Mansoura Journal of Dentistry 2020;7(28):50-53.

COMPARISON BETWEEN STRESS DISTRIBUTION AROUND STRAIGHT AND TILTED POSTERIOR DENTAL IMPLANT WITH DIFFERENT LENGTHS

Ashraf Badawy Ibrahim*, Mohamed Maamoun El-Sheikh, Mohamed Nabeel M. El-gendy***.**

* Dentist in ministry of health and population in Egypt.

** Professor of Prosthodontic and Vice Dean of Community Service and Environmental Development, Faculty of Dentistry, Tanta.

*** Lecturer of Prosthodontics, Prosthodontic Department, Faculty of Dentistry, Tanta.

Abstract:

Aim of the work: The aim of this in-vitro study was to compare between stress distribution around straight and tilted posterior dental implant with different lengths under removable partial denture using electrical strain gauge.

Methods: Four models representing mandibular unilateral distal extension edentulous area in right side were fabricated from epoxy resin and divided into four groups according to the length and angulation of the implant: Group (A), Single vertical straight implant 8mm length was placed at the second molar region. For Group (B): Single vertical straight implant 10mm length was placed at the second molar region. For Group (C): Single 30o mesially tilted implant 8mm length was placed at the second molar region. For Group (D): Single 30o mesially tilted implant 10mm length was placed at the second molar region. Locator abutment was screwed to the implant and removable partial denture was fabricated for every group. 100 N vertical and 65 N oblique static loads were applied at the central fossa of the second molar artificial tooth in the prosthesis. Strain gauge technology was used to measure the microstrains around peri-implant area. Data were collected, tabulated and statistically analyzed using one-way ANOVA and LSD tests.

Results: The results revealed that the microstrain with vertical and oblique static loads in group (A) similar to group (C) and in group (B) similar to group (D) (with variation in implant angulation but constant length), but the microstrain with vertical and oblique static loads in group (A) more than group (B) and in group (C) more than group (D) (with variation in implant length but constant angulation).

Conclusions: The microstrain distribution was quite similar for both vertical and tilted implants but in increased implant length can help reduce the microstrain.

Keywords: Locator attachment, Microstrain, Strain gauge, Tilted Implant.

Introduction

The unilateral distal extension base removable partial denture has always been associated with a number of problems, specifically concerning support, retention and stability. Most of these problems could be attributed to the absence of the posterior abutment (1).

Implant dentistry is often the treatment of choice to replace missing teeth in partially and completely edentulous patients (2).

The creation of posterior implant support for removable prosthesis would appear to be an obvious improvement over the conventional distal extension base. This includes increased stability, increased support, increased patient satisfaction, and the preservation and maintenance of existing hard and soft tissues. Moreover, implant supported removable prosthesis are a less expensive alternative to implant supported fixed prosthesis. Also a posterior implant under removable partial denture can help establish stable occlusal support, which might prevent bone remodeling in the TMJ as well as the residual ridge resorption (3, 4, 5).

Strain gauge was used either clinically or in vitro, to study the pattern of stresses around abutments and dental implants, and it was proved to be simple reliable and accurate method (6).

.

The aim of this in-vitro study was to compare the stress distribution around straight and tilted posterior dental implant with different lengths by using epoxy resin models with the help of strain gauge analysis under vertical and lateral loads.

MATERIALS AND METHODS

In this in-vitro study strain gauge technology was used to measure microstrains induced by partial denture on posterior implant in cases of mandibular unilateral distal extension saddles (Kennedy class II).

Four models* (Fig. 1) representing mandibular unilateral distal extension edentulous area in right side was made from epoxy resin** and divided into four groups according to the length and angulation of the implant placed:

Group (A): Single vertical implant 8mm length was placed at the second molar region.

