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RETENTION AND STRESS DISTRIBUTION OF IMPLANT RETAINED MANDIBULAR COMPLETE OVERDENTURE WITH LOCATOR VERSUS BALL AND SOCKET ATTACHMENTS (AN IN VITRO STUDY)

El Quoriaty H.A [1], Mohamed.A.Q [2] , Helaly.O.A [3]

ABSTRACT

Objective: The object of this in vitro study was to evaluate retention and stress distribution of implant retained mandibular complete overdenture with locator versus ball and socket attachments. **Materials and Methods:** Mandibular experimental acrylic model and dentures were constructed in the laboratory of removable prosthodontic department, faculty of dental medicine, Cairo, boys, Al-Azhar University. Two implants were placed in the corresponding canine areas of the models then dentures were attached to the implants by one of the studied attachment systems (Locator and Ball and socket). Models with dentures were divided in to two groups according to the attachment system; (group I) overdenture with ball/socket attachment, and (group II) overdenture with locator attachment. Retention was evaluated using universal testing machine and stress distribution was evaluated using strain gauge. **Results:** The results of the present study revealed that (group II) exhibited a statistically significant higher retention when compared with (group I). While (group II) exhibited better but non-significant stress distribution when compared to (group I) bilaterally and unilaterally. **Conclusion:** Locator attachment system could provide better retention and stress distribution for implant retained mandibular complete overdenture.

KEY WORDS: Ball and socket, Locator, Overdenture, Retention, Stress distribution

INTRODUCTION

Retention, support and stability are common problems usually associated with edentulous patients wearing conventional complete denture especially mandibular denture [1]. These problems are directly related to continuous residual ridge resorption, which results in the elevation of superficial chewing muscles, and hence denture destabilization[2,4] .

The use of the mandibular conventional complete denture is more problematic than that of the maxillary conventional complete denture due to several factors such as thin mucosal coverage of the edentulous ridge, a reduced support area and the mobility of the floor of the mouth and movement of the mandible and the tongue [2-7]. These factors make the use of dental implants and attachments to convert conventional denture to implant-retained overdenture a common practice to overcome many of these problems [8].

1. Dentist, Egyptian Ministry of Health
2. Assistant Professor, Department of Removable Prosthodontics, Faculty of Dental Medicine Boys, Cairo, Al-Azhar University.
3. Lecture, Department of Removable Prosthodontics, Faculty of Dental Medicine Boys, Cairo, Al-Azhar University.

• ***Corresponding author*:** heshamelqouriaty@gmail.com

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Attachment mechanism in implant supported overdenture provides enhanced retention and stability compared to conventional denture [11]. Attachment systems were proved as important predictive variable influencing some of the oral function parameters as maximum bite force, swallowing threshold, mastication efficiency, stress on alveolar bone, maintenance, retention and stability [12,13].

Retention, stress transfer, restorative space, and maintenance are important factors for choosing attachment; Ball and socket attachments are a widely used attachment system which considered the simplest retainers for mandibular overdenture; They have several advantages such as; relatively lower cost, less technique sensitive, minimal chair time requirements and easier to clean than bars [14-17]. However, they have numerous disadvantages such as higher profile design, higher stress concentration especially at the neck of implant, wear reasonably quickly moreover they are not suitable in case of nonparallel implant [18-20].

Locator attachment is a resilient, non-splinted, prefabricated attachment of minimal vertical height which serves as an advantage for cases with limited inter-occlusal height and can used in case of nonparallel implant [21-23].

Materials and Methods:

This in vitro study was conducted on an experimental acrylic model. Models were duplicated from a commercially available mandibular edentulous stone model without undercuts. Two implants analogs (IMPLANCE Dental Implant System. EGC & Turkey) with 13mm length and 3.7 mm diameter were placed in the canine areas of the model. An approximately 1.5 mm-thick layer of auto-polymerized resilient silicone (Speedex, Coltene A.G., Alsatten, Switzerland) soft lining material was applied to the residual ridge of the model to simulate resilient edentulous ridge mucosa [23].

