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# EFFECT OF DIFFERENT DENTURE MATERIALS ON STRESSES TRANSMITTED TO PERI-IMPLANT AREAS OF IMPLANT-SUPPORTED MANDIBULAR OVERDENTURE

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*ABSTRACT*

**Aim;** This in vitro study was conducted to evaluate the effect of mechanical loading on different denture base materials on supporting structures materials and methods: a total of four implant retained overdentures were used in this study divided into two groups, first group; conventional acrylic overdenture (PMMA) and flexible acrylic overdenture on two polyetheretherketon"PEEK" implants) and second group conventional acrylic overdenture (PMMA) and flexible acrylic overdenture, supported by two implants each ( two Titanium implants) were placed in epoxy resin casts at the canine area using a surgical guide. Soft liner material was used at the distal extension area to mimic the soft tissues.

Two linear strain gauges were bonded buccal and lingual to each implant to measure the peri-implant strains during unilateral and bilateral loading.

**Results:** during bilateral loading the highest strain values were recorded with the flexible acrylic overdenture with PEEK implants, while the lowest strain values were recorded with the conventional acrylic overdenture with titanium implants. During unilateral loading, the highest strain values in the loading side were also demonstrated with the flexible overdenture with PEEK implants, and the lowest strain values were observed with the conventional acrylic overdenture with titanium implants.

**Conclusion:** within the limitations of this in vitro study, flexible overdenture retained by PEEK implants was found to transmit more occlusal stresses at the marginal bone area than the other materials.

**KEYWORDS:** PEEK, Titanium, Flexible acrylic, implant overdenture

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## INTRODUCTION

Patients who were edentulous typically experienced retention issues with their mandibular denture. It has been discovered that implant-based denture retention effectively lowers concerns about non-retentive dentures. The quantity of accessible bone and the number of implants inserted determine the potential treatment options. Only two implants may be utilised in the mandible to support an overdenture. These implants must be positioned in the inter-foraminal region, which is separated into five equal columns of bone between the mental foramina. C is in the midline, B and D are in the canine area, and A and E are in the first premolar area of A, B, C, D, and E.(1). Wolff's law states that, within physiological bounds, bone will be stimulated by load and adjust to it. (2). Moreover, it is true that as strain decreases due to a lack of stimulation, bone density and strength diminish. As a result, following the implantation of an implant or prosthesis, density and strength diminish because of a phenomenon known as stress shielding, which transfers forces from the crestal bone to them rather than the bone. The high difference modulus of elasticity causes the stress shielding phenomena. Human bone has an elastic modulus of 14 GPa, whereas titanium has an elastic modulus of 110 GPa. Polyetheretherketone (PEEK) has an elastic modulus of 12 to 18 GPa. (2). The elastic modulus of traditional acrylic resin used in denture base fabrication is 1602 MPa (3) while that of the flexible acrylic resin is lower than the traditional PMMA(4). Strain gauges are tiny electric resistors that modify the resistance in their current when the object they are inserted in slightly deforms. This allows one to determine the peri-implant strain. After being generated, the electrical impulses are transferred to a board for data capture, where a computer reads them. (5). Strain gauges are tiny electric resistors that modify the resistance in their current when the object they are inserted in slightly deforms. This allows one to determine the peri-implant strain. After being generated, the electrical impulses are transferred to a board for data capture, where a computer reads them.

