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# STRAIN ANALYSIS OF SINGLE IMPLANT OVERDENTURE REINFORCED BY MODIFIED POLYETHER-ETHER KETONE ON THE RIDGE AREA AND AROUND DENTAL IMPLANT (A COMPARATIVE IN-VITRO STUDY)

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## ABSTRACT

**INTRODUCTION**: Conventional complete dentures are the most commonly used treatment option for edentulous patients. To address their drawbacks, a single mandibular midline implant has evolved as an alternative to a two-implant assisting overdenture. Denture bases have been reinforced with a variety of materials to manage unreinforced overdentures' deformation and fracture vulnerability. The modified Polyether-ether ketone is the most recent and strongest non-metallic material introduced in dentistry.

**AIM:** The aim of the study is to evaluate and compare the effect of Biocompatible High Performance Polymer denture base reinforcement material in relation to the conventional acrylic denture base on strain on the ridge area and around a single midline implant mandibular overdenture.

**MATERIALS AND METHODS:** Two identical mandibular epoxy resin models were utilized. One root-form implant was screwed into the midline area of each model. 12 mandibular overdentures were constructed and divided equally into two groups: The denture base in group A was unreinforced, whereas in group B, the acrylic denture base was reinforced with Biocompatible High Performance Polymer (BioHPP). Four linear strain gauges were glued to the epoxy resin, and their lead wire's free ends were attached independently to a strain meter. Under central and unilateral loading of 100 N, strain values were recorded.

**RESULTS:** The findings revealed that there were significant differences in strain values between the acrylic resin group and the reinforced group.

**CONCLUSIONS:** The BioHPP showed lower microstrain values and exhibited a more favorable stress distribution on the ridge and around the implant.

**KEYWORDS:** BioHPP, O-ring attachment, Implant-assisted overdenture, and Denture base reinforcement.

**RUNNING TITLE:** Strain analysis of a reinforced single implant overdenture.

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## INTRODUCTION

Oral health is an essential part of overall health for population welfare. Edentulism, as one of the oral conditions, has a serious detrimental effect on not just one's oral health but also one's general health (1,2). Edentulism is a crippling and permanent disorder that affects the elderly on a prolonged basis (3) and is referred to as the last determinant of disease burden for oral health (4).

Felton reported that edentulous patients had higher rates of osteoporosis, poor nutritional intake, hypertension, and coronary artery diseases. According to the literature, patients who are edentulous are more likely to smoke and to suffer from smoking-related illnesses such as cancer, emphysema, and asthma (5). Hence, individuals' psychological, oral, and general health, in addition to their quality of life, are affected (6).

Complete dentures are the most commonly used treatment option for edentulous people around the world. however, they present frequent drawbacks such as poor retention, poor aesthetics, reduced chewing ability, phonation problems, oral mucosal soreness, ulceration, generalized discomfort in the prosthesis-bearing area, and denture breakage. Furthermore, there is an impairment of taste perception, poor oral and prosthetic hygiene and gagging (7).

Mandibular overdentures retained by implants were evolved and used to address the shortcomings of conventional dentures (8). Mandibular implant overdentures may be the better choice for various benefits, including a reduction in residual ridge resorption and gag reflux, increased stability and retention, and enhanced patient quality of life and satisfaction (9). In addition, when

compared to conventional mandibular dentures, implant retained mandibular overdentures have been shown to improve phonation and chewing ability (10).

Many authors advocated for two mandibular implants as the bare minimum standard to treat totally edentulous patients; however, the low economic status of elderly population is the major impediment (11–13). Consequently, an implant positioned in the midline of the mandible evolved as viable alternative treatment option (14).
In the 1990s, the first report utilizing a single implant to assist a mandibular overdenture has been documented in the literature (Cordioli 1993; Cordioli et al. 1997) (14). A systematic review by Padmanabhan el al. found that a single implant-assisted overdenture treatment is affordable, less invasive, and easy to handle. It can thus be used to restore functions and aesthetics (15) with greater safety for geriatric patients due to relatively high implant and overdentures success rates and few complications (15,16).

Despite the fact that overdentures present the above advantages, they are susceptible to distortion and breakage, particularly in the thinner portions at the midline and over the fulcrum abutments or implant attachments (17). Overdenture fracture occurs in a range of 9.3% to 21.4% of cases (18) and a high fracture incidence in the area near dental implants was reported. Moreover, during chewing, the single mandibular implant serves as the overdenture's fulcrum, causing deformation and later fractures (8).

As a result, different materials such as metal, carbon, fibers, glass fibers (19) and Polyether-ether ketone( PEEK) framework (8) can be used to reinforce denture bases, which enhances flexural properties and protects against overdenture breakage. It also increases stiffness and lessens denture base distortion (19).

