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ORIGINAL ARTICLE

Stresses induced on straight and angulated implants using nylon caps and retention sil material in implant-retained mandibular overdentures (strain gauges analysis)

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Abstract

Background: The effect of the applied forces on a dental implant depends on several factors which are related to each other from which are the duration, direction, and magnitude of the applied forces. Load transfer to the bone-implant interface relies on load type, geometry of the implant surface structure, as well as properties of the implant and denture material, reaching a beneficial stress level has been the target in different loading scenarios.

Aim: The present study aimed to evaluate the effect of implant's angulation on the strains induced around implants in mandibular overdentures retained by two implants with ball attachments using nylon caps or retention sil 600 material.

Methodology: Clear acrylic resin model of a mandibular edentulous arch was made. Two implant beds were prepared at the canine regions using consecutive drills, the left side was held perpendicular to the occlusal plane and parallel to the midline while the right implant was drilled with a 15° distal inclination. Two dental implants were inserted at the canine region bilaterally. A layer of resilient silicone soft lining material about 1.5 mm thickness was applied. The ball attachments were screwed into the corresponding implants with the nylon cap. Two linear strain gauges were attached using adhesive resin at the mesial and distal surfaces of the acrylic resin around each implant. The strain gauges were positioned on the crest of the ridge in a mesiodistal direction perpendicular to the long axis of each implant. A vertical static load of 100 N was applied on the metallic bar. Strains around implants were recorded on the mesial and distal sides after load application. The primer was left to dry and then the retention sil 600 paste was applied into the metal housings. Stresses induced around the implants were recorded. Statistical analysis was performed with SPSS.

Results: The vertically aligned implants had much less stresses than the distally inclined implants with statistically significant difference.

Conclusions: Retention sil 600 may induce less stresses than nylon caps around angled implants in mandibular implant-retained mandibular overdentures.

Clinical Significance: Retention sil 600 should be considered over nylon caps around angled implants in mandibular implant-retained mandibular overdentures.

Introduction

Implant placement should acquire great attention through precisely planning surgical and prosthetic phases; however, consequences of poor surgical techniques may lead to poor implant orientation, which may be further endangered by the lateral vector of the forces of occlusion.[1]

The overdentures attached to implants were developed to increase the denture support, retention, and stability compared to conventional dentures.[2] Several studies had reported that patient's satisfaction is greatly influenced by the degree of overdenture retention.[3,4]

There are many attachment systems successfully used for implant overdentures; however, most of the attachment systems

showed a common trend toward a reduction[5] or total loss in retentive force.[6]

In vitro studies have reported that attachment systems inevitably undergo wear-induced structural changes, leading to a reduction or total loss of their retention.[7] The wear of components of ball attachments was found to be responsible for a decrease in the retention of the attachments.[8]

As the loss of retention results from the wear of the attachments,[9] the number of insertion-removal cycles influences the maximum dislodging force.[3,9]

Increased implant angulation has been reported to reduce the longevity of the attachment retention,[10] by causing premature wear of the components and increased maintenance.[11] Reduction in the attachments' retentive force is increased when the implant's angulation is from 0 to 30 degrees as reported by Wiemeyer *et al.* 2001; Gulizio *et al.*, 2005.[12,13]

Many researchers had reported that non-parallel implants may induce a more important reduction of the peak load-to-dislodgement.[14] This loss was usually abrupt after approximately 500 cycles and reached as high as 80% of the initial value after 2000 cycles.[14,15]

Spherical attachment systems may function appropriately when the implants lack parallelism, particularly if the matrix components in the prosthesis are positioned parallel to the vertical reference plane and to the path of withdrawal of the prosthesis.[12,13]

The present study is an *in vitro* study, conducted to evaluate the effect of implant's angulation on the strains induced around implants in mandibular overdentures retained by two implants with ball attachments using nylon caps or retention sil 600 material.

Materials and Methods

Clear acrylic resin model of a mandibular edentulous arch was made by duplicating a mandibular edentulous stone model (without undercuts) using heat cured acrylic resin [Figure 1a]. The model was accurately replicating the anatomic features of the edentulous ridges.

