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RETENTION AND STRESS DISTRIBUTION INDUCED IN MANDIBULAR IMPLANT-RETAINED COMPLETE OVERDENTURE WITH DIFFERENT INTERIMPLANT DISTANCE

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ABSTRACT

Objective: The loss of retention or adjustment of overdentures was the most commonly reported complication type in the dental office. So, this study was aimed to evaluate the retention and stress distribution induced in implant-retained overdenture with different inter- implant distance in vitro study. **Materials and Methods:** Six implant-retained overdenture models were fabricated on acrylic models with two screwed implants at three-different interimplant distances (19 mm, 23 mm, and 29 mm) to measure the overdenture retention using digital force gauge as well as to the stress distribution around the dental implant using strain gauge with unilateral load application at the second premolar, first molar, and the second molar sites. **Results:** The results of the retention test, revealed no statistically significant difference among the tested groups. While the strain results showed a statistically significant difference between all tested groups. **Conclusion:** The smaller interimplant distance could improve the retention of the overdenture as well as it could allow better stress distribution around the dental implants.

KEYWORDS: Interimplant distance, Overdenture, Retention, Stress-distribution

INTRODUCTION

Before the era of the dental implant, the conventional complete denture (CCD) was considered the traditional standard in the rehabilitation of the edentulous patients for more than a century especially for most individuals when there is an economic limitation [(1)]. Use of CCD is associated with several problems, such as lack of denture stability, support, and retention resulting in reduced chewing efficiency especially of the mandibular denture [(2)]. This is possibly caused by changes to the support structures after teeth loss, resulting in instability mainly of the mandibular prosthesis [(3)].

To overcome the problems of conventional mandibular complete dentures, the implant-retained overdentures have been introduced as it provided a significant improvement in retention, stability, as well as patient satisfaction [(1-3)]. So, edentulous patients who have problems with CCD alternatively treated with an implant-retained overdenture, mainly in the mandible [(4)]. The use of two implants in the inter-foraminal region to retain a mandibular overdenture has been recommended as the first treatment choice for the edentulous mandible, especially with the financial limitation that prevents more than two-implant to be placed [(4,5)].

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The prognosis of the mandibular overdenture depends mainly on denture retention as well as the proper stress distribution. Thus, overdenture must be carefully designed to achieve adequate retention, and stability, with optimal form, contour, esthetics, and the patient's best comfort (6.7). Denture retention plays a significant role in denture function as well as patient satisfaction (8). It was reported that the inter-implant distance between the two-implants can affect the retention of implant-retained overdenture depending on the type of attachment used (6).

The optimal stress distribution is required to reduce the forces on the implants and the denture movement (9). The degree of the occlusal load transmitted to the attachments is related to their resiliency (10). It was found that the ball attachment system transmitted a lesser amount of stress to the implants on the non-loading side (9,10).

So, the purpose of this study was to evaluate and compare the retention and stress distribution of implant-retained overdenture at different inter-implant distance. The hypothesis was that the inter-implant distance has a significant effect on the retention and stress distribution outcomes of the overdenture.

MATERIALS AND METHODS:

In this in-vitro study, the experimental design included the fabrication of a simulated two implant-retained mandibular overdenture with three different inter-implant distance. For this purpose, a standardized acrylic model of an edentulous mandible was fabricated with a heat-cured acrylic resin (Heat curing material, DENTSPLY LIMITED. Weybridge, England) by using a standard readymade, completely edentulous mandibular stone models (Elite dental stones; Zhermack) (11).

A total number of six acrylic cast models were used in this study. The study was divided into three main groups according to inter-implant distance (n=2). Then, each group was subjected to retention and stress distribution tests.

Group I: Acrylic cast model with inter-implant distance 19 mm "control group".

Group II: Acrylic cast model with inter-implant distance 23 mm.

Group III: Acrylic cast model with inter-implant distance 29 mm.

Two implants analogs with 11mm length and 3.4 mm diameter [Egyptian Company for Dental Implants (ECDI) Dr. W. Alaasar & Co], were vertically inserted with crystal bone position at the top of the ridge in the anterior part of each model, by the help of an acrylic template to control the parallelism of the two implants. The inter-implant distance was measured and adjusted by the help of a 50 mm-long plastic flexible ruler. O-ring ball attachment system (ECDI) was used as an attachment system in this study (11,12).

Each acrylic model in each group was used to make a final impression using rubber-based impression material (Speedex, Coltene A.G., Alsatten, Switzerland). Then, the impression was poured with improve dental stone, to produce stone casts with ball housing for overdenture construction. The complete overdenture was fabricated with a conventional curing method according to the manufacturer instructions, then, the attachment was secured in its place to the overdenture with aid of self-cured acrylic resin (11,12).

To simulate the resilient mucosal ridge of edentulous patients; the denture bearing area was uniformly reduced with round bur of 2 mm diameter, then the reduced edentulous area was painted by rubber adhesive after that light body rubber base material was applied to the denture bearing area and the overdenture was repositioned on the acrylic models until impression setting to produce an approximately 2 mm even thick layer of the light body. Then 2 holes in this mucosal-like layer were made at the site of the attachment to proper securing of the attachment system (11,12).

