with
light body silicone material stabilized with a regular set putty. Each replica was sectioned buccolingually and mesiodistally and then evaluated at six pre-determined sites using a stereomicroscope at 30× magnification. The restorations were cemented then clinical evaluation of these crowns was assessed regarding patient satisfaction and secondary caries during each recall visit using questionnaire. These measurements were repeated after two, four, six, eight, ten and twelve months respectively.

**Results:** The mean marginal gap values of PEEK crowns showed non significant higher marginal gap than Zirconia crowns (P-value = 0.260, Effect size = 0.507). There was no statistical significance difference between both groups in bucco-lingual and mesio-distal direction. PEKK crowns have accepted internal fit because of the absence of a sintering process and, therefore, of contraction.

**Conclusion:** BioHPP PEEK-based crowns showed clinically similar and accepted internal fit as zirconia crowns. So BioHPP PEEK-based crowns may be used as an alternative tooth-colored metal-free fixed restoration for one year.

**Keywords:** BioHPP, internal fit, Patient satisfaction, PEEK, zirconia.

**INTRODUCTION**

Dental restorations success is mainly evaluated by their biocompatibility, esthetics, marginal adaptation and resistance to fracture. Marginal adaptation is the function of the degree of cement film exposure in the oral cavity as poor fit can shorten the longevity of restoration.\(^1\)

One of the key factors for the success of restoration esthetically is the internal fit of indirect restorations.\(^2\) Excellent internal fit will enable crown seating without marginal gap, so marginal adaptation is considered the functional key of internal fit. Marginal gap may cause marginal leakage and crown failure.\(^3\)

In dentistry, the introduction of computer-aided design/computer-aided manufacture (CAD/CAM) technology has enabled the successful use of a variety of materials. In compare to conventional procedures, using digital methods to produce fixed restorations has gained popularity. Furthermore, this technology allows for the precise shape of materials, which is difficult to achieve with the traditional manual method of making a dental replacement.\(^4\)
PEEK (BioHPP polyetheretherketone) has shown high biocompatibility, high temperature resistance, good mechanical properties, high, chemical stability, polishability, good wear resistance, low plaque retention, and high bond strength with veneering composites and luting cements, despite its recent introduction in dentistry. Polyetheretherketone (PEEK) is a polymer that has many potentials uses in dentistry. Polyetheretherketone (PEEK) can be used to support fixed dental prostheses. However, information about physio mechanical characterization is still scarce.

Patients’ desire for maximum esthetics and translucency were met with the development of all-ceramic crowns. The introduction of zirconia material highlighted a true advancement in development of ceramic restorations because of its excellent unique combination between high fracture toughness and flexural strength. In addition, the absence of glass and dense polycrystalline microstructure provides resistance to hydro-fatigue.

Therefore, this study was carried out to evaluate the internal fit of milled BioHPP polyetheretherketone (PEEK) –based versus zirconia-based single crowns. The research hypothesis was null hypothesis as there will be no difference in internal fit between BioHPP PEEK crowns and zirconia based crowns.

MATERIALS AND METHODS

Study design:

This study was performed in Fixed Prosthodontics Department clinics, Faculty of Dentistry, Cairo University, Cairo, Egypt. A total of 20 esthetic crowns were included in the study and completed by one operator (the researcher) who followed a strict clinical procedure. Two groups (10 crowns in each group) were included in the study. The crowns were fabricated by one experienced dental technician. This study was a randomized controlled clinical trial with a 1:1 allocation ratio.

Participant’s selection:
The patients were selected for the study with an age range between 18 to 50 years old. Each participant received a full coverage restoration for a posterior tooth. Their chief complaint was to protect the tooth or restore function properly. The treatment plan was explained for each patient. Then, they agreed to sign the informed consent before proceeding to clinical work. They were able and willing to maintain good oral hygiene measures.

They were recruited during the time from January 2020 till July 2020 from the outpatient clinic of Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt. Screenings of patients were carried out until target number was reached. This study was completed by August 2021. Full medical and dental history was obtained from all participants.

