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ZIRCONIA-PEEK VERSUS ACRYLIC-METAL MANDIBULAR FULL ARCH FIXED DETACHABLE IMPLANT PROSTHESES: TWO-YEAR CLINICAL, RADIOGRAPHIC AND PROSTHETIC OUTCOMES

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Aim: To compare the clinical, radiographic, and prosthetic outcomes of zirconia-polyether ether ketone (PEEK) versus acrylic resin-metal mandibular full-arch fixed detachable implant prostheses (FDIP) during a two-year follow-up.
Materials and methods: Twelve completely edentulous participants were selected. For each patient, six implants were installed in the mandible using a flapless surgical technique. Participants were randomly assigned to one of two groups: zirconia-PEEK FDIP or acrylic-metal FDIP. The clinical and radiographic parameters were assessed at prosthesis insertion, then after one and two years. The prosthetic complications were recorded from the time of prosthesis insertion for two years.
Results: There were statistically significant differences in plaque and gingival indices as well as probing depth between the two groups, where the acrylic-metal group showed higher clinical outcome values than the zirconia-PEEK group. The zirconia-PEEK group showed significantly higher crestal bone loss than the acrylic-metal group. During the whole follow-up period, there were (n = 36, 62% of the total complications) prosthetic complications in the acrylic-metal group and (n = 22, 38 % of the total complications) in the zirconia-PEEK group. The total number of prosthetic complications was not significantly greater in the acrylic-metal group than in the zirconia-PEEK groups. There were no fractures of the prosthetic framework or abutment in either group.
Conclusion: Within the limits of this study, zirconia-PEEK full-arch FDIP produces better clinical and prosthetic outcomes than acrylic-metal FDIP. However, zirconia-PEEK FDIP may lead to higher crestal bone loss than acrylic-metal FDIP.

Keywords: Zirconia-PEEK, acrylic-metal, fixed detachable implant prosthesis, clinical, radiographic, prosthetic outcomes.

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Introduction

Conventional complete dentures have proven problematic for edentulous patients with resorbed mandibular ridges owing to compromised load bearing tolerance, reduced masticatory efficiency and biting force, and diminished oral sensation. Fixed detachable implant-supported prostheses (FDIP) have proven to be the most effective treatment strategy for rehabilitating an atrophied edentulous mandible.[1,2]

If the bone loss in the edentulous region is moderate to severe, FDIP is often recommended as the fixed prosthetic treatment option. Other terms for this prosthesis are "hybrid prosthesis" and "fixed complete denture". [3] The FDIP provides benefits such as alveolar bone preservation and considerable improvements in prosthesis function, stability, adaptation, and comfort. Some authors have claimed that FDIP should be considered the standard of treatment, particularly in mandibular ridges where poor alveolar bone support might threaten conventional denture retention.[4]

The FDIP involves installing four to six implants in the edentulous ridge, according to the anatomic limitations and patients' demands. Four implants are used to treat a completely edentulous mandible using "all on four" concept when there is insufficient bone height posteriorly.[5] However, in this treatment modality, cantilever extensions are linked with a higher risk of biological and prosthetic problems, an inequitable distribution of masticatory pressures, and a rise in strain concentrations at the implant next to the cantilevers. The use of six implants supporting mandibular FDIP is a well-documented prosthodontic rehabilitation procedure for the edentulous mandible.[6]

The FDIP consists of a framework veneered with different materials to replace the lost hard and soft tissues. The framework may be constructed of metal, high-performance polymer such as polyether ether ketone (PEEK), or zirconia. Several materials may be used for veneering the frameworks in FDIP, such as porcelains, acrylic resins, composite resins, and zirconia. FDIP has been constructed using a wide range of material combinations. Traditionally, it was fabricated using a metal framework with acrylic or porcelain veneers. [6-8]

A significant drawback of metal/porcelain prostheses is that screw loosening, porcelain veneer fracture, and metal warpage occur during the firing of porcelain, causing a lack of passive fit. Moreover, they are subjected to corrosion and may cause allergies, and they do not absorb shocks or transmit excessive forces to implants. However, the esthetic outcome of them is superb.[8,9]

One of the most thoroughly investigated treatment options for reconstructing an edentulous ridge with an implant-fixed restoration is a acrylic-metal hybrid. These hybrids have a long track record of simplicity in usage, ease of reparability, and low cost. The disadvantage of these prostheses is their increased complication rates in terms of veneered acrylic fracture, denture teeth separation, and abutment or screw loosening. Furthermore, other disadvantages of metal/acrylic FDIP are the absence of natural color, most noticeably in the prosthetic gingiva region, and wear of the occluding surfaces.[10-12]

The thermoplastic polymer of high-performance polyether ether ketone (PEEK) may be used as a metal replacement framework material for over ten years. PEEK's simple manufacturing, chemical stability, low plaque affinity, and high corrosion resistance are advantages over metal alloys. PEEK's lightweight properties also enable its use in the production of lightweight restorations, which may improve patients' comfort, especially in bulky prostheses.[13,14] PEEK's modulus of elasticity

of 4 GPa reduced transmission of masticatory pressures to peri-implant bone to avoid overloading problems. The material has hypoallergenic properties, limited water absorption, resistance to creep, wear, and shock, and exhibits excellent mechanical behavior. Due to PEEK's radiolucency, loose screws may be easily identified.[15] Based on these considerations, PEEK is a viable alternative to metal frameworks in fixed implant restorations. PEEK may be produced by either CAD/CAM (computer-assisted design and computer-aided manufacturing) or injection molding. [16-17]

