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Effect of bone height on stresses developed around dental implant using strain gauge (In-vitro Study)

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Abstract:- Implant dentistry is a boon for restoration of missing teeth. It overcomes many disadvantages of other conventional methods of restoration with removable prosthesis or with fixed prosthesis. The success of the implant depends on the quality of the bone. The quality of the bone is described by its density, length and width. Based on such quality different stresses and strains may develop in bone. When these stresses exceed certain limits this leads to failure of the bone and consequently the implant. The aim of this research is to study the effect of bone height as one parameter of bone quality on stresses developed in surrounding bone. This is an in-vitro study using strain gauge technique. An acryl model was used as representation of mandible bone. Two dental implants with dimension (3mm in diameter and 10, 13 mm in length) are installed in the mandible model. Strain gauges bonded to the four sides of the implant (buccal, lingual, mesial and distal). The implants were loaded with a loading device from zero up to 60 N with 10 N increments. Results show that model with shorter bone height (longer implant) showed lower stresses than longer bone height (shorter implant).

Keywords:- Dental implant, buccel, lingual, distal, mesial.

I. INTRODUCTION

The teeth are constantly subjected to tremendous forces during chewing. These forces are distributed among the teeth. When a tooth is lost these forces are redistributed over the remaining teeth. As more teeth are lost the remaining teeth must absorb more forces. Thus, the remaining teeth may be subjected to overload in addition to loosing the ability of properly chewing the food. The problem of missing teeth can be handled using fixed bridge, removable denture or dental implant. In a fixed bridge solution, the bridge requires irreversible preparation to mount the bridge on the adjacent teeth. On the other hand, patients with removable denture usually complain from inability to chew properly when using such prosthesis. Unlike the fixed bridges and the removable denture dental implants provide support where teeth are missing without putting forces upon the remaining natural teeth. They may be used for the replacement of a single missing tooth or a complete functional set of teeth. Implants will absorb the forces of missing teeth and take the excess stress off of the adjacent teeth. Therefore; dental implants have become the most appropriate way of replacing a missing tooth.

Success of the implants depends on implant stability. The stability of the implant depends on bone quality (height, width) and bone quantity (density) among other factors. The effect of bone height (depth of implant insertion) on a developed stresses can be studied using Finite element model (FEM), photo elasticity and strain gauge technique. Strain gauge has been accepted as good technique which uses in-vitro model resembling the actual jaw geometry.

Overall, the shorter and smaller diameter implants had lower survival rates than their longer or wider counterparts. Long-term studies show a dramatic increase in failures of implants shorter than 7 mm in length [1, 2].Less favorable success rates for shorter implants were observed in clinical studies [3, 4, and 5].

Longer implants have been suggested to provide greater stability under lateral loading conditions. However, reports suggest that increasing the length beyond a certain dimension may not reduce force transfer proportionately [6].

Overloading factors may negatively influence implant longevity [7].Implant failure caused by overload has been classified as a dogma and as such should be abandoned [8].

In general, the use of short implants has not been recommended because the belief is that occlusal forces must be dissipated over a large implant area to preserve the bone [9, 10].

Thus, the aim of this research is to study the effect of bone height (implant length) as a representation of bone quality on stresses developed in surrounding bone in an in-vitro model using strain gauges.

II. MATERIAL AND METHODS

To study the effect of bone height bone height there were two approaches. The first approach is to use a mandible model with an implant of a specific length, then, the implant is removed after measurement, bone height is reduced, implant is re-inserted and measurements were repeated on new height. Another option is to use the same model as before, but instead of reducing the bone height, two implants are used of differing lengths. The shorter implant is inserted at first, then, the longer implant is inserted after measurements were recorded from the short implant and measurements were repeated. The later option was used to avoid any damage to strain gauges or its wires during acryl bone reduction in the first option due to the sensitivity & fragility of strain gauges and its wires.

A. Model of Mandible

A model of the mandible with regular bone height was made of acryl by a dental lab. The model was modified to receive the strain gauge by creating smooth surface on four sides (buccel, lingual, Mesial and Distal) around dental implant insertion. For that purpose some spaces were drilled beside the mesial and distal sides for strain gauge installation as shown in Figure. 1.

Fig 1. **Acrylic Mandible Model.**

B. Dental Implant

After preparing the mandible model for implant insertion, there are two main procedures should be done. The first procedure is implant selection followed by implant insertion.

