Original Article

Thermocycling Effect on Implant Supported Overdenture Using 3D printed Peek Bar following all-on-4 Concept: Randomized Trial-In vitro Study

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Abstract

Objective: Stress analysis and retention evaluation of implant-retained mandibular complete overdenture with different clip materials and distributions.
Methods: This in-vitro study was conducted over implants retained mandibular complete overdenture (all-on-4 concept) using BIOHPP bar attachments constructed using 3 D printing with different clip materials and distributions. This study consisted of 4 groups according to the type and distribution of clips: Group I: hard clips anteriorly and posteriorly, Group II: soft clips anteriorly and posteriorly, Group III: hard clips anteriorly and soft clips posteriorly, and Group IV: soft clips anteriorly and hard clips posteriorly. Stress analysis and retention were evaluated before and thermocycling afterward.
Results: Comparison between stresses in each group before and after thermocycling in central and peripheral implants was performed, revealing stresses in all groups after thermocycling were significantly higher than before thermocycling as P < 0.05. Regarding retention, a comparison between all groups revealed a significant difference between them before and after thermocycling as P<0.05.
Conclusion: There is no effect of clip material distribution regarding stress analysis and retention before and after thermocycling except stresses in central implant before thermocycling as soft clips anteriorly and hard clips posteriorly revealed significant lower stresses than hard clips anteriorly and soft clips posteriorly.

Keywords: Overdenture, Peek, Thermocycling, Digital, Implant

Introduction:

Prosthetic rehabilitation of totally edentulous patients today is a common procedure that clinicians approach in their daily practice. [1] For the edentulous patients the result improved by using implant-supported overdenture if compared with a conventional denture. These improvements include a decrease rate of bone ridge resorption, enhance retention, and support of the prostheses resulting in better life quality, function, mastication, and general health. [2]

In some cases of completely edentulous patients (In atrophied edentulous jaws - an altered skeletal maxilla-mandibular relationship) especially in the posterior part of the maxilla and

mandible, implant-supported prosthesis treatment is often difficult without sophisticated techniques like graft placement or nerve transposition. So All-on-4 concept is a suitable solution for such a case. [3]

The "All on-4" concept is considered as an alternative and potential treatment to avoid complex techniques. This can be achieved by placing four implants, two straight implants anteriorly and two tilted ones with an angle of 30-45° in the posterior region. This improves anchorage of the implants since they engage cortical bone from the anterior part of the maxillary sinus and the nasal passage (nostril) and the inter-foraminal region in the mandible. Reconstructive surgeries or bone graft procedures are avoided thus it is less invasive and financially competitive. [4]

Recently, this concept had become commonly accepted as a treatment plane for edentulous maxillae and mandibles as the posterior tilt of the last implants decreased the length of the cantilever, increase anterior-posterior spread, broaden the prosthetic base, and longer implants can be used. [5]

Moreover, splinting inter-foraminal implants with attachments improve the retention and dentures` stability and achieve greater support by transmitting vertical loads to the bone. [6] Also, bending moments on implants caused by axial load applied to the edentulous region decreased by these attachments because of their stress-breaking action. In implant-based prosthetic dentistry, bar-retained dentures have become a trusted and common treatment option for the edentulous mandibular ridge. [7]

The CAD/CAM technology and the digital advancement is changing the world of dentistry, allow the operator to take three-dimensional (3D) image of the patient, and from such data acquisition, make virtual casts of dentition, face, and bone bases. These data are inserted into the computer-assisted design (CAD) software and superimposed upon each other to obtain the "virtual patient", finally, the devices are processed by the software of computer-assisted manufacturing (CAM), milled or 3D printed, and are available for the dental use. [8-11]