Zirconia ceramic is a polycrystalline material that has been utilized in dentistry for a variety of applications, including crowns, implant abutments, and dental implant.[18] zirconia-based materials have been used in the production of FDIP in order to possibly alleviate some of the problems that have been faced with acrylic-metal hybrids.[19] Zirconia has gained popularity as a metal framework alternative or veneering alternative in the construction of FDIP because of its excellent biocompatibility, lesser plaque and bacteria deposition on its surface, great biomechanical qualities, and reduced staining when compared to acrylic resins. It may be superior to feldspathic dental porcelain as a prosthetic material due to its antimicrobial and low abrasive properties.[20] Studies have been done to increase the bonding between PEEK-zirconia by surface modifications and the use of adhesives as a result of differences in the mechanical and chemical properties of these materials. However, there are certain drawbacks to zirconia prostheses, such as their higher weight as compared to acrylic-metal prostheses and difficulties in modifying and cleaning the prosthesis. CAD/CAM manufacturing is usually utilized in constructing a zirconia prosthesis, improving the fit and precision of the restoration. [21]

To the authors' knowledge, studies evaluating and comparing mandibular FDIP with PEEK framework and with zirconia crowns versus acrylic-metal prostheses are scarce. So, the aim of this study was to compare the clinical, radiographic, and prosthetic outcomes of zirconia-polyether ether ketone (PEEK) versus acrylic resin-metal mandibular full-arch fixed detachable implant prostheses (FDIP) during a two-year follow-up. The null hypothesis was that there would be no difference in clinical, radiographic and prosthetic outcomes between zirconia-PEEK versus acrylic-metal mandibular FDIP.

Materials and methods

I-Participant enrollment

Twelve completely edentulous participants (8 males and 4 females) were selected from the outpatient removable prosthodontics department clinic, with a mean age of 57.62 ± 4.6 (ranging from 47 to 63 years). The following conditions were used as inclusion criteria: (1) patients who complained of mandibular denture looseness and would prefer fixed prostheses; (2) adequate bone quantity and density in the anterior and posterior mandibular areas [22,23] to install six implants (3.3 mm diameter, 11 mm length anteriorly, and 13 mm posteriorly). CBCT scans (CBCT, ICAT, Imaging science Int., USA) taken before surgery confirmed this; (3) adequate inter-arch space to allow for FDIP as verified by tentative jaw relationship. The exclusion criteria were: (1) metabolic disease like osteoporosis or diabetes mellitus; (2) radiotherapy to the neck and head region; (3) heavy smokers; (4) corticosteroid or immunosuppressive therapy; (5) bleeding disorders; and (6) patients with bruxism.

The sample size estimate was based on the findings of a prior study[24] (effect size = 0.90, $\alpha = 0.05$, $\beta = 0.85$). A computer

program (G power 3.1.5) was used to carry out the power analysis. After the patients were informed about the treatment procedures and the need for frequent follow-ups, they signed informed consents. The study protocol gained approval from the Faculty of Dentistry's local ethics committee. The study was done in accordance with the CONSORT standards for clinical trials.

Balanced randomization was done to produce insignificant differences between groups regarding baseline characteristics. Participants received a mandibular full-arch FDIP supported by six implants. They were randomly assigned according to the type of crown materials to two equal groups: zirconia-PEEK group: with PEEK framework and zirconia crowns; and acrylic-metal group: with metal framework and acrylic teeth. Randomization was performed by the random number function in Microsoft Excel spreadsheet. An independent dentist who was blind to the type of FDIP performed the randomization. The allocation was done in a way to guarantee that each group had an equal gender distribution.

II- **Surgical and prosthetic procedures**

New conventional complete dentures with bilateral balanced occlusion were constructed. Patients were instructed to use their dentures for three months before getting implants. Polished palatal and buccal surfaces of the mandibular denture were marked with radiopaque gutta percha as the denture was used as a radiographic template.

Each patient had a double scan procedure using CBCT (i-CATVision, Hatfield, Pennsylvania, United States). The first scan was performed while the patient was wearing his maxillary and mandibular dentures and was occluded in centric occlusion. The second scan was taken only for the mandibular denture with the long axis of the denture was parallel to CBCT table's longitudinal axis. The two scans were superimposed using computer software to generate a three-dimensional image of the edentulous mandible (On Demand3D, Cybermed Inc., Seoul, Korea). The computer software was used to digitally design the mandibular implant site, distribution, and angulation. Using rapid prototyping techniques, a stereolithographic surgical guide with six metal rings placed above the implant positions (In2Guide) was constructed. For three days before surgery and seven days thereafter, patients were given a daily dosage of 0.2% chlorhexidine digluconate mouthwash. They were given amoxicillin and clavulanic acid one hour before surgery, then twice daily for ten days thereafter, and analgesics were given if there was any pain or discomfort.

Using the flapless surgical approach, six implants **(3.3 mm diameter, 11 mm length anteriorly, and 13 mm posteriorly)** (Standard Plus implant, SLActive, Institute Straumann AG, Basel, Switzerland) were inserted into the mandibular bone with the use of the surgical guide. A universal surgical kit was used to perform the osteotomies for the six implants (In2Guide Universal Kit, Cybermed, Inc., USA). The healing abutments were tightened into their corresponding fixtures. The mandibular dentures were relieved at the area opposing the implant sites and relined with a soft liner (Coe Soft, GC, USA). Then the occlusion was refined. Participants were told to consume soft meals and to avoid hard items. To verify correct implant placement, post-operative panoramic radiographs were taken. Patients were also instructed that they would have frequent follow-up sessions to check on their dental hygiene and modify their dentures.

The mandibular dentures were removed after three months of osseointegration. Unscrewing of healing abutments was done and multiunit abutments were screwed into the implants. An abutment-level impression was taken using an open-top tray. Long impression copings were fastened to the multiunit abutments, and they were resin splinted (Duralay, Reliance Dental MFG Co, Worth, IL, USA). The copings were then injected with a light-body rubber base impression material (Zhermack, Badia Polesine, Rovigo, Italy). The impression was completed with a heavy-body rubber foundation in a stock tray. After the posts were unscrewed, the impression was taken out of the patient's mouth. The abutment analogues were fastened to the impression posts. This was followed by the pouring of the impression.

