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STRAIN ASSESSMENT OF COBALT CHROMIUM VERSUS POLY-ETHER-ETHER-KETONE FOR REINFORCING MANDIBULAR OVERDENTURE ASSISTED BY TWO IMPLANTS (A COMPARATIVE IN-VITRO STUDY)

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ABSTRACT

INTRODUCTION: Patients with a traditional denture may have difficulty chewing because of the absence of retention. Recently, using two un-splinted implants assisted overdenture to overcome the retention problem. But still Acrylic material has problems; such as lowers impact, fatigue strengths, and fracture. Reinforcement of acrylic denture base to avoid fracture by a variety of materials such as; Metal reinforcement, fillers like carbon fiber, and Poly-Ether-Ether-Ketone (PEEK) is frequently utilized in dentistry and is seen as a viable alternative to traditional materials.
AIM OF THE STUDY: Compare between Two different denture base reinforcement materials (CoCr) and (PEEK) in comparison to acrylic denture base on strain around two implant-assisted mandibular overdenture and on ridge area.
MATERIALS AND METHODS: 3 epoxy models were used with two implants placed at the canine region. 8 mandibular overdenture were constructed for each group; (group A) Acrylic overdenture without reinforcement, for (group B) and (group c) acrylic overdenture were reinforcement by (CoCr, PEEK) respectively. Six linear strain gauges were used at the mesial and distal of each implant, and under the lower second molars bilaterally. Strain measurements were taken under central and unilateral loading around the two implants and on the ridge regions.
RESULTS: No significant difference between all groups upon application of central load 100N on ridges. However, group C showed lower strain values upon application of central and unilateral loading 100N.
CONCLUSION: PEEK reinforcement material showed less strain values with favorable stress distribution when compared to Acrylic and cobalt chromium reinforcement material for implant-assisted mandibular overdenture.
KEYWORDS: Denture base reinforcement, Cobalt-Chromium alloy, PEEK, Implant assisted overdenture, ball and socket attachment.
RUNNING TITLE: Strain assessment of reinforcing overdenture assisted by implants.

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INTRODUCTION

Modern dentistry's ultimate objective is to return a patient's natural face shape, function, comfort, aesthetics, speech, and health (1). Because of their inability to correctly masticate and talk, edentulous individuals are classified as physically impaired, disabled, and handicapped by the World Health Organization (2).

Pain, lack of stability and retention, difficulties in speaking, gagging, mastication and salivation problems, esthetic and patient uncomfortable and dissatisfaction which are the most problems facing the patients wearing complete denture (3). Management of those patients was the focus of attention and challengeable matter for prosthodontist for long time, to restore mastication, phonetics and esthetic and social interaction (4).

However, the more teeth a patient has missing, the more difficult it is to meet these goals with conventional dentistry. Dental implantology is a term that fits the insertion of alloplastic material into the jaws to give support and retention for prosthetic tooth replacement (5). As Misch points out, the rising demand for and usage of dental implant-related treatment is due to the combined influence of a variety of variables (6).

Overdentures that are implant- assisted or implant-retained are suggested choices for improving retention, stability, and improving edentulous patients functionally and socially (7). Dental implants have substantially improved patient satisfaction, masticatory function, the health of residual supporting structures, and general quality of life for edentulous patients (8).