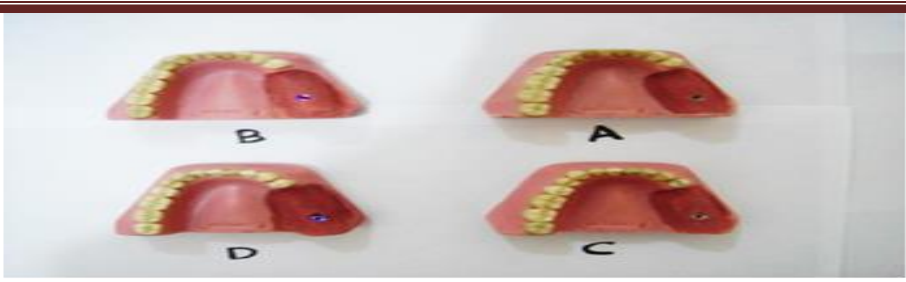
Group (B): Single vertical implant 10mm length was placed at the second molar region.

Group (C): Single 30o mesially tilted implant 8mm length was placed at the second molar region.

Group (D): Single 30o mesially tilted implant 10mm length was placed at the second molar region

* Ramses co., Alexandria, Egypt

****.Huntsman, Ren Cast CW 2215, Germany**



(Fig. 1): ***The four models representing mandibular unilateral distal extension edentulous area.***

For each group metallic removable partial denture was fabricated.

Implant installation:

Tow acrylic resin templates were made. One recess was prepared in the marked placement site at the center of purposed second molar region using surgical drills.

For the first acrylic resin template a metallic vertical hollow cylinder was inserted in the prepared recess vertically by using a conventional transparent plastic triangle had 90o angle (for vertical implant insertion) and the second acrylic resin template a metallic hollow cylinder with 30o mesial tilted by using a conventional transparent plastic triangle had 30o angle (for tilted implant insertion), a metallic hollow cylinder fixed to acrylic resin template by Auto-polymerizing acrylic resin.

Implants* 4.7 mm diameter and 8 mm length in the models (A) and (C) and 10 mm length in the models (B) and (D) were inserted in the prepared site.

Placement of the Locator Abutment:

The locator abutment** was screwed in the implant. Sufficient amount of acrylic resin of the fitting surface of the partial denture corresponding to the locator abutment was cleared. The locator cap with black processing male was inserted into the locator implant abutment. Auto-polymerizing acrylic resin*** was packed into the relieved area in the partial denture to hold the locator. The excess acrylic resin removed by the bur and the denture base was polished. The black processing male was removed and inserted locator replacement male clear in their place.

Installation of strain gauge:

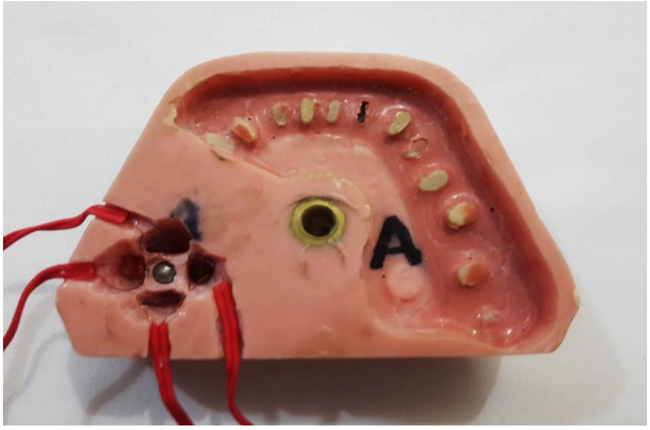
Strain gauges**** were used for this study:-

Steps for installation:

For every model, four holes were prepared in the base of the epoxy resin model just around the implant surface with about 5mm in depth and 3mm in diameter and parallel to the long axis of the implant in mesial, distal, buccal and lingual surfaces, flat surface was prepared for the wall which toward the implant of every hole to minimize the possibility of obtaining incremental apparent microstrain that result from mounting the strain gauges on curved surface.

Every one of the four holes was installed with a strain gauge in the epoxy resin on the surface which was toward the implant in mesial, distal, buccal and lingual surfaces to measure the microstrains in the medium surrounding the implant. (Fig. 2)

.A strain gauge adhesive* was used. The wires of the strain gauges were connected to a digital multichannel strain meter**. The strain meter was run in a quarter bridge circuit and connected to a compatible computer containing the meter control software (PCD 300 A).