1) Implant selection

For the second approach selected at the beginning of this section screw direct one piece implants for one stage surgery were used. Implants are made by implant direct factory with product codes (303010 and 303013). Two dental implants with the same diameter and differing lengths were selected suitable for premolar area (both of 3.0 mm in diameter while lengths were 10 and 13 mm in length).

2) Implant insertion

A drill is used to prepare a hole in the acryl model implant site to insert the implant. The shorter implant was inserted first in the model of the mandible. Later after completion the first measurement phase, the short implant was replaced with the long one and measurements were repeated.

C. Strain gauges

A suitable set of strain gauges was purchased with type (KFG-1-120-C1-11L1M2R), Gage Resistance: 120 ohm, Gage Length: 1mm, Gage Factor: 2.08, temperature coefficient: + 0.008 % .Ten strain gauges were purchased to be used in our work, strain gages were made by Kyowa Company with specification explained above.

The strain gauges were bonded axially parallel to long axis of the implant on the four prepared sites on the model.(buccal, lingual, mesial and distal) using cyanoacrylate glue. The strain gauge is placed on the center of the prepared surface and held in place for about 60 second for the glue to be attached. The gauges wires were fixed on the model using glue to ensure its stability. Fig (2) shows the model after bonding the gauges and inserting an implant.

Fig. 2 : Model with installed implant and strain gauges.

Since measurements will be recorded from each of the four gauges separately, the problem of reading drift due to temperature effect may be present. Therefore, a dummy gauge was used for each of the measuring gauges to eliminate the temperature. For that purpose, a flat acrylic plate of the same model material was constructed..

Measurement for any system follows some steps to collect the desired data, the general system of static measurement consists of three blocks begins with the sensor (strain gauges) which was connected to the switching box when more channels wanted together and then to the data logger or strain meter.

In this study one of the four active gauges with a one of the dummy gauges is connected to one channel of the switching box (CSW-5A) which is consequently connected to the strain meter (Tc-31K) . Thus, there were four channels of the meter used. After connection, we apply stresses on the implants with the loading machine and then collect the data and analyze it. As shown in Figure. 3.

Fig. 3 : Experimental Setup.

D. Experimental procedure

An axial load was applied on the implant using specially designed loading device as shown in Fig 3. The load was increased from 0 to 50 N in increments of 10N on the shorter implant at first. Trials were repeated five times to ensure the reproducibility of the results and allow for statistical analysis with intervals of 3 to 5 minutes between trials to allow for model to return to initial state. Later, the short implant was replaced by the long one and another five trails were carried on. The strain gauges were designated as G1, G2, G3 and G4 indicating buccal, lingual, mesial, and distal gauges respectively.

E. Statistical analysis

Statistical analysis of this study was carried out using SPSS (Statistical package for Scientific Studies) to compare between the two implants readings. Spss program analyze the data by using function called compare mean, paired sample T-Test was applied on the results to see if there is significant difference or not at a significance level $P < 0.05$. After using T-test, all data of long implant were lower in value than the short one and all results are significance difference. Results of the t-test are shown in table 1.

Table 1. Data for Two lengths after paired T-Test

Gauges location	Mean short	Mean Long	Mean Diff	Sig value
Buccel	-8.2500	-1.8500	-6.40000	0.017
Lingual	-1.42E+02	-13.64	-1.29E+02	0.017
Mesial	-3.23E+02	-11	-3.12E+02	0.036
Distal	-1.49E+02	-74.05000	-7.52E+01	0.035
Gauges location	SD short	SD Long	SD Diff	Sig Or not
Buccel	3.92726	1.43643	2.64323	Significance
Lingual	77.80352	4.55939	73.3493	Significance
Mesial	178.0979	6.08167	172.17963	Significance
Distal	88.52917	47.78044	40.95408	Significance

III. RESULTS AND DISCUSSIONS

The results of the five times loading for both short & long implant are detected by strain gauges then the average value are taken after five times repeating for each load and put in one column as shown in the Table (2, 3) then compare between each region for the both two implant length as shown in Fig (4, 5, 6, 7).