**Inclusion criteria:**

1) From 18-50 years old, be able to read and sign the informed consent document.
2) Psychologically and physically able to withstand conventional dental procedures.
3) Have no active peridontal or pulpal diseases, have teeth with good restorations.
4) Patients with teeth problems indicated for single posterior crowns:
   a) Badly decayed teeth
   b) Teeth restored with large filling restorations
   c) Endodontically treated teeth
   d) Spacing between posterior teeth
   e) Malformed teeth
   f) Malposed teeth (Tilted, over-erupted, rotated, etc.)
5) Able to return for follow-up examinations and evaluation

**Exclusion criteria**

1) Patient age less than 18 or more than 50 years
2) Patient has poor oral hygiene and uncooperative patients
3) Patients with active resistant periodontal diseases
4) Pregnant women
5) Psychiatric problems or unrealistic expectations
6) Patients in the growth stage with partially erupted teeth
7) The opposing dentition is missed in the area of interest
8) Patients suffer from parafunctional habit
9) Smokers

Randomization:

Randomization was carried out using computerized sequence generation (https://www.randomizer.org) in the Center of Evidence Based Dentistry, Cairo University. Participants were assigned in two groups (1 or 2) according to the material type of the restoration received. Each participant received a sealed opaque envelope with their randomized number. Group (1) received zirconia single posterior crowns while group (2) received BioHPP PEEK single posterior crowns. (Table I): Sample grouping

<table>
<thead>
<tr>
<th>Group (A)</th>
<th>Group (B)</th>
<th>Total number of crowns</th>
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<tbody>
<tr>
<td>Intervention group</td>
<td>Control group</td>
<td></td>
</tr>
<tr>
<td>BioHPP PEEK crowns (n=10)</td>
<td>Zirconia crowns (n=10)</td>
<td>(n=20)</td>
</tr>
</tbody>
</table>

Table I Sample grouping

Blinding:

The outcome assessors (prosthodontist colleagues) and the participants were blind (double blinding) to the material while the operator (the researcher) will not due to the difference in restorative material presentation and application protocol.

Clinical procedure:

Diagnostic phase:
16 patients with 20 molars, 13 in the mandible and 7 in the maxilla were treated. All patients received the same clinical protocols by the same experienced operators. After patient’s history (medical, dental) followed by dental examination was done including assessment of remaining tooth structure, occlusal scheme, periodontal condition, oral hygiene, dental caries and parafunctional habits.

Radiographic examination to assess the quality of the endodontic treatment, alveolar bone level and crown/root ratio. Scaling and polishing were performed for each patient before start of tooth preparation to remove any dental plaque and calculus which will affect the results and shade selection. Pre-operative photographs for each patient were taken using 105 mm Nikon macro lens with twin flash R1C1 mounted on Nikon D7100 DSLR camera (Nikon, Japan.) For teeth with substantial loss of tooth structure resulting from caries or fracture, endodontically treated (at least 1mm of tooth structure above the gingival), composite core (Build-It FR, Pentron clinical. USA) were used along with glass-fiber posts (FibreKleer 4X, Pentron clinical. USA), if required, to create the required proper retention and resistance form. The shade of the teeth was recorded visually using VITA 3D-Master and Vita Classic shade guide system (VITA, Zahnfabrik, Germany) for e.max and Bio HPP crowns respectively.

**Tooth preparation phase:**

Teeth preparation started with orientation grooves on the occlusal, buccal and lingual surfaces to in order to standardize the amount of the preparation and ensure equal thickness of the restorative materials.

Tooth preparation was done for the axial wall reduction (1mm) by tapered stone with round end (head length=10mm and end Ø =1.1 mm) (850-314-016, Komet, Germany), occlusal reduction (2 mm), deep chamfer finish line thickness (1mm), cavosurface angle of the preparation was 90° to prevent unfavorable distribution of forces on the crown.

All sharp line angles that might serve as a point for stress concentration were rounded. Functional cusp bevel was performed with 45° to the long axis of the functional cusps.

