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REHABILITATION OF THE EDENTULOUS MAXILLA WITH ALL-ON-FOUR HYBRID PROSTHESIS AND BAR-CLIP RETAINED OVERDENTURE IN PATIENTS WITH MANDIBULAR HYBRID PROSTHESES: CLINICAL, RADIOGRAPHIC, AND PROSTHETIC OUTCOMES

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ABSTRACT

Purpose: The purpose was to compare the clinical, radiographic, and prosthetic results of an All-On-Four maxillary hybrid prosthesis and a bar-clip retained maxillary overdenture after one year of follow-up in patients with mandibular hybrid prostheses. **Materials and methods:** Twelve participants with completely edentulous maxillae and mandibular hybrid prostheses were selected. Participants were randomly assigned to one of two groups: All-On-Four maxillary hybrid prosthesis group (HP) and bar-clip retained maxillary overdenture (BO) group. In the HP group, the patients received four maxillary implants in accordance with the All-On-Four concept. The implants were functionally loaded with maxillary fixed detachable hybrid prostheses. In the BO group, the patients received four parallel implants supporting bar-clip retained maxillary overdentures. **Results:** At 12 months, there were significant differences in gingival and plaque indices and probing depth between both groups for anteriorly placed implants. The plaque and gingival indices, and probing depth of the HP group were significantly greater than those of the BO group. For anterior implants, there was no difference in implant stability or marginal bone loss between the two prostheses. Group comparisons at the posteriorly placed implants revealed significant differences in plaque and gingival indices at 12 months. The total number of prosthetic complications required for the BO group was significantly higher than for the HP group. **Conclusion:** Within the limitations of this study, it was possible to conclude that, in patients with mandibular hybrid prostheses, both All-On-Four hybrid prostheses and bar-clip retained overdentures may be effectively utilized for rehabilitation of the edentulous maxilla using four implants since the clinical, radiological, and prosthetic outcomes were clinically acceptable and manageable. However, bar-clip retained overdentures may produce better clinical outcomes than All-On-Four hybrid prostheses, but they require more prosthetic maintenance.

KEYWORDS: All on four, hybrid prosthesis, bar clip overdenture, maxilla.

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INTRODUCTION

Prosthetic rehabilitation of the edentulous maxilla using implants is more complicated than it is on the mandible due to vertical and horizontal alveolar bone loss and the low quality of the remaining bone. Also, the maxillary sinus may be subjected to sinus pneumatization and thin trabecular bone.[1] Increased gingival thickness, which is commonly associated with an increased abutment height and therefore a longer vertical lever arm, is another issue. Cantilever prostheses or sinus lift treatments can be utilized to compensate for bone quality and quantity that are lacking.[2] Distal cantilevers increase implant failures due to biomechanical complications, whereas sinus lift therapy necessitates repeated surgical procedures. This could increase patient morbidity and raise the risk of complications such as longer recovery periods, higher expenses, and low patient satisfaction. [3]

Treatment of the edentulous maxilla with an implant supported prosthesis has been shown to provide greater comfort, masticatory function, and patient satisfaction when compared to a full denture. A common issue with maxillary implant supported prosthesis is a lack of adequate bone volume for implant insertion.[4] One technique is to augment the alveolar bone, allowing for the insertion of an ideal number of implants in an optimal location. But bone augmentation treatments may have surgical risks and are linked with problems like donor site morbidity and infection, as well as extended treatment durations that are more expensive and time-consuming.[5] As an alternative to bone augmentation, treatment procedures including fewer implants have resulted in satisfactory clinical results. The positive clinical results of protocols that use four implants to support a hybrid prosthesis seem to suggest that more implants may not be needed.[6,7]

The "All-On-Four" treatment concept includes a fixed prosthetic appliance supported by four implants. Two implants are inserted anteriorly in an axial orientation, and two implants are installed posteriorly with a 30°-45° distal tilt.[8] This concept has gained popularity as a treatment plan for edentulous maxillae and mandibles. The tilting of posterior implants has a number of benefits, including shorter cantilever lengths, better anterior-posterior spread, the ability to utilize longer implants, and a larger base of the prosthesis. [9] The All-On-Four treatment protocol has a number of benefits, such as making the best use of remaining bone to prevent bone grafting and placing a temporary prosthesis for immediate loading and preservation of oral functions. Also, it has the advantages of lower financial costs and reduced treatment time. [10,11]

For maxillary implant restoration, three types of final prostheses might be used: fixed prostheses that are either screwed or cemented over implants; fixed-detachable hybrid prostheses; and overdentures. A fixed-detachable hybrid prosthesis not only replaces missing teeth, but it also mimics the lost tissues of the mouth. Because of the different characteristics of the materials utilized in its manufacture, it is referred to as a hybrid. Acrylic resin and metal, or metal and ceramic, or newly developed materials such as polyetherether ketone with acrylic or composite, are the most common materials used in hybrid prostheses.[12,13] It has been emerged as an alternative prosthodontic therapy with great survival rates in edentulous patients with severe alveolar bone loss and a lack of appropriate soft tissue support. It has been shown to be advantageous than fixed implant restorations in terms of lip support, phonetics and esthetics in the atrophied maxilla. [14,15] In cases of moderate to severe ridge resorption, four implants supporting hybrid prosthetic appliances or overdentures can be used to restore the edentulous maxilla with improved aesthetic results. [16,17]

Maxillary implant overdentures are considered a reliable treatment option because of their high success rates, consistent clinical parameters, and greater patient satisfaction. The use of implants to

support overdentures is an option for people who couldn't afford full-arch hybrid prostheses or who have speech or cosmetic issues such as decreased lip support, increased inter-arch space, and poor jaw relationship.[18,19] Another advantage of overdentures over hybrid prostheses is the possibility of removing them at night to reduce bruxism concerns. Also, the screw-retained nature of hybrid prostheses and the presence of prosthetic flanges make it harder for patients to perform oral hygiene measures.[20,21]

There are several attachment options available for implant overdentures. The bar design offers biomechanical benefits and may deliver more predictable clinical outcomes, particularly for maxillary edentulous individuals. Bar-clip attachments are often used because of their benefits, such as stress distribution on retaining implants and bone. They splint implants together and act to restrict displacing forces in vertical and oblique orientations. Depending on the shape of the cross-section, they allow different amounts of denture mobility toward the tissue.[22]

There are several advantages to implant-supported bar overdentures in terms of both clinical and prosthodontic aspects. It has prosthetic benefits that are similar to those of removable dentures and clinical benefits that are similar to those of fixed prostheses.[23] Dentures have comparable retention and stability to that of fixed prostheses, and the occlusal plane's stability prevents ridge loss. However, the use of these attachments requires an acceptable vertical dimension in order to accommodate the denture base, acrylic teeth, and bar-clip attachment system in the ideal restorative area for bar-clip overdentures.[24] Also, bars raise the cost of overdentures. When compared to hybrid prostheses, the appearance of bar fixation screws on the vestibular side has no effect on the aesthetics of the overdenture. The bar system has also been linked to poor oral hygiene and mucositis because it is hard to clean the area around the implant.[25,26]

Reviewing the literature revealed that there are clinical studies comparing the effects of mandibular four implant supported fixed prosthesis and bar overdenture on peri-implant tissues. [27-32] To the best of the authors' knowledge, only two clinical studies have compared an All-On-Four screw-retained prosthesis to overdenture retained by un-splinted implants.[33,34] Hence, the objective of this study was to compare the clinical, radiographic, and prosthetic results of an All-On-Four maxillary hybrid prosthesis and a bar-clip retained maxillary overdenture after one year of follow-up in patients with mandibular hybrid prostheses. The null hypothesis was that there would be no difference between the two prostheses in clinical, radiographic, or prosthetic outcomes.

