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EVALUATION OF STRESS DISTRIBUTION AROUND IMPLANTS RETAINING MANDIBULAR OVER-DENTURES WITH TWO DIFFERENT ATTACHMENT SYSTEMS:AN IN- VITRO COMPARATIVE STUDY

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KEYWORDS

Novaloc , Equator attachments, Implants

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ABSTRACT

The clinical success of dental implant depends on the biomechanics and proper distribution of the occlusal load, the use of thermoplastic materials as (peek & nylon) in implant supported overdentures is an excellent choice to overcome occlusal overload. **Aim:** The aim of this in-vitro study is to evaluate stress distribution around implant retaining mandibular over-dentures with two different attachment systems (Novaloc & Equator). **Materials and Methods:** A mandibular 3D-printed cast model from the epoxy resin was used for this study after selection of the implant sites, surrounded by four channels of estimated depth, to allow a 2mm thickness of epoxy resin between the strain gauge rosettes and the implant. Two implants were inserted parallel to their sites in the 3D-printed model, attachments were screwed to implants. Sixteen attachments were divided into two groups (eight Novaloc attachment and eight Equator attachment). Strain gauges were cemented around the implants to measure the micro strain. Vertical and oblique (unilateral & bilateral) load was applied using a universal testing machine, and stress analysis was made. Results were collected and analyzed using statistical software. **Result:** There was a significant different between Novaloc and Equator on Stress Distribution around Implants in Implant-Supported Prostheses. **Conclusion:** Both Novaloc and Equator attachments are less traumatic to underlying bone in implant supported overdenture, with Novaloc attachment being less traumatic under oblique loading than Equator attachment.

INTRODUCTION

Loss of natural teeth is the terminal outcome of multifactorial process involving both biological factors (caries, periodontal diseases, pulp pathology, trauma and oral cancer) and non- biological factors related to dental procedures (1). Construction of complete denture was the only solution for edentulous arch for many decades, this treatment modality faced many problems (decreased area of coverage, high rate of bone resorption, flooding action of saliva and tongue action) that result in denture instability (2).

Overdenture is the best modality to overcome compete denture drawbacks and to preserve alveolar ridge by maintaining one or more natural roots to support overdenture (3). Tooth-supported overdenture had many problems including dental caries, periodontal diseases, technical problems, necessity of oral hygiene maintenance and regular recall appointment [4]. An implant-supported overdenture increases retention and stability of denture by various attachment systems [5].

Implant overdenture attachment is a mechanical device used for fixation, retention and stabilization of prosthesis, consisting of female(matrix) part and male(patrix) part [6]. Various attachments could be used to retain an implant overdenture, i.e., stud, bar, magnetic and telescopic attachment[7]. Stud attachments are classified into resilient and non-resilient attachments based on its behavior during function, stud attachments incudes o-ring, ball attachment, ERA, locator, equator and novaloc attachment [8].

Equator attachment is considered the smallest attachment system available with the least overall dimension, it is the solution for limited inter arch space, it has advantages of both ball attachment(simplicity) and locator attachment (easy of use and variety levels of retention) [9].

Resiliency of equator attachment permits denture movement in every direction and stress distribution, induces less stress on bone around implant so decreasing crestal bone loss around implant which is a significant indicator of implant health [10].

Novel stud attachment called Novaloc attachment was introduced in 2016, based on mechanical retention from PEEK matrix on a cylindrical patrix, which is more resistant to wear than nylon used in other attachment systems [11]. Amorphous Like Diamond Carbon (ALDC) material covering Novaloc abutment tend to increase wear resistance by abutment roughness [12].

Novaloc design of PEEK retention insert helps to absorb lateral stresses during insertion and removal as well as during function [13].

To evaluate stress distribution in peri-implant bone, different methods are used as photo-elastic analysis, Finite Element Analysis (FEA) and strain gauge analysis [14].

Strain gauges are the most widely used transducers in experimental mechanics in-vitro and in-vivo at a point under static or dynamic loading [15].