According to a review of the literature, mandibular two implant retained overdentures are a preferable option than conventional mandibular full dentures.(9) Since 2002, implant- assisted overdentures with two implants have been regarded as the gold standard of treatment for fully edentulous patients because they are straight forward, less invasive, cost-effective, and effective (10).
Two implants in the mandible appear to be sufficient for good stabilization of the removable prosthesis, and there are no statistically significant differences in terms of survival rate and patient comfort between insertion of two or four implants, solidified by a bar or with connections that do not constrain the implants (i.e., ball-attachment or other individual attachment) (11).
Splinted attachments and un-splinted attachments are the two types of attachments used to keep implant assisted overdentures in place. Un-splinted attachments having the benefit of requiring less inter-arch space, being simpler to clean, and being less expensive and easier to manufacture than splinted attachments (12).
Because of its simplicity and inexpensive cost, the ball and socket attachment is the most well-known un-splinted attachment for retaining a mandibular overdenture. Masticatory functional stress is typically transmitted to the peri-implant bone via the implants. Controlling functional forces is a contributing element in implant success (13).
The most common material used to make full denture bases is poly methyl methacrylate (PMMA) (14). It offers advantages such as ease of use, aesthetics, low cost, low solubility, and heat conductivity. However, due to material characteristics such as high thermal expansion coefficient, low resistance and fatigue, low modulus of elasticity, low traction resistance, and low flexibility, its lifespan expectancy is restricted (15).
The application of reinforcement in full denture construction might help to avoid or reduce denture base fractures, thereby increasing denture resistance and long life span (16).
Heat cured (PMMA) has a number of mechanical and physical problems, such as lowers impact and fatigue strengths, as well as low thermal conductivity and hardness. Furthermore, remaining monomer promotes tissue irritation and high porosity, resulting in long-term denture hygiene and cosmetic issues (17).
As a result, a variety of techniques for denture base reinforcement have been developed. Metal reinforcement, rubber-reinforced poly-methyl methacrylate, fillers such as carbon fiber, aramid fiebrs, glass fiber, Nylon, Hydroxyapatite, and nanoscale reinforcing materials were all mentioned (18).
Impressively, a novel restorative material known as (PEEK) has been effectively employed in the medical and orthopedic fields in recent years, as showed less antibacterial adhesion and more compatible with bone in Osteointegration process, PEEK has strong mechanical and electrical characteristics, as well as great biocompatibility and resistance to hydrolysis and high temperatures. PEEK is frequently utilized in dentistry and is seen as a viable alternative to traditional materials (19).
Moreover, PEEK has widely uses in dentistry field as temporary abutment, crowns, fixed prostheses, removable denture framework, finger prostheses, because PEEk has unique properties as shock absorber, low modulus of elasticity and stable color and stress distribution, Surface modification of PEEK enhances the cell adhesion, proliferation, biocompatibility, and osteogenic properties of PEEK implant materials(20).
Accordingly the aim of this study was to evaluate the effect of two different reinforcement material types on strain around two implants assisted mandibular overdenture and on the ridge areas by means of strain gauge analysis.
The null hypothesis is that the (CoCr) reinforcement material and (PEEK) reinforcement material will have no significant differences regarding the strain around the implant and on the ridge areas.

MATERIALS AND METHODS

Ramses medical products factory, Alexandria, Egypt, provided a ready-made totally edentulous maxillary and mandibular models constructed of epoxy resin. The canine portion of the mandibular model was 7.5 mm wide. The epoxy resin was coated with a 3 mm thick mucosa simulating substance consisting of flexible silicon. For the production of overdentures, these models were copied into mandibular stone models. (Figure 1)

Fabrication of the mandibular overdentures
Fabrication of the Acrylic mandibular overdentures (group A)

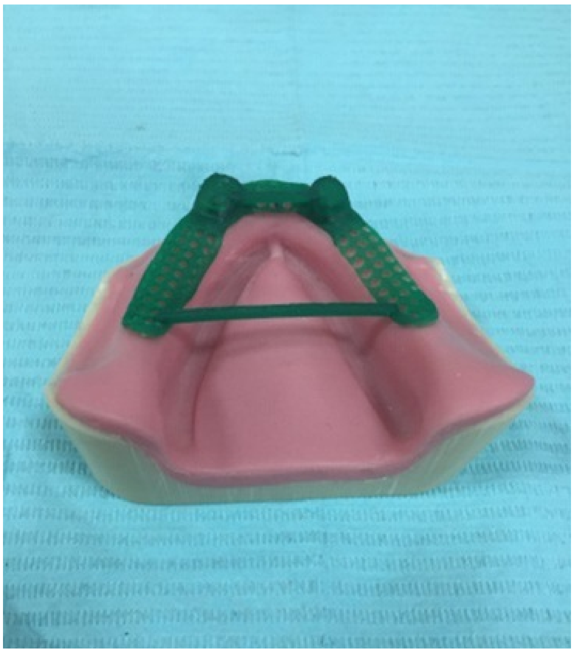
On replicated stone models, maxillary and mandibular trial denture bases with wax occlusion rims were built and installed on a mean value articulator, on which maxillary and mandibular acrylic teeth were positioned and adjusted.
In the mandibular arch, the inter-canine distance was 22 mm (each was 11 mm from the midline), simulating the space between two natural canines, each implant has a diameter of 4 mm and a length of 10 mm. The length of 10 mm was chosen because it is thought to be appropriate for achieving optimal stress distribution around the implant (21).
On the replicated stone model, Twenty-four mandibular trial denture bases were built. To assure uniformity of all mandibular overdentures, the same size mandibular acrylic teeth (size 22, Acrostone cross-linked acrylic teeth, Cairo, Egypt) were set on all trial denture bases using the opposing maxillary trial denture and the same mounting.