Retention Test:

A digital force gauge (DS2-500N; 175 × 66 × 32•8 mm, weight: 0•42 kg) was used as the retention measuring device, it was secured to the stand to allow tensile tests perpendicularly to the base of the stand. Each of the overdenture's models was subjected to 120 insertion/removal cycles each to dislodge the overdenture from the acrylic model, and the force values as indicated on the digital indicator were tabulated [5,13].

Stress Distribution Test:

The strain gauges (KFG-3-120-C1-11, Kyowa Electronic Instruments Co, LTD Tokyo, Japan) were used to measure the strain that resulted in the overdenture when the load applied unilaterally on second premolar, first molar, and second molar sites. The strain gauge was installed to the left / right implant (loading side) in each model, at the mesial, distal, labial, and lingual wall in the socket of each implant. A strain-meter with a three-channel was used to record the micro-strains transmitted to each strain gauge while the machine was adjusted to apply to load. On the lading side, a 60 N static load was applied five times by computer operating universal testing machine (Lloyd LR5K, Japan) at these six points at speed of 0.5 mm/sec [14,15].

Statistical Analysis

Data were collected, tabulated, and statistically analyzed using SPSS® Statistics Version 25 for Windows to detect whether significant differences existed between the means of the various studied groups.

RESULTS

Retention:

The statistical analysis of retention test for all tested groups revealed that; there is no statistically significant difference as indicated by the *One-way ANOVA* test, between the recorded mean retention values (Newton) among the different tested groups. It was found that the highest retention mean value was recorded for Group I at an inter-implant distance 19 mm, followed by Group and Group III at inter-implant distances 23, and 29 mm respectively (Table 1).

TABLE (1): Comparison of retention test results of the overdenture in all tested groups.

Group	Mean (N)	S. D	*P*-value
Group I	19.05[a]	6.19	0.81
Group II	19.5[a]	4.69	
Group III	18.05[a]	4.19	

**Significantly at (P-value ≤ 0.05).*

Different superscript small litter indicates statistically significant difference.

Stress Distribution:

The strain at different inter-implant sites:

Statistical analysis indicated by the *Kruskal-Wallis* test showed a significant difference (p-value ≤ 0.05) between the strain values recorded at the different load sites of all tested groups. Moreover, there was a significant difference in the strain values recorded at the second molar of Group I, Group II, and Group III. However, *Mann-Whitney* test statistical analysis among the groups showed that there was no statistical difference between strain values recorded at the sits of the second premolar and first molar of Group II and Group III.

It was found that the highest mean strain value measured was at the site of the second molar, followed by strain recorded at first molar, and the second premolar in Group I respectively, where the inter-implant distance was 19 mm. However, the lowest mean strain value measured was at the site of the second premolar in Group III where the inter-implant distance was 29 mm (Table 2).

TABLE (2) Strain (Means and S.D) of all tested groups at different loading times.

Strain gauge site \ Group	Group I	Group II	Group III	*P*-value
Strain at second premolar	15.80 (5.92)^{Cc}	25.07 (8.78)^{Cb}	54.49 (15.53)^{Ca}	< 0.000*
Strain at first molar	8.46 (2.43)^{Bb}	9.54 (4.97)^{Bb}	36.89 (16.53)^{Ba}	< 0.000*
Strain at second molar	6.42 (2.32)^{Ab}	7.62 (2.95)^{Ab}	29.39 (8.66)^{Aa}	< 0.000*
***P*-value**	< 0.000*	< 0.000*	< 0.000*	

*Different superscript capital litter indicates statistically significant difference in the same column. *Significantly at (P-value ≤ 0.05).*

Different superscript small litter indicates statistically significant difference in the same row.

**Significantly at (P-value ≤ 0.05).*

The strain at different sites regardless of the distance between the implants:

The statistical analysis of different loading sites indicated by the *Kruskal-Wallis* test showed that there was a statistically significant difference between the strains recorded at the different tested sites (p-value ≤ 0.05), while, the statistical analysis among the tested groups; *Mann-Whitney* test showed statistically significant difference. The highest mean strain value was recorded at the second molar site followed by the first molar site, while, the lowest mean strain value was recorded at the site of the second premolar (Table 3).

TABLE (3): The strain (means and S.D) values recorded at different sites regardless of the distance between implants.

Site	Mean (m/m)	S. D	*P*-value
Second premolar	58.44^{a}	19.62	
First molar	29.05^{b}	17.17	< 0.000*
Second molar	12.91^{c}	9.12	

Different superscript small litter indicates statistically significant difference.

**Significantly at (P-value ≤ 0.05).*

The strain recorded for each group regardless of the site of strain:

The statistical analysis of different loading sites indicated *by the Kruskal-Wallis* test showed that there was a statistically significant difference between the strains recorded at the different tested inter- implant distances (p-value ≤ 0.05). While, among the groups; *Mann-Whitney* test indicated that, there was a statistically significant difference between the strain recorded for Group III and both Groups II and I. However, there was no statistically significant difference in strain recorded between Group II and Group I. The highest mean strain value recorded was for Group III followed Group II, Group I for inter-implant distance 29, 23, and 19mm respectively (Table 4).