Strain gauges have been used to calculate rather than measure tissue stress and strain. Electrical resistance of strain gauge is based on the fundamental concept that the electrical resistance of wire changes as function of strain, so during application of load if a wire is isolated by packing material and cemented to a structure, change of resistance can be converted to strain measurements [16].

MATERIALS AND METHODS

Table (1) *Materials used, Description and Manufacturer used in the study:*

Materials	Description	Manufacture
Attachment Locator system	Equator ® Retentive System	Neodent Straumann® Brazil.
Attachment Locator system	Novaloc ® Retentive System	Neodent Straumann® Brazil.
Implant system	Neodent Straumann® Dental Implant System	Neodent Straumann® Brazil.
Kyowa strain gauge	Strain gauge rosettes	KYOWA, Japan
Mollosil	Chairside soft relining material	DEXTA, Germany
Overdenture base	heat-cure acrylic resin material	Acrostone®, Cairo, Egypt
Riva	Light cured reinforced Glass Ionomer	SDI, Australia

a- Study design:

This study is an in-vitro comparative study approved by Ethical Approval Committee Faculty of dentistry Suez Canal University with a protocol number, evaluate stress distribution around implant retaining mandibular over-dentures with two different attachment systems, where implants were inserted within canine region in mandibular 3d printed cast.

b- Cast Model:

A three-dimensional(3d) printed cast model that mimics human jaw was used in this study. Standard edentulous mandibular cast scanned and designed using exocad velta 3.0 with 3d printing material (HARZ labs) by A 3D printer (ANYCYBIC-Photon). A 2mm cut back will be created to receive 2mm of silicon resilient material, which will be used to simulate the soft tissue of the oral mucosa. Two implant holes will be drilled in the lower cuspid areas, separated by buccal, lingual, mesial, and distal channels with flat walls at the crestal region and parallel to the implant's long axis. The purpose of these channels is to receive rectangular strain gauge rosettes (**Figure 1**).

c-Implant Installation:

Activation of implant holes was made using implant surgical kit (Neodent Straumann dental implant system) by gradual drilling to activate implant path of insertion, neodent titanium implants (11.5*4.3) were coated with resin modified glass ionomer (Riva) light cured to mimic Osseo-integration then installed immediately into their location in 3d printed cast (**Figure 2**).

d- Soft tissue construction:

A spacer was made using (cavex molding wax), special tray was constructed using cold cure acrylic material (Acrostone). The spacer was removed, surface area under spacer was scratched, and then implant sites were covered with wax. Finally, chair-side soft relining material (mollosil) was applied by special tray to mimic soft tissue (**Figure 3**).

Fig. (1) A 3D printed cast

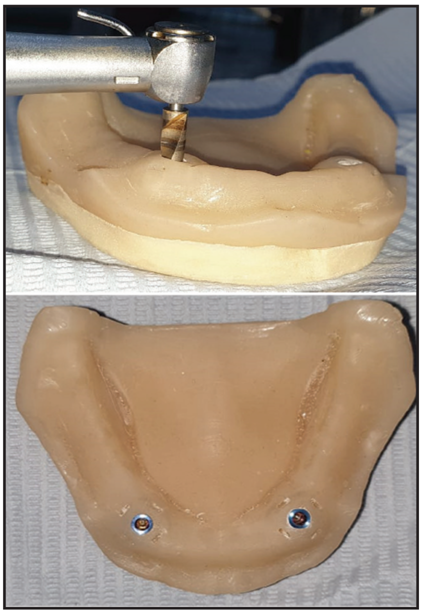

Fig. (2) Drilling and implant installation

Fig. (3) Chairside soft relining material

e- Grouping:

All specimens (sixteen specimens) were divided into two groups (n=8/group) as fellow:

Group 1: Eight **Novaloc** attachments (**Neodent**).

Group 2: Eight **Equator** attachments (**Neodent**).

Straumann® Screwdriver will be used to tighten the Novaloc® and Equator ® abutments into the implant by hand.

f- Denture construction:

A medium viscosity rubber impression was taken to 3d printed cast after blocking implant sites with pink wax, a stone cast was made by pouring impression, denture construction steps were done on stone cast.

g- Pick up procedure:

The areas opposing implants were marked on the fitting surface of the lower denture by alginate impression. Enough relief of the fitting surface of the lower denture was done to receive the housing of the both abutments, sleeves between patrix and matrix part of attachment were used to prevent any escape of cold cured acrylic resin, preventing any lock between two parts of attachment during pick up.