For the Zirconia-PEEK group, the titanium sleeves of multiunit abutments were screwed to the abutment's analogue on the master cast. The model was scanned with a desktop scanner (InEos X5, Dental Lab Scanner, Dentsply Sirona). Using CAD/CAM software (exocad GmbH, Darmstadt, Germany), FDIP was designed to restore gingival tissues, lost alveolar bone, and teeth. The prosthesis was designed with twelve teeth, until the first molar, and with flanges to replace the lost soft tissues. This was followed by 3D printing (Elegoo Mars 3 Ultra 4k mono LCD 3D printer) of the resin pattern of the framework by rapid prototyping using a castable resin (Duralay, Reliance Dental MFG Co, Worth, IL, USA).

The resin pattern was checked for passive fit in the patient's mouth. The resin pattern of the framework was invested and processed into the PEEK framework (Bredent GmbH & Co. KG, Senden, Germany) with the injection molding processing method. As PEEK was preheated at 400° for 20 minutes by a thermo-pressing unit (Thermoflex 400). This was followed by the injection of the heated, softened PEEK into the mold by 950 megapascal pressure and 6 bars in 240 seconds of velocity. The cementation of the titanium sleeves to the PEEK framework on the cast was performed using resin cement (Kleber resin cement, Bredent, Germany). The PEEK framework with the titanium sleeves was next tested for passive fit in the patient's mouth using the single screw test. ***(Fig.1)***

For the construction of the composite-gingival portion, PEEK frameworks were blasted with 110 µm at a distance of 3 cm under 2-3 bar pressure, then cleaned with alcohol saturated Bruch. The gingival tissues were constructed by painting the adhesive provided by the manufacturer (Visio. Link, Bredent GMbH) over the PEEK framework to allow bonding of composite veneer material (Visio. Lign, Bredent GMbH) that replaced the lost gingival tissues. After that, intra-oral checking of the framework was done. The jaw relationship was registered and then scanned for the construction of zirconia crowns. A bilateral balanced occlusion was used.

Designing of zirconia crowns was done using CAD/CAM software (exocad GmbH, Darmstadt, Germany) then zirconia blocks (Prettau Zirconia, XH40, Zirkonzahn) were milled with a milling machine. A resin cement was used to cement zirconia crowns to the PEEK framework (Superbond C&B; Sun Medical). ***(Fig. 2)***

For the acrylic-metal group, the sleeves of multiunit abutments were joined to the abutment's analogue on the master cast, and their heights were adjusted. The wax pattern of the metal framework was constructed over the master cast. Using the lost wax method, the wax pattern was then turned into a cast metal substructure using cobalt-chromium (Co-Cr Heraeus-Kulzer GmbH, Hanau, Germany). The metal framework was tried in the patient's mouth

for passive fit using the single screw test. The mandibular record blocks were made and utilized to register the jaw relationship. This was followed by mounting the casts on a semi-adjustable articulator. A bilateral balanced occlusion was used. Acrylic artificial teeth were arranged over the framework and waxing up was completed. This was followed by an intraoral try-in with the waxed-up framework with denture teeth to evaluate aesthetics and occlusion. After flasking, the prosthesis was processed into heat-cured acrylic resin. ***(Fig. 3)***

In both groups, the final prostheses were finished, polished, and then screwed intra-orally. The screw access holes were closed with composite resin, and the prostheses were delivered to the patients. Strict oral hygiene measures were instructed to the patients. Follow-up visits were scheduled at one- and two-years following prosthesis insertion.

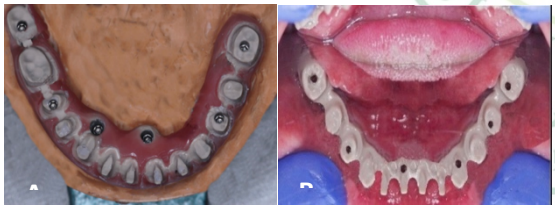

Fig. 1 (A) : PEEK framework on the master cast, (B): Intra-oral try in of the PEEK framework.

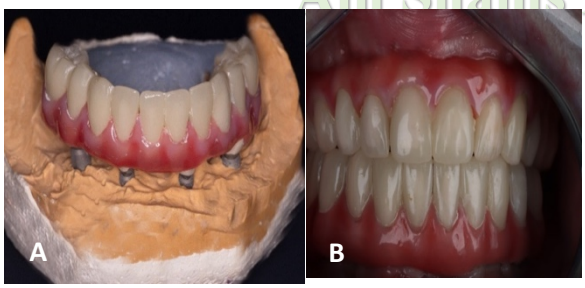

Fig.2: Zirconia-PEEK FDIP (A): On the master cast. (B) Intra-oral frontal view.

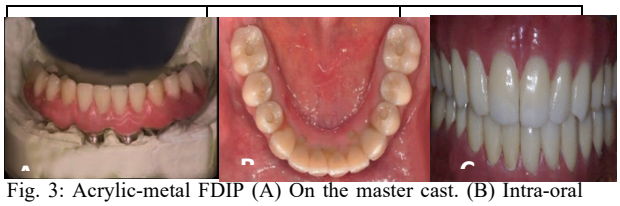

Fig. 3: Acrylic-metal FDIP (A) On the master cast. (B) Intra-oral occlusal view (C) Intra-oral frontal view.