TABLE (4): Strain recorded for each group regardless of the site of strain.

Group	Mean m/m	S. D	*P*-value
Group I	10.76 ^{b}	5.53	
Group II	13.81 ^{b}	6.43	< 0.000*
Group III	32.34 ^{a}	4.82	

Different superscript small litter indicates statistically significant difference.

**Significantly at (P-value ≤ 0.05).*

DISCUSSION

The use of implant-retained overdenture has been suggested as one of the most commonly used treatment in edentulous patients[16]. Implant-retained overdenture is considered as a desirable rehabilitation approach because of its simplicity, non-invasiveness, and cost-effectiveness, especially when finances prevent more implants to be placed[5]. The stabilization of the mandibular denture with two inter-foraminal implants has provided reliable and more predictable prosthodontics outcomes than those offered via CCD. Therefore, the two-implant supported overdenture is regarded as the minimum standard of care for edentulous patients[17]. However, the prognosis of the mandibular overdenture depends mainly on two important factors namely; retention and stress distribution[6,7].

The attachment mechanism in the implant-retained overdenture provides enhanced retention and stability compared to the conventional complete denture[18]. O-ring ball attachment system is commonly used and it optimizes load transmission while minimizing overdenture movement[12]. Additionally, ball attachments were considered the simplest type of attachments for clinical application with implant-retained overdentures with favorable clinical results[19]. Additionally, the inter-implant distance should be considered during the construction of the mandibular overdenture, as the inter-implant distance can affect the retention and stress distribution of implant-retained overdenture in combination with the attachment system [6,20].

In this study, we choose inter-implant distances 19, 23, and 29 mm as a 3 different inter-implant distance to approximate the location of canines among the population. Also, in this study, we choose the inter-implant distance of (19 mm) as a "control group" as it was found to be the minimum inter-implant distance that allows enough space for the attachment system [21]. While it was found that the inter-implant distance of 23 mm is the mean inter-canine distance for mature untreated Angle Class I dentition [22]. Moreover, in a study carried out by some investigators they choose a value of 29 mm as an inter-implant distance to better account for anatomic limitations such as the curvature of the mandibular arch [21].

In this study, the acrylic resin was used in the construction of the experimental model because of the nearly in modulus of elasticity between the compact bone and acrylic resin [19,23]. Furthermore, a resilient rubber-based material covering the residual ridge to act as a substitute for the resilient mucosa [24]. The unilateral loading on the second premolar site, first molar site as well as the second molar site was selected in this study as the stress analysis revealed that the highest value of the stress was seen in the distal bone adjacent to the ipsilateral implant. However, with increasing cantilever length, there no important change in the stress distribution pattern. The highest stress in the posterior edentulous ridge was observed in the premolar area and by moving to more distal regions, the resultant stress was decreased [25].

In this study, each overdenture model was subjected to 120 cycles of repeated insertion and removal to simulate two-months of clinical function (on the assumption of two removals/insertions per day to clean the denture) [13]. According to the retention results of this study, the effects of parameters of inter-implant distances (19, 23, and 29 mm) under applying vertical forces on attachment retention values were statistically non-significant. This finding in the agreement of other investigators [21,26,27]. This may be attributed to the attachment material (titanium ball/titanium socket attachments)[28] used in this study, which show the same wear value for both initial and fatigue retention in all tested groups, regardless of the inter-implant distance [29]. Therefore, all groups show no statistically significant value.

Generally, the implant seems to transfer stress by vertical stress forces [14]. Therefore, in this study, we choose the vertical load, as a typical load of choice to evaluate the stress distribution at the different tested inter-implant distances. The results of this study showed that there is a significant statistical difference in strain values at a different inter-implant distance (19mm, 23mm, and 29mm). Also, the increased strain values simultaneously with the decreased of the inter-implant distance and the increased distance between the implant and loading point.

This finding may be due to the larger the distance between the implant and loading point such as the second molar region, the smaller the lateral load will transfer to the implant, and the larger the tissue-word movements of denture base [30]. Therefore, it well reduces the stresses generated on the implant, due to absorbance of more energy from the applied load via the resilient tissue, and transfers lesser energy to the implant [9]. This can explain the results of this study, as there was a gradual increase in strain values for the different inter-implant distance (19mm, 23mm, and 29mm) when the load applied at second premolar, first molar, and second molar respectively.

Additionally, it was found that on unilateral loading, with ball/socket attachment, the strain was concentrated on the loading side implant. This is because the ball attachments are not splinted together and react to load separately[24,31]. This can explain the results of this study when the unilateral load applied, there was higher tensile strain at the loaded side, as well as lower strain at the unloaded side.

CONCLUSION

Within the limitations of this in-vitro study and based on its result, it was concluded that; the inter-implant distance did not affect vertical retention of mandibular overdenture however, placing implants with less inter-implant distance could be advantageous in inducing better stress distribution as well as increasing the retention of overdentures.

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