The base of each acrylic resin model was trimmed parallel to the anterior alveolar residual ridge, as recommended by Dong *et al.*, 2006.[16]

- A mandibular complete denture was constructed on the mandibular acrylic resin model. Two implant beds were prepared at the canine regions using consecutive drills, the left side was held perpendicular to the occlusal plane and parallel to the midline while the right implant was drilled with a 15° distal inclination (away from the midline), the drill inclination was controlled by transparent plastic protractor placed on the anterior alveolar residual ridge of the acrylic model to measure the angle. Two dental implants (screw implant legacy1 3.5 and 11.5 mm, implant direct, USA) were inserted at the canine region bilaterally [Figure 1b].
- A layer of resilient silicone soft lining material (Mollosil, Detax GmbH& Co. KG, Germany) about 1.5 mm thickness was applied onto the model to simulate mucosa covering the residual ridge.[17]
- The silicone soft liner material was removed from the implants using a sharp scalpel.
- The ball attachments (implant direct legacy ball abutment 4 mm length and 3.5 platform) were screwed into the corresponding implants with the nylon cap (N cap) in its housing being attached to the ball abutment.
- The previously constructed dentures were functionally fitted onto the ball attachments.
- Sufficient relief opposite to the ball attachments housings was made. Two lingual escape holes were made to allow escape of excess relining material.
- Chair-side relining material was injected in the relieved areas in the denture fitting surface, left to polymerize under minimal pressure application to avoid forcing the denture into the soft tissue which would prevent accurate seating.
- Denture was then removed with the nylon caps picked-up in its fitting surface [Figure 1c].

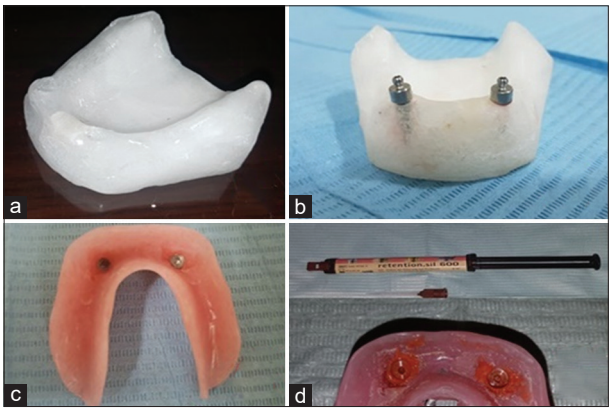

Figure 1: (a) Acrylic resin model (b) Implant placed in the acrylic resin model (c) Picked up nylon caps (d) Retention sil in the fitting surface of the denture

Strain gauges application

- Two linear strain gauges (KFG-1-120-C1-11L1M2R; KYOWA Electronic Instruments Co., Ltd., Tokyo, Japan; resistance 119.6 ± 0.4% Ω; gauge length: 1 mm; gauge factor: 2.08 ± 1.0%) were attached using adhesive resin (CC-33A, EP-34B., KYOWA Electronic Instruments Co., Ltd.), at the mesial and distal surfaces of the acrylic resin around each implant.[18]
- The strain gauges were positioned on the crest of the ridge in a mesiodistal direction perpendicular to the long axis of each implant. Two vertical slots were prepared at the buccal surface of the acrylic resin model (3 mm wide and 10 mm length); 1 mm away from implants mesially and distally. Strain gauges were secured into their slots with a quick set adhesive to prevent any possible movement of the wires which might affect the reading accuracy [Figure 2a].
- The strain gauges were labeled as follows; RD: Distal side of the implants, RM: Mesial side of the implants, LM: Mesial

side of the implants, and LD: Distal side of the implants.

- The acrylic model with the denture was placed on the compression grip of the universal testing machine (LLOYD LR 5K, England) Figure 2b.
- A transverse metal bar was placed on the occlusal surface at the premolar-molar region connecting both sides of the denture.
- Load application: A vertical static load of 100 N was applied on the metallic bar.

Stresses on the mesial and distal sides of implants were recorded with nylon caps and retention sil 600.

