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# Effect of cantilever extension on marginal bone loss around implants supporting all-on-4 CAD/CAM screw-retained prostheses: a randomized controlled clinical trial

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**Aim:** To evaluate the effect of cantilever extension on peri-implant marginal bone loss in patients restored by immediately-loaded CAD/CAM All-on-4 definitive prostheses with PEEK superstructure.

**Materials & Methods:** 112 implants were placed according to All-on-4 concept principles in maxillary and mandibular arches for fourteen edentulous patients (eight implants for each patient, four implants per arch). Patients were divided into two equal groups at random (n=7) and were immediately restored by CAD/CAM screw-retained PEEK-Resin prosthesis constructed without cantilever extension for group I and with one-unit cantilever extension for group II. A follow-up protocol of 6, 9, and 12 months was scheduled to assess the peri-implant marginal bone loss (MBL). The independent t-test was used to compare MBL between the groups, the Repeated measures ANOVA was used to compare bone loss between follow-ups, and intragroup comparison between maxilla and mandible was performed using the Paired t-test ($P \leq 0.05$). **Results:** For both arches and at all the study intervals, the independent t-test revealed a significantly higher bone loss in the cantilever group II than in group I without a cantilever ($P<0.05$). Both groups showed significant increases in bone loss over time ($p<0.001$). The average bone loss around maxillary implants was significantly higher than around mandibular implants in both groups at all intervals ($P<0.05$).

**Conclusion:** Immediately loaded CAD/CAM PEEK-Resin prostheses constructed with cantilever extension induce greater peri-implant bone loss compared to prostheses without cantilevers, however, both can provide predictable results if appropriate guidelines for treatment planning, implant placement, prosthesis designing, and fabrication are strictly followed.

**Keywords:** All-on-4; Screw-retained definitive prostheses; CAD/CAM; Peri-implant marginal bone loss; Cantilever length.

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## Introduction

A high success and satisfaction rate have been reported for full-arch implant-supported prostheses. [1,2] However, in the absence of sufficient bone volume in the posterior jaw, rehabilitation becomes more complicated; the greater cantilever length of the framework that results from too close implant placement may increase the torque applied to the implants. [3] The "All-on-4" treatment concept was developed to rehabilitate the edentulous jaws with fixed restoration on only four implants; two anterior parallel implants and two distally inclined implants in the posterior region. Tilting not only allows placement of longer implants without grafting, but also increases inter-implant distance, eliminates or reduces the cantilever extensions, and improves anchorage in native bone. [4,5] It has been revealed that in the All-on-4; implant survival rates and marginal bone loss may not be impacted by angled implant placement, particularly with shorter cantilever lengths that don't intensify the stress around the implants [3,6,7]
Cantilever is the portion of superstructure extending posterior to the most distal implant, while the anteroposterior (AP) spread provides an approximate estimate of the implant's geometric distribution, and is quantified as the distance between the lines that connect; the two implants that are most anterior, and the two most posterior implants. [8] Some studies' findings indicate that the maximum cantilever length for fixed prostheses held up by four to six implants should not exceed twice the AP spread. Others have shown that full-arch, screw-retained prostheses with cantilever/AP ratios less than 1 resulted in prostheses that are nearly free of complications. [9-12] The presence of a cantilever may be inevitable which increases the risk of complications and causes a decline in the All-on-4 prosthetic survival rate, nevertheless, not many studies have stated the clinical impacts of cantilever extensions in All-on-4 prostheses and issues including; fractured prostheses, broken porcelain crowns, abutment, and prosthetic screw loosening, could be linked to having a lengthy cantilever. [13-15]

An additional crucial element for the long-term clinical success of All-on-4 prosthetics is selecting the appropriate framework material to transfer the stress to the implants. [16,17] A finite-element study was conducted for stress-strain analysis on a mandible rehabilitated with a hybrid prosthesis using poly-ether-ether-ketone PEEK in the fabrication of All-on-4 frameworks with different bone densities, it has been determined that the use of PEEK rather than titanium in the construction of All-on-4 prostheses increased mucosal stress and decreased stresses and strains on the cortical and spongy bones, PEEK material was also recommended to lessen the stresses and strains on various bone tissues in the low-density model. [18] Concurrently, PEEK-acrylic resin prosthesis showed promising results in one- and three-year clinical trials when used in All-on-4 full-arch implant-supported rehabilitations. [19,20]

Immediate implant loading permits immediate restoration of esthetics and functions, lessens the risk of complications from a second surgical procedure, and makes functional rehabilitation easier. [21] As there is a chance that an implant may not osseointegrate sufficiently or at all, the All-on-4 approach typically calls for an instant temporary fixed restoration, and the final permanent restoration is fabricated Just following successful osseointegration. [22,23] However, the increased treatment burdens and expenses associated with the immediate provisionals motivated Michael Korsch et al [24] to conduct retrospective research investigating whether the immediate fixed definitive restoration as part of the All-on-4 treatment protocol compared to provisional ones is reasonable or not; throughout the observation period, the complication rates for definitive and provisional restorations were similar, and implant losses solely occurred in the male patient's posterior maxilla. [24]