(Fig. 2) The four models representing mandibular unilateral distal extension edentulous area.

Measurements of the stresses transmitted to the model:

•Each model of the four models was placed on the base of the loading device of universal testing machine (LLOYD instrument***) by two ways and the characteristics of the loading device are shown in :

1. In the vertical load measurement: every model was placed with the removable partial denture in its place on a horizontal plane of the loading device base.

2. In an oblique load measurement: every model was placed with the removable partial denture in its place on the surface of an oblique wooden segment which made angle equal 65o with the applied load and angle equal 25o with a horizontal plane of loading device base.

•Point of load application was selected at the central occlusal fossa of the second molar of the removable partial denture and notched with a diamond point

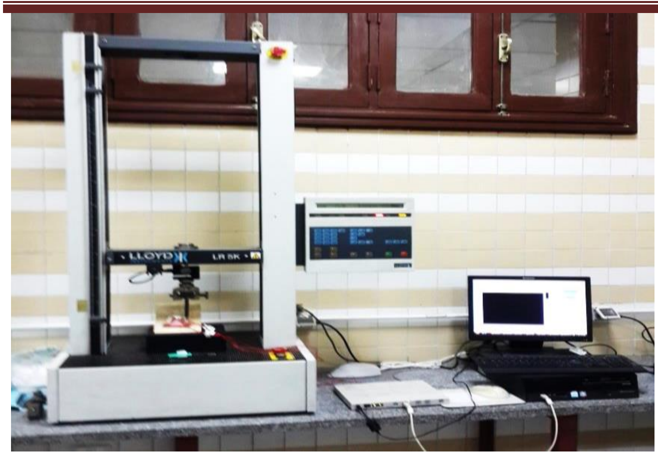
•For every model, 100 N a vertical static load was applied on the central fossa of right second molar of the removable partial denture on the horizontal plane of the loading device base then 65 N oblique load was applied on the central fossa of right second molar of the removable partial denture on the oblique surface of the wooden segment which was on the loading device base.

•The load is applied 6 times for each model vertically and also obliquely to ensure the reproducibility of the results with at least 5minutes interval between the readings to allow.

•Data were analyzed using software package (Kywa PCD 300A).

* Implant Direct, Colobosas Hills, CA 91301 USA.
** Implant Direct LLC, Locator abutment, Colobosas Hills, CA 91301 USA
*** Acrostone, Egypt.
**** Electronic instrument ca, LTD Tokyo - Japan.

* CC-33 Strain gauge cement, Kyowa electronic instrument co. LTD Tokyo, Japan.
** PCD-300 A. Kyowa elec(tronic insruments co. LTD Tokyo, Japan.
*** LLOYD LRX, LLOYD instruments Ltd., Fareham, Hampshire, UK



(Fig. 3) Universal testing machine.

Statistical analysis:

The descriptive statistics of peri-implant strain values included mean, stander deviation, range minimum and maximum. General linear model (one-way ANOVA) was used to compare recorded microstrains values between different groups (A, B, C and D) and between different surfaces followed by post hoc test and (LSD) least significant differences for multiple comparisons. To compare recorded microstrains values between loading applications.

The (SPSS) statistical package for social science version 22 was used for data analysis.

RESULTS

The data of this study was collected, and statistically analyzed. ANOVA was used to compare between the four groups. To determinant the effective of every one of the four groups we used LSD test; the significance level was set at $P \leq 0.05$.

(Table 1): shows comparison among the mean values and standard deviations of microstrains induced in groups (A), (B), (C) and (D) when applied 100 N vertical static load and shows the following:

•When comparing group (A) with group (B) there was statistically significant difference ($P \leq 0.05$) in all surfaces.
•When comparing group (A) with group (C) there was statistically no significant difference ($P > 0.05$) in all surfaces.
•When comparing group (A) with group (D) there was statistically significant difference ($P \leq 0.05$) in mesial surface.
•When comparing group (B) with group (C) there was statistically significant difference ($P \leq 0.05$) in all surfaces.
•When comparing group (B) with group (D) there was statistically no significant difference ($P > 0.05$) in all surfaces.
•When comparing group (C) with group (D) there was statistically significant difference ($P \leq 0.05$) in all surfaces

(Table 1): Comparison among microstrains induced in groups (A), (B), (C) and (D) when applied 100 N vertical static load.