Table 2. Short implant strain gauges reading

Loads	Buccel	Lingual	Distal	Mesial
10 N	-4.6	-48	-56.6	-127.2
20 N	-6.2	-91	-108.6	-254.4
30 N	-8.6	-138.6	-168.8	-360.4
40 N	-13.6	-190.6	-262.8	-548.2
50 N	-18.6	-244	-363.2	-740.2

Table 3. Long implant strain gauges reading

Loads	Buccel	Lingual	Distal	Mesial
10 N	-0.4	-7	-27.4	-3.4
20 N	-1.6	-12	-48.6	-9.2
30 N	-2.4	-13.8	-83.4	-14
40 N	-3.4	-16.4	-136.8	-17.4
50 N	-4.2	-19	-161.8	-21

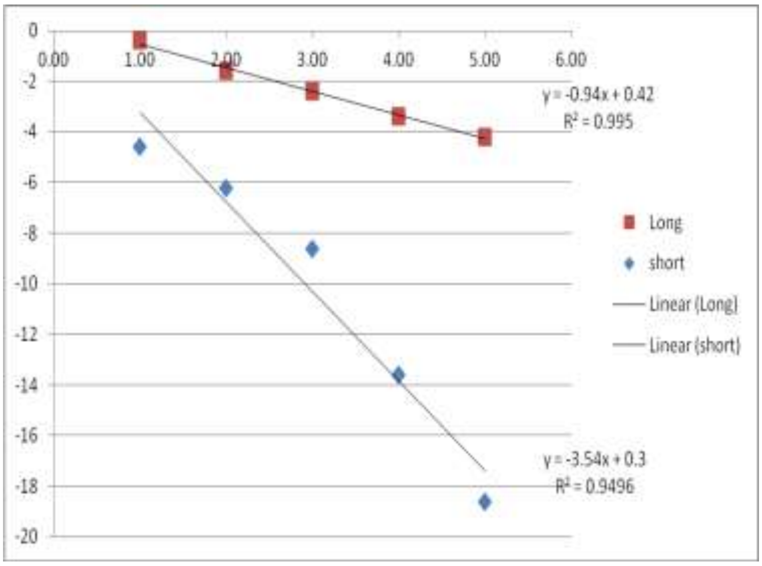

Fig. 4 : Comparison between two implants at the buccel region.

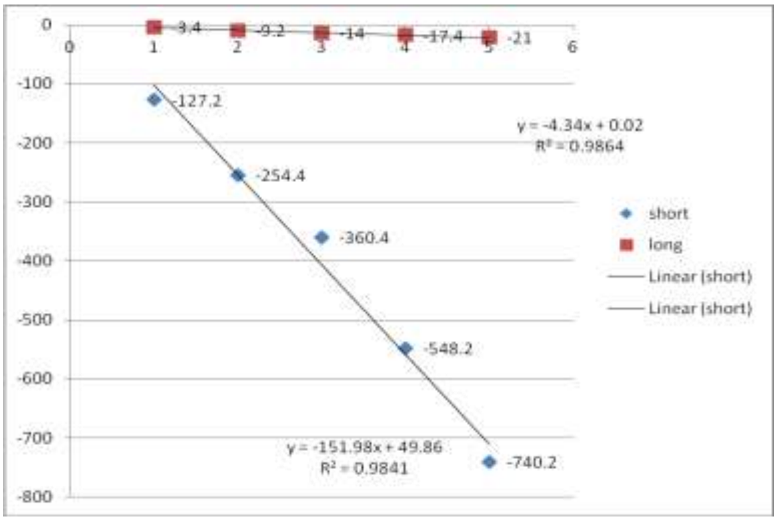

Fig. 5: Comparison between two implants at the Lingual region.

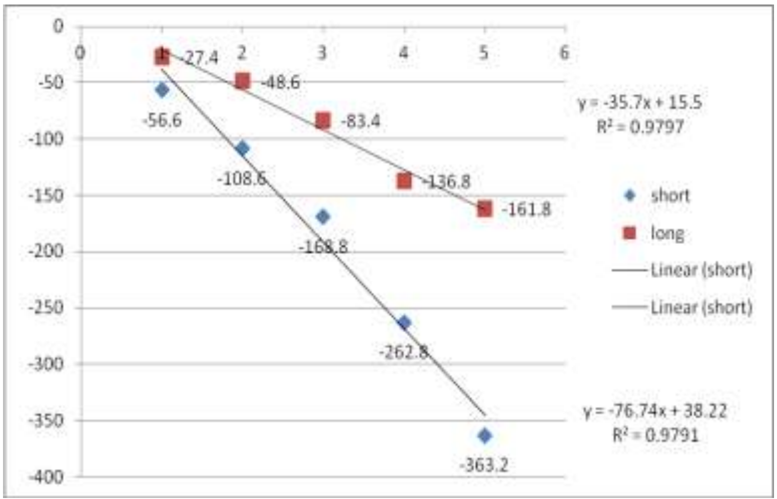

Fig. 6: Comparison between two implants at the Distal region.