A retraction cord (AtriaPak, South Korea) was used to allow accurate impression making. Final impressions were taken using Polyvinyl siloxane (PVS) addition silicon (Zhermack, Elite® HD + Putty soft, fast set, Italy) in plastic stock trays with two steps impression technique. Once the dental laboratory received the final impression, the master cast was poured with a type IV dental stone according to manufacturer’s instruction to produce the master cast.
**Laboratory procedure:**

Regarding to the crown coping of both materials, it was fabricated digitally but for the veneering material, it was added manually to the coping. An extra oral scanner (InEos X5, Cerec, Sirona) was used to scan the master cast and a three-dimensional image was obtained for abutment tooth on the computer screen. Designing was done using Exocad software (Exocad software, Exocad GmbH, Germany) and the captured pictures were saved in the preparation folder. The software calculated a virtual model from the scanned pictures and an automatic margin finder was used for preparation margin detection. Regarding zirconia copings, marginal thickness was set at 0.3-0.5 mm and axial wall thickness and occlusal thickness were set at 0.3-0.5 mm, that’s according to manufacturer instructions. According to Emax veneering material, axial wall thickness was set at 0.5 mm and the occlusal thickness was set at 1 mm, that’s according to manufacturer instructions. Regarding PEEK copings, marginal thickness was set at 0.7-1 mm and axial wall thickness was set at 0.7–1 mm, that’s according to manufacturer instructions. According to composite veneering material, the axial wall thickness was set at 0.3 mm and the occlusal thickness was set at 0.5 mm, that’s according to manufacturer instructions. Using 5-axis milling machine the provisional/try in crowns were milled from the PMMA blocks. The CAD/CAM PMMA was initially tried to check marginal fit, shape, contacts, contour and then the overall integration with the cheeks and finally with the teeth face. This was then used as the provisional restoration which can be considered as functional try in.

**Replica technique:**

The internal fit of the restoration was evaluated clinically by two dimensionally replica technique. After provisional crowns removal in the clinic, the preparation were cleaned. Before fit recording, a try-in stage was performed to ensure that each crown was completely seated, and flossing was possible with light click. Each crown was filled with the light body material (low viscosity silicone) and seated onto the abutment tooth and held in place with maximum finger pressure to simulate clinical crown cementation. (Figure 1 a,b)
Figure 1: a) Crown filled with light impression material and b) seated with finger pressure

Excess silicone material was removed with a cotton pellet. After the Intra-oral setting time of the impression material, the crown was carefully removed. A thin film of the light body impression was adherent to the inner surface of the crown in all cases. Each crown was inspected to ensure that the inner surface was completely covered with the light body material, in presence of any defect or distortion in this layer, this step was repeated. (Figure 2 a,b)

Figure 2: a) Excess material removed with cotton pellet and after setting of the light impression material, b) crown was removed and inspected for complete coverage of light body

In order to support the thin film, heavy bodied material of contrasting colors was used (to obtain a good contrast for the discrimination of the different layers). The heavy body silicon material was injected over the light layer and placed against glass slab until complete setting of the material. (Figure 3)
Figure 3: Heavy body impression material was injected to support the light body layer.

After setting, the crowns and the two layers of silicon were separated. (Figure 4 a,b)

Figure 4: a) The two layers separated from the crown, b) final replica.

The replica was sectioned with razor blade mesio-distally and buccolingually, yielding four slices per crown. Replica film thickness was captured by means of a stereomicroscope (M-125, Leica, Bensheim, Germany) at magnification factor x40, with a built-in charge-couple device camera (Hitachi CCTV HV-720E, Hitahi Ltd., Tokyo, Japan). Image analysis software (Leica Application Suite, Leica, Bensheim, Germany) was used to measure film thickness. The
gaps of the light body layer were then measured at predefined points:

Fossa discrepancy (P1): Measured from the coping to the abutment at the lowest point of the fossa of the preparation.

Crest discrepancy (P2): Measured from the coping to the abutment at highest point of the cusp tip.

Crest discrepancy (p3): Measured from the coping to the abutment at highest point of function cusp bevel in bucco-lingual direction.

Axial adaptation (P4): Was the perpendicular measurement from the internal surface of the coping to the axial wall of the preparation.

Chamfer discrepancy (P5): The distance from the coping to the abutment surface at the finish line of the preparation.

Marginal gap (P6): The shortest distance from the coping to the abutment surface close to the preparation finish line.