The All-on-4 treatment concept is currently being investigated; various research has advanced the All-on-4 regimen but further research is still required; for instance, to examine the factors that could improve clinical outcomes of immediate rehabilitation with a definitive restoration. Among the long-term clinical assessments used to determine successful implant rehabilitation; is the recording of changes in the marginal bone height around the implants. If changes in marginal bone exceeded physiological bounds, bone height would be lost surrounding the osseointegrated implant. It has been established that a bone loss of about 1.5 mm after the first year of loading with an additional 0.2 mm of bone loss every year is within physiological limitations. [25,26] Hence, and based on the aforementioned, the present study aimed to evaluate the influence of eliminating cantilevers on peri-implant bone height changes in patients restored by immediately loaded CAD/CAM maxillary and mandibular All-on-4 implant-supported prostheses with peek superstructure. The null hypothesis was that there would be no differences in marginal bone loss around the implants between the contrasting All-on-4 prosthetics formed with or without cantilever extensions.

## Materials and methods

The procedures of this study were conducted at the Department of Oral and maxillofacial prosthodontics, faculty of Dentistry, Ain Shams University. Fourteen male patients aged between 50 and 60 years who met the study inclusion criteria were recruited. These included having; fully edentulous ridges, ovoid or tapered arch form, Angle class I maxillomandibular relationship, sufficient inter-arch distance, no parafunctional habits, a history of free medical conditions, and substantial bone volume to accommodate four implants in each jaw according to All-on-4 concept principles. Patients signed the consent form supplied by the Beni-Suef University, Faculty of Dentistry Ethical Approval Committee, granting permission to participate in this research and have their implants surgically placed. Based on the findings of a prior study; [27] sample size calculations were performed using G*Power version 3.1.9.7. [28] A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there is no difference between tested items. By adopting an alpha level of (0.2) and a beta of (0.80), i.e., power =90%, and effect size (d) of (0.669), the anticipated sample size was 96 implants to be installed for 12 participants (8 implants for each patient). One patient was added to each group to account for withdrawals; thus, fourteen patients were recruited and randomly distributed using the sealed envelopes method into two groups in a 1:1 ratio. All participants received 4 implants in the maxillary as well as in the mandibular arches at the lateral incisor/canine regions and second premolar regions bilaterally, over which maxillary and mandibular CAD/CAM All-on-4 implant-supported prostheses were constructed without cantilever extension for group I and with a single unit cantilever extension group II.

- **Preoperative digital planning**

Each patient in this study received conventional maxillary and mandibular complete dentures constructed according to the standard techniques, then dentures were prepared for use as a scan prosthesis following the dual scanning protocol. [29,30] After cone beam computed tomography (CBCT) imaging (Planmeca ProMax® 3D Mid, Finland) precise planning for prosthetically-driven implant positioning along with the surgical guide planning, (DDS-Pro surgical template planning, Poland) and CAD modeling of the provisional prosthesis (Exocad GmbH, Hessen, Germany) were all executed based on the jaw bone and dentures aligned scans. [31] (Fig.1A&B) The provisional prosthesis design was created without a cantilever

extension for group I patients, and with a cantilever extension for group II patients.

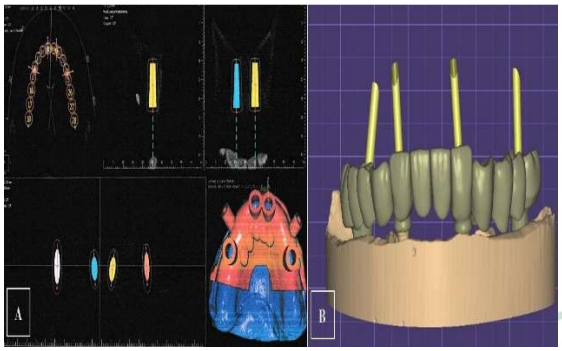

**Fig.1. Virtual planning of implant positioning and surgical guide (A), CAD modeling of the provisional prosthesis (B)**

- **Surgical and Prosthetic workflow**

The stereolithographic surgical guides and the provisional prostheses were 3D-printed. (Formlabs 3Dprinter, Somerville, Massachusetts, USA) Each surgical guide was tested for fit and stability in the patient's mouth and was correctly seated before surgery aided by the previously obtained bite index. [27,30] Flapless drilling and implant placements (JDENTALCARE® Implant System, Italy) were done through the CAD/CAM guide in compliance with the manufacturer's guidelines (In2 guide universal kit cyber med, Seoul, Korea), (Fig.2) with insertion torque not less than 35Ncm. A resonance frequency analysis (RFA) device (Osstell ISQ device, Goteborg, Sweden) was used to measure implant stability quotient (ISQ) values to confirm it is not less than 75 ISQ before loading. [32]