III- Outcomes assessment:

1- Clinical outcomes

The pocket depth was measured using a periodontal probe (Vivadent) from the marginal gingiva to the depth of the pocket (PD). Gingival index (GI) and plaque index (PI) were also calculated.[25] Each implant's GI, PI, and PD were evaluated distally, buccally, mesially, and lingually. After receiving instruction and proper training, two calibrated clinicians measured clinical parameters. It was not practicable to blind assessors to the prosthetic design. Clinical outcomes were assessed at the time of insertion of the prostheses, then at one and two-years later.

2- Radiographic outcomes

Using periapical radiographs taken with the standard long cone paralleling technique, the peri-implant crestal bone loss was assessed radiographically. The images were analyzed by digital software (Romexis Viewer software, Planmeca, Helsinki, Finland) to obtain the linear measurements of peri-implant crestal bone height. ***(Fig. 4)***

To ensure a standardized exposure, a specialized acrylic stent was constructed. Each implant's mesial and distal distances from the crestal bone height to the implant-abutment junction were measured, and the mean was calculated. The problems with magnification were overcome by calibrating the images with the parameters of the implant.

In order to calculate crestal bone loss, the bone level at the recall visits (at one and two years) was compared to the bone

level at baseline. Two different examiners took the measurements of the crestal bone level after being trained and calibrated.

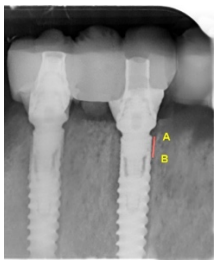

Fig. 4: Linear measurement of peri-implant crestal bone height. AB: The distance between crestal bone level and the implant-abutment junction on the proximal surface of the implant.

3- Prosthetic outcomes

The frequency of the following prosthetic complications was measured for each group: prosthesis fracture, abutment fracture, crown fracture or veneer separation, crown loosening, gingival fracture, and tooth fracture or tooth wear. It also includes abutment fracture, prosthetic screw loosening/fracture, and abutment screw loosening/fracture. The overall prosthetic complications were calculated for each group. Then the percentage of each complication to the total number complications for both groups was measured. The prosthetic complications were measured from the time of prosthesis insertion to two years.

IV- Statistical analysis

The Cronbach α test was used to assess measurement inter- and intra-examiner reliability. The Friedman test was used to reveal significant differences across observation periods, followed by Dunn's multiple comparisons test to detect significant changes between observation periods. Mann-Whitney test was used to calculate the difference in the clinical outcomes between the two groups. The Chi-Square test was used to compare prosthetic problems. $P<0.05$ was chosen as the threshold of significance. The data was statistically analyzed using SPSS software version 22. (SPSS Inc.).

Results

In both groups, no patient dropout occurred. The implant success rate following definitive prosthesis placement was 100% after two years of follow-up.

There were statistically significant differences in plaque and gingival indices as well as probing depth between the two groups, where the acrylic-metal group showed higher clinical outcome values than the zirconia-PEEK group. Within-group comparisons revealed significant differences in all measured clinical outcomes in the two groups across different follow-ups. A comparison between the measured clinical outcomes across follow-up times and groups is shown in ***Table 1.***

Peri-implant crestal bone loss increased significantly from the time of prosthesis insertion until the end of the two-year follow-up period for both groups. The zirconia-PEEK group showed significantly higher crestal bone loss than the acrylic-metal group after one year ($P = 0.004$) and two years ($P = 0.003$). ***Table 1.***

The influence of prosthesis type on the complications that occurred was statistically insignificant. During the whole follow-up period, there were (n=36, 62% of the total complications) prosthetic complications in the acrylic-metal group and (n=22, 38 % of the total complications) in the zirconia-PEEK group. The total number of prosthetic complications was not significantly greater in the acrylic-metal group than in the zirconia-PEEK groups. There were no fractures of the prosthetic framework or abutment in either group. The frequency and percentage of prosthetic complications in the two groups are shown in ***Table 2***.

In the Zirconia-PEEK group, prosthesis screw loosening (n=7, 12%) was

the most common complication, followed by gingival fracture (n=6, 10%), abutment screw loosening (n=5, 9%), then crown fracture (n=4, 7%). The most evident prosthetic complications in the acrylic-metal group were tooth wear (n=15, 26%), prosthesis screw loosening (n=10, 17%), veneer separation or abutment screw loosening (n=4, 7%), and gingival fracture (n=3, 5%).

Table 1: The clinical and radiographic results compared across follow-up intervals and groups.

	At insertion	One year	Two years	P/
Plaque Index				
Zirconia-PEEK group Median (minimum-maximum)	0.01 (0.00-0.10) aA	0.00 (0.00-1.00) bA	1.00 (0.00-2.00) cA	0.0184*
Acrylic-metal group Median (minimum-maximum)	0.15 (0.00-1.00) aA	3.00 (3.00-3.00) bB	3.00 (3.00-3.00) cB	0.0001*
P	0.5611	0.0013*	0.002*	
Gingival index				
Zirconia-PEEK group Median (minimum-maximum)	0.50 (0.00-1.00) aA	1.00 (1.00-2.00) bA	1.00 (0.00-2.00) cA	0.0081*
Acrylic-metal group Median (minimum-maximum)	1.00 (0.00-1.00) aA	1.50 (1.00-2.00) bB	3.00 (2.00-3.00) cB	0.0001*
P	0.1003	0.0037*	0.0131*	
Pocket depth				
Zirconia-PEEK group Median (minimum-maximum)	0.49±0.05 aA	1.97±0.17 bA	2.02±0.17 cA	0.0001*
Acrylic-metal group Median (minimum-maximum)	0.62±0.11 aA	0.21±2.75 bB	0.34±2.93 cB	0.0015*
P	0. 319	0.0027*	0.0046*	
Per-implant crestal bone loss				
Zirconia-PEEK group Median (minimum-maximum)	-	0.77±0.02 bA	0.98±0.05 cA	0.003*
Acrylic-metal group Median (minimum-maximum)	-	0.65±0.04 bB	0.87±0.02 cB	0.002*
P	-	0.004*	0.003*	

P: P-value of Mann-Whitney test P/: P-value of Freidman test
*Significant if P<0.05
It is statistically significant to have different upper-case characters in the same column and lower-case letters in the same row.