According to certain studies, rigid metal reinforcement reduces strains beneath the denture base and spreads masticatory stresses on the underlying remaining alveolar ridge more evenly. Furthermore, it might reduce stress on the underlying implants (17,19).

Interestingly, a modified PEEK called Biocompatible High Performance Polymer (BioHPP), has been introduced in dentistry. BioHPP offers high thermal resistance, strong mechanical behavior, excellent biocompatibility, and chemical stability (20–22).

In addition, it possesses excellent physical characteristics with reference to (toughness, hardness, lightweight, and elasticity) (23). Due to its ability to lessen stress transfer to the implant and hence promote bone remodeling around the implant, BioHPP serves a suitable material for an abutment for implant and as a framework for implant-assisted prostheses as well as for removable ones (24).

This study assessed the effect of BioHPP reinforcement material on strain on the ridge areas and around the single midline implant mandibular overdenture by means of strain gauge analysis.

## MATERIALS AND METHODS

Two identical, completely edentulous mandibular epoxy resin models were employed. (Ramses Medical Products Factory, Alexandria, Egypt). The 2 mm thick of resilient silicone soft lining material was added as mucosal simulating layer.

Protocol of implant placement

A thermoplastic vacuum sheet guide template made using a completely dentate mandibular acrylic model was used to guide and standardize the midline implant placement. A hole was made in the guide template that matched the mandibular epoxy model's midline location using a round bur.

Placement of dental implants.

In the symphysis of each model, a single root-form implant that was 4 mm wider and 10 mm longer was inserted. The manufacturer's implant kit (Neobiotech Co. Ltd, Seoul, Korea) was used for implant placement procedures as follows: Sequential drilling passing through a hole in the guide template was employed to penetrate into the epoxy resin model. A 2.2 mm diameter pilot drill (850 rpm, 45 Ncm) initiated the hole, and a parallel pin (Neobiotech Co. Ltd, Seoul, Korea) was used to check the correct orientation of a half-length.

Afterwards, an intermediate drill of 3.0 mm was used. Lastly, a 3.5 mm drill was inserted 1mm below the top of the epoxy resin model. With the help of a torque wrench, a single implant that was 10mm longer and 4mm wider was driven into the prepared hole at 45 N.

Fabrication of the reinforcement frameworks

The titanium ball abutments were fixed to the implants with a torque of 20N-cm on an epoxy resin model, and then metal retainer rings were attached to the ball abutments. (Figure 1)

The epoxy resin model containing the fixture, ball abutment, and retainer ring (Neobiotech Co. Ltd, Seoul, Korea) was then scanned using an extra-oral scanner (Extra-oral scanner: EDGE, Germany), and an STL file was generated and saved. The STL file was then sent to the designing machine. On the model, the framework was lengthened posteriorly to the first molar area on both sides, leaving a 0.5 mm space between it and the simulating mucosa.

Once the design was finished, a try-in framework was printed using a Rasdent 3D printer (MODEL SP; S/N:20213203, Germany) in biocompatible resin, finished, and tried on the model. (Figure 2)

Milling of BioHPP disc (CAD/CAM)(25)

Following a resin framework try-in on the epoxy model and the verification of the BioHPP blank discs, they were inserted into the milling machine (CORTEC 250i Milling Machine, Germany) and a breCAM. Cutter (Ø 2 mm) was used to dry mill each breCAM BioHPP disc into its precise shape. (Figure 3)

Mandibular overdentures construction

The trial denture base was produced utilizing auto-polymerizing polymethyl methacrylate on mandibular stone casts, following which the wax occlusion rims were then created. The acrylic teeth of the same size were set and adjusted. The trial denture bases with acrylic teeth were flasked, packed with heat-cured acrylic resin (Acrostone acrylic resin material, Cairo, Egypt), and conventional techniques were applied during curing. Then, after the deflasking process, they were completed and polished. (Figure 4)

Pick up of metal retainer rings

The marked O-ring attachment was delineated in the overdenture by seating the overdentures on the epoxy resin models. A hole was drilled into the overdentures' intaglio surface to receive the O-ring attachment. Care was taken to prevent any premature contact between the block-out material and the overdenture.

In order to allow any extra acrylic resin to escape, small vents were made from the receiving area out of the lingual surface of the overdenture using a small bur.

Auto-cured polymethyl methacrylate material was mixed and employed when it was still in the dough stage in the overdentures relieved holes, and then sat on the epoxy resin model until it hardened. After the extra material had been eliminated, the overdentures were polished and completed. The final nylon caps were put in their place after the processing inserts were taken out. (Figure 5)

Strain analysis

By applying a load of 100 N both centrally and laterally, this study used a strain gauge stress analysis method to measure the strain around implant-retained overdentures (right and left), as well as on the right and left ridge regions.