All measurements were recorded in microns and exported to a spreadsheet (Microsoft Excel 2007, Microsoft Corp. USA). The overall misfit discrepancy was also calculated so as to obtain an overall misfit comparison between the two groups. (Figure 5)

Figure 5: Photo of replica under stereomicroscope with measurements at predefined points

**Cementation of the crowns:**

In order to remove remnants of provisional cements that may cause a significant decrease in the bond strength of the luting agent, a prophylaxis paste and polishing brush mounted on low speed contra angle was used for cleaning the tooth surfaces prior to bonding. Then, isolation was granted through the use of cotton rolls. The fitting surfaces of PEEK
group were conditioned by blasting the restorations at 2 to 3 bar blasting pressure with aluminum oxide (110 µm and 50 µm). The crowns of both groups were cemented on the abutments using a resin luting cement (BisCem®, Bisco, U.S.A). A waxed dental floss was used inter-dentally for complete removal of excess cement in between crown and adjacent teeth. Moreover, an articulating paper was used to check for any occlusal interferences after complete curing.

The patients were instructed to perform brushing and flossing regularly, using non-abrasive fluoridated tooth paste and soft brush.

Follow up sessions:

3 evaluators assessed the outcomes of each group. The total duration time of the study was 1 year. Data were collected from the patients pre-operatively, post cementation (Base-line), 3, 6, 9 and 12 months.

Statistical analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Age data showed normal (parametric) distribution while gap distance and patient satisfaction scores data showed non-normal (non-parametric) distribution. Data were presented as mean, standard deviation (SD), median and range values. For parametric data, Student’s t-test was used to compare between mean age values in the two groups. For non-parametric data, Mann-Whitney U test was used to compare between the two groups. Friedman’s test was used to study the changes by time within each group. Dunn’s test was used for pair-wise comparisons when Friedman’s test is significant. Qualitative data were presented as frequencies and percentages. Fisher’s Exact test was used to compare between the two groups. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

A. Internal fit (Gap distance -µm)

1-Bucco-Lingual (BL) direction: (Figure 6 )

a. Comparison between groups:
At all points; there was no statistically significant difference between median gap distances in the two groups (P-value = 0.091, Effect size = 0.794), (P-value = 0.057, Effect size = 0.912), (P-value = 0.495, Effect size = 0.336), (P-value = 0.725, Effect size = 0.154), (P-value = 0.139, Effect size = 0.682) and (P-value = 0.138, Effect size = 0.702), respectively. As regards to the overall gap distance (mean of all points of measurement); there was no statistically significant difference between median gap distances in the two groups (P-value = 0.260, Effect size = 0.507).

b. Comparison between points of measurement within each group:

As regards to PEEK group; there was a statistically significant difference between gap distances at different points of measurement (P-value <0.001, Effect size = 0.762). Pair-wise comparisons between the points revealed that P2 showed the statistically significantly highest median gap distance. P1 showed statistically significantly lower median value followed by P3 then P6 with a statistically significant difference between these points. There was no statistically significant difference between P4 and P6 points; both showed the statistically significantly lowest median gap distance values. As regards Zirconia group; there was no statistically significant difference between gap distances at different points of measurement (P-value = 0.194, Effect size = 0.147).

Figure 6: Box plot representing median and range values for gap distance measurements of the two groups in the Bucco-Lingual direction (Stars and circles represent outliers)

2-Mesio-Distal (MD) direction: (Figure 8)
a. Comparison between groups

At all points; there was no statistically significant difference between median gap distances in the two groups (P-value = 0.067, Effect size = 0.872), (P-value = 0.181, Effect size = 0.611), (P-value = 0.480, Effect size = 0.555), (P-value = 0.382, Effect size = 0.398), (P-value = 0.944, Effect size = 0.031) and (P-value = 0.138, Effect size = 0.702), respectively. As regards to the overall gap distance (mean of all points of measurement); there was no statistically significant difference between median gap distances in the two groups (P-value = 0.139, Effect size = 0.682).

b. Comparison between points of measurement within each group

In both groups; there was no statistically significant difference between gap distances at different points of measurement (P-value = 0.231, Effect size = 0.186) and (P-value = 0.921, Effect size = 0.071).

Figure 7: Box plot representing median and range values for gap distance measurements of the two groups in the Mesio-Distal direction.