Table (2): Comparison of prosthetic complications in both groups from the time of insertion to two years.

Prosthetic complication	Groups				P
	Zirconia-PEEK (n=6)		Acrylic-metal (n=6)		
	Frequency	%	Frequency	%	
Prosthesis fracture	0	0%	0	0%	-
Abutment fracture	0	0%	0	0%	-
Crown fracture or veneer separation	4	7%	4	7%	0.124
Crown loosening	0	0%	0	0%	-
Tooth fracture	0	0%	0	0%	0%
Tooth wear	0	0%	15	26%	0.213
Gingival fracture	6	10%	3	5%	0.414
Abutment-screw loosening	5	9%	4	7%	0.434
Abutment-screw fracture	0	0%	0	0%	-
Prosthesis screw loosening	7	12%	10	17%	0.632
Prosthesis screw fracture	0	0%	0	0%	-
Total complications	22	38%	36	62%	0.453

Horizontally, values superscripted with different lower-case letters are statistically significant (P<0.05).
% percentage of each complication to the total number of complications of both groups.

Discussion

The overall survival rate in the two groups (100%) was similar to that obtained by some authors, who reported a 100% implant survival rate for FDIP after one year.[26,27] To the best of the authors' knowledge, no clinical studies have examined the impact of zirconia-PEEK versus acrylic-metal full-arch FDIP on clinical, radiographic, and prosthetic outcomes. As a consequence, the findings of this research cannot be compared to the findings of another study conducted in a similar manner. The null hypothesis, that there would be no difference in clinical, radiographic, and prosthetic outcomes between zirconia-PEEK versus acrylic-metal FDIP, was rejected.

The results of this study revealed that all clinical parameters significantly increased with time. These findings were consistent with some studies on FDIP.[16,18,28] The

increased gingival and plaque indices in the two studied groups might be because the patients in this research did not follow the oral hygiene guidelines. This may be due to the age-related reduction in manual dexterity of older participants that resulted in improper cleaning. Another factor might be greater plaque retention in the inaccessible areas as well as patients' inability to remove the prosthesis to practice oral hygiene measures. These results are contradicted by Patzelt et al[29] who found a gradual decline in these indices with FDIP.

Zirconia-PEEK prostheses had significantly lower gingival and plaque indices than acrylic-metal FDIP. One possible explanation is that PEEK material has a lower plaque accumulation compared to metal.[30,31] This is in accordance with Wachtel et al.[32] who discovered that compared to metallic superstructures, PEEK material prevents bacterial leakage due to its sealing property against bacterial leakage at the abutment implant interface.

The lower plaque index in FDIP with PEEK framework was consistent with the findings of Sturz et al,[33] who discovered that after finishing and polishing veneered PEEK framework, the surface roughness and contact angle were reduced, which facilitates oral hygiene. Also, zirconia-based restorations enhance periodontal results, reduce inflammation, and improve oral hygiene conditions. As Zirconia has little effect on periodontal tissues and instead increases the periodontium's defensive systems. Furthermore, CAD/CAM-produced zirconia restorations produce better results in terms of marginal fit, inflammation reduction, maintenance, and the restoration of periodontal health and oral hygiene.[34] On the other hand, the increased measured clinical outcomes in the acrylic-metal group might be attributable to acrylic resin's porosity and wear, which could increase plaque formation and make it harder for patients to maintain good home oral hygiene.[35]

In the two groups, the increase in pocket depth with time might be related to increased bone resorption, gingival inflammation, and enlargement of the peri-implant mucosa. A similar finding was obtained in prior studies using FDIP.[36,37] Landazuri-Del Barrio et al[38], on the other hand, found stable soft tissue status with a decline in pocket depths over time in the majority of implants. The insignificantly reduced pocket depths of the zirconia-PEEK group compared to the acrylic-metal group may be due to the fact that the PEEK framework has a lower modulus of elasticity than the cobalt-chromium framework, which is nearer to the modulus of elasticity of bone. As a result, PEEK material has a shock-absorbing effect and is superior to metal in reducing opposing dentition occlusal stresses. Furthermore, PEEK frameworks have an excellent marginal fit, making them a feasible alternative to metal as a framework. This marginal fit is critical because a mismatch may raise pressure on the implants and have a detrimental impact on peri-implant tissues.[39]

After two years, the two groups had peri-implant crestal bone loss of less than 1 mm. This number falls within the generally agreed-upon range described in the literature, which is approximately 1.2 in the initial year and decreases to 0.2 mm per year in the following years. Both groups experienced a significant increase in bone loss during the follow up period, which may be attributable to bone remodeling in conjunction with elevated functional stresses.[40] The acrylic-metal group had significantly less crestal

bone loss than the zirconia-PEEK group. This is because the acrylic resin teeth have a low modulus of elasticity, so more energy is absorbed from the applied force and transmits fewer forces to the underlying structures, accordingly, reducing the stresses transmitted to the implant-bone interface. Furthermore, acrylic resin teeth absorb shock from the occlusal stresses. On the other hand, zirconia crowns have a high modulus of elasticity, so they transmit more forces to the bone implant interface and increase crestal bone loss.[41,42]

On the contrary to the radiographic results, Kortam et al[16] concluded that the PEEK framework reduces the peri-implant bone loss as the material has a dampening effect that reduces the occlusal forces of opposing occlusion. The difference in our results might be due to the presence of zirconia combined with PEEK, which may reduce its shock absorbing effect, increase the stresses on bone, and thus increase bone resorption. The type of crown material or prosthetic teeth might influence the stresses transferred to the crestal bone more than the framework material. Moreover, the processing of PEEK was done using the injection molding technique rather than CAD/CAM milling; this may lead to a lack of passive fit, and the presence of vertical gaps between metal sleeves and abutments may have contributed to the increased bone loss in the Zirconia-PEEK group. These gaps may exist on a microscopic scale, making them difficult to detect with the single screw test during the try-in of the metal framework. [43]