Epoxy model preparation for installation of the strain gauges (26,27)

Four insulated strain gauges (KFG-1-120-C1-11L1M2R, KYOWA strain gauges, Tokyo, Japan) with a gauge factor of 2.13 ± 1.0 %, 1 mm long, a gauge resistor of 119.6 ± 0.4Ω, and an adoptable thermal expansion of 11.7 PPM/ °C were used. In order to accommodate the strain gauges, four channels in the model were created. The Channels were labelled as follows: channel 1 (Ch1): right side of implant; channel 2 (Ch2): right side of the crest of the ridge; channel 3 (Ch3): left side of implant; and channel 4 (Ch4): left side of the crest of the ridge. The crest of the ridge area corresponded to the mesial fossae of the lower first molars.

The prepared surfaces were aligned and positioned coincident with the implant's long axis. Before installing the strain gauges, the prepared surfaces were smoothed, and a 2 mm thickness was left between the implants and the strain gauges. The strain gauges were attached to the epoxy on the prepared surfaces using cyanoacrylate glue (CC-33A, Kyowa, Japan), which was then allowed to fully cure for 24 hours. To avoid any wire movement that would impact the measurements ‘accuracy, the strain gauge wires were inserted into specially made grooves in the base of the model.

Load application and strain measurements (27)

The epoxy resin model and overdenture were firmly seated on a universal testing machine’s lower flat metal plate. A universal testing machine was utilized to deliver a centrally and laterally compressive load of 100 N at a cross-head speed of 10 mm/min. (Figure 5)

The central loading was applied via a metal bar at the central fossa of the right and left first molars. The left side (simulating the working side) was then unilaterally loaded using a loading pin at the mesial fossa of the first molar that was notched with a diamond round bur to avoid the movement of the pin, while the right side was left unloaded. The same procedure was repeated on the right side.

Each strain gauge was connected to a strain meter, then calibrated and adjusted to zero. Gauge functionality was ensured before being loaded. A computer connected to a quarter bridge circuit multichannel strain meter (Portable Data Logger TDS-150, Japan) was used to read the micro strain values brought on by the applied load.

Under the same conditions, each overdenture in groups A and B underwent the same process. Each overdenture load was measured five times with a five-minute recovery period between each of the five successive measurements, and the mean microstrain values were recorded via specialized software.

Statistical analysis of the data

The obtained data was fed into the computer and statistically analyzed utilizing SPSS version 20.0 (Armonk, NY: IBM Corp.). The Shapiro-Wilk test was employed to verify the distribution’s normality. The range (minimum and maximum), mean, standard deviation, median, and interquartile range (IQR) were used to characterize quantitative data. The significance of the obtained results was judged at the 5% level. For comparison between the control and study groups, the Student t-test for normally distributed quantitative variables was also used.