In prosthetic dentistry, digital advancement has a strong influence as the operator can take optical impressions with intraoral scanner IOS; for planning and production of a whole series of the prosthesis. Patients preferred optical impressions, which the need for ordinary analog impressions with trays and materials (alginate, polyvinylsiloxane, and polyether) are eliminated. The optical impressions also vanish the annoying use of the conventional analog impressions; they are easy to capture for the clinician (even in the presence of undercuts or dental implants), and directly sent to the dental lab by e-mail, with no extra money. The dental technician can show the impressions and give immediate feedback to the dentist, while the patient set in the dental chair. Furthermore, the optical impression gives a high value to the 3D images even makes the IOS useful in marketing to patients. [12-16]

Up to a few years ago, the selected material usually used for making bars was non-precious-metal alloys and titanium. However, non-metal prostheses are now gaining great importance influenced by the fast propagation of computer-aided design and computer-aided manufacturing (CAD-CAM) technology. [17]

A new metal-free material, bio high-performance polymer (BIOHPP) based on polyetheretherketone (PEEK) for the fabrication of dental prostheses was recently introduced as an ideal additive to prosthetic dentistry and implantology due to its good mechanical and physical properties. [18,19] PEEK has shown flexibility with high mechanical resistance to

wear as well as high tensile, fatigue and flexural strength. PEEK is used to produce high-quality plastic parts that are thermo-stable and both electrically and thermally insulating. It also attains low specific mass, Also, providing a cushioning effect due to its low modulus of elasticity of 4 GPa (as elastic as bone) and reduction of stresses transferred to the abutment teeth, but long-term research on its clinical performance and effect on peri-implant structures is still limited. [20-23]

This new material is milled using CAD/CAM technology. CAD-CAM PEEK can be designed by different methods like direct milling of PEEK blanks or 3D printing of a resin/wax pattern framework which is then thermo-pressed using the conventional lost-wax/resin technique [24,25]

The prognosis and success of implant-retained overdentures are primarily affected by two main factors: Retention and Stress distribution. Both are directly related to the used attachment system and clips as the retentive ability of the attachment element are important to function for a long time. [26,27] Choosing the attachment depends on the retention needed, jaw shape, anatomy, the ridge of mucosa, oral function, and patient compliance for recall. [28]

There are two materials of sleeve bar/clip as it may be constructed either from metal or plastic types. Plastic-type or Polyoxymethylene (POM) clip, also known as acetal resin, is reported to have sufficiently high resilience and modulus of elasticity. Moreover, it is more easily replaced if retention has slackened, less expensive, and it produces less attrition of the metal bar than metal clips. However, plastic clips cannot be repaired. [29]

Although PEEK is commonly used in dentistry, only a few studies are available concentrate on the use of this material for CAD-CAM prostheses. This study aimed to evaluate its performance regarding retention and stress distribution before and after thermocycling. [30]

Materials and Methods:

Study design:

This in-vitro paralleled study was conducted as unicentered study in National Research Center, Giza, Egypt over implants retained mandibular complete overdenture (all-on-4 concept) with BIOHPP bar attachments of different clip materials and different clip distributions anteriorly and posteriorly. The bar-retained overdenture manufactured from bio high-performance polymer (BIOHPP) based on polyetheretherketone (PEEK) and constructed over computer-generated 3D models simulating a completely edentulous lower arch. This study divided into 4 groups according to type and distribution of clip:

Group I: Bilateral hard clips anteriorly (between central and peripheral implant) and posteriorly (on distal extension posterior to peripheral implant).

Group II: Bilateral soft clips anteriorly (between central and peripheral implant) and posteriorly (on distal extension posterior to peripheral implant).

Group III: Bilateral hard clips anteriorly (between peripheral and central implant) and bilateral soft clips posteriorly (on distal extension posterior to peripheral implant).

Group IV: Bilateral soft clips anteriorly between peripheral and central implant) and bilateral hard clips posteriorly (on distal extension posterior to peripheral implant).

