EVALUATION OF STRAIN AROUND LABIALLY INCLINED IMPLANTS RETAINING MANDIBULAR OVERDENTURES WITH TITANIUM-SILICONE ATTACHMENTS (COMPARATIVE IN-VITRO STUDY)

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ABSTRACT

INTRODUCTION: The strain around labially inclined implants supporting mandibular overdentures with titanium – silicone attachments is still unclear.
OBJECTIVE: To evaluate strain around labially inclined implants retaining mandibular overdentures by using titanium –silicone attachments
MATERIAL AND METHODS: Sample size was estimated based on the following assumptions: alpha error= 5% and study power= 80%. Sample size was calculated to be 8) number of groups × number per group= 4 X 5= 20.
Two duplicate mandibular epoxy models were used. For each model resilient soft lining material was used to mimic resilient edentulous ridge mucosa. The epoxy models were scanned, CAD CAM surgical guides were fabricated to place two dummy implants in each model in the canine regions with the following degrees of labial inclinations: group A (control); 0°, group B; 17.5°. Experimental mandibular overdentures were constructed over the models and connected to the models with Ti Si attachments with retentions Sil 400 g / 4 Newton. Strain measurements were performed under central and unilateral loading using universal testing machine and a loading device.
RESULTS: when comparing group A and B under central loading, no significant difference of microstrain was detected around the implants. Microstrain around implants increases as labial implant inclination increases. With unilateral loading, the greater stresses with angled implants were more visible. More stresses were measured at lingual and mesial gauges, and less stresses were recorded at distal and buccal gauges for both groups.
CONCLUSIONS: The maximum microstrain was measured at the lingual sides of the implant in both vertical and inclined implant groups under central and unilateral loading. While the lowest microstrain was recorded at distal and buccal sides of the implant.
In comparing the two groups no significant difference was found with central loading while, with unilateral loading significant increase in microstrain was recorded in the inclined implants group.
KEY WORDS: Labial Implant Inclination, Strain, Ti Si, Snap Attachments, Retention Sil Ti Si.
RUNNING TITLE: Strain around labially inclined implants retaining mandibular overdentures.

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INTRODUCTION

For edentulous individuals, the implant-retained overdenture has become a universally recognized and predictable treatment choice. Because of the significant increase in retention and stability (1).
When patients complain about the lack of stability of their mandibular dentures, an overdenture on two implants is usually the initial treatment modality.
Fabrication of such prostheses is significantly less costly (2, 3).
They may easily adjust aesthetic and phonetic differences and provide greater levels of patient satisfaction (4). Studs, ball anchors, bars, magnets, and telescoping crowns are some of the attachment devices that can be utilized to keep overdentures attached to implants. Each with its own set of biomechanical characteristics (5, 6).
The amount of retention desired, arch shape, patient expectations, cost, soft tissue discomfort, and load distribution to the implants and surrounding tissue all these factors affect attachment system selection. The angle of the implant is also essential when choosing attachments (7).

The loading direction affects the stress transmission between the implant and the bone (8) as well as the design of implant and abutment angulation (9). Implant placement parallel to each other and perpendicular to the occlusal plane is considered ideal (10, 11). An inclined implant is necessary in specific clinical settings, such as mandibular resorption, lingual concavities, or the need to maximize the anteroposterior spread of implants to fit them into the remaining bone (12).

The impact of angled abutment on stress is debatable. However, tilted implants interfere with denture fabrication by impairing a common path of insertion with individual attachments (13) However, there is a scarcity of evidence on peri-implant strain around two-inclined implant-retained overdentures (14-16).

In comparison to parallel implant-retained overdentures with ball anchors, Hong et al. reported larger stresses and less uniform stress distribution in peri-implant bones for all tilted implants. The highest mean increase in stress observed in distal angulation, whereas the lowest mean increase was observed in buccal inclination (16).