In terms of prosthetic problems, none of the prostheses, abutments, or prosthetic screws fractured in either of the two groups. Malo et al.[44] found similar findings. This might be because these problems are often linked with greater biting forces, particularly when natural teeth are in the opposing occlusion. The use of acrylic resin teeth in this research produces a cushion effect for the applied load, and the opposing occlusion contains acrylic resin teeth of the maxillary denture, which produced a dampening effect. Another reason for the lower maximum biting force is that the study included older patients, whose jaw muscles were not as strong as those of younger patients. [37,45] Nobre et al.[46] discovered that the condition of the opposing jaw affected prosthesis survival and that prosthetic failure occurred in patients rehabilitated by FDIP opposed by fixed implant restoration or in patients with bruxism that caused framework fractures, indicating occlusal overload. Furthermore, the PEEK framework's elastic characteristics lower masticatory stresses and protect prosthetic screws with the abutments from fracture. Moreover, in this study, cantilevers were used, and patients with bruxism were excluded.[13,14]

A larger tendency for prosthetic complications was detected in the acrylic-metal group in comparison with the zirconia-PEEK group; however, this difference did not reach statistical significance. During the whole follow-up period, there were (n=36, 62% of the total complications) prosthetic complications in the acrylic-metal group and (n=22, 38 % of the total complications) in the zirconia-PEEK group. Prosthetic screw loosening was the most common prosthetic complication in the zirconia-PEEK group, while tooth wear was the most common complication in the acrylic-metal group.

The prosthetic screw loosening was greater in the acrylic-metal group than in zirconia-PEEK group. This might be due to a lack of ideal passive fit in acrylic-meal FDIP and the existence of tiny gaps between abutments and metal sleeves. The enhanced

passive fit in the zirconia-PEEK group might be attributed to the sleeves bonding directly to the PEEK frame rather than casting. Tekin et al[40] discovered that PEEK reduced stress in the peri-implant bones by dispersing incoming pressures across the implant, crowns, and screws as compared to titanium abutments.

According to the present study, n=15 of the acrylic-metal hybrid prostheses (25% of the total complications) exhibited denture tooth wear. Even though tooth wear has been identified as a major prosthetic complication with acrylic-metal hybrid prostheses, many studies have found that these problems are easy to fix and non-catastrophic.[26] Crown fracture is a common prosthetic problem in zirconia-PEEK. A similar observation was obtained in other studies.[9,11,20,21] This might be attributable to the low fracture resistance of zirconia-PEEK.[13,47] Also, it might be due to the fact that the PEEK framework has a low tolerance to plastic deformation and bending [48]. The same cause might account for the increase in artificial gingiva fractures in the zirconia-PEEK group. According to a 4-year retrospective case study conducted by Papaspyridakos and Lal, [49] a zirconia chipping was shown to be the most common complication in zirconia fixed implant prostheses.

The frequency of gingival portion fracture or separation was n=6 in the Zirconia-PEEK group and n=3 in acrylic-metal FDIP. This may be because PEEK has a lower binding strength with composite resin. Several studies have recently been undertaken to overcome this shortcoming via different surface treatments. [50-53] In this study, the surface of the PEEK was treated according to the manufacturer's instructions, using a method that has been widely used in clinical settings to strengthen the bond between the pink composite and the PEEK. The small number of patients in this study and the fact that clinical and radiographic parameters were not evaluated during the healing phase were both limitations of the study.

Conclusion

Within the limits of this study, zirconia-PEEK full-arch FDIP produces better clinical and prosthetic outcomes than acrylic-metal FDIP. However, zirconia-PEEK FDIP may lead to higher crestal bone loss than acrylic-metal FDIP.

References

1. Johar AO. Clinical Performance of Implant Overdenture Versus Fixed Detachable Prosthesis. J Contemp Dent Pract. 2018;19(12):1480-1486.
2. Messias A, Karasan D, Nicolau P, Pjetursson BE, Guerra F. Rehabilitation of full-arch edentulism with fixed or removable dentures retained by root-form dental implants: A systematic review of outcomes and outcome measures used in clinical research in the last 10 years. J Clin Periodontol. 2022;10.1111/jcpe.13616.
3. Kern J-S, Kern T, Wolfart S, Heussen N. A systematic review and meta-analysis of removable and fixed implant-supported prostheses in edentulous jaws: post-loading implant loss. Clin Oral Implants Res 2016;27: 174–195.
4. Oh SH, Kim Y, Park JY, Jung YJ, Kim SK, Park SY. Comparison of fixed implant-supported prostheses, removable implant-supported prostheses, and complete dentures: patient satisfaction and oral health-related quality of life. Clin Oral Implants Res. 2016;27(2): e31-e37.
5. Goodacre C, Goodacre B. Fixed vs removable complete arch implant prostheses: A literature review of prosthodontic outcomes. Eur J Oral Implantol. 2017;10 Suppl 1:13-34.
6. Rojas-Vizcaya F. Full zirconia fixed detachable implant-retained restorations manufactured from monolithic zirconia: clinical report after two years in service. J Prosthodont. 2011;20(7):570-576.
7. Priest G, Smith J, Wilson MG. Implant survival and prosthetic complications of mandibular metal-acrylic resin implant complete fixed dental prostheses. J Prosthet Dent. 2014;111(6):466-475.