Study outcomes were classified as; **Primary outcome** as stress analysis evaluation of implant supported overdenture using 3d printed peek bar following all-on-4 concept before and after

thermocycling, and **Secondary outcome** as retention measurement of implant supported overdenture using 3d printed peek bar following all-on-4 concept before and after thermocycling. Computer generated program for simple randomization was used to allocate eligible samples to intervention and control groups with allocation ratio 1:1.

Allocation concealment was done using opaque sealed envelopes on which each envelope had a code number which was given to each investigator. Allocation sequence generation was done by principle investigators. Eligible samples enrolled by (Investigator 1) and (Investigator 2) in which each samples received a sealed envelope. Inside each envelope there's a code which only known to (Investigator 3) and (Investigator 4) to assign each sample to their intervention or comparator group.

Investigators could not be blinded as the trial included digital designing of complete dentures on the CAD software and in the steps of the manufacturing techniques which is going to be carried out by (Investigators).

Sample Size Calculation:

The sample size was calculated by PS program and the input data was extracted from similar studies done by ***Radwa Mohsen Kamal Emera et al 2019*** [24] According this study, the response within each subject group was normally distributed with a standard deviation of 0.3. If the true difference in the experimental and control means is 1.1, minimally the study needed 3 subjects in each group to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. The sample size increased to 5 in each group to compensate 20% drop-off due to possible deterioration that may occur during thermocycling.

Construction of the 3D model:

Scanning of a completely edentulous model of the mandibular arch was used. The model was scanned via a 3Shape desktop scanner and an STL file was generated. In this STL file, four implant beds were designed to receive 4 implants (11.5 mm length and 3.7 mm diameter), equally distributed from the midline following the "All on-4" concept:

- Two vertically in the anterior region anterior to the mental foramen in the canine region with an axial orientation.
- Two angled up to an angle of 30 in the posterior region.

Four implant beds were designed with grooves to allow placement of the strain gauges. These grooves were designed with a flat plane parallel to the long axis of the implants and separated by 1 mm from the implant beds. A key index with 2 mm thickness and 2 mm offset with tissue stops was designed to create a space for the mucosa simulator representing the future mucosa as presented in figure (1) with their corresponding stain gauge wire installation sites prepared throughout STL design using 3D printing technology.

The STL files were ready to be directly sent to the manufacturing device, which is based on the idea of Continuous Digital Light Projection (CDLP) which utilizes a DLP chip to print the cast layer by layer utilizing the projection of a UV light to polymerize the layers until the whole cast was printed starting with the base. The raw material used in the production of the printed item a mixture of acrylic acid esters and photo initiators.

A self-cure acrylic resin was mixed and applied to fix the implants in their implant beds. After implant insertion, mucosa simulation was done via gingival mask material which was injected from the double-mix cartridge directly

into the printed index, which was seated over the model.

Implant insertion and preparation

Angled screw-retained multiunit abutments were attached on the posterior implants while straight multiunit abutments were used on the anterior implants using a hex screwdriver to ensure parallelism. A parallel platform between abutments to which the denture could be attached should be obtained. Sleeves were screwed to the multi-unit abutments to allow the insertion of hollowed-out dentures (figure 2).

BIOHPP bar framework construction:

Peek bar was constructed using 3D modeling using multiunit abutments for framework construction as presented in figure (3). The plastic abutments were screwed into place on the multiunit abutments and then surveyed by an electronic surveyor to check the parallelism of the abutments and evaluate areas to be removed. The framework was designed within the confines of the trial overdenture teeth. Copings connected using an acrylic resin material to serve as a foundation for the framework waxing-up.

Overdenture construction:

A labial index was performed on the trial denture after teeth setting using silicone putty to record tooth position and labial borders of the prosthesis concerning the working model, then teeth were removed from trial denture and placed into their respective locations in the silicone putty index using sticky wax. The plastic castable abutments (copings) screwed to the multiunit abutments on the working model using the labial index as a guide for needed modifications. After completion of framework waxing up, retention beads and loops were prepared to retain the added clips.