Photoelastic strain analysis, Finite element approach, and strain gauge analysis are methods for measuring the strain created around dental implants (17) A strain gauge is an instrument that is commonly used to measure the strain that develops around experimental materials such as prosthesis and implant both in vivo and in vitro. Strain gauges are small electric resistor that used to measure the deformation of an object where they are applied. The captured deformation is transmitted as digital signal to the computer to be read (17).

The name Ti Si. Snap attachment stands for Titanium-silicone with snap effect (18). The Ti Si. Snap abutments' high guiding cone enables for safe and reliable denture fixation with only two implants, resulting in complete control of the denture during removal and integration (19).

Retention Sil material can be used as silicone matrix for implant overdenture, in place of the attachment system component in the denture base, as it has an adequate short-term and medium-term behavior (19).

When there is a lack of bone height, the implants can be angled to make optimum use of the local bone. The use of angled Ti Si. Snap abutments on implants with oblique placement, thus, adjusts the path of insertion (18). The goal of this study is to determine strain around implants retaining mandibular overdentures with labial inclination to retain mandibular overdenture with Ti Si snap attachments. The null hypothesis of this study is that there is no significant difference in strain surrounding labially inclined implants supporting mandibular overdentures with titanium-silicone snap attachments.

MATERIAL AND METHODS

This study was carried out after getting clearance from the Ethical Committee of the Faculty of Dentistry at Alexandria University in Egypt, (IIRB NO: 00010556-IORG 0008839). Sample size was estimated based on the following assumptions: alpha error= 5% and study power= 80%. Sample size was calculated to be [8)] number of groups × number per group= 4 X 5= 20.

Two readymade edentulous mandibular epoxy models (Kemapoxy 150 JM, CBM International) were used. For each model, an autopolymerized resilient silicone soft lining material was used with 1.5-mm-thickness to simulate resilient edentulous ridge mucosa (Softliner®, Promedica, GmbH, and Neumunster, Germany) (15). **(Figure 1)**

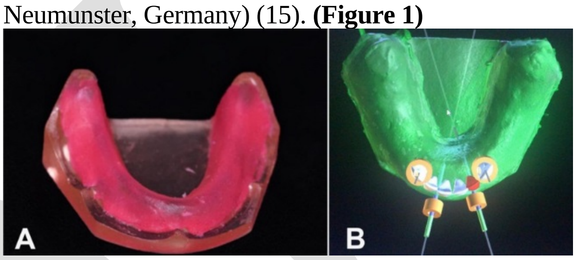

Figure (1):

Figure (1): A. Epoxy model with pink silicone rubber material, B. 3D CAD planning software

The epoxy models were scanned using CBCT, the obtained DICOM data were converted into STL models**.** The 3D CAD planning software was used for planning implant location and labial inclination (0°, 17.5°). The designed 3D surgical guides were printed by 3D printer (Printer: mogassam dent 1, Scanner: amanngirrbach ceramill map400, Resin: phrozen). according to the labial implant inclination (0°, 17.5°). **(Figure 2)**

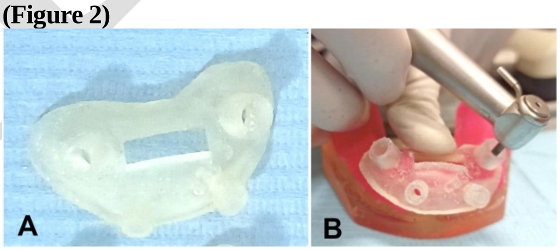

Figure (2):

Figure (2): A. Designed 3D surgical guides 17.5°, B. Model with two recesses prepared at the canine regions by

In each model, two implants (Bredent ,medical GmbH & CoKG Germany) of 10 mm length and 4 mm diameter were placed bilaterally in the canine regions using CAD CAM surgical guide and CAD CAM surgical kit. According to implant angulations were divided into two groups, Group A (Control group) implants were inserted at zero inclination (vertical) with straight Ti Si snap abutments, and Group B implants were inserted at labial inclination of 17.5°and with angulated 17.5° Ti Si snap abutments. **(Figure 3, 4)**