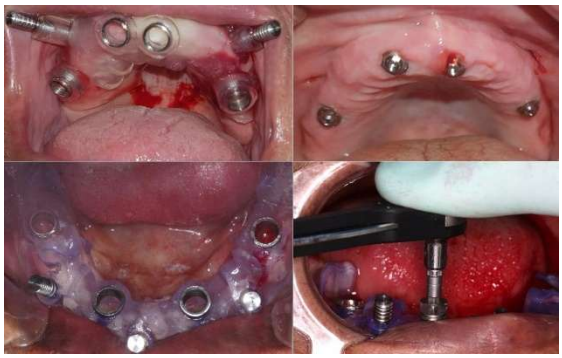

**Fig.2. All-on-four guided surgical implant placement.**

Straight and 30º-angulated appropriate-height multiunit abutments were connected to the anterior axial and the distal inclined implants respectively (straight and 30° Angulated Conical Abutment, JDEvolution, JDENTALCARE® Implant System, Italy), the standard temporary titanium cylinders were mounted (Temporary Abutment Non-Engaging Conical Abutment JDEvolution, JDENTALCARE® Implant System, Italy), and the 3D-printed PMMA provisional prosthesis was directly realigned and fixed in the patient's mouth by adjusting and filling the gaps between the abutments and the prosthesis and between the prosthesis and the soft tissues with auto-polymerizing resin (Dura-Liner II, Dental Mfg Co., Keliance). An articulating paper (Accufilm, Parkell, Inc.Edgewood, NY, USA) was used to adjust and equilibrate the occlusion according to the implant-protected occlusion (IPO) principles, [33] and when needed, wax was added to the outer flanges to produce pleasing gingival contours and facial support. (Fig.3)

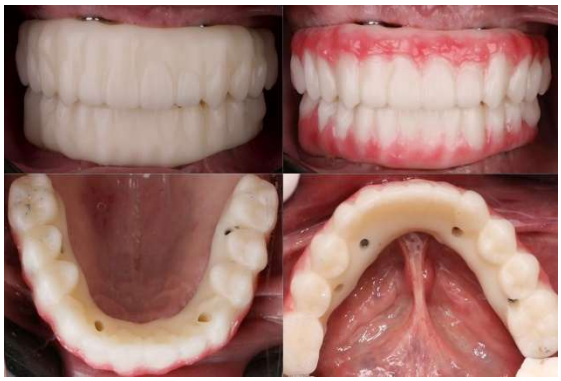

**Fig.3. PMMA provisional prosthesis directly realigned in the patient's mouth ready for scanning after verification of acceptable gingival contours and occlusal contacts.**

After radiographic verification of passive seating and confirmation of the precisely equilibrated occlusal contacts of the interim prosthesis, an intraoral scanner IOS (MEDIT I700 intraoral scanner, Seoul, Korea) was used to acquire an intraoral optical scan for the opposing provisionals while preserving the current centric relation and occlusal vertical dimension, then the

scanner was used to scan the gingival, buccal, lingual, and occlusal surfaces of the adjusted provisional prosthesis extra-orally. [34] After that, scan bodies were mounted intraorally (Scan Body Conical Abutment JDEvolution, JDENTALCARE® Implant System, Italy), and postsurgical implant positions were acquired with the IOS. After finishing and polishing, the preoperatively-fabricated intraoperatively-adapted interim prosthesis was delivered to the patient on the day of surgery, screw access holes were covered with light-cured composite resin (Z350 composite 3M ESPE, Germany), and postoperative instructions, and medications were given to the patients before they were dismissed.

The acquired scans were merged and used to accurately transfer the information from the implant-supported interim prototype to the definitive restoration. The final prosthesis design was accordingly established using CAD modeling software. (Exocad GmbH, Hessen, Germany) The definitive rehabilitation had been a PEEK-Resin full-arch hybrid prosthesis that comprised; reinforcing standard titanium abutments, PEEK superstructure (breCAM.BioHPP® © bredent UK), acrylic resin crowns (Brilliant Crios Disc, Coltène/Whaledent, Switzerlandt), and Visio-lign veneering was used to generate gingiva. (Visio-lign; Bredent GmbH & KG, Weissenhorner Senden, Germany). They were delivered to the patients and placed in occlusion within 72 hours after implant placement. (Fig.4)

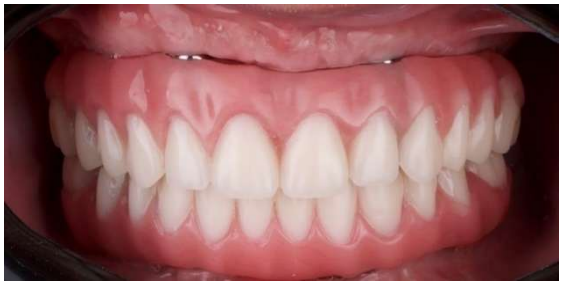

**Fig.4. Intra-oral frontal view of the maxillary and mandibular PEEK–Resin implant-supported prostheses in function.**

Periapical radiographs were taken when the implants were being loaded. (baseline assessment). The patients were part of a maintenance regimen that comprised digital periapical radiography for radiographic evaluations at six, nine, and twelve months, as well as clinical evaluations every two months. The absence of clinical implant mobility, persistent peri-implant radiolucency, and the absence of symptoms including pain, infections, and dysesthesia were all confirmed as criteria for implant success. [35]

- **Radiographic evaluation**

In this clinical trial, four assessments were performed; at 0, then at 6, 9, and 12 months after baseline assessments. Following the standardized long cone paralleling approach, digital peri-apical radiographs were used to track changes in the peri-implant bone height. [36] The real implant dimensions and the implant dimensions measured on the radiograph were compared in order to account for dimensional distortion and magnification. On the Digora software (DIGORA 2.5 Soredex Software, Tuusula, Finland), a blinded operator measured the changes in marginal bone height over time. Bone level measurements were taken mesially and distally to each implant and the average was calculated. The level of the vertical marginal bone (mm) was determined by measuring the distance from a line drawn tangent to the implant apex to the most crestal point of contact between the bone and the implant. The amount of marginal bone loss MBL at different intervals was obtained by calculating the difference between bone levels at that interval from the baseline measurement.