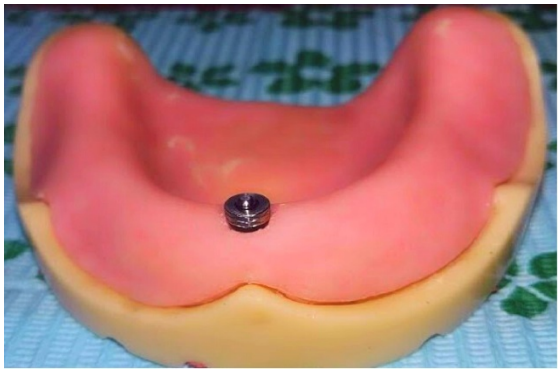

**Figure 1**: Ball abutment with metal retainer ring

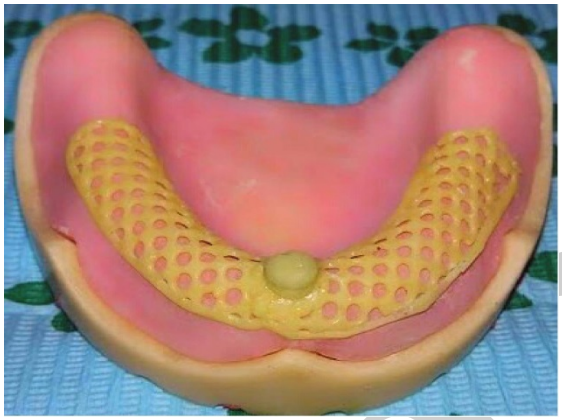

**Figure 2**: A trial resin framework

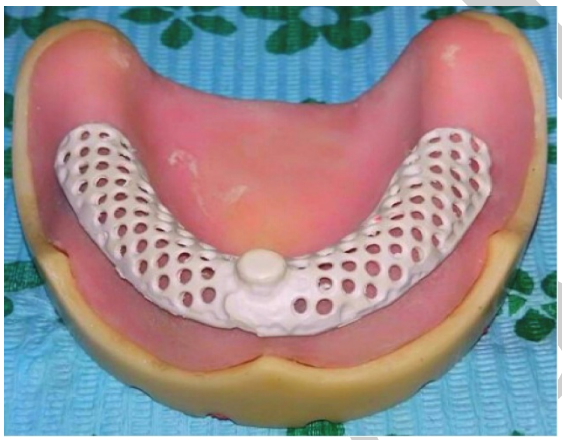

**Figure 3**: BioHPP framework on epoxy resin model.

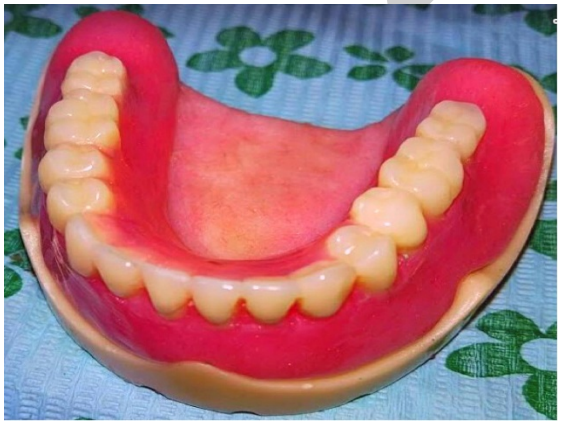

**Figure 4**: Single implant mandibular overdenture

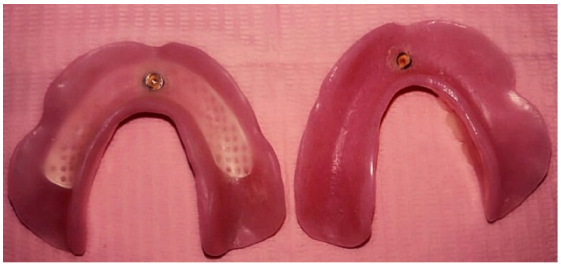

**Figure 5**: Pick up metal retainer rings

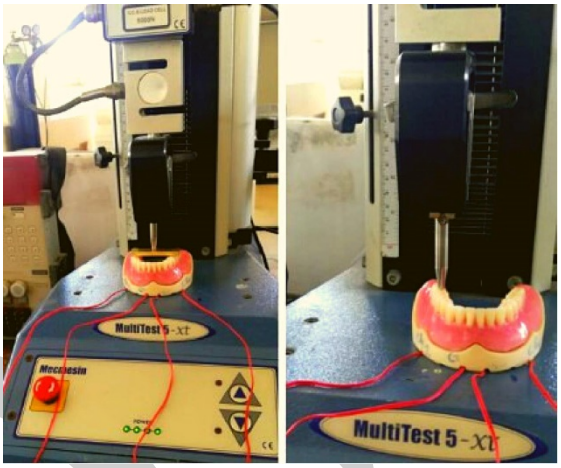


**Figure 6**: Central and unilateral loading

## RESULTS

In this study, micro-strain values were assessed on the ridge areas and around a single implant in groups A (acrylic) and B (BioHPP) and compared following the application of a compressive loading of 100 N. The obtained data was tabulated and statistically displayed as follows:

The study group (BioHPP) demonstrated statistically significant ($p \leq 0.05$) less micro-strain values than the control group (acrylic resin) at central and lateral loadings.

After the central loading, a statistically significant difference was noticed between the control group (acrylic) and the study group (BioHPP). The mean micro strain values in the acrylic group were higher (37.53, 23.78, 27.13, and 28.05) than in the BioHPP group, with a mean of (3.49, 3.34, 9.83, and 9.93) on the right side of the implant, left side of the implant, right side of the ridge, and left side of the ridge, respectively ($p<0.023$). (Table 4.1)

Similarly, to central loading, the lateral right loading showed a statistically significant difference between the control group (Acrylic) and the study group (Acrylic-BioHPP), as the study group showed less micro-strain values with a mean of (4.14, 2.75, 24.12, and 11.46) than in the control group with a mean of (22.28, 20.69, 73.89, and 37.95) on the right side of the implant, left side of the implant, right side of the ridge, and left side of the ridge, respectively ($p\leq 0.001$). (Table 4. 2)

Moreover, the lateral left loading presented a statistically significant difference

between the control group (Acrylic) and the study group (Acrylic- BioHPP), as the study group showed less micro-strain values with a mean of (4.05, 4.99, 11.43, and 25.35) than in the control group with a mean of (20.29, 22.16, 37.47, and 74.15) on the right side of the implant, left side of the implant, right side of the ridge, and left side of the ridge, respectively ($p \leq 0.001$). (Table 4. 3)