	Group (A)	Group (B)	Group (C)	Group (D)	ANOVA	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	F	P-value.
Mesial	67.50 ± 9.35	51.67 ± 9.83	69.17 ± 8.61	52.50 ± 7.58	6.73	0.003*
Buccal	54.17 ± 10.68	43.33 ± 8.76	59.17 ± 7.36	45.83 ± 7.36	4.32	0.017*
Distal	66.67 ± 12.52	51.67 ± 8.76	68.33 ± 6.06	54.17 ± 7.36	5.36	0.007*
Lingual	57.50 ± 9.35	44.17 ± 7.36	60.83 ± 9.35	46.67 ± 7.53	4.17	0.019*

SD; Standard deviation, ***;** Significant.

(Tables 2): Shows comparison among the mean values and standard deviations of microstrains induced in groups (A), (B), (C) and (D) when applied 65 N oblique static load and shows the following:
•When comparing group (A) with group (B) there was statistically significant differences ($P \leq 0.05$) in all surfaces.
•When comparing group (A) with group (C) there was statistically no significant differences ($P > 0.05$) in all surfaces.
•When comparing group (A) with group (D) there was statistically no significant differences ($P > 0.05$) in all surfaces.
•When comparing group (B) with group (C) there was statistically significant differences ($P \leq 0.05$) in mesial, buccal and distal surfaces.
•When comparing group (B) with group (D) there was statistically no significant differences ($P > 0.05$) in all surfaces.
•When comparing group (C) with group (D) there was statistically significant differences ($P \leq 0.05$) in all surface.

(Table 2): Comparison among mirostrains induced in groups (A), (B), (C) and (D) when applied 65 N oblique static load (65 N).

	Group (A)	Group (B)	Group (C)	Group (D)	ANOVA	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	F	P-value
Mesial	42.50 ± 5.24	36.67 ± 8.17	39.17 ± 11.58	37.50 ± 9.35	7.57	0.001*
Buccal	32.50 ± 9.35	29.17 ± 5.85	30.83 ± 7.36	29.17 ± 7.36	3.67	0.029*
Distal	51.67 ± 6.83	42.50 ± 5.24	53.33 ± 10.80	39.17 ± 10.21	5.77	0.005*
Lingual	40.83 ± 5.85	32.50 ± 9.35	40.83 ± 7.36	30.83 ± 5.85	4.16	0.011*

SD; Standard deviation, *; Significant.

DISCUSSION

When comparing the induced microstrains with vertical and 30o tilted implant under 100 N vertical load and 65 N oblique load with constant implant length in group (A) with group (C) and in group (B) with group (D) were statistically analyzed and no significant differences were found. This agreed with the study of (Cruz et al.) [7], their study was finite element stress analysis of dental prostheses supported by vertical and tilted implants and their results were that the tilted system did not induce a stress concentration in any point around the implants that was different from that of the straight system. The stress distribution was very similar in both systems.

On the other hand these results disagreed with the study of (Canay et al.) [8], their study was comparison of stress distribution around vertical and tilted implants with finite-element analysis and their results were when vertical loading was applied to vertical and tilted implants, the stress especially the compressive stress, formed around the tilted implants were found to be in excess of that around the vertical implant.

When comparing the induced microstrains with short and long implant under 100 N vertical load and 65 N oblique load with constant implant angulation in group (A) with group (B) and in group (C) with group (D) were statistically analyzed and significant differences were found and this agreed with the study of (Cynthia and John) (9), their study was comparative evaluation of implant designs: influence of diameter, length, and taper on strains in the alveolar crest: A three-dimensional finite element and their results were reported when increased implant length can help reduce microstrain in the bone, and also matches the results of (Qian et al.) (10), their study was effect of implant diameter, insertion depth, and loading angle on stress/strain fields in implant/jawbone systems: finite element analysis and their results were that a greater insertion depth reduces the magnitude and improves the distribution pattern of stress and strain.