MATERIALS AND METHODS

Participant enrollment and study design

Twelve patients (6 males and 6 females) from the removable prosthodontics outpatients' clinic were selected, with a mean age of 55.5±4.31. The patients had completely edentulous maxillae and mandibular hybrid prostheses. The included patients had the following criteria: 1) loose and unstable maxillary dentures; 2) sufficient maxillary anterior bone volume and density (Cawood and Howell[35] classes IV-VI bone volume and Lekholm and Zarb[36] classes 1-3 bone density) to support four implants. This was confirmed by cone beam computerized tomography that was done before surgery; 3) adequate maxillary inter-arch space (class I as defined by Ahuja and Cagna[37]) to allow the insertion of fixed and overdenture prostheses. This was verified by mounting the diagnostic casts, utilizing a tentative jaw relationship. The exclusion criteria were: 1) metabolic diseases like osteoporosis and diabetes mellitus; 2) bleeding disorders; 3) TMJ problems; 4) smoking; 5) immunosuppressive therapy or recent head and neck radiotherapy; 6) bruxism; and 7) neuromuscular illnesses.

The sample size estimate was based on the findings of a prior study[34] that found a significant difference in the clinical and radiographic parameters between implant overdentures and fixed prostheses when used to restore an edentulous maxilla (effect size = 0.95, $\alpha = 0.05$, $\beta = 0.95$). To account for possible dropouts, the calculated sample of 10 patients was raised to 12 patients. A computer program (G power 3.1.5) was used to carry out the power analysis.

After the participants were informed about the treatment sequence and the need for follow-up visits, they all signed an "informed consent" form. The research protocol was approved by the Faculty of Dentistry's local ethics committee. The study was carried out in accordance with the CONSORT standards for clinical studies.

Participants were randomly assigned to two equal groups: All-On-Four fixed detachable maxillary hybrid prosthesis group (HP) and bar-clip maxillary overdenture group (BO). This was done by the random number function in Microsoft Excel spreadsheet. An independent dentist who was blind to the type of prosthesis performed the randomization. Allocation was done in a way to guarantee that each group had an equal gender distribution. In the HP group, the patients received four maxillary implants in accordance with the All-On-Four concept. The implants were functionally loaded with fixed detachable maxillary hybrid prostheses. In the BO group, the patients received four parallel implants supporting bar-clip retained maxillary overdentures.

Surgical and prosthetic interventions

New maxillary conventional dentures with bilateral balanced occlusion were constructed, while the old mandibular hybrid prosthesis was assessed and any necessary adjustments were performed. The patients were instructed to wear their dentures for two months prior to implant placement. After adding gutta percha radiopaque markers to the polished palatal and buccal sides of the maxillary denture, the denture was used as a radiographic template

Each participant had a double scan procedure utilizing cone beam computed tomography (i-CATVision, Hatfield, Pennsylvania, U.S.) while wearing maxillary and mandibular prostheses and was occluded in centric occlusion. A second separate scan was performed for the maxillary denture alone. To create a three-dimensional picture of the edentulous maxilla, the two scans were superimposed on each other using computer software (On Demand 3D, Cybermed Inc., Seoul, Korea). The maxillary implant location, angulation, and distribution were digitally designed for the two prostheses using the design software. A mucosa-born stereolithographic surgical guide was created using rapid prototyping technology (In2Guide). The stent was designed with circular sleeves positioned around implant locations. Patients received a daily dose of 0.2% chlorhexidine digluconate mouth-wash for three days pre-surgery and seven days thereafter. One hour prior to surgery, they received amoxicillin and clavulanic acid; then twice daily for ten days after surgery; and if there was pain or discomfort, analgesics were administered postoperatively. With the aid of the surgical guide, four implants (Standard Plus implant, SLActive, Institute Straumann AG, Basel, Switzerland) were inserted into the maxillary bone using the flapless surgical technique. An interocclusal record and fixation pins were used to secure the surgical guide to the maxilla. The osteotomies for the four implants were done using a universal surgical kit (In2Guide Universal Kit, Cybermed, Inc., USA).

In the HP group, four implants (3.3 mm diameter, 11 mm length anteriorly and 13 mm posteriorly) were inserted in the maxilla. Both anteriorly placed implants were inserted axially in lateral incisors or canine locations, parallel to one another and at a right angle to the occlusal plane. The two posteriorly

installed implants were placed in the premolar regions at a 30-degree distal angle. Multiunit abutments (Straumann AG, Basel, Switzerland) were tightened into the implant fixtures with their temporary metal caps threaded to the abutments. Postoperative radiographs were used to assess implant location and abutment passive seating. The maxillary denture, which had its flanges and second molar teeth removed, was used for immediate loading. Opposite to the metal caps, the maxillary denture was hollowed out. During the picking-up steps, a spacer was added to the abutment to prevent the resin from entering into the gingival tissues around the implants. Using self-cured acrylic resin, the caps were picked up into the modified denture while the patient closed in centric occlusion. The occlusal contact on inclined implants was eliminated. Patients were informed to consume soft foods and to practice good oral hygiene. They were also informed of regular follow-up appointments (twice a week for the first four weeks, then once a week after that) to check on their oral hygiene and make adjustments to their dentures.

Following six months of osseointegration, the maxillary denture was removed. An open-top tray abutment level impression was performed. The long impression copings were fastened to the multiunit abutments and splinted. Then, around the copings, a light-body (Zhermack, Badia Polesine, Rovigo, Italy) rubber base impression material was injected. This was followed by a heavy body rubber base in a stock tray to finalize the impression. The impression copings were unscrewed; the abutment analogues were tightened to the impression posts. This was followed by pouring the impression.

A metal-ceramic screw-retained hybrid maxillary prosthesis was planned for the HP group using the computer software (Exocad GmbH, Germany) after scanning the cast using a benchtop scanner (Swing, Seoul, Korea). The prosthesis was designed with 12 teeth (without the second molar teeth) and with pink porcelain to replace the lost soft tissues. Then it was milled in resin (Duralay, Reliance MFG) and checked for passive fit in the patient's mouth. Using the lost wax method, the resin pattern was then turned into a cast metal using cobalt chromium Co-Cr (Heraeus-Kulzer GmbH, Hanau, Germany) metal substructure. The metal framework was tested for passivity in the patient's mouth. Jaw relations were taken, followed by mounting the casts on a semi-adjustable articulator. A bilateral balanced occlusion was used. The metal structure was then given an opaque covering, and then porcelain powder was mixed, painted, fired, and finished. After performing the appropriate occlusal adjustments, the prosthesis was provided to the participants. ***Figure (1)***

For the BO group, four parallel implants (3.3 mm diameter and 11 mm length) were inserted in the maxilla. The two anterior implants were placed in the area of the canines, and the two posterior implants were installed in the second premolar region. Bar abutments (Straumann AG, Basel, Switzerland) were tightened into the implant analogues and the implants were joined with a bar attachment (OT bar multiuse, RHEIN 83, Italy). The clearance space between the bar and the edentulous ridge was left at 2 mm. The plastic burned out pattern of the bar was luted to the bar abutments using sticky wax. The assembly was sprued, invested, and cast into the Co-Cr alloy (Heraeus-Kulzer GmbH, Hanau, Germany). The bar was tested for passivity in the patient's mouth. New maxillary dentures were fabricated following the conventional technique. On the master models, the retentive clips were fastened to the bar abutments in between the implants. The maxillary overdentures were relieved at the area opposite to the retentive clips (yellow, medium retention, RHEIN 83, Italy). Then the self-cured resin was used to pick up the clips and attach them to the fitting surface of the dentures. After making the necessary occlusal adjustments, the maxillary overdentures were then delivered to the participants. ***Figure. (2)*** Patients in both groups were taught a

plaque control technique, and they were reminded of this at their follow-up visits.

Outcome measures

Clinical and radiographic evaluations for each implant were recorded at definitive prosthesis insertion then after 6 and 12 months. The clinical outcomes measured were Mombelli et. et. [38] modified plaque index and gingival indices, pocket depth, and implant stability. These parameters were measured on each implant's mesial, buccal, distal, and lingual sides. The measurements were taken to the nearest millimeter. The implant stability quotient (ISQ) was measured using the Osstell device (Integration Diagnostics Ltd).