## MATERIALS AND METHODS

### Fabrication of the test model and overdentures:

Casts made of clear epoxy resin were used for the study. An impression of a fully edentulous mandibular ridge was created using additional silicone rubber base to create the models. Unwanted undercuts were sealed off after the cast was poured, and a silicone mould was created to guarantee that the models' ridge and arch shapes would always be the same. Next, a thin layer of Vaseline was painted on the silicone mould to serve as a separating medium and facilitate the easy removal of the epoxy model once it had set, readying the silicone mould for the creation of the model casts. The silicone mould was filled with a clear epoxy resin mixture that was prepared in accordance with the manufacturer's instructions. For the second cast, the same steps were taken. After that, Occlutec spray was applied to the stone cast, and a desktop scanner (Medit t710) was used to scan it. In order to correlate the implant locations with the canine region, a digital wax-up prosthesis was placed over the surgical guide. [6] Figure **1**. To guarantee uniform implant positioning and parallelism, a surgical guide was created using a digital copy of the cast. Figure **2** After that, a clear acrylic resin 3D printer (Phrozen, Sonic mini 4k) was used to print the surgical guide design. [7]. Additionally, the implant that was intended to be used was selected throughout the design phase.

Using Solidworks SP5 software, a digital replica of the titanium implant (Implant Direct, USA) was created. Its dimensions were identical to the titanium implant, measuring 11.5 mm in length and 3.7 mm in diameter. **Figure 3**. A five-axis milling machine (ED5X, Emar Mills, Egypt) was used to mill two PEEK implants that were identical. **Figure 4** in order for their designs to be identical and to not alter the distribution of stress (8). Once that was done, the implants were positioned using the surgical guide.

To replicate the osseointegration process, the implants were fixed in the casts using a fresh mixture

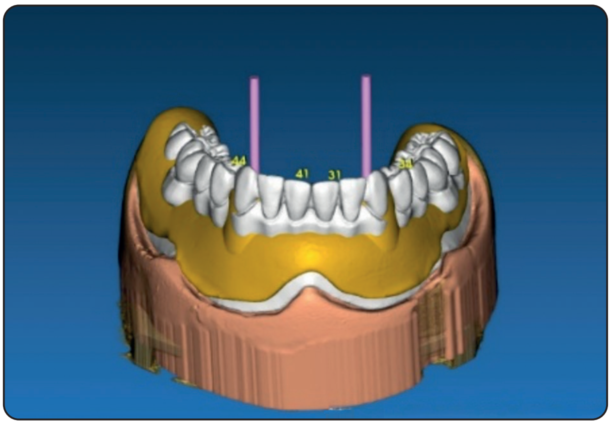

Fig. (1) Determining the positions of the implants.

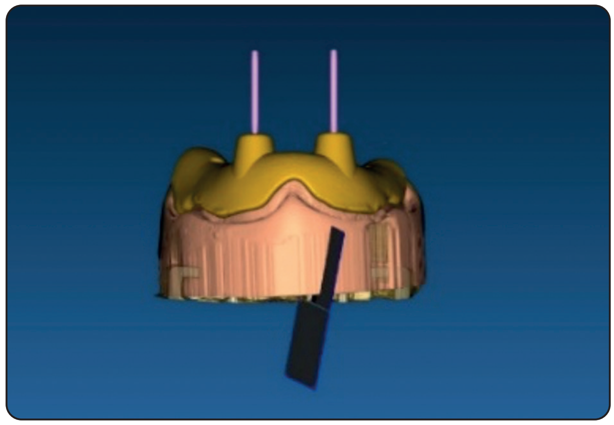

Fig. (2) Checking the parallelism of the implants.

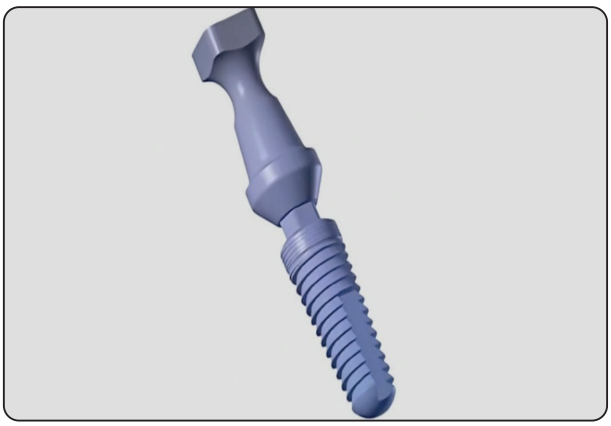

Fig. (3) Digital copy of the titanium implant.