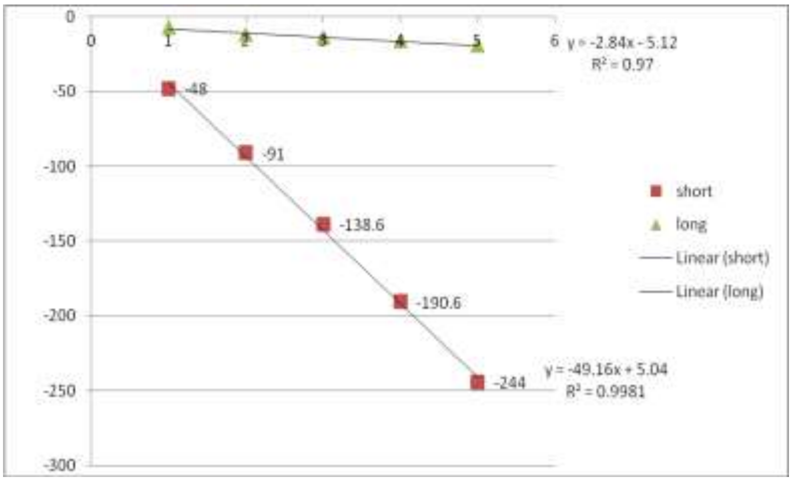

Fig. 7 : Comparison between two implants at the Mesial region.

The strains around dental implants are affected by many factors. The present study was concerned mainly with the effect of the implant length. The stress distribution in the bone around the implant depends upon the shape and size of the implant. The results of this study have shown that the implant length was more important for improving the stress distribution.

Strain gauges analysis was used to evaluate the stresses occurred due to loading device around dental implant with the different length, strain gauge is the most common technique used in experimental mechanics to evaluate strain at a certain point. Strain gauges provides several advantages that overcome the disadvantages encountered while using the other techniques of stress analysis specially FEA and photoelastic model techniques. It is Simple, flexible, low cost and it is available in markets. The most important reason of using strain gauges in this research, it is used in a real model so the results are different from one experiment to another as a result of loading and strain gauges fixation, not like FEA which is a static linear model that used in a computerized model so all data are assumed and results are expected.

The results of the study shows larger readings from the short implant compared to the long one is about 5.47 fold, 9.76 fold, 2.1 fold, and 31.5 fold from the buccel, lingual, distal, and mesial gauges respectively. The results of the statistical anlysis indicated a significant difference between the long implant and the short one in the strains developed due to the loading.

There are some variance in reading of the results and specially in buccel gauge due to some reasons, first the strain gauges fixations needs high accuracy and exertion with hand so it may be fixed with slope, the extra glue may be a block between the gauge and the model, the temperature is an important reason for the variance of the reading, finally the wires of the gauges may bended due to moving and connection so the reading affected.

IV. CONCLUSIONS & FUTURE WORK

A Strain gauges analysis study was carried out to evaluate the effect of implant length on stresses distribution around an implant as a result of increasing the loading on it.

The mandible model was made of acryl and the two dental implant were placed in it respectively with the shorter one first, four strain gauges was used , after loading the two implants by using loading device , all reading were recorded and analyzed using SPSS program.

It was found that the stresses in the surrounding bone decrease with the increase of the implant length. From the results of this study, it can be concluded that:

- Increasing the implant length resulted in a decrease of stresses around the dental implant.
- The implant length was found to be more effective factor in the distribution of the overall stresses around the dental implant than did the implant diameter.
- We recommend the use of longest length in conjunction with widest diameter possible for dental implant.

In the next research, it is recommended to study the effect of the implant diameter for the stresses developed around dental implant using strain gauges (in-vitro study) by vertical and oblique loading and make a software that facilitate for doctors choosing the suitable implant for any patient by entering the patient data (name - age - disease) and the software will choose automatically the implant type, design and its dimension.

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