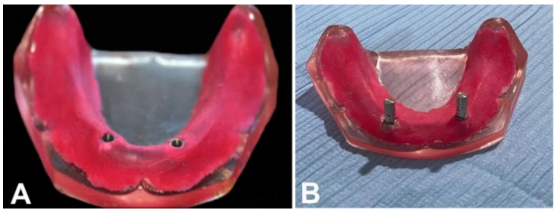

Figure (3): A. Epoxy model with two implants, B. Checking the parallelism with parallel pen

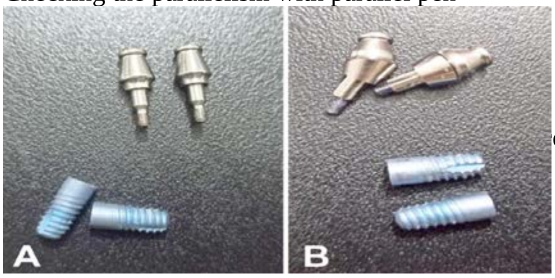

Figure (4): A. Group A, B. Group B 17.5°

Ten acrylic experimental overdentures were fabricated for each group. To accommodate the Ti Si retention Sil 400 gm/ 4N, sufficient relief holes were established on the fitting surface of each overdenture, which corresponds to the implant abutments. **(Figure5)**

Figure (5): A. Retention sil 400mg /4N, B. Using ti si Retention sil 400mg/4N

A self-protected linear gauges were used, buccal, lingual, mesial, and distal surfaces of the implant were constructed with small channels in the epoxy model. Channels were nearly 4mm long, parallel to the implant's long axis, and deep enough to leave just 1mm of epoxy between the strain gauge rosettes and the implant. Flat walls were used to construct the channels, mainly those parallel to the implant where the strain gauge was attached. Application of central loading sixty newtons regarded as maximal occlusal force was delivered to the center of the overdenture on each model in (group A, B) using the universal testing machine. The right and left strain values at mesial, distal, buccal and lingual to peri -implant sites under central loading were estimated for each applied load (15, 20). **(Figure 6)**

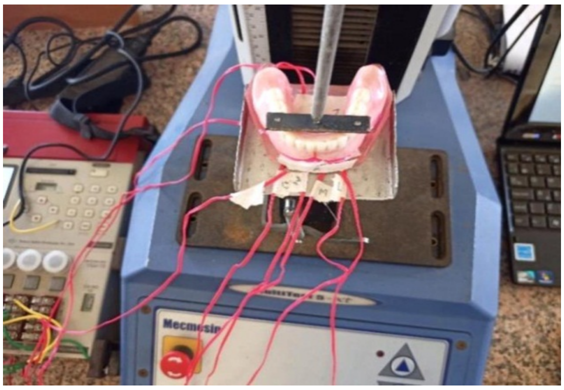

Figure (6): Central loading.

Using lateral loading the right side of the overdenture was left empty to represent the non-working side, while the left side was loaded to simulate the working side. Strain was measured in the loading and non-loading sides at the mesial, distal, buccal, and lingual to peri-implant locations. The technique was repeated with the loaded right side and the unloaded left side (15, 21).

All measurements were performed five times with a five-minute recovery period in between, and the mean of the recorded micro strain was statistically analyzed.

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. **(Armonk, NY: IBM Corp).** For continuous data, they were tested for normality by the **Shapiro-Wilk test**. Distributed data were expressed as mean and standard deviation. For normally distributed quantitative variables **Student t-test** was used to compare two groups while **ANOVA with repeated measures** was used for comparing between more than two positions and followed by **Post Hoc test (Bonferroni adjusted)** for pairwise comparisons. Significance of the obtained results was judged at the 5% level

RESULTS

The goal of this study was to measure and compare the stresses that transmitted to the implant with vertical and 17.5° labial implant angulation and Ti Si retention Sil attachment using strain gauge analysis. The range, mean, and standard deviation of microstrain values were used to assess data obtained and tabulated quantitatively. Student (unpaired-sample) ''t'' test was used to compare between two study groups**.**

Microstrain measurements for Group A (Control group)

Implants were inserted with zero inclination (vertical) and straight Sky Ti Si snap abutments using Ti Si retention Sil 400 Mg/4N.