Fig. (4) Milled PEEK implant.

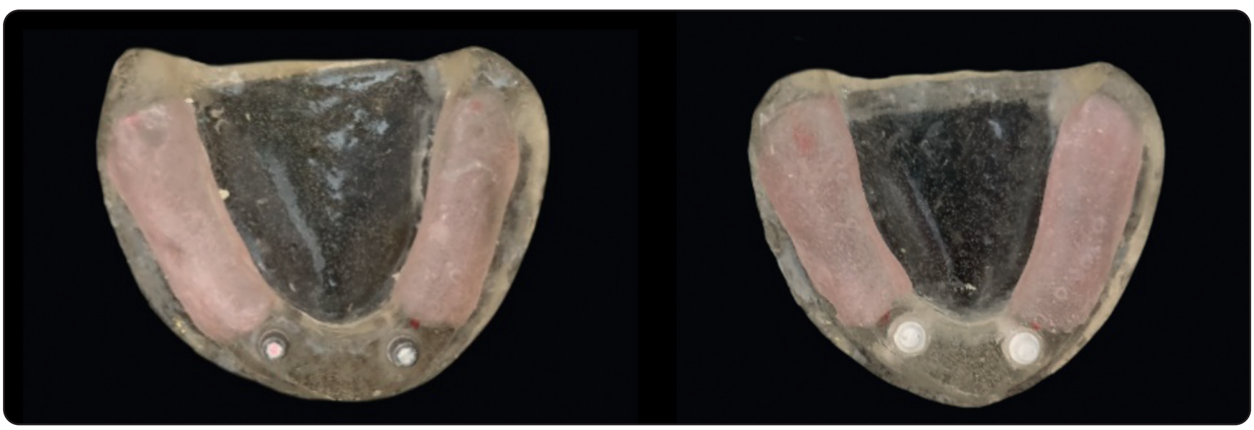

Fig. (5) Soft liner material used as a soft tissue mimic.

of clear epoxy resin. Subsequently, a 2 mm thick layer of soft liner material was inserted at the distal extension to replicate the soft tissues.(9) Figure 5. The level of the occlusal plane was then adjusted to two-thirds the height of the retromolar pad for each cast, and an impression was subsequently taken using an addition silicone rubber base to create a cast on which an overdenture was fabricated.

**Strain gauge analysis**

**Fixation of strain gauges:**

A strain gauge (5) can be used to measure the strain in the epoxy resin, which will give an idea of the stresses placed on the surrounding bone around the implants. To measure the peri-implant strains during loading, two linear strain gauges (KFG-1-120C1-11, Kyowa Electronic Instruments; Resistance 120.2 0.2, gauge length 1 mm, gauge factor 2.11 1.0%) were attached near the crest of the ridge at the buccal and lingual surfaces related to each implant. [10] Figure 6. Every gauge's long axis was aligned with the implants' long axis. The lingual and buccal surfaces of the epoxy resin casts were firmly taped with the gauge wires. A Tinsley Precision Instrument, Model 8692, multichannel digital bridge amplifier had each gauge individually wired into a ¼ bridge..

**Strain gauge measurements**

The occlusal surface of the implant-retained overdentures was subjected to vertical static loads using a universal loading machine (Lloyd LRX, Lloyd instruments). Both unilaterally and bilaterally, loads were applied. Using an I-shaped load applicator, a unilateral load was applied to the right side of the overdenture, with the left side serving as the non-loading side and the right side as the loading side. Figure **7**. Using a T-shaped load applicator, a bilateral load was applied to the left and right sides Figure **8**. Both the unilateral and bilateral loads were applied to an occlusal notch located in the first molar's central fossa. An average denture wearer biting force of 50 N was used. [11,12]. Both unilaterally and bilaterally applied loads caused strains to be measured in the vicinity of the implant at the buccal and lingual surfaces. For every cast, the tests were run three times, with a three-minute recovery period in between. After that, the measured strain values were exported for statistical analysis.