Then, the setting up of the denture teeth was performed with conventional procedures using silicone index, and processing also was performed with conventional procedures using long prosthetic screws during processing. Waxing -up, flasking, wax elimination, packing, and curing of the heat-cured acrylic resin followed by deflasking, finishing, and polishing of the denture was done then clips inserted in the denture following the color coding according to the group then was tried to fit the cast (Figure 4).

Strain gauge installation:

The denture was unscrewed, and the mucosa simulator was removed from the cast and the strain gauges (120.4 ±0.4) ohm gauge resistance - 2.09 ±1.0%. gauge factor) were installed on the distal and lingual aspects of each posterior implant and in the lingual aspect of the anterior implant. All the strain gauges were positioned parallel to the long axes of the implants and bonded in position on the acrylic model with a delicate layer of adhesive cement (Figure 5).

Stress analysis evaluation:

A T-shaped load applicator was made to fit on the denture teeth bilaterally. Simultaneous and even contacts on both sides of the model were achieved. A loading magnitude (70 Newton equivalents to the moderate level of biting force) was applied by turning the handle of the loading device-specific number of complete turns. The load applied was increased from 0 to 100 N at a constant rate of 1 mm/min. The micro-strains of each strain gauge were recorded to measure the strains developed at the implant fixtures. Once the load was completely applied the micro-strain readings were transferred to micro-strain units.

Retention evaluation:

The models were subjected to 100 pulls each to dislodge the overdenture from the acrylic model. The dislodging force was applied in a vertical direction in the center of the acrylic block joining the two metallic clamps holding the overdenture and the force values as were presented on the digital indicator. [31]

Thermo-cycling:

The measured stresses before thermocycling considered as baseline. All the overdentures with the attachments were subjected to manual thermos-cycling using S-U-Poly-tubs; one maintained at $5 \pm 1°$ and the other at $55 \pm 1°$. The test samples were subjected to a total of 5000 cycles with each cycle equivalent to 30 s of dwell time in each temperature-controlled tub with a transfer time of 10 s, with 5000 thermal cycles being equivalent to 6 months of service in the oral cavity. None of the samples failed and the same steps of loading and retention force testing and stress analysis were repeated after thermocycling.

Statistical analysis:

Statistical analysis was performed by Microsoft Office 2013 (Excel) and Statistical Package for Social Science (SPSS) version 20. The significant level was set at $P \leq 0.05$. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess data normality. Data were assumed normally distributed. Collected and tabulated data presented as mean and standard deviation in (3) tables.

Comparison between four groups was performed using the One Way ANOVA test followed by Tukey`s Post hoc test for multiple comparisons, while comparison between before and after thermocycling in each group was performed using Paired t-test. Also, a comparison between central and peripheral implants was performed by Independent t-test.

P-value is statistically significant if it was <0.05 at a confidence interval of 95%.

Results:

In this study, a comparison between central and peripheral implants was performed using an Independent t-test regarding stress analysis in all groups (each group had 3 samples) before and after thermocycling and revealed that stress on peripheral implant was significantly higher than central except group II was significantly lower than central as $P < 0.05$ before thermocycling. After thermocycling, stress on peripheral implant was significantly higher than central in all groups as $P < 0.05$ as presented in table (1). It was summarized as before thermocycling, an increased stresses of peripheral implants more than central implants in group I, III and IV but in group II was decreased. But after thermocycling, an increased stresses of peripheral implants more than central implants in group I, II, III and IV.

Comparison between the 4 groups was performed using One Way ANOVA which revealed a significant difference between them regarding central and peripheral implants in both before and after thermocycling as $P < 0.05$, Tukey`s Post hoc test was performed for multiple comparisons and revealed a significant difference between means with different superscript letters as $P<0.05$ (Group II & all other groups in peripheral implant before thermocycling Group I & all other groups in peripheral & central implant after thermocycling Group (I & II) – (I & VI) – (III & II) – (III & IV) in central implant before thermocycling as presented in table (1). It was summarized as increased stresses of peripheral implants more than central implants in group I, II, III and IV.