Microstrain under central vertical loading

- Microstrain measurements at the different studied positions around the implants under central vertical loading for group A using retention Sil 400 mg/4N. **(Table 1)**

Table (1): Comparison between the microstrain around the implants at the different studied positions in group A (zero angulation)

	Side	Implant	Buccal	Lingual	Mesial	Distal	F	p
TI SI SI Sil 400 Mg /4 N	Central	**Right**	$39.60^{b} \pm 11.46$	$159.0^{a} \pm 9.46$	$32.0^{b} \pm 6.40$	$34.80^{b} \pm 5.26$	214.444^{*}	$<0.001^{*}$
		Left	$30.20^{b} \pm 5.97$	$171.2^{a} \pm 6.26$	$32.80^{b} \pm 8.07$	$33.0^{b} \pm 4.06$	612.486^{*}	$<0.001^{*}$
	Right lateral	**Right**	$41.60^{d} \pm 5.94$	$285.6^{a} \pm 7.30$	$186.4^{b} \pm 1.82$	$113.6^{c} \pm 4.88$	2144.221^{*}	$<0.001^{*}$
		Left	$24.20^{b} \pm 5.17$	$48.40^{a} \pm 4.39$	$20.40^{b} \pm 3.36$	$21.40^{b} \pm 2.97$	62.008^{*}	$<0.001^{*}$
	Left lateral	**Right**	$15.80^{b} \pm 4.32$	$16.40^{b} \pm 2.30$	$57.20^{a} \pm 9.58$	$16.0^{b} \pm 5.10$	45.612^{*}	0.001^{*}
		Left	$103.6^{c} \pm 8.17$	$234.8^{b} \pm 4.32$	$283.2^{a} \pm 10.18$	$51.0^{d} \pm 6.28$	1110.681^{*}	$<0.001^{*}$

- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual side of implants at right and left side.

2- Under central loading, the highest microstrain mean value was recorded at lingual side for both right and left implant. Right side (169.0 a ± 9.46) and left side (171.2 a ± 6.26) while the lowest microstrain mean value was recorded at distal side of the implants for both right side ($30.80^{b} \pm 5.26$) and left side ($30.0^{b} \pm 4.06$).

Microstrain under unilateral vertical loading (right side)

- Microstrain measurements at the different studied positions around the implants under unilateral right vertical loading for group (A) using retention Sil 400 are shown in (Table 1).
- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual side of implants at right and left side using Ti Si retention Sil 400 under unilateral right side loading

1- Under unilateral right loading, the highest microstrain mean value was recorded at the lingual side of right implant **(**$285.6^{a} \pm 7.30$**)** , while the lowest microstrain mean value was recorded at distal side ($41.60^{d} \pm 5.94$).

Microstrain under unilateral vertical loading (left side)

- Microstrain measurements at the different studied positions around the implants under unilateral left vertical loading for group (A) using retention Sil 400/4N are shown in (Table 1).
- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual side of implants at right and left side, under unilateral left side loading.

1- Under unilateral left loading, the highest microstrain mean value was recorded at the lingual side of left implant **(**$283.2^{a} \pm 10.18$**)** , while the lowest microstrain mean value was recorded at distal side ($51.0^{d} \pm 6.28$).

Microstrain measurements for Group B

Implants were inserted with labial inclination of 17.5°and angulated 17.5° Sky Ti Si snap abutments.

Microstrain under central vertical loading

- Microstrain measurements at the different studied positions around the implants under central vertical loading for group B using retention Sil 400 mg/4 N **(Table 2).**
- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual side of implants at right and left side under central vertical loading.