The radiographic evaluation of the peri-implant marginal bone level was performed by indirect digital periapical radiographs (Digora Optime, Orion Corp/Soredex) using the long-cone technique. A customized acrylic stent was constructed to standardize the exposure conditions. The distance between peri-implant marginal bone level and the implant-abutment junction on the mesial and distal sides of the implants was measured and an average was taken. To account for magnification problems, images were calibrated based on known implant parameters. The bone level during recall visits was compared to the bone level at baseline to determine marginal bone loss. Following instruction and calibration, two examiners took the marginal bone level measurements. It was not possible to blind examiners to treatment conditions.

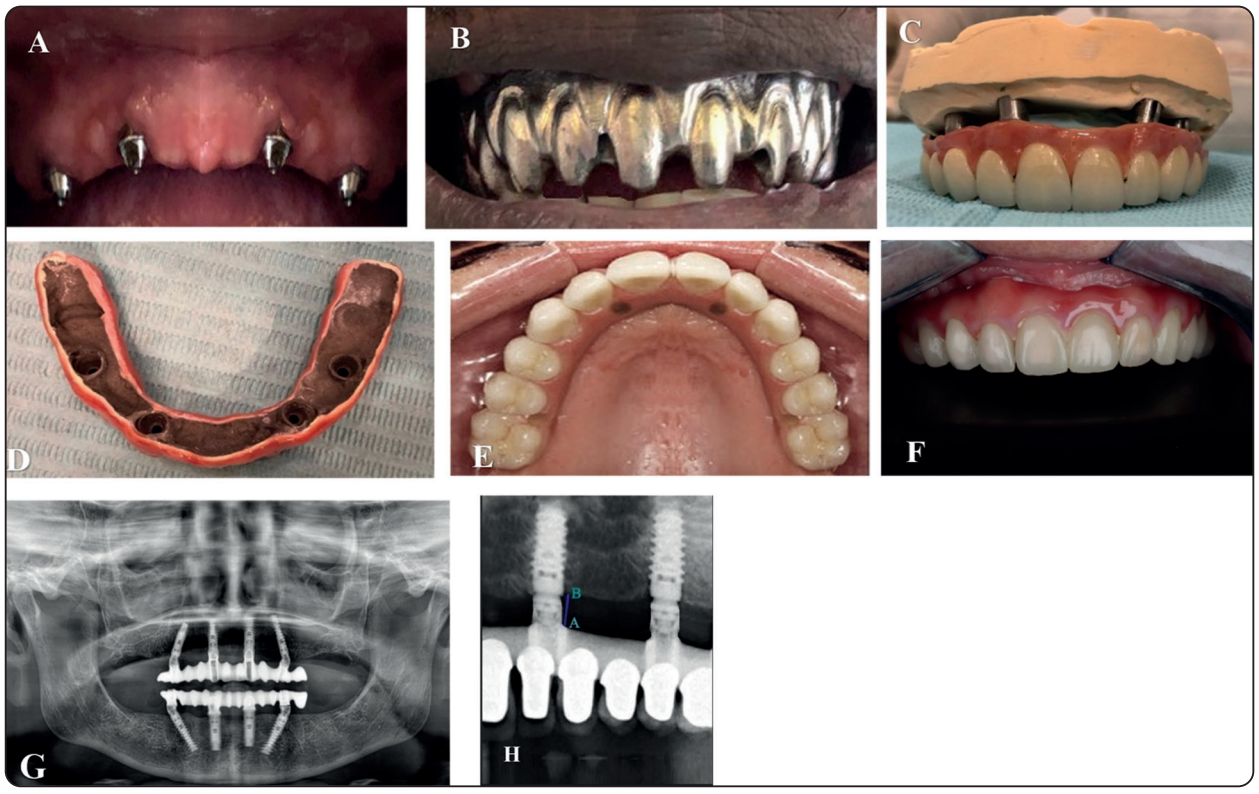

Fig. (1): All-On-Four maxillary hybrid prosthesis HP group: (A) Tightened multiunit abutments to their fixtures; (B) Trying the metal framework inside the patient's mouth; (C-F) Different views for the finished prosthesis: (C) On the cast; (D) Fitting surface of the finished prosthesis; (E) Intra-oral occlusal view; (F) Intra-oral frontal view; (G) Post-prosthesis insertion panoramic radiograph; and (H) A periapical radiograph of the anterior implants with marginal bone loss measurement. AB: The distance between marginal bone level and the implant-abutment junction on the distal side of the implant.

The prosthetic complications evaluated were: abutment-bar fracture, abutment-screw loosening, bar clip wear, bar clip fracture, fracture or adjustment of overdenture teeth, overdenture fracture, denture margin adjustments, and denture relining. The prosthetic outcomes were reported after 12 months of prosthesis placement.

Statistical analysis

The inter-examiner and intra-examiner reliability of measurements were tested by the Cronbach α test. To detect significant differences between observation times, Friedman test was used to discover significant differences between observation periods, followed by Dunn's multiple comparisons test. Comparisons between the two groups were made using Mann-Whitney test for clinical and radiographic outcomes and chi-square test for prosthetic complications. The level of significance was set at $P<0.05$. The statistical analysis of the data was performed with SPSS software version 22 (SPSS Inc.).

RESULTS

In both groups, implant survival following definitive prosthesis placement was 100%. Over time, plaque index, probing depth, implant stability quotient, and marginal bone loss increased significantly in both the anterior and posterior implants of the two groups ($P < 0.05$). There was no variation in gingival index between observation periods for the BO group. On the other hand, the gingival index increased significantly over time

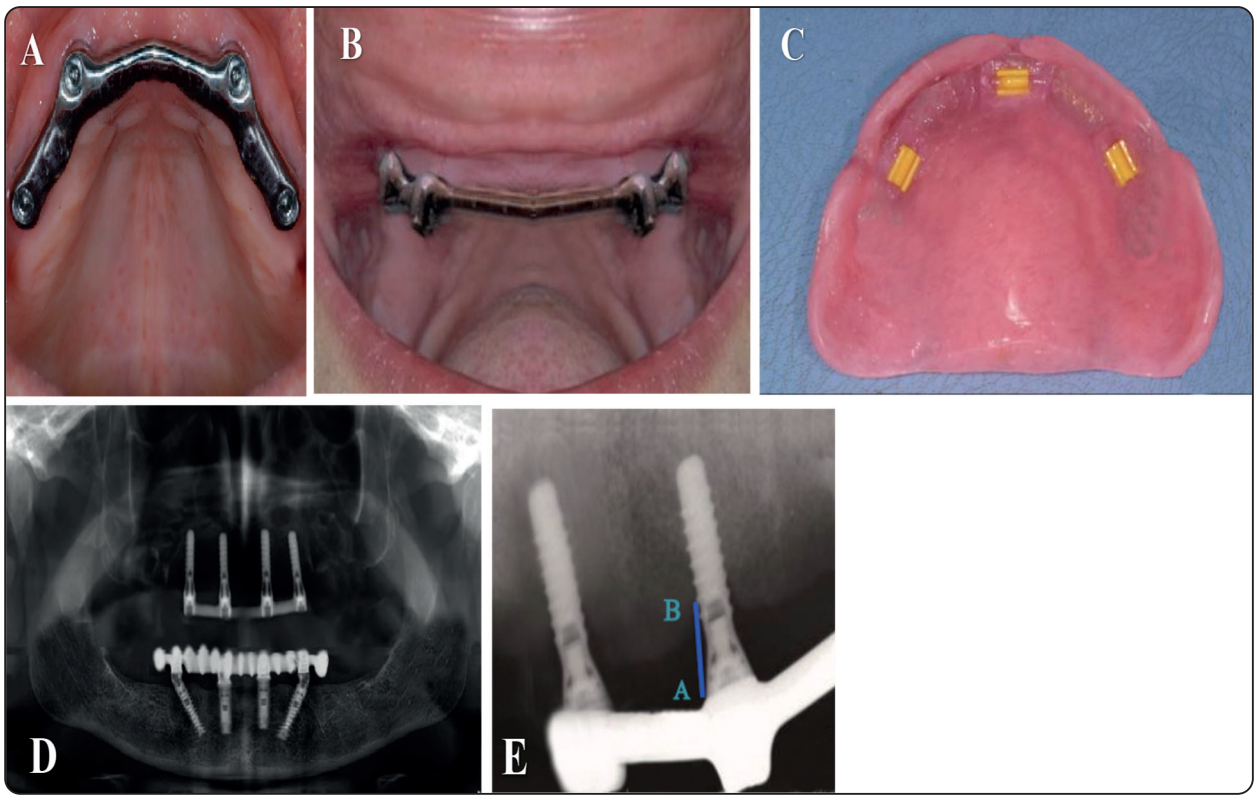

Fig. (2): Bar-clip maxillary overdenture BO group: (A-B) Intraoral views of the bar attachment: (A) Occlusal view; (B) Frontal view; (C) The overdenture fitting surface with clips in place; (D) A panoramic radiograph taken after the bar has been placed; and (E) Periapical radiographic measurement of marginal bone loss. AB: The distance between marginal bone level and the implant-abutment junction on the distal side of the implant.