Sample grouping:

A total number of four acrylic cast models were used in this study. Study was divided into two main groups according to type of attachment (n=2). Group I: Acrylic resin model with ball and socket attachment (n=2), Fig(1). Group II: Acrylic resin model with locator attachment (n=2), Fig(2).

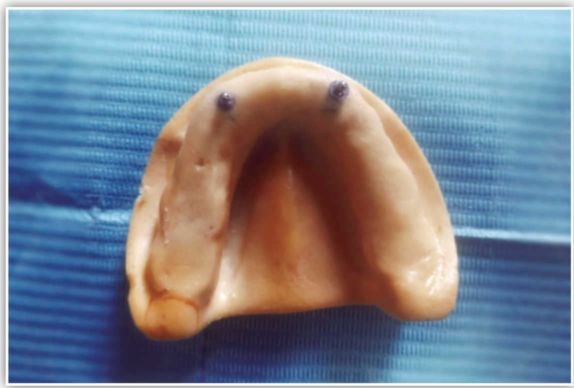

FIG (1) Model with ball and socket

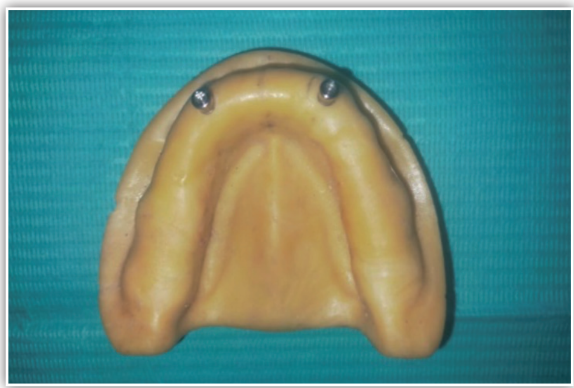

FIG (2) Model with locator attachment

Fabrication of experimental overdentures:

A total number of four acrylic resin models were fabricated by using ready-made mandibular edentulous stone model. A rubber base impression for the stone cast was made using silicone impression material. Molten base plate wax was poured into the impression using a mechanical vibrator and was left to harden. After complete hardening, the cast in wax was removed. The cast in wax was processed into pink heat-cured acrylic resin through flasking, wax elimination, packing and curing at 140˚C for one hour and left to bench cool for two hours before deflasking. Then, finishing and polishing was carried out to produce acrylic resin model [17]. Two implants fixtures with 13mm length and 3.7 mm diameter were inserted in each acrylic resin model in the corresponding canine area of the mandible by the help of parallel-meter of a milling machine to control the parallelism of the two implants. The two implant fixtures were aligned parallel to each other and perpendicular to the horizontal occlusal plane [17]. The implant fixtures were placed in the acrylic resin models via simulating the conventional placement procedures of implant in osteotomy site in the mandible and subsequently secured with self-cured acrylic resin to simulate osseointegration. Acrylic resin model was drilled using a 4 mm diameter cylindrical drill to produce 2 holes, with their centers at canine areas of each acrylic resin model. For overdenture construction, rubber base impressions were made for the acrylic resin models with the ball/socket or locator attachment screwed in implants. Impressions were poured in hard dental stone to produce stone casts with ball and socket or locator housing. A wax-up trial denture base will be constructed over the acrylic model. The trial set-up was positioned on to the acrylic resin model. The inner matrix of the ball attachment was attached to the outer matrix, and the assembly was plugged into corresponding ball laboratory implants on the ball master cast. Also, Locator inserts were attached to the locator matrix, and the assembly was plugged into Locator laboratory implants on the Locator master cast.

A single-mix condensation silicone impression of the wax-up trial denture base was made to produce a mold for fabrication of duplicate dentures, Heat-cured acrylic resin overdentures were constructed following the conventional fabricating technique in accordance with the specifications of the manufacturer. Then, the dentures were finished according to standard finishing procedures for acrylic resin denture bases.