- **Statistical analysis**

Statistical analysis was performed with SPSS 16 ® (IBM, Cary, NC, USA), Graph pad Prism ® (Dotmatics Insightful Science, Boston, MA, USA), and Windows Excel. Data exploration for normality was performed using the Shapiro-Wilk test and Kolmogorov-Smirnov test. P-values ≤0.05

were considered significant. The independent t-test was used to compare MBL between the groups, the Repeated measures ANOVA test was used to compare bone losses between the study follow-ups, and intragroup comparison between maxilla and mandible was performed using the Paired t-test.

## Results

No implant failures were found, and the success rate was 100%. Throughout the follow-up period, none of the definitive prosthesis broke. All data were presented as means and standard deviation of average bone losses around the implants. Descriptive statistics are illustrated in Tables (1&2). Both groups showed significant progressive increases in bone loss over time; significant differences ($p<0.001$) were observed between measurement intervals for both groups. The highest bone level changes occurred at the 6- and 9-month intervals, with smaller changes at the 12-month interval. (table 1) For both arches and at all the study intervals, the independent t-test revealed a significantly higher bone loss in the cantilever group than in group I without a cantilever ($P<0.05$). The Paired t-test revealed that average bone loss around maxillary implants was significantly higher than around mandibular implants in both groups at all the study intervals ($P<0.05$). (table 2)

**Table 1: Results of ANOVA for intragroup comparisons of vertical bone loss (mm) between study intervals.**

| | | Interval | Min | Ma | Mean | Standard deviation | P value |
|---|---|---|---|---|---|---|---|
| with cantilever | Maxillary implants | 6 Months | 0.355 | 0.388 | 0.370 | 0.010 | <0.0001* |
| | | 9 Months | 0.740 | 0.765 | 0.756 | 0.009 | |
| | | 12 Months | 0.943 | 0.970 | 0.954 | 0.009 | |
| | Mandibular implants | 6 Months | 0.320 | 0.338 | 0.329 | 0.006 | <0.0001* |
| | | 9 Months | 0.705 | 0.725 | 0.712 | 0.007 | |
| | | 12 Months | 0.915 | 0.925 | 0.921 | 0.004 | |
| without cantilever | Maxillary implants | 6 Months | 0.310 | 0.340 | 0.322 | 0.010 | <0.0001* |
| | | 9 Months | 0.640 | 0.680 | 0.659 | 0.013 | |
| | | 12 Months | 0.903 | 0.918 | 0.909 | 0.005 | |
| | Mandibular implants | 6 Months | 0.290 | 0.310 | 0.301 | 0.008 | <0.0001* |
| | | 9 Months | 0.620 | 0.658 | 0.638 | 0.013 | |
| | | 12 Months | 0.878 | 0.903 | 0.888 | 0.009 | |

***Significant difference as P<0.05.**

**Table 2: Results of independent t-test for intergroup comparisons, and Paired t-test for intragroup comparisons between maxillary and mandibular arches for peri-implant bone loss throughout the evaluation period.**

| | | With cantilever | | without cantilever | | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | | | Lower | Upper | |
| 6 Months | Maxillary implant | 0.370 | 0.010 | 0.322 | 0.010 | 0.047 | 0.005 | 0.036 | 0.059 | 0.0001* |
| | Mandibular implant | 0.329 | 0.006 | 0.301 | 0.008 | 0.028 | 0.004 | 0.020 | 0.037 | 0.0001* |
| | P value | 0.0001* | | 0.0001* | | | | | | |
| 9 Months | Maxillary implant | 0.756 | 0.009 | 0.659 | 0.013 | 0.096 | 0.006 | 0.084 | 0.109 | 0.0001* |
| | Mandibular implant | 0.712 | 0.007 | 0.638 | 0.013 | 0.074 | 0.006 | 0.062 | 0.086 | 0.0001* |
| | P value | 0.0001* | | 0.0003* | | | | | | |
| 12 Months | Maxillary implant | 0.954 | 0.009 | 0.909 | 0.005 | 0.045 | 0.004 | 0.037 | 0.054 | 0.0001* |
| | Mandibular implant | 0.921 | 0.004 | 0.888 | 0.009 | 0.032 | 0.004 | 0.025 | 0.040 | 0.0001* |
| | P value | 0.0001* | | 0.0001* | | | | | | |