Construction of reinforcement framework

Ball abutment and socket (Neobiotech Co. Ltd, Seoul, Korea) were inserted and screwed over the two implants with torque (20N) on epoxy model, Epoxy model with two ball and socket abutments scanned by extra oral scanner then the framework was designed by using Dentsplay sirona in lab software (Dentsplay Sirona Global, NC,USA).
The framework extended distally till the first molar area bilaterally on model and leaving a space for acrylic resin about 0.5 mm between the framework and the mucosa.
After designing the framework, PMMA disc was inserted inside the milling machine and the cut was done by using (bur 1.0 PMMA). After that finishing and polishing and removing sharp areas of the framework were performed.
PMMA framework was used as a trial to assure if the framework was fully seated over the abutments or the design needs some modifications before investing of (Co-Cr) framework and milling (PEEK) framework disc.

Fabrication of the mandibular overdentures with CoCr reinforcement (group B)

For group B metal housings of the implants' ball abutments were fastened in place, and these models were then scanned using a benchtop scanner ARCTICA Auto Scan (Kavo Co, Biberach, Germany) to create a virtual model on which PMMA framework was produced and securely checked on model for passive fit. (Figure 2)



Then To produce the refractory castings on which the cobalt chromium (TALLADIUM Vi-Tal, Batch # 060413, Talladium, Inc. CA, USA), PMMA framework patterns were created Casting rods (or sprues) are cylindrical pieces of wax that were attached to the PMMA pattern to allow the PMMA to melt out and make a passage to molten metal alloy to inter into mould pattern (22). (Figure 3)

For group B research models, they were duplicated. In order to establish a passive fit on the metal housings of the implants' ball abutments, the metal frameworks were then placed on the research models. The metal housings were then sealed with acrylic resin. To create the eight overdentures of group B), the mandibular full overdentures were constructed to the wax stage and flasked on copies of the study model to which the metal frames were fastened.

Fabrication of the mandibular overdentures with PEEK reinforcement (group C)

Study models for group C, the metal housings of the implants' ball abutments were fastened in place, and these models were then scanned using a benchtop scanner ARCTICA Auto Scan (Kavo Co, Biberach, Germany) to create a virtual model on which the PEEK frameworks were designed to be 0.8 mm in thickness, milled using PEEk disc (JunHua Co, Changzhou, China), with the Sirona CAD/CAM. (Figure 4)

In a similar manner to the methods used in group A, 8 overdentures were created the frameworks of groups B. This was done to guarantee passive fit over the metal housings of the abutments. In the three research groups, traditionally heat-cured acrylic resin (Acrostone heat-cure material, Cairo, Egypt) was utilized in compression molding with a gradual heat-curing cycle at 74 C for nine hours to create the overdentures.

The Twenty-four mandibular trial denture bases were flasked and packed with heat-cure polymethyl methacrylate (Acrostone heat-cure material, Cairo, Egypt). All of the overdentures were finished and polished using the traditional process.

Acrylic drilling template fabrication and implant installation

To assure the correct position of implant drilling in the canine area bilaterally, a light-cure acrylic resin drilling template was produced over the completed overdenture using a vacuum-forming machine.

Drilling was done in the following order: cortical drill, pilot drill, body drill (core drill), head drill, and then body drill again to remove debris. During the drilling of the second implant, the paralleling pin (Neobiotech Co. Ltd, Seoul, Korea) was used to assess the parallelism of the two implants.