Comparison between stresses in each group before and after thermocycling in central and peripheral implants was performed using Paired T-test which revealed, stresses in all groups after
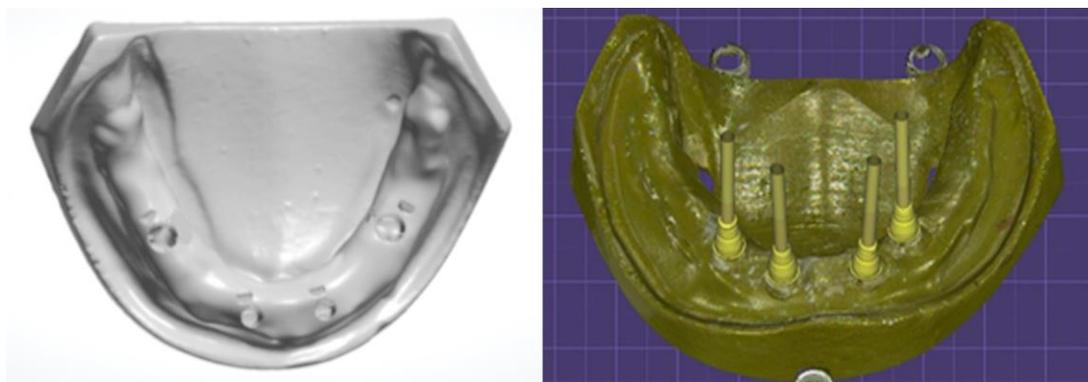
Figure 1: Virtual cast in STL files.

**Figure 2:** Implant insertion in the cast.
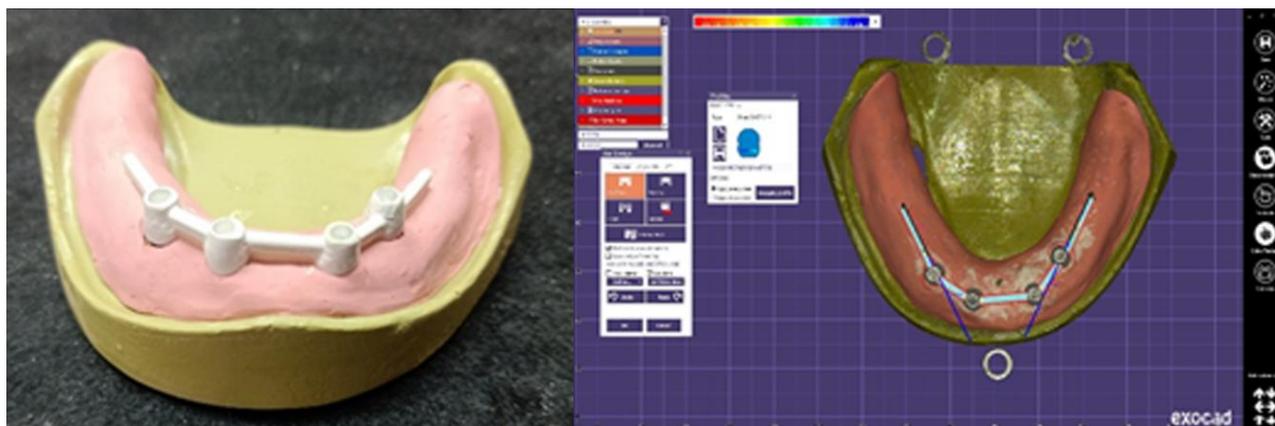
Figure 3: Peek bar was constructed using 3D printing technology.