**Table (4. 1):** Comparison between the control group (Acrylic) and the study group (Acrylic- BioHPP) according to central loading

| Central loading | Acrylic resin (n = 6) | Acrylic-BioHPP (n = 6) | t | p |
|---|---|---|---|---|
| Right Side Implant | | | | |
| Min. – Max. | 27.90 – 58.70 | 2.76 – 4.10 | | |
| Mean ± SD. | 42.35 ± 11.58 | 3.49 ± 0.53 | 8.210* | <0.001* |
| Median (IQR) | 43.52 (31.70 – 48.76) | 3.68 (2.91 – 3.82) | | |
| Left Side Implant | | | | |
| Min. – Max. | 22.16 – 56.80 | 2.56 – 4.0 | | |
| Mean ± SD. | 37.53 ± 13.09 | 3.34 ± 0.53 | 6.394* | 0.001* |
| Median (IQR) | 34.20 (28.70 – 49.10 ) | 3.44 (2.90 – 3.72) | | |
| Right Ridge | | | | |
| Min. – Max. | 7.10 – 33.12 | 6.88 – 11.80 | | |
| Mean ± SD. | 23.78 ± 10.33 | 9.83 ± 1.80 | 3.260* | 0.021* |
| Median (IQR) | 27.33 (15.60 – 32.20) | 10.15 (8.88 – 11.10) | | |
| Left Ridge | | | | |
| Min. – Max. | 11.60 – 47.03 | 7.70 – 11.90 | | |
| Mean ± SD. | 27.13 ± 13.04 | 9.93 ± 1.56 | 3.209* | 0.023* |
| Median (IQR) | 28.05 (14.45 – 33.59) | 10.14 (8.68 – 11.0) | | |

IQR: Inter quartile range SD: Standard deviation t: Student t-test
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$

**Table (4. 2):** Comparison between the control group (Acrylic) and the study group (Acrylic- BioHPP) according to the lateral right loading

| Lateral right loading | Acrylic resin (n = 6) | Acrylic-BioHPP (n = 6) | t | p |
|---|---|---|---|---|
| Right Side Implant | | | | |
| Min. – Max. | 15.70 – 25.20 | 2.40 – 5.68 | | |
| Mean ± SD. | 22.28 ± 3.54 | 4.14 ± 1.28 | 11.815* | <0.001* |
| Median (IQR) | 23.51 (21.06 – 24.70) | 4.29 (3.10 – 5.10) | | |
| Left side Implant | | | | |
| Min. – Max. | 16.80 – 23.12 | 2.32 – 3.15 | | |
| Mean ± SD. | 20.69 ± 2.33 | 2.75 ± 0.32 | 18.695* | <0.001* |
| Median (IQR) | 20.81 (19.70 – 22.90) | 2.76 (2.52 – 3.0) | | |
| Right Ridge | | | | |
| Min. – Max. | 58.0 – 88.0 | 15.68 – 28.10 | | |
| Mean ± SD. | 73.89 ± 10.11 | 24.12 ± 4.37 | 11.071* | <0.001* |
| Median (IQR) | 73.72 (69.92 – 80.0) | 25.39 (24.01 – 26.16) | | |
| Left Ridge | | | | |
| Min. – Max. | 19.80 – 47.90 | 9.40 – 13.10 | | |
| Mean ± SD. | 37.95 ± 10.43 | 11.46 ± 1.36 | 6.166* | 0.001* |
| Median (IQR) | 41.40 (32.10 – 45.09) | 11.50 (10.78 – 12.50) | | |

IQR: Inter quartile range SD: Standard deviation t: Student t-test
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$

**Table (4. 3):** Comparison between the control group (Acrylic) and the study group (Acrylic- BioHPP) according to the lateral left loading

| Lateral left loading | Acrylic resin (n = 6) | Acrylic-BioHPP (n = 6) | t | p |
|---|---|---|---|---|
| Right Side Implant | | | | |
| Min. – Max. | 15.23 – 24.70 | 3.72 – 4.44 | | |
| Mean ± SD. | 20.29 ± 3.44 | 4.05 ± 0.24 | 11.531* | <0.001* |
| Median (IQR) | 20.34 (18.03 – 23.12) | 4.05 (3.90 – 4.12) | | |
| Left Side Implant | | | | |
| Min. – Max. | 16.70 – 26.10 | 4.30 – 6.28 | | |
| Mean ± SD. | 22.16 ± 4.21 | 4.99 ± 0.76 | 9.823* | <0.001* |
| Median (IQR) | 23.77 (17.02 – 25.60) | 4.80 (4.36 – 5.40) | | |
| Right Ridge | | | | |
| Min. – Max. | 20.90 – 49.23 | 8.91 – 13.0 | | |
| Mean ± SD. | 37.47 ± 10.25 | 11.43 ± 1.81 | 6.125* | 0.001* |
| Median (IQR) | 38.98 (32.20 – 44.52) | 12.20 (9.40 – 12.89) | | |
| Left Ridge | | | | |
| Min. – Max. | 58.80 – 86.04 | 17.05 – 31.0 | | |
| Mean ± SD. | 74.15 ± 8.91 | 25.35 ± 4.61 | 11.918* | <0.001* |
| Median (IQR) | 74.55 (72.68 – 78.30) | 26.12 (24.80 – 27.02) | | |

IQR: Inter quartile range SD: Standard deviation t: Student t-test
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$

## DISCUSSION

In the symphyseal region of the epoxy resin model, a single implant that was 4 mm wider and 10 mm longer was placed.