Using a torque wrench, two implants (Neobiotech Co. Ltd, Seoul, Korea) of 10 mm length and 4 mm diameter were put into the drilled holes. 35N was the major stability.

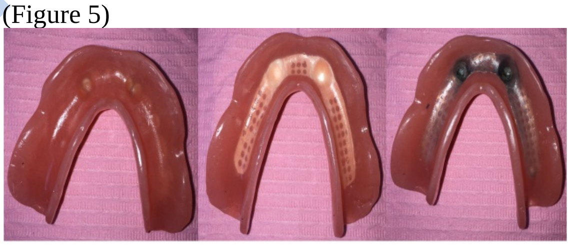
Using a torque wrench, two Ball attachments (Neobiotech Co. Ltd, Seoul, Korea) were fastened to mandibular overdentures at a torque of 20 N. The silicone sleeve was put on the cap with the top of the sleeve below the upper border of the cap and not covering the retentive fins. The cap-sleeve assembly was firmly placed over the abutment until it was firmly seated. To prevent the acrylic resin from locking around the abutment, the sleeve must cover the whole abutment neck that protrudes from the gingival region.

The model was covered with the overdenture. The attachments were marked with a marker so that they could be relieved until the overdenture was fully placed.

Two holes were created in the lingual surface of the overdenture, matching to the attachments' positions, to allow excess self-cure acrylic resin used for cap pick-up to escape.

The model was layered with a separating medium, and the holes were filled with monomer. Cold-cure Polymethyl methacrylate was prepared. When the mixture had reached the dough stage, it was pressed into the overdenture's fitting surface. To pick up the attachments' caps, the overdenture was seated over the model.

The silicone sleeve came out with the overdenture after it had set. The projecting section of the sleeve from the cap was then removed using a scalpel. Finally, the acrylic resin was polished and finished. (Figure 5)



Preparation of the model and installation of strain gauges(23)

Six self-protected linear strain gauges (KFG-1-120-C1- 11L1M2R, KYOWA strain gages, Tokyo, Japan) of a gaugefactor 2.13 ± 1%, a gauge length 1 mm and a gauge resistance of 119.6 ± 0.4Ω were used in this study.

To receive the strain gauges, six channels were created in the epoxy model. Each implant has two channels prepared on the mesial and distal sides. The channels were located in the ridge area, parallel to the implant's long axis, and the strain gauge was positioned between the implant and a 2 mm thick layer of epoxy resin. Flat walls were used to create the channels, particularly the wall parallel to the implant where the strain gauge would be attached, to avoid the risk of acquiring incremental apparent strain from mounting the strain gauge on a curved surface.

To measure the strain around the implants and on the ridge, strain gauges were positioned on their corresponding prepared locations in the epoxy resin model.

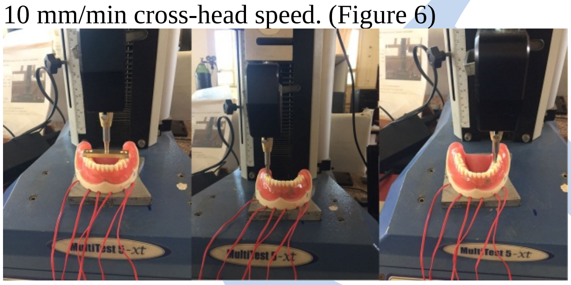
The strain gauges were cemented parallel to the long axis of each implant using a cyanoacrylate adhesive (CC-33A, Kyowa, Japan). To ensure that the glue had completely set, the strain gauges were left for 24 hours.

The strain gauge wires were placed in specifically prepared grooves constructed in the model's base to prevent any wire movement, which might impact the accuracy of the measurements.

The surface to be measured was labeled on all of the wires. A multichannel strain meter was used to connect the wire terminals of the six strain gauges.