***Significant difference as P<0.05.***

## Discussion

It is relevant to restore edentulous patients with full-arch, flapless, instantly loaded, All-on-4, fixed provisionals with

high patient satisfaction and success. However, posterior cantilevers and distally inclined posterior implants are well-known risk factors. [1-6] An additional risk factor for the All-on-4 treatment regimen could be using fixed definitive restorations for immediate loading. Not many studies investigated All-on-4 restorations that have been restored right after implant surgical placement with the definitive fixed prostheses particularly as compared to the provisional ones. [24] In such cases the appropriate selection of the framework material will be very crucial if success is intended, [19,20] and the right guidelines for treatment planning, implant placement, creating cantilevers, prosthesis designing, and fabrication has to be adhered to rigorously. Only a few articles reported that provisional prostheses had small or absent cantilevers, [27] Thus, this study intended to evaluate the effect of cantilever extension on peri-implant marginal bone loss in patients restored by CAD/CAM All-on-4 immediately-loaded implant-supported definitive prostheses with PEEK superstructure. The null hypothesis was rejected because the peri-implant marginal bone loss in the cantilever group was considerably greater than in the group without a cantilever.

The All-on-4 concept in most cases calls for an instantaneous, transient, fixed restoration of the implants, the definitive fixed prosthesis is fabricated only following the accomplishment of osseointegration. [22,23] In addition to the doubt that osseointegration will be successful after immediate loading, the extra expenses of an immediate final fixed restoration would be significantly greater in the case of implant loss during the healing phase since the reiterated implant placement would necessitate the substitution of the entire definitive prosthesis. Immediate definitive restorations were avoided or were not practical in the past because CAD/CAM was not previously efficient for fabricating frameworks. But at present, computer-assisted implantology; which includes guided surgery based on three-dimensional virtual implant planning, and CAD/CAM fabrication of temporary and permanent reconstructions allows for a quick treatment process with predictable functional and aesthetic results. [31,34] According to Michael Korsch et al, [24] A final All-on-4 CAD/CAM-machined cobalt-chromium-molybdenum framework may be loaded within 24 hours of implantation, and only a few circumstances call for the Provisionalization of the fixed restoration.

In this study, patients were treated with a fully digital approach; both surgical and prosthetic procedures. Despite the advancement in software and hardware technology, errors in guided implant placement can still happen and depend on different factors. The guide type, seating, and fixation have an important influence. Thus, in order to enable more precise implant placement in this study, a systematic and clear strategy for carrying out the guided surgery was adopted. [27, 30] The restorative phase also benefited substantially from adopting the new digital workflows made possible by the current technology. Intraoral impressions are typically taken at the beginning of the traditional restorative phase to correlate implants with a master cast, which the dental laboratory uses to design and create the final prosthesis. From the master cast, it would be necessary to ascertain a verification index and determine the centric relation, and occlusal vertical dimension for bite registration following the standard prosthetic techniques. now, you can get around all of this; by scanning the interim prosthesis with intraoral scanners and flipping the image, it is simple to generate digital impressions for the definitive prosthesis. [34] By scanning the gingival, buccal, lingual, and occlusal surfaces of the adjusted provisional restoration for each patient extra-orally, and then scanning the opposing provisionals while the patient maintains the existing occlusal vertical dimension and centric relation intraorally, a

virtual occlusal registration thus was obtained to align virtually each scanned interim prosthesis with the opposing one. By merging this data with IOS-acquired postsurgical implant positions, a highly precise virtual design of the definitive prosthesis was accomplished based upon the corrected interim prototype.

The primary purpose of the provisional PMMA prosthesis was to confirm intraorally the occlusion, function, and aesthetics. It is possible to alter the provisional prosthesis shapes, and occlusion modifications might be necessary so that the ultimate prosthesis's design can be completed more successfully using the accurate data obtained from the temporary prosthesis. The most crucial aspect for attaining effective, accurate definitive restorations by scanning the interim one; is the quality of the interim restoration. No gaps or imperfections should exist where the cylinder and abutments meet. Any misfit should be corrected by reseating the cylinders onto the abutment. [34] In our study, only minor adaptations were required due to the accurate digital preoperative planning and accurate implant placement.

The prosthesis for the present patients comprised two parts: cement-retained composite crowns and a screw-retained PEEK framework with gingiva-colored composite resin. The short-term outcomes of hybrid PEEK-acrylic resin prostheses mounted on arches retained by implants according to the all-on-four concept were documented by Maló et al[19] and De Araújo Nobre et al [20]; their findings indicated that implant-supported hybrid polymer PEEK-acrylic resin prostheses for full-arch rehabilitation could offer a viable therapeutic choice. They also suggested CAD/CAM recommendations for a framework that works clinically; as related to cross-sectional dimensions: a minimal 5 mm occlusogingival height and 4 mm faciolingual width were recommended, and to overcome the fact that in the regions of the titanium sleeves, PEEK material flexes more and is less rigid, a minimal of 6 mm buccolingual width was suggested to compensate for this weak point's bending. A maximum of a single cantilever unit was also recommended.