In their review article, Yadav P et al.(28) reported that 8 to 13 mm implant length is commonly used and closely resembles normal root length; this is important to establish initial implant stability, the amount of bone-implant interaction, as well as resistance to torque or shear pressures when abutments are screwed in. To provide acceptable implant strength, a diameter of at least 3.25mm is needed. A greater implant diameter will enhance the implant's surface area, share stresses across the surrounding bone and provide adequate initial stability.

According to AlSourori A. A. et al.(12), a solitary middle implant to assist a mandibular prosthesis has the same success rate as two implants and is regarded as an alternative therapeutic approach, especially for elderly patients and people with modest incomes. Similar to this, Srinivasan M. et al.(29) indicated that this technique is advantageous to geriatric individuals due to reasons such as physical dependence, mental disability, lower manual dexterity, pre-existing medical conditions, and economic issues.

Moreover, in comparison to two implant-assisted mandibular overdentures, a solitary implant-assisted mandibular overdentures has been shown to be effective, less expensive, have no difference in patient satisfaction, and to share and distribute the load (10).

Due to their small size and ability to quantify quantitatively, strain gauges are an easy and precise way to measure denture base strains (17).

The first molar area was selected as the site of load application because maximum occlusal forces are often applied there, where all elevators muscles are most contracted. Loading was carried out with 100N as moderately average level of biting force with an implant-assist overdenture (30) . A vertical static load was applied bilaterally to the first molars' central fossae. In order to mimic a clinical situation, unilateral loading was also done because the majority of the chewing forces are exerted unilaterally on the working side during mastication (31).

Silva de Paula M. et al. (32) evaluated the incidence and factors associated with the occurrence of fractures in patients treated with a single implant mandibular overdenture( SIMO) opposed by a maxillary complete dental prosthesis. They came to the conclusion that midline denture fracture was a frequent SIMO consequence and that using metal reinforcement might be an option to decrease the incidence of fractures. Additionally, Gonda T. et al.(33) compared the fracture frequency of mandibular prosthesis supported by 1 and 2 implants. They concluded that Overdentures assisted by one or two implants did not significantly differ in denture base fracture occurrence; yet, when fractures did happen, they frequently occurred around the implants.

Gibreel M. F. et al.(34) reported that by increasing the overdenture's flexural characteristics, its base deformation is minimized, and the reinforcement could decrease the incidence of implant overdenture (IOD) fractures. Additionally,

the utilization of the metal reinforcing material reduces and distributes strains on the overdenture foundation area. The residual ridge and the top of the abutments are the best locations for effective overdenture reinforcements.

Over the past few years, PEEK, an innovative material, has been employed with success in orthopaedics and medicine. PEEK frameworks have also been utilized to prevent denture base fracturing due to their excellent performance properties (35).

Hana'a G. Y and Yasser M. S (36) compared crestal bone loss and prosthetic maintenance events of solitary implant-assisted mandibular prosthesis reinforced by Polyetherether ketone (PEEK) and metallic frameworks after a two-year follow-up period. Reinforced SIMO did not fracture during the two-year follow-up, and even though the difference was not statistically significant, SIMO with a PEEK framework lost less crestal bone than SIMO with metal reinforcement. Moreover, it was reported that the modified PEEK, BioHP, offers improved mechanical and aesthetic properties as well as tremendous potential as a framework material (37).

The current study's findings disproved the null hypothesis that there would be no significant differences in the strain on the ridge area and around the implant between the acrylic denture base resin material and the BioHPP reinforcement material.

The acrylic resin group (the control group) recorded higher strain values than the study group (acrylic reinforced with BioHPP). The reason behind this is that denture bases made of acrylic resin are weak and brittle, which increases the likelihood of failure (38).

This is with agreement with Gibreel et al.(17) who evaluated the influence of unidirectional E-glass fiber reinforcement on the mid-line denture base strains of solitary implant-supported overdentures. They discovered that, the reinforced groups had strain values that were much lower by about 50%.