The (PEEK and Polymer) housings were placed and fitted to the (Novaloc and Equator) abutments of the implants. The relieved areas were filled with fast cold acrylic resin, and the denture was seated on cast till final seating and hold until setting of acrylic resin. The denture was removed and excess material was trimmed.

h- Installation of strain gauge rosettes:

To measure the micro strain in the area surrounding implant, a thin film of strain gauge adhesive was used to cement terminal ends of rosettes parallel to the long axis of implant in each channel (mesial, distal, buccal, lingual) in epoxy resin beside implant wall.

i- Test (Load application and strain recording measurement):

Universal testing machine(LLOYD)was used for applying vertical static loads of 100 Newton on the loading points for vertical loads and 65 Newton for oblique loads**,** denture will be placed on the cast, after that all wires were coded according to their side by first capital litter such as (buccal site of right side 1B). Then all wires of both right and left sides respectively were connected to KYOWA (Japan) strain gauge meter Type PCD-300A.

Load application:

Horizontal plate load applicator was fitted on the teeth bilaterally between the lower second premolars and lower first molars. The load applied with a plunger in midpoint of horizontal plate was increased from 0 to 100 N at a constant rate of 0.5mm/min (**Figure 4).**

The same load was applied unilaterally on the right side to represent the working side at the central groove of the first molar using I bar shaped load applicator (**Figure 5**).

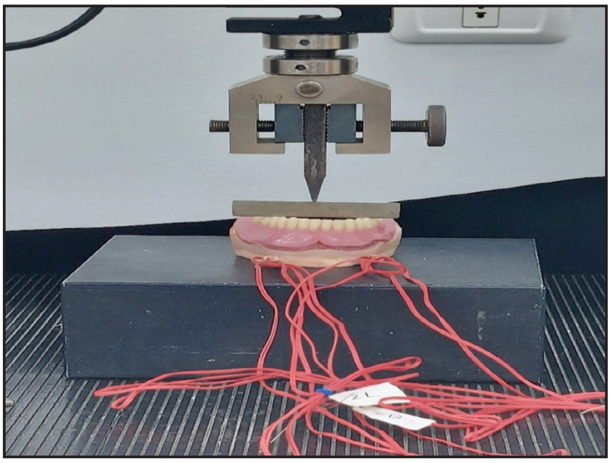

Fig. (4) Bilateral vertical load application

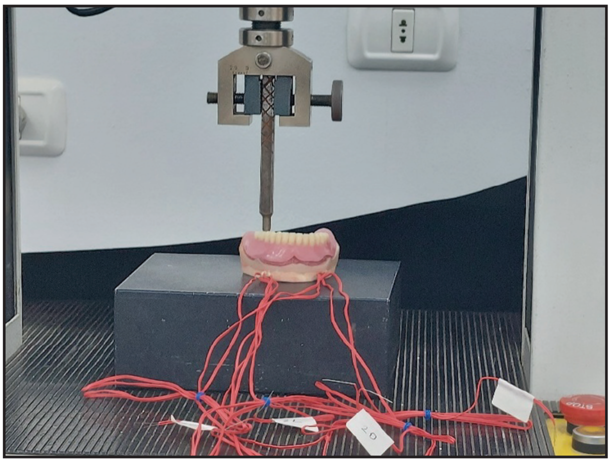

Fig. (5) Unilateral vertical load application

Using the dental surveyor, the angle of the cast model was inclined by 30º to achieve oblique direction, a65N with 0.5mm\min constant rate was applied unilaterally at the central fossa of the right first molar representing unilateral oblique force (**Figure 6).**

Subsequently, the same load was applied at the metal rod seated at the occlusal surfaces on the right and left first molar representing bilateral oblique force (**Figure 7**).