Retention analysis:

Universal testing machine was used as the retention measuring device, metal bar was secured to the denture on the canine of both sides using self-cure acrylic resin to provide attachment for the testing machine, amount of force(in Newton) used to dislodge the denture used to express retention of the overdenture.

Strain gauges analysis:

The strain gauges (KFG-3-120-C1-11, Kyowa Electronic Instruments Co, LTD Tokyo, Japan) were used to measure the strain that resulted in the overdenture when the load applied bilaterally on the center of a metal bar that was positioned between the right and left denture bases at the level of the occlusal plane in the region of the mesial cusp of the first molar, and unilaterally at the central occlusal fossa of the first molar which notched with a diamond bur (15, 23). Six linear strain gauges were bonded to the acrylic resin at 2 mm above the level of the metal housing, at the level of the metal housing and at 2 mm below the level of the metal housing of each (loading side) and (non-loading side) of each implant attachments using a cyanoacrylate adhesive to monitor the strain around the implants during load application. A cyclic load ranging from 10 to 60 N were applied five times in 10-N steps on the occlusal surface of mandibular denture using a loading device (Lloyd LR5K, Japan) to age the gauges [23].

Statistical Analysis:

Data were collected, tabulated, and statistically analyzed using SPSS® Statistics Version 25 for Windows to detect whether significant differences existed between the means of the various studied groups

RESULTS

Retention

The statistical analysis of retention test for the two tested groups revealed that; there is statistically significant difference as indicated by unpaired t- test, the two-tailed P-value equals 0.0005, between the recorded mean retention values among the different tested groups. By conventional criteria, this difference is considered to be extremely statistically significant. So, the different attachment system has different effect on the retention of the overdenture (**Table 1**).

TABLE (1) Comparison of retention test results of the overdenture in the all tested groups.

Variable	Mean (N)	S.D.	*t*-value	*P*-value
G 1: Ball and socket	2.54	0.25	10.1000	0.0005*
G 2: Locator	12.39	1.67		

Stress distribution:

Bilateral strain regardless strain gauges site:

Statistical analysis indicated by unpaired *t*-test showed non-statistically significant difference (*P*-value > 0.05) between the strain values recorded at the strain gauge sites bilaterally of the two tested groups. The two-tailed *P*-value equals 0.0690. By conventional criteria, this difference is considered to be not quite statistically significant. The mean of Group I minus Group II equals 1099.44, the level of 95% confidence interval of this difference: from -90.21 to 2289.10 (**Table 2**).

Unilateral strain at the loaded side regardless strain gauges site:

Statistical analysis indicated by unpaired *t*-test showed not-statistically significant difference (P-value >0.05) between the strain values recorded at the loaded side of the two tested groups. The two-tailed P-value equals 0.1748. By conventional criteria, this difference is considered to be statistically insignificant. The mean of Group I minus Group II equals 166.11, the level of 95% confidence interval of this difference: from -81.88 to 414.10 (**Table 3**).

Unilateral strain at the unloaded side regardless strain gauges site:

Statistical analysis indicated by unpaired *t*-test showed non-statistically significant difference (*P*-value <0.05) between the strain values recorded at the unloaded side of the two tested groups. The two-tailed *P*-value equals 0.0006. By conventional criteria, this difference is considered to be statistically insignificant. The mean of Group I minus Group II equals -177.22, the level of 95% confidence interval of this difference: from -264.78 to -89.66 (**Table 4**).

TABLE (2): Comparison of recorded micro-strain values regardless the strain gauge site bilaterally.

Loading site	Type of attachment	Mean ± S. D (μm/m)	*t*-value	*P*-value
Bilaterally	Ball and socket	1259.44±2483.44	1.8781	0.0690
	Locator	160.00±27.81		

TABLE (3) Comparison of recorded micro-strain values at the loaded side regardless strain gauges site.

Loaded side	Type of attachment	Mean ± S. D (μm/m)	*t*-value	*P*-value
Right	Ball and socket	414.44 ± 318.62	1.4200	0.1748
	Locator	248.33 ± 147.12		

TABLE (4) Comparison of recorded micro-strain values at the unloaded side regardless strain gauges site.