for both anterior and posterior implants in the HP group. ***Table 1*** and ***Table 2*** show the evaluated outcomes for each of the anterior and posterior implants, respectively, across measurement periods and groups.

At 12 months, there were significant differences in gingival and plaque indices and probing depth between both groups for anteriorly placed implants. The plaque and gingival indices, and probing depth of the HP group were significantly greater than those of the BO group (P <0.05). For anterior implants, there was no difference in implant stability or marginal bone loss between prostheses. Group comparisons at the posteriorly placed implants revealed significant differences in plaque and gingival indices at 12 months, while there were insignificant differences in pocket depth, implant stability, or marginal bone loss.

Table 3 compares clinical and radiographical outcomes for anteriorly and posteriorly placed implants during varying observation periods for both groups. For the HP group, the anterior implants had a significantly higher plaque index after 12 months, a significantly higher gingival index at 6 and 12 months, and significantly deeper pockets than posterior implants at 6 months. In terms of

TABLE (1): The clinical and radiographic results for anterior implants compared across follow-up intervals and groups.

		At insertion	6 months	12 months	P/
		Plaque Index			
HP	Median (minimum-maximum)	0.10 (0.00-0.10)	1.00 (0.00-1.00)	3.00 (0.00-3.00)	<0.0001*
BO	Median (minimum-maximum)	0.01 (0.00-0.10)	1.00 (0.00-1.00)	1.00 (0.00-2.00)	0.0127*
	P	0.0671	0.0675	0.002*	
		Gingival index			
HP	Median (minimum-maximum)	0.00 (0.00-1.00)	1.00 (0.00-2.00)	2.00 (1.00-2.00)	0.0011*
BO	Median (minimum-maximum)	0.00 (0.00-1.00)	0.00 (0.00-1.00)	0.00 (0.00-1.00)	0.1632
	P	0.7001	0.0161*	P<0.0001*	
		Pocket depth			
HP	(Mean± Standard deviation)	0.58±0.13	2.05±0.29	2.38±0.32	<0.0001*
BO	(Mean± Standard deviation)	0.49±0.06	1.95±0.13	1.99±0.16	<0.0001*
	P	0.2638	0.5545	0.0028*	
		Implant stability			
HP	(Mean± Standard deviation)	66.66±1.34	68.14±1.55	71.41±2.08	<0.0001*
BO	(Mean± Standard deviation)	65.98±1.67	67.45±1.28	69.89±1.39	<0.0001*
	P	0.3078	0.2222	0.1292	
		Marginal bone loss			
HP	(Mean± Standard deviation)	-	0.35±0.03	0.70±0.04	<0.0001*
BO	(Mean± Standard deviation)	-	0.35±0.04	0.68±0.04	<0.0001*
	P	-	0.9737	0.4485	

P: P-value of Mann-Whitney test ***$P^{/:}$ P-value of Freidman test***

****Significant if P<0.05 horizontally according to Mann-Whitney test & vertically according to Freidman test.***

implant stability and marginal bone loss, there were insignificant differences between anterior and posterior implants in either group.

There was a statistically significant difference in the effect of prosthesis type on the complications that occurred. During the full follow-up period, a total of 7 prosthetic complications were recorded in the HP group and 23 in the BO group. ***Table. 4*** shows the frequency and percentage of prosthetic complications in both groups. The total number of prosthetic complications required for the BO group was significantly higher than for the HP group. There were no prosthesis or abutment fractures in either group. Furthermore, there was no veneer fracture or separation in the HP group, nor clip fracture or denture relining in the BO group. Prosthesis screw loosening (n = 4, 57.15%) was the most common complication in the HP group, followed by abutment screw loosening (n = 3, 42.85%). The most common complications for the BO group were clip wear (n = 16, 69.57%), followed by denture margin adjustment (n = 3, 13.04%) and bar screw loosening and wear/ adjustment of denture teeth (n = 2, 8.70%) each. The HP group had significantly higher prosthesis screw loosening than the BO group (P <0.05).

TABLE (2): The clinical and radiographic results for posterior implants compared across follow-up intervals and groups.

		At insertion	6 months	12 months	P/
		Plaque Index			
HP	Median (minimum-maximum)	0.20 (0.00-1.00)	1.00 (0.00-1.00)	2.00 (0.00-2.00)	0.0042*
BO	Median (minimum-maximum)	0.02 (0.00-1.00)	1.00 (0.00-1.00)	1.00 (0.00-1.00)	0.0129*
	P	0.0749	0.9608	0.0029*	
		Gingival index			
HP	Median (minimum-maximum)	1.00 (0.00-1.00)	1.00 (0.00-2.00)	1.00 (0.00-2.00)	0.0042*
BO	Median (minimum-maximum)	1.00 (0.00-1.00)	1.00 (1.00-1.00)	0.00 (0.00-1.00)	<0.0001*
	P	0.2178	0.4084	0.0281*	
		Pocket depth			
HP	(Mean± Standard deviation)	0.54±0.10	1.75±0.19	2.14±0.21	<0.0001*
BO	(Mean± Standard deviation)	0.47±0.05	1.92±0.14	1.98±0.14	<0.0001*
	P	0.06	0.0758	0.1145	
		Implant stability			
HP	(Mean± Standard deviation)	67.91±1.39	69.30±1.98	72.64±2.48	<0.0001*
BO	(Mean± Standard deviation)	66.45±2.08	68.77±1.64	71.34±1.69	<0.0001*
	P	0.1145	0.4886	0.2912	
		Marginal bone loss			
HP	(Mean± Standard deviation)	-	0.37±0.06	0.71±0.02	<0.0001*
BO	(Mean± Standard deviation)	-	0.36±0.02	0.69±0.05	<0.0001*
	P	-	0.7414	0.4260	

P: P-value of Mann-Whitney test P/: P-value of Freidman test

****Significant if P<0.05 horizontally according to Mann-Whitney test & vertically according to Freidman test.***

TABLE (3): The measured outcomes of anteriorly and posteriorly placed implants for both groups compared across follow-up periods.