Measurements Grouping:

Group (I): Strains around implants were evaluated with nylon caps

Group (II): Strains around implants were evaluated with retention sil 600

Group (I): Measurements (nylon caps):

Nylon caps were applied onto the ball attachments during the overdenture functional fitting as mentioned before.

Strains around implants were recorded on the mesial and distal sides after load application.

For the accuracy of the results, an interval of at least 5 min between each reading was given to give a chance for heat dissipation from the strain gauge sensors.[19]

Group (II) – Measurements (Retention sil 600):

- The nylon caps were removed from their housings, the housings were painted with the retention sil* 600 primer liquid.
- The primer was left to dry and then the retention sil 600 paste was applied into the metal housings
- The denture was then fitted into its place over the OT ball attachments on the acrylic resin model as mentioned before [Figure 1d].
- The model was placed again on the universal testing machine and load of 100 N was applied.
- Stresses induced around the implants were recorded.

Mean values were calculated, tabulated to be statically analyzed.

Statistical analysis

Statistical analysis was performed with SPSS 20®, GraphPad Prism®, and Microsoft Excel 2016 with significant level set at $P \leq 0.05$. Data were presented as means and standard deviation (SD).

RESULTS

The results of this study had revealed that in Group I: In N cap, the mean and standard deviation of stresses induced around implants during compression was 50.2 ± 8.96 and 76.2 ± 16.6 at the left and right implant, respectively.

On the other hand, in Group II retention sil 600, the mean values and standard deviation of stresses induced around implants under compression were 11.3 ± 3.6 and 15.03 ± 2.8 at the left and right implant, respectively, as presented in Table 1 and Figure 3.

Independent *t*-test performed to detect the level of significance between the right and left implant in N cap and retention sil 600 which revealed significant difference as $P < 0.05$, as presented in Table 1, that is, the vertically aligned implants had much less stresses than the distally inclined implants with statistically significant difference $P < 0.05$

On comparing stresses induced around implants in Groups I and II, the results of this study had revealed that stresses were 50.2N ± 8.96 and 11.3N ± 3.6 around vertically placed implant in Groups I and II, respectively. However, the mean values of stresses around distally inclined implants were 76.2N ± 16.6 and 15.0N ± 2.8 in Groups I and II, respectively, as presented in Table 2 and Figure 4.

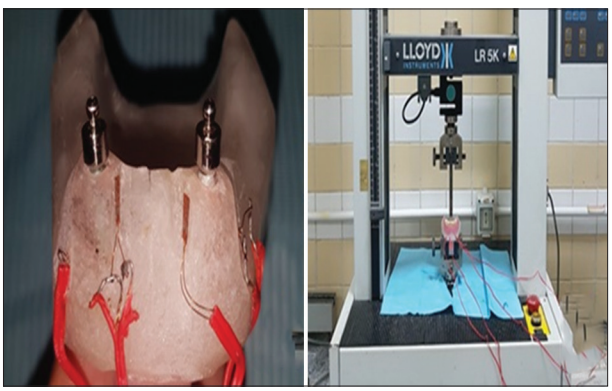

Figure 2: A – strain gauges fixed mesial and distal to the implants B – universal testing machine applying load on implant overdenture

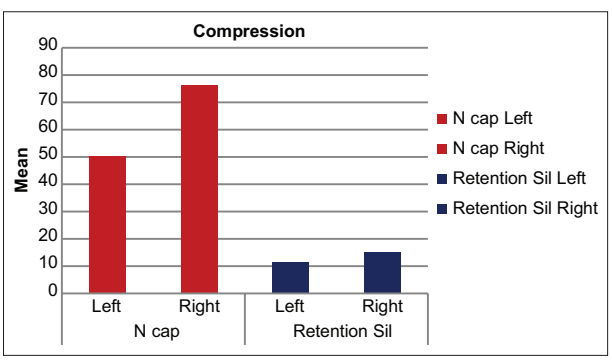

Figure 3: The means of N cap and retention sil 600

Table 1: The mean and standard deviation during compression

		Compression		*P* value
		M	SD	
N cap	Left	50.12	8.96	0.0001*
	Right	76.27	16.62	
Retention sil	Left	11.36	3.6	0.0001*
	Right	15.03	2.8	