Loading application and strain measurement

Vertical load was applied using a universal testing machine (Mecmesin, Multi Test5-XT (5KN), USA) linked to a computer. The load was delivered in compression mode through two metal rods with a 10 mm/min cross-head speed. (Figure 6)



The force was applied in the form of bilateral loading, with metal rods directing the weight to the right and left central occlusal fossae of the first molars, because greatest occlusal pressures are generally exerted in this location, where the elevator muscles are most contracted, the first molar was chosen for loading in this study (24).

The average biting force of totally edentulous patients wearing implant-assisted overdentures was found to be between 50 and 100 N. As a result, it was chosen 100N as the amount of the load applied to the overdentures (25).

Prior to loading, all of the strain gauges were zeroed and calibrated. To measure the stresses caused by the applied load, the strain gauge sensors were connected to a strain meter (Data Logger model TDS-150, Japan) that was connected to another computer.

Under the same circumstances, this method was repeated for each overdenture in all three groups. Between each loading, a five-minute rest period was allowed to allow for convection cooling from the strain gauge sensors (26).

Statistical Analysis

The data was collected and entered into the computer. Statistical Tools for Social Sciences (SPSS) version 20 was used to conduct the statistical analysis (IBM Corp., Armonk, NY). The distribution of the quantitative data was checked using the Kolmogorov-Smirnov test. The Kruskal-Wallis test was used to compare the three groups since the data were not regularly distributed. As a minimal standard, a margin of significance of 5% was established (27).

RESULTS

As indicated in table 1, strain analysis at peri-implant area of mandibular implant-assisted overdentures and on ridge was compared between the three examined groups through measuring strain distribution with strain gauges.

Between the three groups under study, the magnitudes of the stresses that resulted from the application of a load to the mesial and distal areas of the implants, and on both the right and left ridges, were compared.

After the application of central loading of 100 N, there was a statistically significant difference in the value of the total of stresses formed at the peri-implant area in right and left implants in mandibular implant-assisted overdentures between all three groups: group A (Acrylic), group B (Co-Cr), and group C (PEEK), with $p<0.001$.

Additionally, after applying central loading of 100 N on the right and left ridges, there was no statistically significant difference in the value of the total of strains between any of the groups, group A (Acrylic), group B (Co-Cr), or group C (PEEK).

However, after applying a unilateral left loading of 100 N, there was a statistically significant difference in the value of the sum of strains between the three groups, group A (Acrylic), group B (Co-Cr), and group C (PEEK). Group C PEEK demonstrated lower strain value with a mean of (5.58, 2.26, 1.61, 3.82, 4.86, and 35.44 as compared with group B (CO-Cr) and group A (Acrylic) whose mean (9.43, 1.84, 2.76, 4.03, 5.10 and 72.0) and (7.48, 0.92, 7.25, 7.36, 19.44, 40.20) respectively.

Moreover, after applying a unilateral Right loading of 100 N, there was a statistically significant difference in the value of the sum of strains between the three groups, group A (Acrylic), group B (Co-Cr), and group C (PEEK). Group C PEEK demonstrated lower strain value with a mean of (36.34, 2.99, 2.76, 3.34, 3.45, 1.73) as compared with group B (CO-Cr) and group A (Acrylic) whose mean (73.95, 5.18, 7.24 , 3.91, 4.95 and 9.71) and (40.71,3.22, 0.57, 18.98, 2.76, 5.75) respectively.

Table (1): Showing the values of all the strains in both right and left implants and on the ridge between the three studied groups after applying central load 100 N.