1- Under central loading. The highest microstrain mean value was recorded at lingual side for both right and left implant. Right side **($105.8^{a} \pm 10.92$)** and left side **($110.6^{a} \pm 13.26$)** while the lowest microstrain mean value was recorded at distal side of the implants for both right side **($32.20^{c} \pm 7.12$)** and left side **($26.0^{c} \pm 4.18$).**

Microstrain under unilateral vertical loading (right side)

- Microstrain measurements at the different studied positions around the implants under unilateral right vertical loading for group (B) using retention Sil 400 are shown in (Table 2).
- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual sides of implants at right and left sides.

Table (2): Comparison between microstrain around the implants at the different studied positions in group B (17.5 labial angulation).

	Side	Implant	Buccal	Lingual	Mesial	Distal	F	p
TI SI SI Sil 400 mg/4 N	Central	**Right**	$49.60^{b} \pm 3.85$	$105.8^{a} \pm 10.92$	$94.0^{a} \pm 3.39$	$32.20^{c} \pm 7.12$	120.488^{*}	$<0.001^{*}$
		Left	$43.20^{b} \pm 3.42$	$102.6^{a} \pm 13.26$	$110.6^{a} \pm 10.85$	$26.0^{c} \pm 4.18$	95.878^{*}	$<0.001^{*}$
	Right	**Right**	$101.4^{c} \pm 9.04$	$179.8^{b} \pm 3.11$	$248.6^{a} \pm 5.59$	$151.6^{b} \pm 11.78$	245.884^{*}	$<0.001^{*}$
		Left	$53.60^{c} \pm 4.77$	$122.0^{a} \pm 1.58$	$133.6^{a} \pm 4.72$	$74.0^{b} \pm 6.20$	297.675^{*}	$<0.001^{*}$
	Left	**Right**	$52.60^{c} \pm 3.44$	$109.6^{b} \pm 6.23$	$130.6^{a} \pm 4.72$	$59.40^{c} \pm 3.36$	397.301^{*}	$<0.001^{*}$
		Left	$132.4^{c} \pm 1.95$	$163.8^{b} \pm 3.27$	$252.4^{a} \pm 2.88$	$163.8^{b} \pm 5.07$	1702.327^{*}	$<0.001^{*}$

Data was expressed using Mean ± SD.

F: F test (ANOVA) with repeated measures, Sig. bet. periods was done using **Post Hoc Test** (**adjusted Bonferroni)**

p: p value for comparing between the studied positions

*: Statistically significant at $p \leq 0.05$

Means with **Common letters** are not significant (i.e. Means with **Different letters** are significant)

1- Under unilateral right loading, the highest microstrain mean value was recorded at the lingual side of right implant **($248.6^{a} \pm 5.59$),** while the lowest microstrain mean value was recorded at distal side **($101.4^{c} \pm 9.04$)**

Microstrain under unilateral vertical loading (left side)

- Microstrain measurements at the different studied positions around the implants under unilateral right vertical loading for group (B) using retention Sil 400 are shown in (Table 2).
- Data analysis showed statistically significant difference (student t-test, $p<0.05$) between the different studied positions, mesial, distal, buccal and the lingual side of implants.

1- Under unilateral left loading, using Ti Si retention Sil 400 the highest microstrain mean value was recorded at the lingual side of left implant **($252.4^{a} \pm 2.88$)** and, while the lowest microstrain mean value was recorded at distal side (**$132.4^{c} \pm 1.95$)**

Microstrain measurements between the two studied groups according to the average of microstrains with 400 Ti Si retention Sil. **(Table 3)**

Table (3): Comparison between the two studied groups according to average of microstrain using retention sil 400 mg/N.