	At insertion		6 months		12 months	
	HP	**BO**	**HP**	**BO**	**HP**	**BO**
			Plaque index			
Anterior median (minimum-maximum)	0.10 (0.00-0.10)	0.01 (0.00-0.01)	1.00 (0.00-1.00)	1.00 (0.00-1.00)	3.00 (0.00-3.00)	1.00 (0.00-2.00)
Posterior median (minimum-maximum)	0.20 (0.00-1.00)	0.02 (0.00-1.00)	1.00 (0.00-1.00)	1.00 (0.00-1.00)	2.00 (0.00-2.00)	1.00 (0.00-1.00)
Mann-Whitney test	0.1775	0.2270	0.5811	0.1933	0.0416*	0.0981
			Gingival index			
Anterior median (minimum-maximum)	0.00 (0.00-1.00)	1.00 (0.00-1.00)	1.00 (0.00-2.00)	1.00 (0.00-1.00)	2.00 (1.00-2.00)	0.00 (0.00-1.00)
Posterior median (minimum-maximum)	1.00 (0.00-1.00)	1.00 (1.00-1.00)	1.00 (0.00-2.00)	1.00 (1.00-1.00)	1.00 (0.00-2.00)	0.00 (0.00-1.00)
Mann-Whitney test	0.7049	0.6843	0.0161*	0.4084	0.0296*	0.9475
			Pocket depth			
Anterior (Mean± Standard deviation)	0.54±0.10	0.49±0.06	2.05±0.29	1.95±0.13	2.22±0.31	1.99±0.16
Posterior (Mean± Standard deviation)	0.58±0.13	0.47±0.05	1.75±0.19	1.92±0.14	2.00±0.20	1.96±0.15
Mann-Whitney test	0.5952	0.6218	0.0207*	0.2496	0.1119	0.3085
			Implant stability			
Anterior (Mean± Standard deviation)	66.66±1.34	65.98±1.67	68.14±1.55	67.45±1.28	71.41±2.08	69.89±1.39
Posterior (Mean± Standard deviation)	67.91±1.39	66.45±2.08	69.30±1.98	68.77±1.64	72.64±2.48	71.34±1.69
Mann-Whitney test	0.06	0.6215	0.1142	0.0605	0.2001	0.0604
			Marginal bone loss			
Anterior (Mean± Standard deviation)	-	-	0.35±0.03	0.35±0.04	0.70±0.04	0.68±0.04
Posterior (Mean± Standard deviation)	-	-	0.37±0.06	0.36±0.02	0.71±0.02	0.69±0.05
Mann-Whitney test	-	-	0.3051	0.4495	0.3718	0.6929

* Significant if P<0.05 according to Mann-Whitney test.

TABLE (4): Frequency and percentage of prosthetic complications in both groups.

	HP group		BO group	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Prosthesis fracture	0	0%	0	0%
Veneer fracture or separation	0	0%	0	0%
Gingival porcelain fracture	0	0%	0	0%
Abutment fracture	0	0%	0	0%
Abutment-screw loosening	3[a]	42.85%	0	0%
Abutment-screw fracture	0	0%	0	0%
Prosthesis/bar screw loosening	4[a]	57.15%	2[b]	8.70%
Prosthesis screw fracture	0	0%	0	0%
Clip wear	0[a]	0%	16[b]	69.57%
Clip fracture	0	0%	0	0%
Fracture /wear or adjustment of teeth	0[a]	0%	2[b]	8.70%
Denture margin adjustments	0[a]	0%	3[b]	13.04%
Denture relining	0	0%	0	0%
Total complications	7[a]	100%	23[b]	100%

Horizontally, values superscripted with different lower-case letters are statistically significant (P<0.05).

DISCUSSION

In this study, the flapless surgical method was used because it has many benefits, such as less pain and edema after surgery and the ability to load temporary dentures immediately. Also, there was less bone resorption with the flapless method because flap reflection causes mucoperiosteal stripping, which can lead to bone loss around the implants.[39] A stereolithographic surgical stent was employed in conjunction with CBCT for adequate data transfer of the operative field and for implant insertion. This template enables precise 3-dimensional implant insertion at the desired implant location. Traditional stents and panoramic x-rays can't show the jaw bone or important structures in the buccolingual dimension accurately.[40]

The overall survival rate (100%) in both groups was comparable to data reported in the literature for both maxillary All-On-Four hybrid prosthesis and bar overdenture.[15, 41] Both groups had increased plaque and gingival indices over time. Elsyad et. al.[30] reported similar findings with metal-ceramic screw retained prostheses and bar overdentures. This might be attributed to the diminished cleaning ability of aged people, which makes plaque buildup worse.[27] Another factor might be patients' difficulty removing the prosthesis to practice sufficient oral hygiene in HP group.[30] While the presence of bar in BO group hindered the accessibility around the implants and complicated the oral hygiene.[22] Furthermore, it appears that the patients did not follow the oral hygiene protocol. It should be noted that the results of plaque and gingival scores can be adjusted if strict oral hygiene instructions

are followed and maintained. In contrast to these results, Ayub et. al.[15] found a substantial decrease in plaque indices after a one-year assessment period for patients with four implants supported fixed prostheses. This might be due to strict patients' following of the oral hygiene instructions.

In the current study, hybrid prostheses had significantly higher plaque and gingival indices than bar-clip overdentures. This might be attributable to the presence of wide prosthetic flanges on the hybrid restoration, which induces greater plaque accumulation. In addition, patients may experience more plaque formation and gingival irritation because they can't remove the prosthesis and clean the area around the implants. Moreover, the presence of a cantilever in the All-on-Four prosthesis as well as greater spacing between the implants, increases plaque stagnation and makes cleaning more difficult.[42] The retrievability of bar overdentures, on the other hand, helps the patient's oral hygiene performance. These explanations were supported by studies on patient satisfaction with fixed prostheses and bar retained overdentures. They found that bar overdentures were ranked higher for ease of cleaning and oral hygiene than fixed prostheses.[30,43] Because of gingival irritation and inflammation, the higher gingival index in the hybrid prosthesis group may be caused by the elevated plaque index. The link between plaque and gingival irritation has already been shown. The overdenture group had a lower gingival index because there was less plaque buildup. This could also explain the insignificant change in gingival index across observation intervals.[44]

Anteriorly placed implants had considerably higher plaque and gingival indices than posteriorly inserted implants in the hybrid prostheses group. This might be due to the reduced manual dexterity of aged population making it hard to clean the anterior region properly. The resulted increased plaque accumulation might be the reason for the elevated indices. Nevertheless, there was no relevant literature which compared such finding in the maxilla.

For both prostheses, there was a significant increase in pocket depth over time. This was consistent with other studies on implants supporting All-On-Four prostheses.[45,46] Over time, deeper pockets can be caused by mucosal enlargement, increased gingival and plaque indices, and loss of bone around the implant.[45] The variation in pocket depth across the two groups might be explained in the same way. Although the difference was not statistically significant, the hybrid prosthesis group had greater bone resorption as compared to bar-clip overdentures. The higher pocket depth in the hybrid prosthesis group compared to the bar-clip group might be attributed to increased gingival index and bone resorption. Nonetheless, in the study conducted by Landazuri-Del Barrio et. al.[47], the pocket depth reduced significantly with time for mandibular implants. The higher thickness of keratinized mucosa around maxillary implants compared to mandibular implants in the current study might be responsible for the increased pocket depth. After six months, the pocket depth of anterior implants for hybrid prostheses was much deeper than that of posterior implants. This difference went away after a year, though. On the other hand, Krennmair et. al.[45] discovered that the depth of the pockets did not change between anteriorly and posteriorly placed implants. The reduced pocket depth in the overdenture group might be attributed to lower plaque gingival indices. Pontoriero et. al.[48] discovered that greater mucosal inflammation of the soft tissues around the implants was related to increasing peri-implant pocket depth.