DISCUSSION

This study was a randomized, double blinded clinical trial where randomization was carried out by the website (www.randomizer.org) to avoid the risk of selection bias of the included patients. We designed this study as randomized clinical controlled trial because it is the top of hierarchy and hallmark of evidence-based dentistry and form the basis for translating research data into clinical practice.\(^8\)
Since the main investigator performed all the procedures during this study, then, the evaluation of the outcome had to be performed by experienced evaluators who were blinded and did not know the patients belong to which group.

All the teeth included in this study were posterior molar teeth which aimed for standardization of the samples regarding teeth size, location and expected occlusal forces which would affect the outcome of the study.

Conventional full coverage preparation was performed by preparing teeth according to manufacturer's guidelines to have smooth, round contours and angles, equi-gingival chamfer finish line 1 mm deep with round internal angles, occlusal reduction of 2 mm and labial reduction performed in 2 planes.

Patients with poor oral hygiene and motivation, with periodontal disease and bony defects, pregnant women, patients with no opposite occluding dentition in the area intended for restoration, suffering from para-functional habits and smokers were excluded from the study. Smoking lowers oxygen tension in the gingival crevice, affects gingival vasculature by producing endarteritis, and causes alterations in the amounts of cytokines, chemokines, and growth factors in gingival crevicular fluid, it can lead to periodontitis and the failure of permanent restorations.\(^9\) In this study the master cast was scanned with an extra oral scanner and Exocad software was used to design the final shape of the crown. Because of its capacity to regulate the thickness and anatomy of restorations throughout the fabrication process, CAD/CAM technology was used. It also made it possible to standardize the restoration's internal fit as well as the mechanical properties of the restorative materials. Many potentially confounding operator factors, such as the skills and methods used by dental laboratory technicians in the production process, were avoided.\(^10\) The try-in was milled from polymethyl methacrylate (PMMA) block. The CAD/CAM PMMA was initially tried to check marginal fit, shape, contacts, contour and occlusion. Later, this restoration was used as provisional restoration. PMMA have several advantages including good marginal adaptation, more comfortable for the patient, natural looking, highly esthetic, extremely durable and have good mechanical properties.\(^11\) To ensure smooth surface to resist plaque accumulation, in this study zirconia crowns were finished, polished and glazed while Bio HPP were polished using its polishing kit following manufacturer’s instructions. Since Al-Marzok 2009\(^12\), reported that plaque accumulation increase with the surface roughness. Veena Kumari 2019\(^13\) added that improper finishing and polishing with subsequent surface
roughness lead to increase in rate of wear and plaque accumulation which can reduce the longevity of the restoration. Because it has a minimal dimensional change, a quick setting time, and moderate to high rip resistance, the final impression was taken with additional silicon impression material. Impressions are dimensionally stable and may be poured at the convenience of the operator because the polymerization procedure produces no by-products.\(^{(14)}\) In the current study 5-axis CAM S1 milling machine was used to produce CAD/CAM ceramic prostheses with an excellent fit to the abutment tooth with precise dimensions and shape, in comparison with three-axis milling machine. It had the ability to machine complicated shapes with a single setup, which improves efficiency, saves time, reduces costs, and prevents operator error. It also enabled using shorter cutting tools with lowering the head and orient the cutter appropriately producing higher cutting speeds without putting too much pressure on the cutter and also reduce the vibration of the tool, and provide better surface finish. It allows to machine complex parts which require casting. Also, it improved tool life by maintaining a constant chip load and optimum cutting position. It allowed to tilt the table or cutting tool to prevent collisions with the holder of the tool.\(^{(15)}\)