Side	Implant	Group A (n = 5)	Group B (n = 5)	t	p
Central	Right	66.85 ± 2.34	70.40 ± 3.26	2.255	0.054
	Left	66.30 ± 3.08	68.10 ± 3.28	1.888	0.096
Right	Right	156.80 ± 3.15	170.35 ± 2.80	7.185*	<0.001*
	Left	28.60 ± 2.41	95.80 ± 1.78	50.088*	<0.001*
Left	Right	26.35 ± 0.80	88.05 ± 2.71	48.778*	<0.001*
	Left	168.15 ± 4.14	178.10 ± 2.50	4.601*	0.002*

Data was expressed using Mean ± SD.
t: Student t-test
p: p value for comparing between two studied groups
*: Statistically significant at $p \leq 0.05$

- **Under central loading**, data analysis showed non statistically significant difference (student t-test, $p>0.05$) between group A and B

1- Under central loading, the average microstrain mean value was recorded at **group A** at the right implant (66.85 ± 2.34), While the average micro strain mean value was recorded at left implant (66.30 ± 3.08).
2- Under central loading, the average micro strain mean value was recorded at **group B** at the right implant (70.40 ±3.26), While the average micro strain mean value was recorded at left implant (68.10 ±3.28).

- **Under unilateral loading**, data analysis showed statistically significant difference (student t-test, $p<0.05$) between group A and B.

1- Under unilateral right loading, the average micro strain mean value was recorded for group A at the right implant (156.80 ± 3.15) and left implant (28.60 ± 2.41). While the average micro strain mean value was recorded at group B at the right implant (170.35 ± 2.80) and left implant (95.80 ± 1.78).
3- Under unilateral left loading, the average micro strain mean value was recorded at

Group A the right implant (26.35 ± 0.80) and left implant (168.15 ± 4.14), While the average micro strain mean value was recorded at group B at right implant (88.05 ± 2.71) left implant (178.10 ± 2.50).

DISCUSSION

The results of the present study revealed that, in both groups vertical and 17.5 inclined implants under central and unilateral loading, the highest microstrain was recorded at the lingual side of the implant. While the lowest microstrain was recorded at distal side of the implant, which may be because the lingual strain gauge is the nearest one to the load applied followed by the mesial gauge which is the direction of implant inclination.

This result is in agreements with ELsyad et al., who reported that when applying central and unilateral loading, the lingual side with tilted implants received the most stress.

As the implants were distally tilted, ELsyad et al. found stresses at the distal gauges. The discrepancy in the direction of implant inclination between the two studies might explain the contradictory results (15).

According to Hong et al., during bilateral and unilateral load application on the implants supported overdentures through ball attachments, the peri implant bone stress was greatest around distally inclined implants 15° and lowest around buccally inclined implants 15°. (16).

In our study, the comparison between the two groups vertical under central loading, no significant difference of microstrain was detected around the implants in both groups.

When comparing between vertical and inclined implants in all on four concept during central loading this study is in agreements with dawood, et al., There is no statistically significant difference between the two groups, they discovered.

The results of the present study, when comparing the two groups under unilateral loading significant increase in microstrain was recorded at the inclined implants (Group B).

Takahashi et al. agree with the findings of the current study. They found 30 % increase in stress in an inclined angle of posterior implants compared to vertical anterior implants when comparing different angulations of posterior implants in the all-on-4 concept under a 50 N static load.

In addition this study finding is consistent with Delgado-Ruiz et al., The direction of applied forces is crucial because vertical force might cause more strain during unilateral loading and less strain during bilateral loading.

CONCLUSIONS

Based on the findings of this in vitro comparative study, the following conclusions were drawn**:**

1- In both groups, vertical and 17.5 labially inclined implants under central and unilateral loading, the highest microstrain was recorded at the lingual side of the implants. While the lowest microstrain was recorded at distal side of the implants.

2- In comparing the two groups, vertical and 17.5 labially inclined implants no significant difference was found with central loading, while, with unilateral loading significant increase in microstrain was recorded with labial inclined implants.

3- Microstrain around two implants supported overdentures increase as labial implant inclination increase.

Recommendations

The impact of observed stress levels on peri-implant bone structures, as well as the possible problems and maintenance of two-implant-retained mandibular overdentures with labial implant inclination, will require long-term clinical investigation.

Conflict of Interest

The authors declare that they have no conflict of interest.

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