Central loading	Group A (n = 8)	Group B (n = 8)	Group C (n = 8)	H	p
Right Ridge					
Min. – Max.	1.84 – 2.76	0.92 – 4.60	0.92 – 5.52	1.173	0.556
Mean ± SD.	2.30 ± 0.49	2.42 ± 1.39	2.19 ± 1.39		
Median (IQR)	2.30(1.8 – 2.8)	1.84(1.4 – 3.7)	1.84(1.8 – 1.8)		
DR Implant					
Min. – Max.	3.92 – 3.68	1.84 – 7.36	4.36 – 3.28	15.478	<0.001*
Mean ± SD.	3.80 ± 1.15	5.29 ± 2.29	3.82 ± 0.48		
Median (IQR)	2.76(1.8 – 3.7)	5.52(3.7 – 7.4)	3.36(4.4 – 3.3)		
Sig. bet. Grps.	p_1=0.086,p_2<0.001*,p_3=0.027*				
MR Implant					
Min. – Max.	23.00 – 24.84	6.44 – 11.04	0.92 – 1.84	21.057*	<0.001*
Mean ± SD.	23.81 ± 0.59	9.78 ± 1.55	1.61 ± 0.43		
Median (IQR)	23.92(23.5 – 23.9)	10.12(9.2 – 11.0)	1.84(1.4 – 1.8)		
Sig. bet. Grps.	p_1=0.022*,p_2<0.001*,p_3=0.022*				
ML Implant					
Min. – Max.	29.44 – 46.00	0.00 – 2.76	0.92 – 0.98	18.897*	<0.001*
Mean ± SD.	34.04 ± 5.18	2.19 ± 0.98	0.93 ± 0.02		
Median (IQR)	32.20(31.3 – 35.0)	2.76(1.8 – 2.8)	0.92(0.92 – 0.92)		
Sig. bet. Grps.	p_1=0.010*,p_2<0.001*,p_3=0.084				
DL Implant					
Min. – Max.	18.40 – 22.08	0.92 – 7.84	4.25 – 3.12	20.879*	<0.001*
Mean ± SD.	20.13 ± 1.34	4.38 ± 0.48	3.68 ± 0.45		
Median (IQR)	19.78(19.3 – 21.2)	0.92(0.92 – 1.8)	3.28(4.3 – 3.1)		
Sig. bet. Grps.	p_1<0.001*,p_2=0.022*,p_3=0.022*				
Left Ridge					
Min. – Max.	1.62 – 3.66	0.95 – 4.30	1.10 – 6.02	1.948	0.378
Mean ± SD.	2.64 ± 0.45	2.16 ± 1.13	2.20 ± 1.56		
Median (IQR)	1.65(1.6 – 3.1)	1.79(1.4 – 2.9)	1.74(1.7 – 1.8)		

IQR: **Inter quartile range** SD: **Standard deviation**

H: H for **Kruskal Wallis test,** Pairwise comparison bet. Each 2 groups was done using **Post Hoc Test (Dunn's for multiple comparisons test)**

p: p value for comparing between the studied groups

p_1: p value for comparing between **Group A** and **Group B**

p_2: p value for comparing between **Group A** and **Group C**

p_3: p value for comparing between **Group B** and **Group C**

*: Statistically significant at $p \le 0.05$

Table (2): Showing the values of all the strains in both right and left implants and on the ridge between the three studied groups after applying unilateral left loading 100 N.

Left loading	Group A (n = 8)	Group B (n = 8)	Group C (n = 8)	H	p
Right Ridge					
Min. – Max.	3.68 – 8.28	9.20 – 10.12	4.20 – 6.96	18.914*	<0.001*
Mean ± SD.	7.48 ± 1.59	9.43 ± 0.43	5.58 ± 0.88		
Median (IQR)	8.28(7.4 – 8.3)	9.20(9.2 – 9.7)	5.02(4.0 – 7.1)		
Sig. bet. Grps.	p_1=0.010*,p_2<0.001*,p_3=0.084				
DR Implant					
Min. – Max.	0.00 – 2.76	0.92 – 3.68	1.84 – 2.68	12.250*	0.002*
Mean ± SD.	0.92 ± 0.85	1.84 ± 0.85	2.26 ± 0.70		
Median (IQR)	0.92(0.46 – 0.92)	1.84(1.4 – 1.8)	1.76(2.3 – 2.2)		
Sig. bet. Grps.	p_1=0.080,p_2<0.001*,p_3=0.080				
MR Implant					
Min. – Max.	5.52 – 11.96	1.84 – 4.60	0.92 – 1.84	19.735*	<0.001*
Mean ± SD.	7.25 ± 1.99	2.76 ± 0.85	1.61 ± 0.43		
Median (IQR)	6.44(6.4 – 7.4)	2.76(2.3 – 2.8)	1.84(1.4 – 1.8)		
Sig. bet. Grps.	p_1=0.011*,p_2<0.001*,p_3=0.059				
ML Implant					
Min. – Max.	6.44 – 8.28	3.68 – 4.60	3.20 – 4.44	16.942*	<0.001*
Mean ± SD.	7.36 ± 0.70	4.03 ± 0.48	3.82 ± 0.98		
Median (IQR)	7.36(6.9 – 7.8)	3.68(3.7 – 4.6)	3.28(3.4 – 4.5)		
Sig. bet. Grps.	p_1=0.003*,p_2=0.347,p_3<0.001*				
DL Implant					
Min. – Max.	17.48 – 20.24	4.60 – 5.52	4.44 – 5.28	20.879*	<0.001*
Mean ± SD.	19.44 ± 0.91	5.10 ± 0.43	4.86 ± 0.70		
Median (IQR)	19.32(19.3 – 20.2)	5.22(4.6 – 5.5)	8.28(7.4 – 8.3)		
Sig. bet. Grps.	p_1<0.001*,p_2=0.022*,p_3=0.022*				
Left Ridge					
Min. – Max.	35.80 – 47.00	62.30 – 75.35	33.89 – 37.14	20.227*	<0.001*
Mean ± SD.	40.20 ± 3.49	72.00 ± 4.36	35.44 ± 0.89		
Median (IQR)	40.40(37.4 – 41.6)	73.29(70.7 – 75.2)	35.42(35.2 – 35.7)		
Sig. bet. Grps.	p_1=0.021*,p_2=0.028*,p_3<0.001*				