The right and left sides of the implant in both groups showed significantly reduced micro-strain values compared to the ridge areas after applying the central and unilateral loading of 100 N. This can be attributed to BioHPP's properties, including being shock-absorbing. In their review, Ruchika et al.(24) reported that BioHPP is regarded as an appropriate material for abutments and frameworks because it minimizes stress transfer to the underlying implant, stimulating bone remodeling around the implant.

Additionally, the O-ring attachment used has a true resiliency, which could lessen stress on the implant. Dina Bahgat El Talawy (16) evaluated crestal bone loss and patient satisfaction of ball and socket and O-ring attachments used to retain a single implant-retained mandibular overdenture after one year and recommended the utilization of O-ring housing instead of a ball and socket attachment for single implant mandibular overdentures in terms of peri-implant bone preservation.

## CONCLUSIONS

In comparison to acrylic resin, BioHPP as a reinforcing material for mandibular implant overdentures exhibits a more favourable stress distribution around the dental implant and on the ridge area.

With the application of a central and unilateral loading to mandibular overdentures, there were differences in the strain values between the acrylic resin group and the BioHPP reinforcing material on the ridge area and around the dental implant.

CONFLICT OF INTEREST:

The authors declare that they have no conflicts of interest.

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## REFERENCES

1. Tung H, Ford R. Incident edentulism and number of comorbidities among middle-aged and older Americans. Gerodontology. 2023;00:1–7.
2. Kailembo A, Preet R, Stewart Williams J. Common risk factors and edentulism in adults, aged 50 years and over, in China, Ghana, India and South Africa: Results from the WHO Study on global ageing and adult health (SAGE). BMC Oral Health. 2017;17:1–16.
3. Sutariya PV, Shah HM, Patel SD, Upadhyay HH, Pathan MR SR. Mandibular implant‐supported overdenture: A systematic review and meta‐analysis for optimum selection of attachment system. J Indian Prosthodont Soc. 2021;21:317–27.
4. Al- Rafee MA. The epidemiology of edentulism and the associated factors : A literature Review. J Fam Med Prim Care. 2020;9:1841–3.
5. Damian JC and Paola CS. Management of Edentulous Patients. Dent Clin North Am. 2019;63:249–61.
6. Alam-Eldein A, Mabrouk E, Mostafa amer. Effect of Calcium Channel-Blockers on Clinical Outcomes of Implant Retained Overdenture in Hypertensive Patients. Egypt Dent J. 2017;63:949–61.
7. Gupta A, Felton DA, Jemt T, Koka S. Rehabilitation of Edentulism and Mortality: A