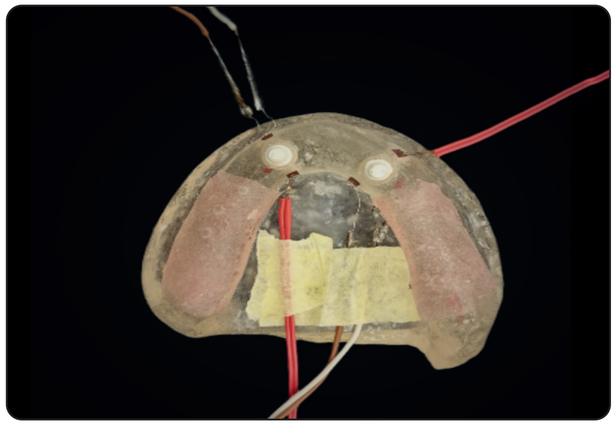

Fig. (6) Strain gauge fixation

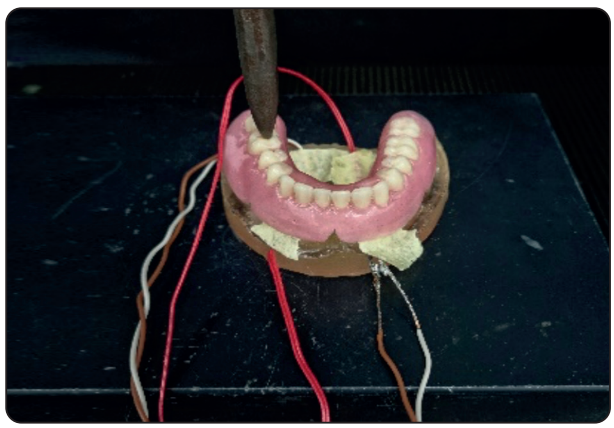

Fig. (7) Unilateral load application.

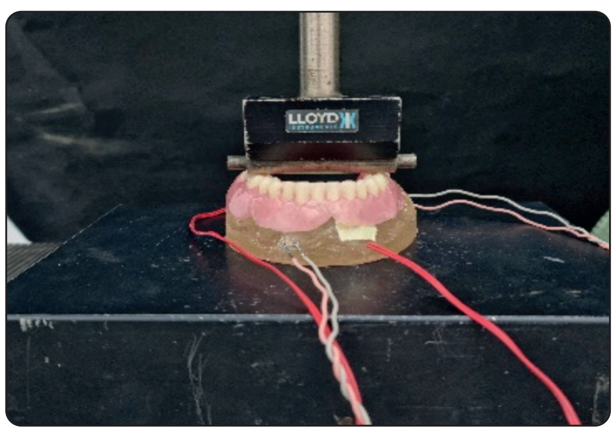


Fig. (8) Bilateral load application.

### Statistical analysis

Data were statistically described in terms of mean ± standard deviation (± SD). Because the groups are large enough, comparison between the study groups was done using One Way Analysis of Variance (ANOVA) test with Tukey's posthoc multiple 2-group comparisons. Two-sided p values less than 0.05 was considered statistically significant. IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows was used for all statistical analyses.

## RESULTS

### During bilateral load application

The strain values revealed a **significant difference** (p-value <0.001) between Acrylic OD on PEEK and Titanium implants. The Flexible Overdenture with PEEK implants showed the highest values of stresses transmitted to supporting structures, as represented by strain values; the Acrylic Overdenture with Titanium implants showed the lowest values of strain values. Additionally, the Flexible OD with PEEK implants and the Flexible OD with Titanium implants showed **significant difference** in the values. (Table 1).

### During unilateral load application

The strain values, at the loading side, showed **a highly significant difference** between loading side of Acrylic OD with PEEK and with titanium (p-value < 0.001), and **a highly significant difference** between Flexible OD with PEEK and titanium (p-value < 0.001) as well Table 2. The highest strain values at the loading side were recorded with Flexible OD with PEEK implants. The lowest strain values at the loading side were recorded with Acrylic OD with titanium implants.