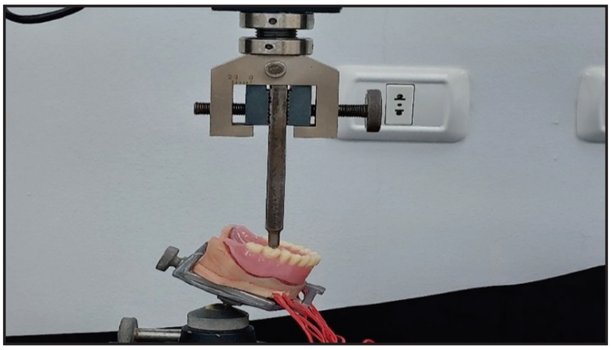

Fig. (6) Unilateral oblique load application

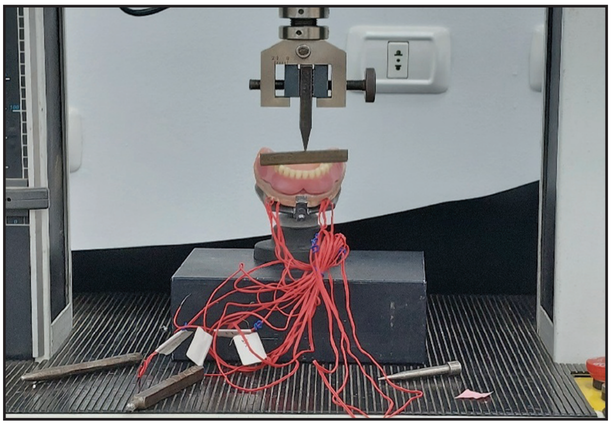

Fig. (7) Bilateral oblique load application

For each tested attachment, load was applied, micro-strains were recorded with the (KYOWA) strain gauge mater, and stress distribution around the implant were statistically evaluated.

RESULTS

Vertical load application:

Comparison between (**Novaloc and Equator**) method mean of micro-strains around implants under vertical load application (unilateral & bilateral), statical analysis showed significant difference between **Novaloc** method and **Equator** method groups for the micro strains around the implants the

Novaloc method group recorded high values than **Equator** method group using independent t-test at p value <0.05 (**Figure 8**).

Oblique load application:

Comparison between (**Novaloc and Equator**) method mean of micro-strains around implants under vertical load application (unilateral & bilateral), statical analysis showed significant difference between **Novaloc** method and **Equator** method groups for the micro strains around the implants the **Equator** method group recorded high values than **Novaloc** method group using independent t-test at p value <0.05 (**Figure 9**).

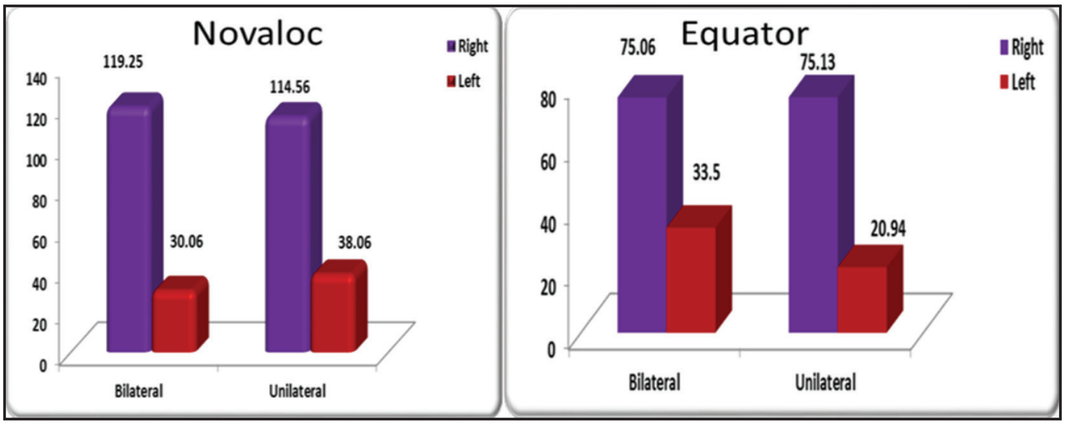

Fig. (8) Micro-strains around implants in (Novaloc & Equator) groups under vertical load application