Materials with a higher elastic modulus, such as titanium and ceramics, showed less ability to absorb shock than materials based on resin as demonstrated by an in vitro study conducted by Rosentritt et al. [37] who investigated the ability of implant-supported molar crowns composed of titanium, zirconia, PEEK, composite, lithium disilicate, and polymethyl methacrylate to absorb force. In another study, Stawarczyk et al. [38] assessed the fracture load and surface characteristics of a three-unit PEEK fixed dental prosthesis. They found that the mean fracture load was 1383 N and the plastic deformation cut-off point was 1200 N. Based on these findings, they concluded that PEEK might be a good material for fixed dental prostheses, particularly in load-bearing areas. Clinical use of PEEK as a framework in fixed prosthetic rehabilitation of All-on-4 cases is widely accepted too; excellent effects on the patient's subjective assessment and quality of life were noted, along with low rates of biological complications, minimal bone loss, and elevated prosthetic/implant survival rate. [19,20] Therefore, in the present study, PEEK was selected to be investigated further as part of a full-arch immediately-loaded All-on-4 definitive rehabilitation.

Cantilevers are a part of the full-arch All-on-4 prosthetics when taking into account the need for at least 12 functional teeth. [10-13] A prior study proposed an edentulism classification and assessed the results of the all-on-four concept, they reported different implant placements based on the amount and density of the bone that is available; [15] for the availability of bone up to the second premolar region they reported the anterior implants could be installed in the canine region and the distal tilted implant on the molar region not including cantilevers; or the anterior implants would be placed in the

lateral incisor region and the distal tilted to the second premolar region with the incorporation of a single unit cantilever if the bone is accessible up to the first premolar; while the presence of bone only up to the canine region obliges the anterior implant placement in the central incisor area and the distal implant tilting to the first premolar with the incorporation of a two units cantilever. In the current investigation, to account for the potential inclusion of a single-unit cantilever, patients were selected following the CBCT preoperative assessment to identify to which category of this classification they belong, taking into account the imperative of implant placement at the lateral incisor/canine areas and premolar areas with sufficient AP spread. [3]

The peri-implant bone height changes in our study were monitored by digital peri-apical radiographs taken with a standardized long cone paralleling technique to overcome the faults in the reproducible alignment of successive radiographs and obtain standardized serial radiographic images. [36] The two groups under investigation experienced a progressive rise in vertical bone loss, as demonstrated by a statistical analysis of the radiography results. This could be brought about by bone remodeling that happens after implant placement combined with functional stresses. After one year of immediate loading, the mean marginal bone loss for both groups was less than 1 mm, which was in line with the results of earlier research [19,20,30] and was within the typical range documented in the literature.[39] The flapless implant placement that preserves the bone height after surgery, the splinting effect of the definitive prosthesis, the implant's high primary stability, the precise CAD/CAM surgical and prosthetic workflow, committing to a minimum cantilever length that is no more than one times the A-P spread, the occlusal acuity, and the shock absorbing characteristics of the employed prosthesis could all be contributing factors to the reduced vertical bone loss. [8,16,19,20,24,27, 37,38]

Results of the current study indicated a significantly higher bone loss around the implants in the cantilever group than in the non-cantilever group which is in line with the findings of previous studies. [15, 19, 30] It has been demonstrated that the extent of resorption of the mandibular or maxillary crest positively correlates with the presence of cantilevers in full-arch All-on-4 prosthesis. [15] Axial and bending forces are the two primary forces operating on a cantilevered prosthesis. The Class I lever arm and bending moment acting on the implants supporting the prosthesis increase with more cantilever length, and consequently complications and failures with the implants and prosthesis are more anticipated. [8] In a clinical study that included nine prostheses with more than a one-unit cantilever; the use of cantilever units did not result in an increase in mechanical problems or a decline in implant or prosthesis survival, however, was related to the observed technical complications; problems with veneer adhesion was ascribed to greater cantilever lengths, suggesting that the distal cantilever of the PEEK framework may have flexed as a contributing factor.

The average bone loss around maxillary implants was significantly higher than around mandibular implants in both groups at all the intervals of this investigation. This is not surprising because the diminished bone quality of the maxilla participates to greater bone loss than compact bone in the mandible's front. [8] However, a systematic review supported different results that maxillary and mandibular implants supporting all-on-4 prostheses did not significantly differ in terms of vertical bone loss after a year. [40]

The short observation period is considered one of the limitations of this study. The viability of restoring the patient with an immediate definitive prosthesis after all-on-4 surgery and the superiority of one treatment over another must be

confirmed by long-term monitoring. Another limitation is that it's unclear how accurate the definitive digital impression of the temporary prosthesis generated through intraoral scanners is; more research is required to assess the technique's accuracy. However, the study's prospective design and low dropout rate contributed to its strengths in terms of higher internal validity. Future studies should investigate and compare the clinical outcomes of different polymeric and non-polymeric CAD/CAM materials used for immediate definitive all-on-4 rehabilitations.

## Conclusions

Within the limited observation period of this study, it could be concluded that immediately loaded CAD/CAM PEEK-Resin prostheses constructed with cantilever extension induce greater peri-implant bone loss compared to prostheses without cantilevers, however, both can provide predictable results if appropriate guidelines for treatment planning, implant placement, prosthesis designing, and fabrication are strictly followed.