IQR: **Inter quartile range** SD: **Standard deviation**
H: H for **Kruskal Wallis test,** Pairwise comparison bet. Each 2 groups was done using **Post Hoc Test (Dunn's for multiple comparisons test)**
p: p value for comparing between the studied groups
p_1: p value for comparing between **Group A** and **Group B**
p_2: p value for comparing between **Group A** and **Group C**
p_3: p value for comparing between **Group B** and **Group C**
*: Statistically significant at $p \le 0.05$

Table (3): Showing the values of all the strains in both right and left implants and on the ridge between the three studied groups after applying unilateral Right loading load 100 N.

Right loading	Group A (n = 8)	Group B (n = 8)	Group C (n = 8)	H	p
Right Ridge					
Min. – Max.	36.80 – 46.0	64.40 – 77.28	34.96 – 37.72		
Mean ± SD.	40.71 ± 3.54	73.95 ± 4.48	36.34 ± 0.98	18.596*	<0.001*
Median (IQR)	41.40(36.8 – 43.2)	76.36(71.8 – 76.8)	35.88(35.9 – 37.3)		
Sig. bet. Grps.	p_1=0.011*,p_2=0.081,p_3<0.001*				
DR Implant					
Min. – Max.	2.76 – 3.68	4.60 – 5.52	1.84 – 3.68		
Mean ± SD.	3.22 ± 0.49	5.18 ± 0.48	2.99 ± 0.82	16.471*	<0.001*
Median (IQR)	3.22(2.8 – 3.7)	5.52(4.6 – 5.5)	3.22(2.3 – 3.7)		
Sig. bet. Grps.	p_1=0.001*,p_2=0.770,p_3<0.001*				
MR Implant					
Min. – Max.	0.0 – 0.920	6.440 – 8.280	0.920 – 3.680		
Mean ± SD.	0.575 ± 0.476	7.245 ± 0.590	2.760 ± 0.852	20.431*	<0.001*
Median (IQR)	0.920(0.0 – 0.92)	7.360(6.9 – 7.4)	2.760(2.8 – 3.2)		
Sig. bet. Grps.	p_1<0.001*,p_2=0.034*,p_3=0.017*				
ML Implant					
Min. – Max.	18.40 – 20.24	3.68 – 4.60	2.76 – 4.60		
Mean ± SD.	18.98 ± 0.68	3.91 ± 0.43	3.34 ± 0.68	17.784*	<0.001*
Median (IQR)	18.86(18.4 – 19.3)	3.68(3.7 – 4.1)	3.22(2.8 – 3.7)		
Sig. bet. Grps.	p_1=0.003*,p_2<0.001*,p_3=0.242				
DL Implant					
Min. – Max.	1.84 – 3.68	4.60 – 5.52	2.76 – 3.68		
Mean ± SD.	2.76 ± 0.85	4.95 ± 0.48	3.45 ± 0.43	17.701*	<0.001*
Median (IQR)	2.76(1.8 – 3.7)	4.60(4.6 – 5.5)	3.68(3.2 – 3.7)		
Sig. bet. Grps.	p_1<0.001*,p_2=0.272,p_3=0.003*				
Left Ridge					
Min. – Max.	4.60 – 6.44	8.88 – 11.23	0.92 – 3.68		
Mean ± SD.	5.75 ± 0.65	9.71 ± 0.93	1.73 ± 1.04	20.732*	<0.001*
Median (IQR)	5.52(5.5 – 6.4)	9.40(9.1 – 10.3)	1.38(0.92 – 2.3)		
Sig. bet. Grps.	p_1=0.023*,p_2=0.023*,p_3<0.001*				