Resonance frequency analysis was utilized to assess implant stability. This non-invasive method enables the measurement of implant stability throughout healing and at later follow-up visits.[15] The literature claims that implants with a stability quotient of 60 or more can be loaded instantaneously. In our study, both prostheses' implant stability got better over time.[49,50] The implant stability values

recorded were more than 60. This may be due to increased implant-to-bone contact at the interface over time, which enhances implant anchoring in the soft maxillary bone and remodeling of the bone throughout the osseointegration process. Chen et. al.[51] made a similar observation, finding a substantial rise in implant stability values of maxillary implants from baseline to one year after loading. The absence of significant difference in implant stability between both prostheses was not surprising and agreed with a previous study finding.[30] This could be attributed to the implants being splinted by a hybrid prosthesis or a bar overdenture, which distributes functional stresses uniformly across all implants. [52] Consistent with the findings of previous studies, there was no difference in the stability of implants that were placed posteriorly with tilting and anterior axial implants.[15,50] This might be because tilting implants allow for longer implants, which enhance bone-to-implant contact. Furthermore, utilizing a hybrid prosthesis or a bar overdenture to stabilize the implants across the arch reduces individual implant micromovement following prosthesis installation.[30, 52]

Marginal bone loss around the implants is often reported to be less than one millimeter during the first year after implant insertion and then fewer than 0.2 millimeters annually. [53,54] Implants in both groups showed a normal range of marginal bone loss that was 0.70, 0.71 millimeters, for the hybrid prosthesis group and 0.68, 0.69 millimeters for the bar-clip overdenture group in the anterior and posterior implants, respectively. Increased bone resorption over time might be related to bone reactivity to healing as well as functional stress. The greater bone loss in the hybrid prosthesis group might be attributed to a lack of passive fit and the occurrence of vertical gaps between metal caps and abutments as a result of metal dimension changes throughout the investing and casting processes. These gaps may exist on a microscopic level and are difficult to detect during a metal try-in using the single screw test. According to the findings of this study, mismatch and gaps might be one of the causes of increased screw loosening. According to Weinstein and colleagues[55], bone loss around axial and inclined implants for a full arch fixed prosthesis was 0.61 millimeters and 0.71 millimeters, respectively. For anterior and posterior implants, the mean values of bone loss of bar-clip overdenture were 0.68 millimeters and 0.71 millimeters, respectively. Also, Krennmair et. al.[45] discovered a considerable decrease in bone loss in individuals with All-On-Four fixed prostheses. The marginal bone loss of anterior implants was much less than that reported in the literature around four vertical implants supporting a bar in an edentulous jaw. The difference in results could be because posterior implants in our study were placed with a distal tilt. This allows for shorter cantilever length, more antero-posterior spread, and less stress on the bone around the implant than when posterior implants are placed vertically.[56]

There was no statistically significant difference in marginal bone loss between the two groups. Ayna et. al.[27] discovered insignificant differences in marginal bone loss between All-On-Four implant hybrid prostheses and bar-clip retained overdentures. The hybrid prostheses, however, showed slightly greater bone resorption values than the bar-clip overdentures. This increased bone resorption values may be caused by deformation of the metal framework of the hybrid prosthesis, as well as higher occlusal force transfer to the implants by the hybrid prosthesis's porcelain teeth. But in implant overdenture, the bar may have lower bone resorption values because it splints the implants efficiently and because the acrylic resin teeth don't transfer as much force to the implants. This was consistent with Khatami and Smith [57], who argued that prosthesis rigidity over inclined implants, as well as implant antero-posterior spread, could reduce bending forces. Pozzi et. al.[58] investigated bone resorption in four-implant bar-supported overdentures and discovered that the bar reduced bone resorption. They discovered a mean bone resorption of 0.29 mm at the one-year follow-up.

After 12 months, there was insignificant difference in marginal bone loss between the anteriorly and posteriorly placed implants. Other trials for All-On-Four implant-supported prostheses revealed similar results.[45,59] Despite the difference was statistically insignificant, anteriorly placed implants demonstrated more bone loss than posteriorly tilted implants. This might be attributed to patients' anterior eating habits that may lead to anterior hyper-occlusion and concentration of stresses on anterior implants, although they were advised not to bite food with their anterior teeth. Also, this could be attributed to the tilting of distal implants which increases the anterior-posterior spread, thus reducing cantilever length and peri-implant bone stress compared to vertical implants.[60] These results were consistent with previous studies, which revealed that tilted implants supporting fixed prostheses had lower bone resorption values than upright implants. [61, 62]

There was a statistically significant difference in the effect of prosthesis type on the complications that occurred. During the full follow-up period, a total of seven prosthetic complications were recorded in the hybrid prosthesis group and 23 in the bar-clip overdenture group. However, each group reported prosthetic complications comparable to what is reported in the literature.[11,27,64-66] As maxillary bar overdentures are reported to have a relatively high number of complications, especially during the first year of function.[67] But, it has been claimed that prosthetic complications associated with bar-retained acrylic overdentures could be repaired more cheaply than those associated with metal-ceramic prostheses, because acrylic dentures could be mostly repaired in situ, whereas the hybrid prostheses had to be removed and repaired in the laboratory. No prosthesis or abutment fractures occurred in either group, and the prostheses had a 100% survival rate. This might be due to the elderly patients included in the study who had reduced masticatory muscle strength compared to younger individuals and also due to the exclusion of patients with bruxism.[63,65]

Prosthetic screw loosening was the most prevalent prosthetic problem in the hybrid prosthesis group (n = 4, 57.15%). The increased screw loosening might be attributable to several factors. First, the lack of passive fit and the existence of tiny vertical gaps between the prosthesis and abutments. This was in agreement with Landazuri-Del Barrio et al. [47] who reported a lack of passive fit in 81% of All-On-Four prostheses. Second, the cantilevered parts of both types of prostheses might put more stress on the implants and cause the screws to come loose more quickly. Third, the opposing implant hybrid prosthesis conveyed greater occlusal forces to the prosthesis, which might loosen the screw. Finally, the increased occlusal force exerted by patients as a consequence of implant rehabilitation enhances masticatory efficiency, which might lead to screw loosening. [68,69]

The second most common complication was abutment screw loosening (n = 3, 42.85%). This could be due to the high impact strength of porcelain fused to metal in the hybrid prosthesis group, which increased force transmission to the implant and resulted in abutment screw loosening. On the contrary, the acrylic resin in the overdenture group has shock-absorbing ability, which decreases the forces transmitted to implants and reduces screw loosening.[70] The prosthetic problems of provisional restorations throughout the healing period were not assessed in this study. This presents a major concern in that, according to Patzelt et. al.[9], the most common prosthetic complications of All-On-Four restorations are fracture and loosening of the temporary acrylic prosthesis.

The most common complication in bar-clip overdenture patients was a high rate of clip wear (n = 16, 69.57%). This may be attributed to the increased modulus of elasticity of the metal housing, which has been shown to increase the concentration of tensile and shear stress forces on the prosthesis intaglio surface, resulting in an increased rate of clip wear and damage. Plastic clips between the rigid bar

and the metal housing components accelerated the wear. Because of the increasing wear on the metal housing, the plastic clips became the primary means of retention. This increased wear and fracture of these clips, and consequently, the clips had to be replaced.[27] Also, clip attachment wear increased when implant overdenture opposed an implant fixed hybrid prosthesis, as in our study. Furthermore, improved results may be obtained if the bar was computer milled. The second common complication was denture margin adjustment (n = 3, 13.04%) and bar screw loosening and wear/adjustment of denture teeth (n = 2, 8.70%) each. All these findings are in accordance with previous studies' results. [71,72] These complications might be due to overdenture movement under occlusal forces and increased masticatory forces due to implant installation and opposing fixed implant hybrid restorations.

The study's limitations were a limited sample size, a short assessment time, and a lack of assessment of clinical and prosthetic outcomes throughout the critical healing phase. Further long-term studies involving a larger group of patients with different opposing prosthetic implant restorations will be required to assess more accurately the outcomes of All-On-Four maxillary hybrid prostheses and bar-clip retained maxillary overdentures.

CONCLUSION

Within the limitations of this study, it was possible to conclude that, in patients with mandibular hybrid prostheses, both All-On-Four hybrid prostheses and bar-clip retained overdentures may be effectively utilized for rehabilitation of the edentulous maxilla using four implants since the clinical, radiological, and prosthetic outcomes were clinically acceptable and manageable. However, bar-clip retained overdentures may produce better clinical outcomes than All-On-Four hybrid prostheses, but they require more prosthetic maintenance.