Figure 4: A; Labial index, B; PEEK bar constructed overcast, C; Overdenture fabrication, D; Clips insertion in the denture.
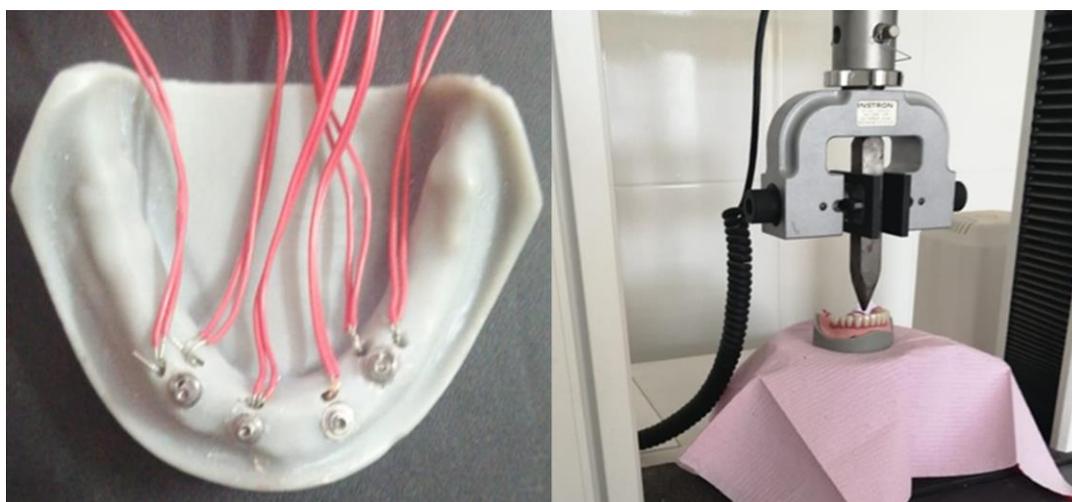
Figure 5: Stain gauge installation and stress analysis using the universal testing machine.

thermocycling were significantly higher than before thermocycling as P < 0.05 as presented in table (2). Stresses induced within peripheral and central implants before thermocycling were lower than stresses induced within peripheral and central implants after thermocycling.

Regarding retention, Comparison between all groups was performed using the one Way ANOVA test which revealed a significant difference between them before and after thermocycling as P<0.05, followed by Tukey`s Post Hoc test for multiple comparisons which revealed a significant difference in means with a different superscript letter as P < 0.05 (Group I and all other groups before and after thermocycling), while the revealed insignificant difference between means with the same superscript letters as P>0.05 (Group II & III & IV before and after thermocycling) as presented in table (3). Retention values within peripheral and central implants before thermocycling were higher than stresses induced within peripheral and central implants after thermocycling.

Discussion:

The all on four concept uses four dental implants in the anterior part of completely edentulous jaws to support a screw retained and immediately loaded prosthesis. The two most anterior dental implants are placed axially, whereas the two posterior dental implants are tilted distally to maximize anteroposterior spread, and minimize cantilever length. [32]

During bilateral loading, the highest strain was recorded for the lingual position for ball and magnetic attachments. The greater micro-strains recorded from the lingual strain gauge may be explained by the slight lingual anatomic inclination of the mandibular abutment teeth. During unilateral load application, comparison between strain gauge positions yields variable results according to the type of attachment. For ball attachment, the highest strain was recorded at lingual position of non-loading side. While load was applied on the loading side, the denture may displace inward on the non-loading side causing a stress concentration at lingual position of non-loading side around abutments due to the upper edges of the cortical bone plate which had the potential tendency to be displaced inward in the horizontal plane as mentioned previously. [33]

It was observed that unilateral loading created lateral and vertical displacement of the IARPD and an offaxis lever is created on non-loading side, resulting in a twisting of the metal structure. For magnetic attachments, the highest strain was recorded at buccal position of loading side. This may be due to magnets offer little resistance to lateral forces at loading side which may cause shift of the denture in buccal direction and stress concentration buccal position of the abutment at loading side. [34]