IQR: **Inter quartile range** SD: **Standard deviation**
H: H for **Kruskal Wallis test,** Pairwise comparison bet. Each 2 groups was done using **Post Hoc Test (Dunn's for multiple comparisons test)**
p: p value for comparing between the studied groups
p_1: p value for comparing between **Group A** and **Group B**
p_2: p value for comparing between **Group A** and **Group C**
p_3: p value for comparing between **Group B** and **Group C**
*: Statistically significant at $p \le 0.05$

DISCUSSION

Denture base material might fracture as a result of the weak mechanical properties of acrylic material. This material fractures because of its weak fatigue, transverse, and impact resistance. Strengthening of the acrylic overdenture can be beneficial for both; supporting implants and underlining structure (28). Therefore it may be essential to reinforce acrylic denture base by a rigid material, however the properties of the reinforcement material may affect the load transmitted to the ridge or around dental implants.

PEEK has strong mechanical and electrical characteristics, as well as great biocompatibility and resistance to hydrolysis and high temperatures. PEEK is frequently utilized in dentistry and is seen as a viable alternative to traditional materials (19).

The results obtained from this study showed statistically significant difference in the value of the sum of strains between the (PEEK) and (Co-Cr) after applying the unilateral right and left loading 100 N. where PEEK reinforcement showed less stress around the implant assessed overdenture than the Co-Cr reinforcement, due to PEEK frameworks have a capacity to absorb shock and lowering the occlusal load delivered to the prosthesis and implants.

While the stresses transmitted were higher with used of Co-Cr as reinforcement material, Because of its rigidity and high elastic modulus, it transmits stresses to supporting structures more readily than PEEk (29).

The findings of this study are in agreement with El-Anwar and Aboelfadl, since they found that PEEK bar produced the lowest Von Mises stress on overdenture compare with other metal materal (30). **Additionally, Kortam,** founds that the median strains of Co-Cr reinforcement are significantly higher than median strains of PEEK reinforcement as it achieved low peri-implant strains during unilateral and bilateral loading (31).

Ibrahim explained the less stress transmitted by PEEK by the difference in the modulus of elasticity of Co-Cr and PEEK, since the low modulus of elasticity of PEEK interprets its ductility and less transmission of stress to the ridge and around dental implants (32). **The outcomes of**

the current study is also in line with that of Tannous et al, who claimed that thermoplastic resins had a higher degree of flexibility than traditional Co-Cr due to their low elasticity modulus (33).
Cobalt chromium has many disadvantages according to Takahashi findings, strain around implants supporting a palate less maxillary overdenture with metal reinforcing and a palatal bar was less than reinforcement without a palatal bar, which was supported by the increased peri-implant stresses with cobalt chromium reinforcement (34).

CONCLUSION

Within the limitations of this study, the following conclusions were obtained:

1- There was difference in strain values between Acrylic, Co-Cr and PEEK as reinforcement material upon application of central and unilateral loading for implant assisted mandibular overdenture.
2- PEEK as reinforcement material for mandibular implant overdenture shows more favorable distribution of stresses around dental implants and on the ridge area when compared with Acrylic and Co-Cr reinforcement materials.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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