Systematic Review. J Prosthodont. 2019;28:526–35.
8. Ibrahim MA, Ibrahim AM, Ahmed WA, El-waseel FA. Single Implant Mandibular Overdentures: A Clinical Study of Cobalt Chromium vs. PEEK Reinforced bases on Ridge Base Relation. Oral Heal Dent Sci. 2020;4:1–6.
9. Kutkut A, Bertoli E, Robert F, Pinto-Sinai G, Hidalgo RF JS. A systematic review of studies comparing conventional complete denture and implant retained overdenture. J Prosthodont Res. 2018;62:1–9.
10. Nora MS. Comparing patient satisfaction, retention and maintenance for different solutions of midline fracture of implant retained mandibular overdentures. Egypt Dent J. 2017;63:2747–57.
11. Kashyap S, Mittal S, Sharma N, Sukhija U, Kamra M, Gupta N. Evaluation of patient satisfaction and masticatory performance in mandible single implant-assisted overdenture. Tzu Chi Med J. 2021;33:406.
12. AlSourori AA, Mostafa Mh, Kaddah AF, Fayyed AE, Swedan MS A-AA. Impact of single implant versus two-implant mandibular retained overdentures on retention and success rate in totally edentulous patients. A randomized controlled clinical trial. J Osseointegration. 2018;10:79–86.
13. Alqutaibi AY, Esposito M, Algabri R, Alfahad A, Kaddah AF, Farouk M, et al. Single vs two implant-retained overdentures for edentulous mandibles: A systematic review. Eur J Oral Implantol. 2017;10:243–61.
14. Kern M, Att W, Fritzer E, Kappel S, Luthardt RG, Mundt T, et al. Survival and Complications of Single Dental Implants in the Edentulous Mandible Following Immediate or Delayed Loading: A Randomized Controlled Clinical Trial. J Dent Res. 2018;97:163–70.
15. Padmanabhan H, Kumar S.M AVK. Single Implant Retained Overdenture Treatment Protocol: A Systematic Review and Meta-Analysis. J Prosthodont. 2020;29:287–97.
16. El Talawy DB. A randomized controlled trial of ball and socket vs o-ring attachments for single implant-retained mandibular overdentures. A study of crestal bone loss and patient satisfaction. Egypt Dent J. 2021;67:3629–41.
17. Gibreel M, Lippo VJL, Timo ON, Leila P VK. Midline denture base strains of glass fiber-reinforced single implant-supported overdentures. J Prosthet Dent. 2021;126:407–12.
18. Abd El Aziz MS and Abd El Sattar Abd El Megid ET. Fully digital workflow for reinforced mandibular implant overdenture – A novel method. J Indian Prosthodont Soc. 2022;22:205–9.
19. Fathy M, Khalifa A, Moustafa M, Mahanna F, El-amier N, Närhi TO, et al. Biomechanical aspects of reinforced implant overdentures: A systematic review. J Mech Behav Biomed Mater. 2019;91:202–11.
20. Shawky A, Lotfy S. Zirconia Versus BioHPP Frameworks On Stresses Induced In Implants Supporting Structures Using ALL-ON-4® Protocol (Strain Gauge Analysis). Egypt Dent J. 2018;64:373–81.
21. Reda R, Zanza A, Galli M, De Biase A, Testarelli L, Di Nardo D. Applications and Clinical Behavior of BioHPP in Prosthetic Dentistry: A Short Review. J Compos Sci. 2022;6:1–14
22. Zoidis P, Papathanasiou I, Polyzois G. The Use of a Modified Poly-Ether-Ether-Ketone ( PEEK ) as an Alternative Framework Material for Removable Dental Prostheses . A Clinical Report. J Prosthodont. 2015;1–5.
23. Amer MM, Elsheikh MM, Haleem MM, Ghoraba SF, Salem AA. Short-Term Comparative Evaluation of BioHPP and Cast Cobalt – Chromium as Framework for Implant Supported Prostheses : A Split Mouth Clinical Randomized Trial. J Int Oral Heal. 2021;13:564–70.
24. Ruchika S I, Suchitra S.R, Divya H, Cora A C PA. Biohpp: Properties and Applications in Prosthodontics a Review. J Res Dent. 2020;7:72–76.
25. Antonio L. High-performance polymers for the digital workflow. bredent GmbH & Co, editor. Senden; 2023. 1–36 p.
26. Elsyad MA, Setta FA, Khirallah AS. Strains around distally inclined implants retaining mandibular overdentures with Locator attachments: An in vitro study. J Adv Prosthodont. 2016;8:116–24.
27. Rashad AHM, Hamdi Abo AH ANN. Stress analysis of two different attachments for a single implant retained mandibular overdentures in the midline (In vitro study). Egypt Dent J. 2021;67:689–97.
28. Yadav P, Tahir M, Shetty P, Saini V PD. Implant Design and Stress Distribution. Int J Oral Implantol Clin Res. 2016;7:34–9.
29. Srinivasan M, Makarov NA, Herrmann FR MF. Implant survival in 1- versus 2-implant mandibular overdentures : a systematic review and meta-analysis. Clin oral Implantol. 2014;1–10.
30. Abdallah MTH. Comparison Between Single Implant and Two Implants With Locator Attachment Retaining Mandibular Overdenture (in Vitro Study). Egypt Dent J. 2017;63:2515–23.

31. Abdallah HTM and Hanan M. Comparison between locater and magnetic attachment systems for single implant retained mandibular overdenture (strain gauge analysis). Egypt Dent J. 2017;63:3507–17.
32. de Paula MS, Cardoso JB, de Menezes EEG, Nogueira TE, McKenna G, Leles CR. A prospective cohort on the incidence of fractures in single-implant mandibular overdentures. J Dent. 2020;103.
33. Gonda T, Maeda Y, Walton JN, MacEntee MI. Fracture incidence in mandibular overdentures retained by one or two implants. J Prosthet Dent. 2010;103:178–81.
34. Gibreel MF, Khalifa A, Said MM, Mahanna F, El-Amier N, Timo O et al. Biomechanical aspects of reinforced implant overdentures: a systematic review. Finland; 2019. 1–24 p.
35. Heba WA. Clinical Comparative Study of Retention for Single Versus TwoImplant Mandibular Overdentures Reinforced by PEEK Framework. Assiut Dent J. 2023;6:35–44
36. Hana'a G. Y and Yasser M. S. Single implant-retained mandibular overdentures reinforced with polyether ether ketone and metallic frameworks: a comparative study of crestal bone loss and prosthetic maintenance. Egypt Dent J. 2023;69:1–14.
37. Aboelnagga M M. and El Sadat O. The effect of BioHPP versus Zirconia CAD/CAM-fabricated fixed-detachable prosthesis rehabilitating single maxillary arches on the peri-implant bone level changes. Egypt J Oral Maxillofac Surg. 2022;13:35–45.
38. Alhareb AO, Hazizan Md ZA. Impact strength, fracture toughness and hardness improvement of PMMA denture base through addition of nitrile rubber/ceramic fillers. Saudi J Dent Res. 2017;8:26–34.