## Declarations

**Ethics approval and consent to participate;** We certify that we have obtained all appropriate patient consent forms. In the form, the patients consented to images and other clinical information to be reported in the journal. Patients signed the consent form supplied by the Beni-Suef University, Faculty of Dentistry Ethical Approval Committee, granting permission to participate in this research and have their implants surgically placed adhering to the Consolidated Standards of Reporting Trials (CONSORT) minimum guidelines for publication of randomized clinical trials; the date of the ethical approval was 1/12/2023, and the approval number: # REC-FDBSU/07122023-01. All the authors have read and approved the manuscript. The requirements for authorship have been met. All authors believe that the manuscript represents honest work. On behalf of all the contributors, I will act as a guarantor and correspond with the journal from this point onward.

**Availability of data and materials;** The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

**Competing interests;** The authors declare no conflict of interest.

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## References

1. Barootchi S, Askar H, Ravidà A, Gargallo-Albiol J, Travan S, Wang H-L. Long-term clinical outcomes and cost-efectiveness 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.
2. Youssef H and Shawky Y. Zirconia- peek versus acrylic-metal mandibular full arch fixed detachable implant prostheses: two-year clinical, radiographic and prosthetic outcomes. ASDJ.2022; 25: 1-14.
3. Ozan Oguz, Kurtulmus-Yilmaz Sevcan. Biomechanical Comparison of Different Implant Inclinations and Cantilever Lengths in All-on-4 Treatment Concept by Three-Dimensional Finite Element Analysis. Int J Oral Maxillofac Implants. 2018;33(1):64–71.
4. Taruna M, Chittaranjan B, Sudheer N, Tella S, Abusaad MD. Prosthodontic perspective to all-on-4® concept for dental implants. JCDR. 2014; 8(10):16.
5. Estafanous EW, Osswald M, Oates TW, Ellingsen JE, Huynh-Ba G, Chvartszaid D. All-on-four": where are we now? Int J Oral Maxillofac Implants. 2014; 1;29(2):285-288.
6. Chrcanovic BR, Albrektsson T, Wennerberg A. Tilted versus axially placed dental implants: A meta-analysis. J Dent. 2014; 43:149–170.
7. Saleh Saber F, Ghasemi S, Koodaryan R, Babaloo A, Abolfazli N. The Comparison of Stress Distribution with Different Implant Numbers and Inclination Angles in All-on-four and Conventional Methods in Maxilla: A Finite Element Analysis. J Dent Res Dent Clin Dent Prospects. 2015;9(4):246–53.
8. Misch CE. Dental implant prosthetics. St. Louis: Elsevier Mosby. 2005; Principles for screw-retained prostheses; 452–471.

9. Maló P, Rangert B, Nobre M. All-on-4 immediate-function concept with Brånemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res. 2005;7(1):88–94.
10. Drago Carl. Ratios of Cantilever Lengths and Anterior-Posterior Spreads of Definitive Hybrid Full-Arch, Screw-Retained Prostheses: Results of a Clinical Study. J Prosthodont. 2018;27(5):402–408.
11. Sertgöz A, Güvener S. Finite element analysis of the effect of cantilever and implant length on stress distribution in an implant-supported fixed prosthesis. J Prosthet Dent. 1996;76(2):165–9.
12. McAlarney ME, Stavropoulos DN. Determination of cantilever length-anterior-posterior spread ratio assuming failure criteria to be the compromise of the prosthesis retaining screw-prosthesis joint. Int J Oral Maxillofac Implants. 1996; 11:331–339.
13. Wang Q, Zhang Zz, Bai Sz. Biomechanical analysis of stress around the tilted implants with different cantilever lengths in all-on-4 concept. BMC Oral Health. 2022; 22: 469.
14. Torrecillas-Martínez L, Monje A, Lin GH, et al. Effect of cantilevers for implant-supported prostheses on marginal bone loss and prosthetic complications: systematic review and meta-analysis. Int J Oral Maxillofac Implants. 2014;29(6):1315-1321.
15. Maló P, Nobre Md, Lopes A. The rehabilitation of completely edentulous maxillae with different degrees of resorption with four or more immediately loaded implants: a 5-year retrospective study and a new classification. Eur J Oral Implantol. 2011;4(3):227-243.
16. Delucchi, F. et al. Framework materials for full-arch implant-supported rehabilitations: A systematic review of clinical studies. Materials (Basel, Switzerland). 2021;14(12): 3251.
17. Kelkar, K., Bhat, V. & Hegde, C. Finite element analysis of the effect of framework materials at the bone-implant interface in the all-on-four implant system. Dental Res J. 2021; 18: 1.
18. Shash YH, El-Wakad MT, Eldosoky MAA, Dohiem MM. Evaluation of stress and strain on mandible caused using "All-on-Four" system from PEEK in hybrid prosthesis: finite-element analysis. Odontology. 2023;111(3):618-629.
19. Maló, P.; de Araújo Nobre, M.; Moura Guedes, C.; Almeida, R.; Silva, A.; Sereno, N. 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: 692–702.
20. DeAraújo Nobre M, Moura Guedes C, Almeida R, Silva A, Sereno N. The All-on-4 Concept Using Polyetheretherketone (PEEK)—Acrylic Resin Prostheses: Follow-Up Results of the Development Group at 5 Years and the Routine Group at One Year. Biomedicines. 2023; 11(11):3013.
21. Mostafa H M A, Henri D, Enas A A E G. Significance of Implant Distribution on a Screw-retained Implant-Supported Mandibular Hybrid Restoration of PEEK framework with Immediately Loaded Implants applying All-On-Six Protocol: A Two Years Clinical Study. Adv Dent & Oral Health. 2018; 9(1): 555751.
22. Penarrocha-Diago M, Penarrocha-Diago M, Zaragozi-Alonso R, Soto-Penaloza D. Consensus statements and clinical recommendations on treatment indications, surgical procedures, prosthetic protocols and complications following All-On-4 standard treatment. 9th Mozo-Grau Ticare Conference in Quintanilla, Spain. J Clin Exp Dent. 2017;9(5):712–715.
23. Grandi T, Guazzi P, Samarani R, Grandi G. Immediate loading of four (all-on-4) post-extractive implants supporting mandibular cross-arch fixed prostheses: 18-month follow-up from a multicentre prospective cohort study. Eur J Oral Implantol. 2012;5(3):277–85.
24. Korsch, M., Walther, W., Hannig, M. et al. Evaluation of the surgical and prosthetic success of All-on-4 restorations: a retrospective cohort study of provisional vs. definitive immediate restorations. Int J Implant Dent. 2021; 7: 48.
25. Karoussis IK, Brägger U, Salvi GE, Bürgin W, Lang NP. Effect of implant design on survival and success rates of titanium oral implants: a 10-year prospective cohort study of the ITI Dental Implant System. Clin Oral Implants Res. 2004; 15:8–17.
26. Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P, Steigmann M, Rebaudi A, Palti A, Pikos MA, Schwartz-Arad D, Choukroun J, Gutierrez-Perez JL, Marenzi G, Valavanis DK. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. Implant Dent. 2008; 17:5–15.
27. 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.
28. Faul F, Erdfelder E, Lang AG, Buchner A."G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences." Behav Res Methods. 2007 May;39(2):175-191.
29. Ramasamy M, Giri, Raja R, Subramonian, Karthik, Narendrakumar R. Implant surgical guides: From the past to the present. J Pharm Bioallied Sci. 2013;5(1):98-102.
30. Khorshid HE, Issa NO, Ekram AM. Effect of implant diameter and cantilever length on the marginal bone height changes and stability of