8. Venezia P, Torsello F, Cavalcanti R, D'Amato S. Retrospective analysis of 26 complete-arch implant-supported monolithic zirconia prostheses with feldspathic porcelain veneering limited to the facial surface. J Prosthet Dent. 2015;114(4):506-512.
9. Wang J, Wu P, Liu HL, et al. Polyether ether ketone versus titanium CAD-CAM framework for implant-supported fixed complete dentures: a retrospective study with up to 5-year follow-up. J Prosthodont Res. 2022;66(2):279-287.
10. de Araújo Nobre M, Moura Guedes C, Almeida R, Silva A, Sereno N. Hybrid Polyether ether ketone (PEEK)-Acrylic Resin Prostheses and the All-on-4 Concept: A Full-Arch Implant-Supported Fixed Solution with 3 Years of Follow-Up. J Clin Med. 2020;9(7):2187.
11. Maló P, de Araújo Nobre M, Moura Guedes C, et al. Short-term report of an ongoing prospective cohort study evaluating the outcome of full-arch implant-supported fixed hybrid polyether ether ketone-acrylic resin prostheses and the All-on-Four concept. Clin Implant Dent Relat Res. 2018;20(5):692-702.
12. Ionescu RN, Totan AR, Imre MM, et al. Prosthetic Materials Used for Implant-Supported Restorations and Their Biochemical Oral Interactions: A Narrative Review. Materials (Basel). 2022;15(3):1016.
13. Gouveia DDNM, Razzoog ME, Sierraalta M, Alfaro MF. Effect of surface treatment and manufacturing process on the shear bond strength of veneering composite resin to polyetherketoneketone (PEKK) and polyetheretherketone (PEEK) [published online ahead of print, 2021 Mar 4]. J Prosthet Dent. 2021;S0022-3913(21)00069-X.
14. Keul C, Liebermann A, Schmidlin PR, Roos M, Sener B, Stawarczyk B. Influence of PEEK surface modification on surface properties and bond strength to veneering resin composites. J Adhes Dent 2014;16:383-92.
15. Silthampitag P, Chaijareenont P, Tattakorn K, Banjongprasert C, Takahashi H, Arksornnukit M. Effect of surface pretreatments on resin composite bonding to PEEK. Dent Mater J 2016;35:668-74.
16. Kortam SA, ELsyad MA, Awad SS, ElHelbawy NE. Metal-Ceramic and Polyether Ether Ketone-Composite Maxillary Fixed Prosthesis Supported by Four Implants and Opposed by Removable Distal Extension Partial Dentures: A Comparative Study of Clinical and Prosthetic Outcomes. Int J Oral Maxillofac Implants. 2022;37(1):181-189.
17. El talawy, D., Ali, S. Prosthetic complications and patient satisfaction with maxillary polyether ether ketone hybrid prosthesis veneered with acrylic or composite resin for patients rehabilitated by "All on four" concept. Egyptian Dental Journal, 2021; 67(2): 1333-1343.
18. Schimmel M, Janner SFM, Joda T, Wittneben JG, McKenna G, Brägger U. Mandibular implant-supported fixed complete dental prostheses on implants with ultrashort and standard length: A pilot treatment. J Prosthet Dent. 2021;126(2):137-143.
19. Shetty R, Singh I, Sumayli HA, et al. Effect of prosthetic framework material, cantilever length and opposing arch on peri-implant strain in an all-on-four implant prostheses. Niger J Clin Pract. 2021;24(6):866-873.
20. Cabello-Domínguez G, Pérez-López J, Veiga-López B, González D, Revilla-León M. Maxillary zirconia and mandibular composite resin-lithium disilicate-modified PEEK fixed implant-supported restorations for a completely edentulous patient with an atrophic maxilla and mandible: A clinical report. J Prosthet Dent. 2020;124(4):403-410.
21. Jung BY, Park WS, Woo CW, Jeong SA, Jung BY. Zirconia-veneered polyetherketoneketone frameworks of implant-supported complete arch fixed dental prostheses: A report on 5 patients. J Prosthet Dent. 2022; S0022-3913(22)00497-8.
22. Cawood JI, Howell RA. A classification of the edentulous jaws. Int JOral Maxillofac Surg 1988; 17:232–236.
23. Lekholm U, Zarb G. Patient selection and preparation. In: Branemark PI, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
24. Mombelli A, van Oosten MA, Schurch E Jr, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987;2:145–151.
25. Moustafa Ali, R., Helmy, M. Poly ether-ether ketone veneered with composite Versus Porcelain fused to metal Full arch fixed screw retained prosthesis for atrophied mandibular ridges. One year randomized clinical and radiographic trial study. Egyptian Dental Journal, 2020; 66: 2439-2449.
26. Barootchi S, Askar H, Ravidà A, Gargallo-Albiol J, Travan S, Wang HL. Long-term Clinical Outcomes and Cost-Effectiveness of Full-Arch Implant-Supported Zirconia-Based and Metal-Acrylic Fixed Dental Prostheses: A Retrospective Analysis. Int J Oral Maxillofac Implants. 2020;35(2):395-405.
27. Rojas Vizcaya F. Retrospective 2- to 7-Year Follow-Up Study of 20 Double Full-Arch Implant-Supported Monolithic Zirconia Fixed Prostheses:

Measurements and Recommendations for Optimal Design. J Prosthodont. 2018;27(6):501-508. 27.
28. Mohamed LA, Khamis MM, El-Sharkawy AM, Fahmy RA. Evaluation of immediately loaded mandibular four vertical versus tilted posterior implants supporting fixed detachable restorations without versus with posterior cantilevers. Oral Maxillofac Surg. 2022;26(3):373-381.
29. Patzelt SB, Bahat O, Reynolds MA, Strub JR. The all-on-four treatment concept: A systematic review. Clin Implant Dent Relat Res 2014; 16:836–855.
30. Hahnel S, Wieser A, Lang R, Rosentritt M. Biofilm formation on the surface of modern implant abutment materials. Clin Oral Implants Res 2015; 26:1297–1301.
31. Zoidis P, Papathanasiou I, Polyzois G. The use of a modified polyether-ether-ketone (PEEK) as an alternative framework material for removable dental prostheses. A clinical report. J Prosthodont 2016; 25:580–584.
32. Wachtel A, Zimmermann T, Sutel M, et al. Bacterial leakage and bending moments of screw-retained, composite-veneered PEEK implant crowns. J Mech Behav Biomed Mater 2019; 91:32–37.
33. Sturz CR, Faber FJ, Scheer M, Rothamel D, Neugebauer J. Effects of various chair-side surface treatment methods on dental restorative materials with respect to contact angles and surface roughness. Dent Mater J 2015; 34:796–813.
34. Avetisyan A, Markaryan M, Rokaya D, et al. Characteristics of Periodontal Tissues in Prosthetic Treatment with Fixed Dental Prostheses. Molecules. 2021;26(5):1331.
35. Srimaneepong V, Heboyan A, Zafar MS, et al. Fixed Prosthetic Restorations and Periodontal Health: A Narrative Review. J Funct Biomater. 2022;13(1):15.
36. Delucchi F, De Giovanni E, Pesce P, et al. Framework Materials for Full-Arch Implant-Supported Rehabilitations: A Systematic Review of Clinical Studies. Materials (Basel). 2021;14(12):3251.
37. ELsyad MA, Alameldeen HE, Elsaih EA. Four-implant-supported fixed prosthesis and milled bar overdentures for rehabilitation of the edentulous mandible: A 1-year randomized controlled clinical and radiographic study. Int J Oral Maxillofac Implants 2019; 34:1493–1503.
38. Landazuri-Del Barrio RA, Cosyn J, De Paula WN, De Bruyn H, Marcantonio E Jr. A prospective study on implants installed with flapless-guided surgery using the all-on-four concept in the mandible. Clin Oral Implants Res 2013; 24:428–433.
39. Tekin S, Değer Y, Demirci F. Evaluation of the use of PEEK material in implant-supported fixed restorations by finite element analysis. Niger J Clin Pract 2019; 22:1252–1258.
40. Ueda T., Kremer U., Katsoulis J. and Mericske-Stern R.: Long-term results of mandibular implants supporting an overdenture: implant survival, failures, and crestal bone level changes. Int J Oral Maxillofac Implants. 2011; 26:365-372.
41. Menini M, Conserva E, Tealdo T, Bevilacqua M., Pera F., Signori A. and Pera P.: Shock absorption capacity of restorative materials for dental implant prostheses: an in vitro study. Int J Prosthodont. 2013; 26(6):549-556.
42. Conserva E., Menini M., Tealdo T., Bevilacqua M., Ravera G., Pera F., Pera P.: The use of a masticatory robot to analyze the shock absorption capacity of different restorative materials for prosthetic implants: a preliminary report. Int J Prosthodont. 2009; 22(1):53-55.
43. Tekin S, Değer Y, Demirci F. Evaluation of the use of PEEK material in implant-supported fixed restorations by finite element analysis. Niger J Clin Pract 2019;22:1252–1258.
44. Suwannaroop P, Chaijareenont P, Koottathape N, Takahashi H, Arksornnukit M. In vitro wear resistance, hardness and elastic modulus of artificial denture teeth. Dent Mater J 2011; 30:461–468.
45. Malo P, de Araujo Nobre M, Lopes A, Ferro A, Nunes M. The All-on-4 concept for full- arch rehabilitation of the edentulous maxillae: A longitudinal study with 5–13 years of follow-up. Clin Implant Dent Relat Res 2019;21: 538–549.
46. Alrajhi MS, Askar O, Habib AA, ELsyad MA. Maxillary bone resorption with conventional dentures and four implant supported fixed prosthesis opposed by distal extension partial dentures. A preliminary five-year retrospective study. Int J Oral Maxillofac Implants 2020;35: 816–823.
47. de Araújo Nobre M, Moura Guedes C, Almeida R, Silva A, Sereno N. Hybrid Polyetheretherketone (PEEK)-Acrylic Resin Prostheses and the All-on-4 Concept: A Full-Arch Implant-Supported Fixed Solution with 3 Years of Follow-Up. J Clin Med. 2020;9(7):2187.
48. Stawarczyk B, Thrun H, Eichberger M, et al. Effect of different surface pretreatments and adhesives on the load-bearing capacity of veneered

3-unit PEEK FDPs. J Prosthet Dent 2015; 114:666–673.
49. Mugnai R, Tarallo L, Capra F, Catani F. Biomechanical comparison between stainless steel, titanium and carbon-fiber reinforced polyetheretherketone volar locking plates for distal radius fractures. Orthop Traumatol Surg Res 2018;104:877–882.
50. Papaspyridakos P, Lal K. Complete arch implant rehabilitation using subtractive rapid prototyping and porcelain fused to zirconia prosthesis: a clinical report. J Prosthet Dent. 2008;100(3):165-172.
51. An HS, Park JM, Park EJ. Evaluation of shear bond strengths of gingiva-colored composite resin to porcelain, metal and zirconia substrates. J Adv Prosthodont. 2011;3(3):166-171.
52. Kitayama S, Nikaido T, Takahashi R, Zhu L, Ikeda M, Foxton RM, Sadr A, Tagami J. Effect of primer treatment on bonding of resin cements to zirconia ceramic. Dent Mater 2010; 26:426-32.
53. Shakal, M. Comparative Fracture Resistance of Composite Veneered Polyether Ether Ketone Crowns with Ceramic and Composite Veneered Zirconia Crowns. Egyptian Dental Journal, 2018; 64: 711-719.