Peripheral implants demonstrated the highest peri implant strain. In agreement with this finding, several biomechanical studies also reported an increase in peri implant stress with angled implants compared to vertically oriented implants. Watanabe et al. 41 reported that, with angled implants, the force was not directed toward the long axis of the implant, causing an uneven distribution of the load, which resulted in an increase of the stress magnitudes. Hong et al. 22 found that, during bilateral or unilateral load application on the implants used to retain overdentures by ball attachments, the peri implant bone stress was the greatest around distally inclined implants (15°) and the lowest around buccally inclined implants (15°). The increased peri implant strain with Locator attachments, used to retain mandibular overdentures to inter foraminal implants inserted with different degrees of inclinations, was in line with the results of other studies.9,23,36

Table (1): Comparison between stress analysis in central and peripheral implants in all groups before and after thermocycling

		Peripheral	Central	CI Upper	CI Lower	P-value
Before	Group I	168 [a] ±45.9	98 [a] ± 26.78	16.40	123.60	0.01*
	Group II	34 [b] ±5.65	48 [b] ± 11.7	-26.46	-1.54	0.03*
	Group III	121 [a] ± 37.68	68 [a] ± 26.55	6.36	99.64	0.03*
	Group IV	133 [a] ± 36.48	54 [b] ± 17.54	37.94	120.06	0.002*
	P value	0.001*	0.007*			
After	Group I	378 [a] ± 103.57	223 [a] ± 61.1	31.55	278.45	0.02*
	Group II	194 [b] ± 53.15	119 [b] ± 32.6	11.15	138.85	0.02*
	Group III	298.5 [b] ± 82.33	156.5 [b] ± 45.88	45.538	238.462	0.009*
	Group IV	300.5 [b] ± 81.33	154.5 [b] ± 42.88	51.90	240.10	0.007*
	P value	0.02*	0.02*			

Table (2): Comparison between stress analysis before and after thermocycling in both groups regarding central and peripheral implants

		Before M ± SD	After M ± SD	% Change	CI Upper	CI Lower	P-value
Peripheral	Group I	168 ±45.9	378 ± 103.57	125.00	-325.92	-94.08	0.003*
	Group II	34 ±5.65	194 ± 53.15	470.59	-214.90	-105.10	0.0001*
	Group III	121 ± 37.68	298.5 ± 82.33	146.69	-269.77	-84.23	0.002*
	Group IV	133 ± 36.48	300.5 ± 81.33	125.94	-258.41	-75.59	0.002*
Central	Group I	98 ± 26.78	223 ± 61.1	127.55	-193.38	-56.62	0.002*
	Group II	48 ± 13.7	119 ± 32.6	147.92	-106.62	-35.38	0.0001*
	Group III	68 ± 26.55	156.5 ± 45.88	130.15	-141.60	-34.40	0.005*
	Group IV	54 ± 17.54	154.5 ± 42.88	186.11	-146.73	-53.27	0.001*

Table (3): Comparison of retention between different groups before and after thermocycling

	Group I	Group II	Group III	Group IV	P-value
Before	2.53 ± 0.39 [a]	1.69 ± 0.38 [b]	1.95 ± 0.43 [c]	2.01 ± 0.46 [c]	**0.025***
After	1.66 ± 0.36 [a]	1.107 ± 0.20 1 [b]	1.38 ± 0.21 [b]	1.33 ± 0.311 [b]	**0.04***
% Change	-34.39	-34.50	-29.23	-33.83	
P-value	**0.005****	**0.014***	**0.017***	**0.014***	

In another study,36 Locator blue was associated with increased retentive and lateral forces on the implants compared to ball anchors and magnets, especially with increased implant inclination (up to 30°). [35]