TABLE (1) Comparison of microstrains during bilateral loading.

| Bilateral Loading | **(I)** | **(J)** | **Mean diff. (I-J)** | ***p* value** |
|---|---|---|---|---|
| **Overall** | Acrylic with PEEK | Acrylic with Titanium | 82.73 | 0.000* |
| | Flexible with PEEK | Flexible with Titanium | 98.43 | 0.004* |

***Significance level p≤0.05, *significant***

TABLE (2) Comparison of microstrains at the loading side during unilateral loading.

| Loading side | | Mean difference. (I-J) | p-value |
|---|---|---|---|
| (I) | (J) | | |
| Acrylic with PEEK | Acrylic with Titanium | 106.19 | 0.000* |
| Flexible with PEEK | Flexible with Titanium | 118.3 | 0.001* |

***Significance level p≤0.05, *significant***

## DISCUSSION

Depending on the prosthesis type, loading type, and attachment type, different loads will be transferred to the surrounding bone and the peri-implant area. Additionally, the quantity and distribution of implants affect how much weight is transferred from the implants to the supporting structures.[13]. A study revealed that, even with telescopic attachment for a two-implant retained mandibular overdenture having a long history of clinical success, a rigid telescopic coping holding the overdenture in place would act as a firm, unbending lever, exerting a significant amount of force that would be transferred from the implant to the surrounding bone[14]. The lingual surface of the non-metallic implants exhibited greater strain than the buccal side during bilateral load application, according to the study's results. This can be explained by the distal saddles of the denture cantilevering when a load is applied occlusally due to the mucosal mimic's resilience, which creates a lever action with the lingual side acting as a fulcrum.[15]. When posterior loading is applied to the anteriorly positioned implants (in the inter-foraminal area), the implant overdenture has a tendency to hinge and rotate. In comparison to PEEK implants, titanium implants in the canine area demonstrated the lowest peri-implant strain values, according to the results. This may be explained by titanium's greater elastic modulus. [16], delivering the greatest level of crestal part stress shielding. Due to the bone's atrophy from lack of use, its use would therefore result in the highest marginal bone loss among the materials tested. On the other hand, overall, the highest strain values were observed with the flexible acrylic overdenture supported by Polyetheretherketone (PEEK) implants.

The low elastic modulus of PEEK material and the flexibility of flexible acrylic, which bring its value closer to the surrounding structures, are responsible for these findings[17]. Conversely, low strain values were observed in the conventional acrylic overdenture held in place by titanium implants, demonstrating the stress-shielding effect of the material's notably high modulus of elasticity and stiffness [18]. The loading side strain values of PEEK implants demonstrated a noteworthy distinction between the conventional acrylic overdenture with titanium and the flexible acrylic overdenture. This disparity in stress shielding effect was attributed to the overdenture's stiffness and modulus of elasticity [10,19].

The study had several limitations, such as not applying load non-axially during the masticatory process, which could cause the occlusal forces to change and cause a different pattern of peri-implant stresses; not measuring strain at the mesial and distal peri-implant sites due to limited area, which would have recorded strain over wide area rather than at the crestal region around the neck of the implant; and not using different types of epoxy resin to simulate different bone quality. The data obtained from strain gauge analysis, like in previous in vitro studies, is typically descriptive only because the properties of epoxy resin do not replicate the complex structure of living bone.

## CONCLUSION

The following conclusion can be made, given the limitations of this in vitro study: flexible acrylic overdentures with titanium implants demonstrated low strain levels, indicating their stress-shielding effect, even though they did not exhibit the lowest strain values among the materials compared. In comparison to conventional acrylic overdentures with both implants and flexible acrylic overdentures with implants, flexible acrylic overdentures with Polyetheretherketone (PEEK) implants demonstrated the highest peri-implant strain levels. This allowed for the avoidance of the stress shielding issue that other materials caused.

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