REFERENCES

1. Riemann M, Wachtel H, Beuer F, Bolz W, Schuh P, Niedermaier R, Stelzle F. Biologic and Technical Complications of Implant-Supported Immediately Loaded Fixed Full-Arch Prostheses: An Evaluation of Up to 6 Years. Int J Oral Maxillofac Implants. 2019;34 (6):1482-1492.
2. Bedrossian E, Bedrossian EA. Implant-Supported Vs. Tissue-Supported Prosthesis: Biomechanical Principles for Fixed Full-Arch Restorations. Compend Contin Educ Dent. 2019;40(8):524-529.
3. Chrcanovic BR, Kisch J, Larsson C. Retrospective evaluation of implant-supported full-arch fixed dental prostheses after a mean follow-up of 10 years. Clin Oral Implants Res. 2020;31(7):634-645.
4. Lambert FE, Weber HP, Susarla SM, Belser UC, Gallucci GO. Descriptive analysis of implant and prosthodontic survival rates with fixed implant-supported rehabilitations in the edentulous maxilla. J Periodontol. 2009;80(8):1220-1230.
5. Jemt T, Johansson J. Implant treatment in the edentulous maxillae: a 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. Clin Implant Dent Relat Res. 2006;8(2):61-69.
6. Tealdo T, Bevilacqua M, Pera F, Menini M, Ravera G, Drago C, Pera P. Immediate function with fixed implant-supported maxillary dentures: a 12-month pilot study. J Prosthet Dent. 2008;99(5):351-360.
7. Maló P, de Araújo Nobre M, Lopes A, Francischone C, Rigolizzo M. "All-on-4" immediate-function concept for completely edentulous maxillae: A clinical report on the medium (3 years) and long-term (5 years) outcomes. Clin Implant Dent Relat Res 2012;14(suppl 1):e139–e150.
8. Chan MH, Nudell YA. All-on-4 Concept Update. Dent Clin North Am. 2021;65(1):211-227.
9. Patzelt SB, Bahat O, Reynolds MA, Strub JR. The all-on-four treatment concept: a systematic review. Clin Implant Dent Relat Res. 2014;16(6):836-855.
10. Afrashtehfar KI. The all-on-four concept may be a viable treatment option for edentulous rehabilitation. Evid Based Dent. 2016;17(2):56-57.
11. Durkan R, Oyar P, Deste G. Maxillary and mandibular all-on-four implant designs: A review. Niger J Clin Pract. 2019;22(8):1033-1040.

12. Messias A, Nicolau P, Guerra F. Different Interventions for Rehabilitation of the Edentulous Maxilla with Implant-Supported Prostheses: An Overview of Systematic Reviews. Int J Prosthodont. 2021;34: s63-s84.

13. 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.

14. Kwon T, Bain PA, Levin L. Systematic review of short- (5-10 years) and long-term (10 years or more) survival and success of full-arch fixed dental hybrid prostheses and supporting implants. J Dent. 2014;42(10):1228-1241

15. Ayub KV, Ayub EA, Lins do Valle A, Bonfante G, Pegoraro T, Fernando L. Seven-Year Follow-up of Full-Arch Prostheses Supported by Four Implants: A Prospective Study. Int J Oral Maxillofac Implants. 2017;32(6):1351-1358.

16. Stumpel LJ, Haechler W. The Metal-Zirconia Implant Fixed Hybrid Full-Arch Prosthesis: An Alternative Technique for Fabrication. Compend Contin Educ Dent. 2018;39(3):176-181.

17. Ouzer A. The Evolution and Fabrication of Implant-supported Full-arch Hybrid Prostheses. From Conventional Casted Metal to an All-Ceramic Zirconia. N Y State Dent J. 2015;81(6):44-49.

18. Hatakeyama W, Takafuji K, Kihara H, Sugawara S, Fukazawa S, Nojiri T, Oyamada Y, Tanabe N, Kondo H. A review of the recent literature on maxillary overdenture with dental implants. J Oral Sci. 2021;63(4):301-305.

19. Castillo-Oyague R, Suarez-Garcia MJ, Perea C, Rio JD, Lynch CD, Gonzalo E, Torres-Lagares D, Preciado A. Validation of a new, specific, complete, and short OHRQoL scale (QoLFAST-10) for wearers of implant overdentures and fixed-detachable hybrid prothesis. J Dent 2016; 49: 22-32.

20. Fonteyne E, Burms E, Matthys C, Van Lierde K, De Bruyn H. Four-implant-supported overdenture treatment in the maxilla. Part II: Speech- and oral health-related quality of life in patients with implant-supported overdentures in the maxilla-A prospective 3-year follow-up. Clin Implant Dent Relat Res. 2021;23(5):680-691.

21. Doornewaard R, Sakani S, Matthys C, Glibert M, Bronkhorst E, Vandeweghe S, Vervaeke S, De Bruyn H. Four-implant-supported overdenture treatment in the maxilla. Part I: A randomized controlled split mouth trial assessing the effect of microthreads and abutment connection type on 4 years peri-implant health. Clin Implant Dent Relat Res. 2021;23(5):671-679.

22. Leão RS, Moraes SLD, Vasconcelos BCE, Lemos CAA, Pellizzer EP. Splinted and unsplinted overdenture attachment systems: A systematic review and meta-analysis. J Oral Rehabil. 2018;45(8):647-656.

23. Wadia R. Implant retained overdentures - bar vs ball attachments. Br Dent J. 2019;227(5):373. Lian M, Zhao K, Wang F, Huang W, Zhang X, Wu Y. Stud vs Bar Attachments for Maxillary Four-Implant-Supported Overdentures: 3- to 9-year Results from a Retrospective Study. Int J Oral Maxillofac Implants. 2019;34(4):936–946.

24. Mangano F, Luongo F, Shibli JA, Anil S, Mangano C. Maxillary overdentures supported by four splinted direct metal laser sintering implants: a 3-year prospective clinical study. Int J Dent. 2014; 2014:252343.

25. Borges GA, Barbin T, Dini C, et al. Patient-reported outcome measures and clinical assessment of implant-supported overdentures and fixed prostheses in mandibular edentulous patients: A systematic review and meta-analysis. J Prosthet Dent. 2022;127(4):565-577.

26. Di Francesco F, De Marco G, Capcha EB, Lanza A, Cristache CM, Vernal R, Cafferata EA Patient satisfaction and survival of maxillary overdentures supported by four or six splinted implants: a systematic review with meta-analysis. BMC Oral Health. 2021;21(1):247.

27. Ayna M, Gülses A, Acil Y. A comparative study on 7-year results of "All-on-Four™ " immediate-function concept for completely edentulous mandibles: metal-ceramic vs. bar-retained superstructures. Odontology. 2018;106(1):73-82.

28. Abd El_Wahab, A., Ahmed, A., Tolba, E. Evaluation of patient satisfaction and prosthetic maintenance of fixed detachable prosthesis used as treatment modality in completely edentulous patient. Egyptian Dental Journal, 2018; 64(2): 1531-1537.

29. ELsyad MA, Elgamal M, Mohammed Askar O, Youssef Al-Tonbary G. Patient satisfaction and oral health-related quality of life (OHRQoL) of conventional denture, fixed prosthesis and milled bar overdenture for All-on-4 implant rehabilitation. A crossover study. Clin Oral Implants Res. 2019;30(11):1107-1117.

30. ElSyad MA, Alameldeen HE, Elsaih EA. Four-implant-supported fixed prosthesis and milled bar overdentures for rehabilitation of the edentulous mandible: A 1-year ran-

domized controlled clinical and radiographic study. Int J Oral Maxillofac Implants. 2019;34(6):1493–1503.