Zirconia was chosen in this study due to its high mechanical strength and acceptable esthetic qualities when veneered.\(^{(16)}\) Smooth surface of Zirconia crowns made them with high biocompatible, reduce plaque accumulation and prevents dark discoloration of the surrounding gingiva. Together with its high flexural strength, zirconia consider as a high durability restoration.\(^{(17)}\) Lithium disilicate (LD) was chosen as the veneering material for Zr core restorations (the control group), as it is documented in literature as a successful restoration. IPS e.max is biocompatible lithium disilicate glass-ceramic through which lithium oxide crystals are dispersed.\(^{(18)}\) On the other hand BioHPP PEEK was used as the intervention group in this study as very little documentation is present regarding its clinical performance as fixed prostheses regarding internal fit, secondary caries and patient satisfaction. Bio HPP is a high-tech thermoplastic polymer based on PEEK. It contains ceramic micro-particles for better polishing of the restorations. These ceramic fillers have a size of about 0.3-0.5 microns and occupy 20% of the total volume of Bio HPP. Because of their micro size, homogeneity is achieved in the macrostructure of the polymer together with its low modulus of elasticity. Moreover; the high degree of polishability of the material resulted in color stability and a lack of plaque retention over time.\(^{(19,20)}\)
Zirconia veneered crowns and Bio HPP were cemented using Bis Cem dual-cure self-adhesive resin cement, following the manufacture recommendations to eliminate variables during the bonding procedures. Several studies suggested that the resin cement provide chemical and micromechanical bonding to the tooth structure and that resin cement bonding decreases the marginal discrepancy and provide high retention. Self-adhesive resin cements were marketed to simplify the clinical procedures and overcome the technique sensitivity of multiple-step systems.\(^{21}\)

Regarding to internal fit, there was no statistical significance difference between both groups in bucco-lingual and mesio-distal direction. PEKK crowns have accepted internal fit because of the absence of a sintering process and, therefore, of contraction.\(^{22}\) In our study, the mean marginal gap values of PEEK crowns showed non significant higher marginal gap than Zirconia crowns (P-value = 0.260, Effect size = 0.507). 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. 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.\(^{22}\) 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.\(^{23}\)

As regards PEEK group; there was a statistically significant difference between gap distances at different points of measurement (P-value <0.001, Effect size = 0.762). Pair-wise comparisons between the points revealed that P2 showed the statistically significantly highest median gap distance. P2 highest value because the axial line angles of the occlusal surface of the molar region was not an exact reproduction due to the bur diameter limitation at this area.\(^{10}\) The production of the fine details by milling is mainly dependent on the diameter of the smallest milling bur which is normally about 1 mm, however, smaller diameter milling burs do not appear to produce fine detail for accuracy.\(^{24}\) reported that, in order to mill the internal angle with a diameter less than the diameter of the smallest fitting bur, a drill compensation feature has to be incorporated within the software to provide
room for the bur movement. When used, however, this feature was found to produce negative fit errors and dramatically increase the internal space between the restoration and the prepared tooth surface.\(^{(25)}\) However, the measurement value of the occlusal region in the present study was clinically acceptable according to previous reports.\(^{(24)}\)

The null hypothesis of this study was accepted because the milled BioHPP PEEK-based single crowns offered statistically similar internal fit, patient satisfaction and secondary caries to zirconia-based single crowns.

**CONCLUSION**

Within the limitations of this study, the following conclusions and recommendations could be drawn as follows:

1. Both BioHPP PEEK and zirconia crowns showed successful clinical performance regarding internal fit, patient satisfaction and secondary caries.
2. After a year of observation, PEEK single crowns demonstrated good clinical survival rates, adequate internal fit, patient satisfaction, and no secondary cavities.
3. BioHPP PEEK crowns can be used as an alternate tooth-colored metal-free fixed restoration.

**REFERENCES**

2. Gaintantzopoulou, M. D., and H. M. El-Damanhoury. "Effect of preparation depth on the marginal and internal adaptation of computer-aided design/computer-assisted manufacture endocrowns." Operative dentistry.616-607 ;(2016) 41.6


11- CLAUDIA FLORINA ANDREESCU, DOINA LUCIA GHERGIC, OANA BOTOACA, HORIA MIHAIL BARBU, IOAN SEBASTIAN CERNUSCA MITARIU, DAN NICOLAE PATROI. The Advantages of High-density Polymer CAD/CAM Interim Restorations in Oral Implantology. MATERIALE PLASTICE 54No.1 2017.


22- Park, Jin-Young, et al. "Evaluation of the marginal and internal gaps of three different dental prostheses: comparison of the silicone replica technique and three-dimensional superimposition analysis." The journal of advanced prosthodontics :(2017) 9.3 .159

23- Abdullah, Lena Sabah, and Adel Farhan Ibraheem. "The effect of finishing line designs and occlusal surface reduction schemes on vertical marginal fit of full contour CAD/CAM zirconia crown restorations (a comparative in vitro study)." Int J Dent Oral Health .6-1 :(2017) 4.1