implants supporting screw-retained prostheses: A randomized double-blinded control trial. J Adv Prosthodont. 2023;15(3):101-113.
31. Gastaldi G, Gherlone E, Manacorda M, Ferrini F, Bova F, Vinci R, Cattoni F. A 3-D CAD/CAM technique in full-arch implant supported rehabilitations: the Virtual Implant-Prosthetic Procedure (VIPP Technique). A prospective longitudinal study. J Osseointegr 2018;10(1):2-10.
32. Raj, Komal; Dodwad, Vidya; Gavali, Neelam; Jadhav, Nikhil1; Halli, Raj Shekar2. Immediate Implants, Immediate Loading, and Milled Double Bar Prosthesis (Titanium, Biohpp): A Case Report. Journal of Dental Research and Review. 2023; 10(1):45-48.
33. Misch, CE. 2015. 'Occlusal consideration for implant-supported prostheses: implant protective occlusion in Dental implant prosthetics.' 2nd ed., St Louis (MO): Mosby Elsevier; 874.
34. An X, Fang JH, Jeong SM, Choi BH. A CAD-CAM technique for conversion of interim-to-definitive restoration in patients with complete edentulism. J Prosthet Dent. 2018;120(2):190-193.
35. Roos J, Sennerby L, Lekholm U, Jemt T, Grondahl K, Albrektsson T.A qualitative and quantitative method for evaluating implant success: a5-year retrospective analysis of the Branemark implant. Int J Oral Maxillo ac Implants 1997;12:504-14.
36. Messias A, Paulo TJ, Rocha S, Reis R, Nicolau P, Guerra F. Acrylic Customized X-Ray Positioning Stent for Prospective Bone Level Analysis in Long-Term Clinical Implant Studies. Open J Radiol. 2013; 3: 136.
37. Rosentritt M, Schneider-Feyrer S, Behr M, Preis V. In vitro shock absorption tests on implant-supported crowns: influence of crown materials and luting agents. Int J Oral Maxillofac Implants. 2017; 33(1): 116-122.
38. Stawarczyk B, Beuer F, Wimmer T. Polyetheretherketone suitable material for fixed dental prostheses? J Biomed Mater Res B Appl Biomater. 2013; 101: 1209-1216.
39. Hsu YT, Fu JH, Al-Hezaimi K, Wang HL. Biomechanical implant treatment complications: a systematic review of clinical studies of implants with at least 1 year of functional loading. Int J Oral Maxillofac Implants. 2012; 27: 894-904.
40. Patzelt SB, Bahat O, Reynolds MA, Strub JR. The all-on four treatment concept: a systematic review. Clin Implant Dent Relat Res. 2014; 16:836-55.