31. Shaheen, N., Ali, S. Biologic and prosthetic complications with acrylic and porcelain fixed hybrid prosthesis used for rehabilitation of edentulous mandible according to the "All on four" implant concept. A 3-year prospective study. Egyptian Dental Journal, 2019; 65(4): 3687-3698.
32. Abdelwahab, K., ABDALLA, M. Evaluation of Patient Satisfaction with Mandibular Screw Retained Hybrid Prosthesis Versus Mandibular Implant Over-Dentures Retained by Telescopic Attachments. Egyptian Dental Journal, 2021; 67(4): 3457-3463.
33. Hartmann R, de Menezes Bandeira ACF, de Araújo SC, et al. Cost-effectiveness of three different concepts for the rehabilitation of edentulous mandibles: Overdentures with 1 or 2 implant attachments and hybrid prosthesis on four implants. J Oral Rehabil. 2020;47(11):1394-1402.
34. Alam, H., Aboelnagga, M. All on four fixed prostheses versus implant overdentures for management of edentulous maxilla opposing mandibular 2- implant assisted overdentures. Egyptian Dental Journal, 2021; 67(4): 3421-3434.
35. Cawood JI, Howell RA. A classification of the edentulous jaws. Int J Oral Maxillofac Surg 1988;17: 232–236.
36. Lekholm U, Zarb G. Patient selection and preparation. In: Branemark PI, Zarb G, Albrektsson T (eds). Tissue Integrated Prosthesis: Osseointegration in Clinical Dentistry. Chicago: Quintessence Publishing,1985:199–209.
37. Ahuja S, Cagna DR. Classification and management of restorative space in edentulous implant overdenture patients. J Prosthet Dent. 2011;105(5):332-337.
38. 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.
39. Campelo LD, Camara JR. Flapless implant surgery: a 10-year clinical retrospective analysis. Int J Oral Maxillofac Implants. 2002; 17:271-6.
40. Lal K, White GS, Morea DN, Wright RF. Use of stereolithographic templates for surgical and prosthodontic implant planning and placement. Part II. A clinical report. J Prosthodont. 2006; 15:117-22.
41. Zou D, Wu Y, Huang W, Wang F, Wang S, Zhang Z, Zhang Z. A 3-year prospective clinical study of telescopic crown, bar, and locator attachments for removable four implant-supported maxillary overdentures. Int J Prosthodont. 2013 Nov-Dec;26(6):566-73.
42. Abi Nader S, Eimar H, Momani M, Shang K, Daniel NG, Tamimi F. Plaque Accumulation Beneath Maxillary Allon-4 Implant-Supported Prostheses. Clin Implant Dent Relat Res. 2015; 17:932-7.
43. Brennan M, Houston F, O'Sullivan M, O'Connell B. Patient satisfaction and oral health-related quality of life outcomes of implant overdentures and fixed complete dentures. Int J Oral Maxillofac Implants 2010; 25:791–800.
44. Maló P, de Araújo Nobre M, Moura Guedes C, Almeida R, Silva A, Sereno N, Legatheaux J. Short-term report of an ongoing prospective cohort study evaluating the outcome of full-arch implant-supported fixed hybrid polyetheretherketone-acrylic resin prostheses and the All-on-Four concept. Clin Implant Dent Relat Res. 2018;20(5):692-702.
45. Krennmair S, Weinländer M, Malek M, Forstner T, Krennmair G, Stimmelmayr M. Mandibular full-arch fixed prostheses supported on 4 implants with either axial or tilted distal implants: A 3-year prospective study. Clin Implant Dent Relat Res 2016; 18:1119–1133.
46. Mericske-Stern RD, Taylor TD, Belser U. Management of the edentulous patient. Clin Oral Implants Res 2000;11(suppl 1):108–125.
47. 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.
48. Pontoriero R, Tonelli MP, Carnevale G, Mombelli A, Nyman SR, Lang NP. Experimentally induced peri-implant mucositis. A clinical study in humans. Clin Oral Implants Res 1994;5: 254–259.
49. Glauser R, Sennerby L, Meredith N, Rée A, Lundgren A, Gottlow J, Hämmerle CH. Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading. Successful vs. failing implants. Clin Oral Implants Res 2004; 15:428–434.
50. Balshi SF, Allen FD, Wolfinger GJ, Balshi TJ. A resonance frequency analysis assessment of maxillary and mandibular immediately loaded implants. Int J Oral Maxillofac Implants 2005; 20:584–594.
51. Chen MH, Lyons K, Tawse-Smith A, Ma S. Resonance frequency analysis in assessing implant stability: A retrospective analysis. Int J Prosthodont 2019; 32:317–326.

52. Shafie H, Obeid G. Principles of attachment selection for implant supported overdentures and their impact on surgical approaches. British Association of Oral and Maxillofacial Surgeons 2013; 19:1–36.
53. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.
54. Zarb GA, Albrektsson T. Consensus report: Towards optimized treatment outcomes for dental implants. J Prosthet Dent 1998; 80:641.
55. Weinstein R, Agliardi E, Fabbro MD, Romeo D, Francetti L. Immediate rehabilitation of the extremely atrophic mandible with fixed full-prosthesis supported by four implants. Clin Implant Dent Relat Res 2012; 14:434–441.
56. Bellini CM, Romeo D, Galbusera F, Taschieri S, Raimondi MT, Zampelis A, Francetti L. Comparison of tilted versus nontilted implant-supported prosthetic designs for the restoration of the edentuous mandible: a biomechanical study. Int J Oral Maxillofac Implants. 2009;24(3):511-517.
57. Khatami AH, Smith CR. "All-on-Four" immediate function concept and clinical report of treatment of an edentulous mandible with a fixed complete denture and milled titanium framework. J Prosthodont 2008; 17:47–51.
58. Pozzi A, Tallarico M, Moy PK. Four-implant overdenture fully supported by a CAD-CAM titanium bar: A single-cohort prospective 1-year preliminary study. J Prosthet Dent. 2016;116(4):516-523.
59. Sannino G, Bollero P, Barlattani A, Gherlone E. A retrospective 2-year clinical study of immediate prosthetic rehabilitation of edentulous jaws with four implants and prefabricated bars. J Prosthodont 2017; 26:387–394.
60. Francetti L, Agliardi E, Testori T, Romeo D, Taschieri S, Del Fabbro M. Immediate rehabilitation of the mandible with fixed full prosthesis supported by axial and tilted implants: Interim results of a single cohort prospective study. Clin Implant Dent Relat Res 2008;10: 255–263.
61. Wismeijer D, van Waas MA, Mulder J, Vermeeren JI, Kalk W. Clinical and radiological results of patients treated with three treatment modalities for overdentures on implants of the ITI Dental Implant System. A randomized controlled clinical trial. Clin Oral Implants Res 1999; 10:297–306.
62. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: A prospective 1-year clinical study. Clin Implant Dent Relat Res 2005;7(suppl 1): s1–s12.
63. 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.
64. Abdraboh AE, Elsyad MA, Mourad SI, Alameldeen HE. Milled Bar with PEEK and Metal Housings for Inclined Implants Supporting Mandibular Overdentures: 1-Year Clinical, Prosthetic, and Patient-Based Outcomes. Int J Oral Maxillofac Implants. 2020; 35(5): 982-989.
65. 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.
66. Naeini EN, De Bruyn H, Bronkhorst EM, D'haese J. Case Series on the Long-Term Effect of Three Different Types of Maxillary Implant-Supported Overdentures on Clinical Outcomes and Complications. J Clin Med. 2022;11(8):2251.
67. Sadowsky SJ. Treatment considerations for maxillary implant overdentures: a systematic review. J Prosthet Dent. 2007;97(6):340-348.
68. Elsyad MA, Khairallah AS. Chewing efficiency and maximum bite force with different attachment systems of implant overdentures: a crossover study. Clin Oral Implants Res. 2017; 28(6):677-682.
69. Bozini T, Petridis H, Garefis K, Garefis P. A meta-analysis of prosthodontic complication rates of implant-supported fixed dental prostheses in edentulous patients after an observation period of at least 5 years. Int J Oral Maxillofac Implants. 2011; 26:304–18.
70. Kawano F, Ohguri T, Ichikawa T, Mizuno I, Hasegawa A. Shock absorbability and hardness of commercially available denture teeth. Int J Prosthodont. 2002;15(3):243-247.
71. Karabuda C, Yaltirik M, Bayraktar M. A clinical comparison of prosthetic complications of implant-supported overdentures with different attachment systems. Implant Dent. 2008; 17:74–81.
72. Ciftci G, Somay SD, Ozcan I, Ozcelik TB, Yilmaz B. Prosthetic complications with mandibular bar-retained implant overdentures having distal attachments and metal frameworks: A 2- to 12-year retrospective analysis. J Prosthet Dent. 2022; S0022-3913(21)00649-1.