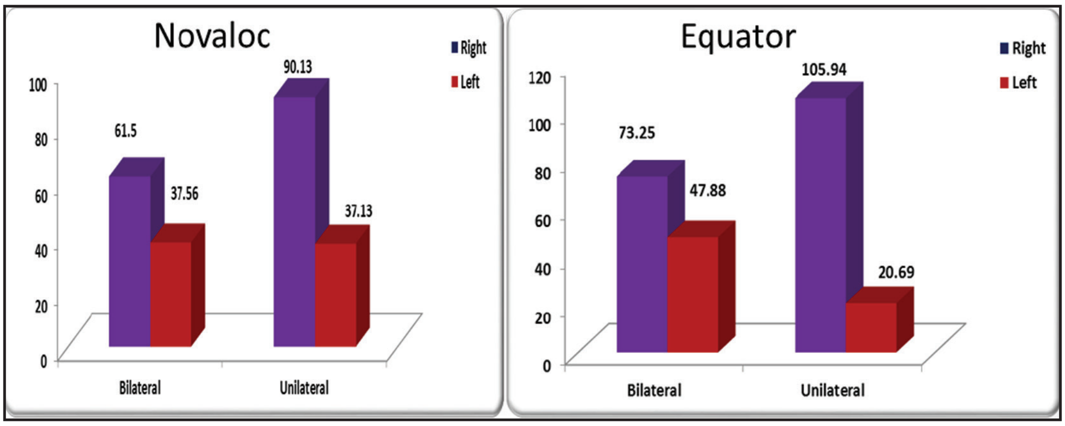

Fig. (9) Micro-strains around implants in (Novaloc & Equator) groups under oblique load application

DISCUSSION

Results obtained from this study showed that when the two models subjected to bilateral loading, stresses delivered to the supporting implants under prosthesis were reduced and the load was distributed on the alveolar residual ridge and the implants in comparative to unilateral loadings, while unilateral loadings the stresses were concentrated at the loaded implant and ridge.

Forces over a square area under bilateral load involved more planes and the favorable support achieved with the quadrilateral design due to its potential to dissipate the stresses uniformly between both the ridge and the implants with its splinting effect. While, under unilateral loadings, the rotational movement of the prosthesis concentrates the stresses at the loaded implants and ridge (17).

Low profile design of both attachments (Novaloc and Equator) has a role in dissipating occlusal loads through the abutment to the implant fixture in a more favorable distribution and magnitude. Furthermore, the damping effect of the resilient cap in both attachments which tend to optimize stress distribution over the implants retaining the overdenture (18).

Vertical (unilateral & bilateral) loading revealed significant difference between Novaloc and equator attachment systems on the average stresses falling on four implants and their supporting structures. Novaloc attachment transfer high values of the applied load to underlying bone, while Equator attachment reduce the transmitted forces to, this may be attributed to resiliency of the equator permits denture movement in every direction and distribution of stress induce lower stress on bone around implant (10).

Also it seems to be due to the cushion effect of the nylon cap of locator attachment, which tend to dissipate and absorb the induced stresses transmitted to the attachment implant complex than the more rigid PEEK matrix of Novaloc attachment (18).

Oblique (unilateral & bilateral) loading revealed significant difference between Novaloc and equator attachment systems on the average stresses falling on four implants and their supporting structures. Equator attachment transfer high values of the applied load to underlying bone, while Novaloc attachment reduce the transmitted forces to bone, this may be attributed to Novaloc design of the PEEK retention insert helps to absorb lateral pressure that occurs on insertion and removal, as well as during function, also it may be attributed to that the yield strength of the PEEK material of Novaloc is much higher than that of Equator nylon cap and could withstand these stresses (18).

CONCLUSION

Within the limitations of this in-vitro study and based on its results, there was a statistically significant difference.

It was concluded that:

Both Novaloc and Equator attachments are less traumatic to underlying bone in implant supported overdenture, with Novaloc attachment being less traumatic under oblique loading than Equator attachment.

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