Unloaded side	Type of attachment	Mean ± S. D (μm/m)	*t*-value	*P*-value
Left	Ball and socket	30.56 ± 12.86	4.2908	0.0006*
	Locator	207.78 ± 123.24		

DISCUSSION

The outcome of implant-retained overdenture as an alternative choice for treatment of edentulous patients is predictably and significantly better than that of conventional denture treatment as patient satisfaction is improved remarkably with implant-retained overdentures [(24)].

Generally, mandibular implant-retained overdentures result in better retention with greater patient satisfaction, ease of chewing, stability, and comfort compared with conventional removable dentures [(25)].

Following Prombonas et al, two duplicate experimental mandibular overdentures were used to ensure the same denture base thickness, and the same size and position of the artificial teeth, which have a great influence on the amount of denture base deformation [(26)].

Although the use of one experimental denture with attachments directly picked up to its fitting surface with auto-polymerized resin ensures standardization, the resiliency of the soft tissue may affect the load on the attachments and therefore can affect their retentive values. Therefore, in the present study a silicon resilient material was used to convert the residual ridge as an acceptable mucosal substitute, in agreement with Elsyad et al. [(23)].

In the present study the strain gauges was used to evaluate the stress that induced by the two different studied attachment systems because the strain gauges can assess strain induced into a loaded structure by converting the change in resistance of an electric wire into strain measurement , agreement with Elsyad et al. [(23)].

Following Yoo et al. a vertical load was used to evaluate the stress distribution by the two different tested attachment systems, because in mandibular implant overdentures the implants seem to transfer stress by vertical stress forces [(28)].

In this study the bilateral loading applied at the occlusal surface of the first molars, while, the unilateral force was applied to central fossa of the first molar of mandibular overdenture retained by implant in agreement with El-Abd et al [(29)] .

The first molar was chosen for loading because maximum occlusal forces are often exerted in this area where there is maximum contraction of all elevator muscles [(30)].

The mechanical retention of the Locator attachment is gained by a shallow undercut on abutment in which the outer margin of attachment is snapped. While, the frictional retention is provided by the nylon patrix head, which is slightly oversized compared to its matrix component (34). Therefore, the patrix, when fully seated in the matrix, engages the outer and inner surface of the matrix part (dual retention); so this can clearly explain the statistically significant retentive values of the Locator attachment [(35)].

The present study revealed that the ball/socket attachment exhibited a higher stress than Locator attachment. These results agreed with El-Abd et al.,[(29)] who concluded that less stresses were generated by the locator attachment on cortical and cancellous bone as well as around the implant than by ball attachment. This is possibly related to its lowprofile design and to rotational pivoting character of its abutment, that is also advocated in combination with close to parallel internal connection implant, to lower the rotational center that potentially reduce the resulted stress [.36].

While, in the unilateral loading regardless the strain gauge site, the ball/socket attachment exhibited higher mean strain value of at the loading side (right) when compared to Locator attachment. This may be due to, in the ball/socket attachment with higher-profile design may be resulted lack of intimate extension base contact with the edentulous ridge can cause high stress transfer to the ipsilateral terminal implant when cantilevered segments are used [36] .

While, the distal extension of locator attachment with lower-profile showed more intimate contact with the underlying model [29]. This can be explained by reducing the lever arm length resulting in a better mechanical advantage [37]. At the non-loading side, ball/socket attachments recorded lower strain mean value than Locator attachments. This could be explained by the fulcrum created by the ball attachment at the loading side, which led to disengagement of the 11 denture from the ball attachment at the non-loading side [23]. On the other hand, the resiliency of Locators permits vertical movement of the denture on the loading side (38). Therefore, the overdenture cannot disengage on the non-loading side because of the double frictional flanges of the Locators, and deformation increases compared to ball attachments [33].

CONCLUSION

Within the limitations of this in-vitro study and based on its result, it was concluded that; the use of Locator attachment significantly improves the vertical retention of mandibular overdenture and allow better stress distribution around the dental implants.

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