When comparing group (A) and group (D) using 100 N vertical load and 65 N oblique load no statistically significant differences were found except at mesial surface with 100 N vertical load.

A mixture of tensile and compressive stresses was obtained around each implant upon loading. The mode of implant loading usually rules the nature of bone strains; for example, a combination of tensile and compressive microstrains may occur due to bending moments occurred following loading of implant retained removable partial dentures (Cehreli et al) [11].

In the present study, all mesial peri-implant sites experienced a tensile (positive) microstrain while distal implant sites showed a compressive (negative) microstrain. This was somewhat unexpected since after load application, implant tended to intrude into the epoxy resin. This implant penetration was reported to be hindered by the resin resistance due to hardness (Thayer and Caputo) [12].

Implant length has a significant effect on stress/strain fields in implant and jawbone. Various implant length were investigated that a greater implant length reduces the magnitude and improves the distribution pattern of stress and strain. The reason for the reduction of stress/strain fields in an implant/jawbone system in the case of greater implant length may be the result of an increased implant/jawbone contact area and thereby helped to improve the biomechanical environment of bone/ implant systems (Thayer and Caputo) [12].

CONCLUSION

Within limitations of this study it was concluded that:

1. Both 30o mesial tilted and vertical implants induce similar peri-implant microsrains.

2. Increasing length of vertical and 30o mesial tilted implants will decrease peri-implant microstrains in mandibular posterior region.

References

1. *Wilson HJ, Mansfield MA, Heath JR, Spence D. Dental technology and materials for students. Blackwell Scientific Publications, 8th ed Oxford London 1987.*
2. *Huang SC, Tsai CF. Finite element analysis of a dental implant. Biomed Eng 2003;15:82-5.*
3. *Mitrani R, Brudvik JS, Phillips KM. Posterior implants for distal extension removable prostheses: A retrospective study. Int J Periodontics Restorative Dent 2003;23:353-9.*
4. *Halterman SM, Rivers JA, Keith JD. Implant supported for removable partial overdenture. A case report. Implant Dent 1999;8:74-80.*
5. *Maeda Y, Sogo M, Tsutsumi S. Efficacy of a posterior implant support for extra shortened dental arches: a biomechanical model analysis. J Oral Rehabil 2005;32:656-60.*
6. *Stafford GD, Glantz P. Intraoral strain gauge measurements or complete dentures; a methodological study. J Dent 1991;19: 80-4.*
7. *Cruz M, Wassall T, Toledo EM, da Silva Barra LP, Cruz S. Finite element stress analysis of dental prostheses supported by straight and angled implants. Int J Oral Maxillofac Implants 2009;24:391-403.*
8. *Canay S, Hersek N, Akpinar I, Askik Z. Comparison of stress distribution around vertical and angled implants with finite element analysis. Quintessence Int 1996;27:591-8.*
9. *Cynthia SP, John LW. Comparative evaluation of implant designs. Influence of diameter, length, and taper on strains in the alveolar crest. A three-dimensional finite element analysis. Clin Oral Implants Res 2005;16:486-94.*
10. *Qian L, Todo M, Matsushita Y, Koyano K. Effects of Implant Diameter, Insertion Depth, and loading Angle on Stress/Strain Fields in Implant/Jawbone Systems: Finite Element Analysis. Int J Oral Maxillofac Implants 2009;24:877-86.*
11. *Cehreli M, Duyck J, De Cooman M, Puers R, Naert I. Implant design and interface force transfer. A photoelstic and strain gauge analysis. Clin Oral Implants Res 2004;15:249-57.*
12. *Thayer HH, Caputo AA. Photoelastic stress analysis of overdenture attachments. J Prosthet Dent 1980;43:611-7. in the esthetic zone: a randomized controlled clinical trial. Journal of Osseointegration. 2017;9(4):317-22.*