M: Mean, SD: Standard deviation, P: Probability level, % *Significantly difference

Table 2: Comparison between N cap and retention sil

Compression	Left				Right			
	N cap		Retention sil		N cap		Retention sil	
	M	SD	M	SD	M	SD	M	SD
	50.12	8.96	11.36	3.6	76.27	16.62	15.03	2.8
P value	0.0001*				0.0001*			

M: Mean, SD: Standard deviation, P: Probability level, %; *significantly difference

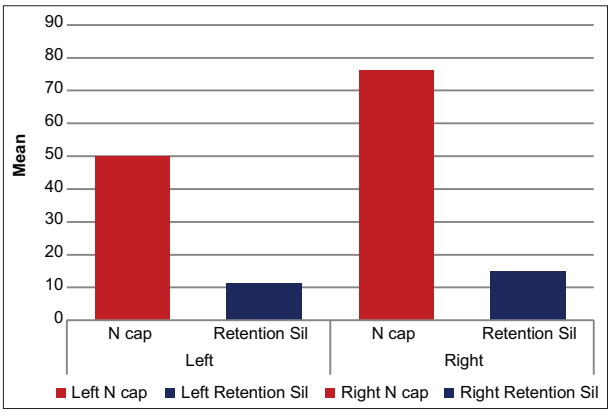

Figure 4: Comparison between N cap and retention sil 600

Independent *t*-test performed to detect the level of significance between the right and left implant in N cap and retention sil 600 revealed significant difference regarding the left and right implant as *P* value < 0.05, as presented in Table 2, that is, Group II implants had much less stresses than Group I with statistically significant difference *P* < 0.05.

DISCUSSION

The results of this study had revealed that there was inevitable stresses induced around implants with ball retained mandibular implant overdentures.

This may be due to the retention mechanism of the ball attachments, which is frictional contact between nylon caps and the outer surface of the ball abutment. This frictional force may induce stresses on the implant attachment system under functional loading or during denture insertion and removal on daily use.[6]

It was found that stresses induced around the axially placed implant were much less than the angled implants in the two study groups. This may be attributed to the fact that the axially placed implants absorb the vertically applied force and transmit them along the implant's longitudinal axis with the least amount of stresses transmitted along the implant-bone interface. This of course may decrease the crestal bone loss around the implant and consequently improve the long-term success of the installed implants.

On the other hand, it was reported that the greater implant angulation may result in increased micro-motions around the two unsplinted implants. When these micro-motions exceed 100 μm, it may induce greater bone resorption.[20]

Moreover, the anatomical configuration of the mandibular residual ridge may lead to mesial shifting of the denture under vertical load application.[21]

The nylon cap retention system has high frictional force, this would prevent the denture separation from the implants; consequently, much more compression forces would be transmitted to the angled implants leading to higher strain values arising from the compression resistance of the acrylic resin of the denture.[22]

The results of this study had also revealed that retention sil 600 had induced much less stresses around vertically and distally inclined implants with statistically significant difference. This finding may be attributed to the greater shock absorbing nature of the retention silicon than implants of Group-I (nylon cap group).

Moreover, this finding may be explained by the higher retention values of the nylon caps arising from the frictional forces between them and the ball abutments than the retention sil 600 material transmitting more stresses onto the implants during overdenture insertion and removal.

The major shortcoming of the *in vitro* stress analysis methods is the use of materials that frequently fail to simulate the nature of living bone regarding mechanobiology and osseointegration. Therefore, the results of this study are only descriptive.[23]

On a clinical background, it was found that the retention sil material had induced statistically significant less peri-implant bone loss than nylon caps in patients rehabilitated with two implant-retained mandibular overdentures attachments throughout the 12 months follow-up period.[24,25]

Future biomechanical studies are recommended to test the effect of different degrees of mesial, buccal, and lingual implant inclination on peri-implant stress around two implant overdentures retained by ball attachments. Furthermore, clinical research is still required to determine the influence of different implant angulations on peri-implant tissue under these overdentures.

CONCLUSIONS

Within the limitation of the present study, retention sil 600 may induce less stresses than nylon caps around angled implants in mandibular implant-retained mandibular overdentures.

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