CAD/CAM fabricated PEEK selected in this study as an attachment retaining implant-supported overdentures, as it revealed great success in previous clinical studies when constructed in overdenture supported by 4 implants in fully edentulous patients. After a year in function, no implants were lost and an 80% success rate for implant-supported overdentures was found. Moreover, a clinical report also suggested implant-supported overdenture with the receptor part of the bar milled from PEEK polymerized into a zirconia framework can be used for the rehabilitation of an edentulous patient. High patient satisfaction with function and esthetics was reported by authors after 6 months. [36,37]

The clinical success of CAD/CAM fabricated PEEK bar may be attributed to its decrease weight and higher elasticity which may decrease the risk of mechanical implications, and to its low elastic modulus which acts as cushioning that reduces occlusal forces to supporting alveolar bone and decrease stresses in the frameworks, implants, and abutments. Also, the lowest solubility, water absorption, significantly higher wear resistance for PEEK when compared with PMMA-based material. [38,39]

The underlying principle in employing retentive implant-overdenture systems for the treatment of edentulous patients is to increase denture retention, stability and improve stress distribution, thereby promoting chewing function as well as patient comfort and compliance. [40]

CAD/CAM PEEK bar reduces stresses and distal force on the abutment teeth during mastication due to its high elasticity if compared with other materials. In agreement with this statement, a three-dimensional finite element analysis was performed partially edentulous patients and revealed that PEEK frameworks caused lower stress values on periodontal ligament than cobalt-chromium and titanium alloy. Thus, PEEK RPDs could be recommended for poor periodontal attachment patients. Another study demonstrated that, despite high stresses induced by PEEK frameworks on the mucosa on the free-end saddle, but PEEK ones showed significantly lower stresses when compared with metal frameworks. [41,42]

Retention force was measured by evaluating peak loads or maximum dislodging forces, which is defined as the maximum developed forces till complete separation of attachment components from teeth or implant abutments, and used commonly for prosthesis retention measurement. Previously mentioned measuring technique was used in this study and

proved that the PEEK framework combined with acrylic resin denture teeth and heat-cured acrylic resin denture for Kennedy Class I RPD fabrication revealed adequate fit and patient satisfaction for retention and esthetics was good. [43]

During thermocycling, the hot water may have accelerated the uptake of water which resulted in the plasticization of the polymer and decreased the mechanical properties. Conversely, the hot water may also have accelerated the release of degradation products and unreacted monomer molecules, promoted further free-radical polymerization reactions and increased the degree of conversion in addition to cantilever effect on peripheral implants. [44]

It has to be kept in mind that for the current in vitro experiment, only mono-directional forces were applied, which does not represent a realistic model for a clinical situation with overdentures. There, the main forces are generated in the region of the first molars which lead to rotational forces on the attachments through leverage.

Conclusion:

Stresses over the peripheral implant are higher than central implant, also stresses increased and retention decreased after thermocycling in all groups. Stresses and retention in group I (hard clip) was the highest, while in group II (soft clip) was the lowest.

Regarding induced stresses values after thermocycling, group I revealed increasing in induced stresses by (125%) and (127.55%) for peripheral and central implants respectively. While for group II, it revealed increasing in induced stresses by (470.59%) and (147.92%) for peripheral and central implants respectively. For group III, it revealed increasing in induced stresses by (146.69%) and (130.15%) for peripheral and central implants respectively. Finally, for group IV, it revealed increasing

induced stresses by (125.94%) and (186.11%) for peripheral and central implants respectively.

Regarding retention values after thermocycling, group I revealed decreasing in retention values by (34.39%). While for group II, it revealed decreasing in retention values by (34.5%). For group III, it revealed decreasing in retention values by (29.23%). Finally, for group IV, it revealed decreasing in retention values by (33.83%).

Recommendation:

More investigations were required concerning thermocycling effect follow up on different clip material distribution as the objective of this study was unique and had not been investigated enough in previous studies.

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Conflict of Interest:
There is no conflict of interest.

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