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Research Article

The Effect of Ball Attachment Versus Curved Bar Attachment on Stress Distribution in Implant Retained Mandibular Overdenture (An *In Vitro* Study)

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Abstract

One model was constructed representing mandibular completely edentulous case. On this model, two implants were placed in the canine regions. Two identical experimental overdentures were constructed. The first overdenture was fitted to two ball attachments while the second one was fitted to a curved bar attachment following the arch curvature connecting the two implants. Four strain gauges were installed, on the labial and distal sides of each implant to record the strain induced by the loads applied. A special loading device was used to apply standardized static vertical load on lower central incisors and bilaterally on first molars for each experimental overdenture. It was found that curved bar induce more stresses than ball attachments. It was concluded that Stresses transmitted to the implants using curved bar were much higher than that transmitted by the use of ball attachments.

Keywords: Ball Attachment; Stress; Implant; Mandibular; Overdenture

Introduction

Edentulism is defined as the state of being edentulous; without natural teeth [1]. It is the terminal outcome of a multifactorial process involving biologic processes (caries, periodontal disease, pulpal pathology, trauma, oral cancer) as well as non-biologic factors related to dental procedures (access to care, patient preferences, treatment options, etc.) [2]. For many years, complete dentures were the only solution for edentulism and they were satisfactorily capable of fulfilling the esthetic and functional needs of many patients. However some patients feel their social life is affected significantly because of the embarrassment they feel from using their complete dentures. Denture movement, mandibular discomfort and poor function (mastication, speech and appearance) were the major complaints of these patients [3].

One possibility of solving the problems of complete dentures is the use of implants to which an overdenture can be attached [4]. The use of dental implants offers several advantages among which maintaining bone, proper occlusion, improving masticatory performance, increasing stability and retention, improving phonetics, less complaints and higher overall satisfaction when compared with conventional complete denture [5-9].

Attachments used to retain Implant supported overdentures can be mainly classified into splinted attachments and non-splinted attachments [10]. The non-splinted attachments have a greater advantage of less inter-arch space requirement, ease of cleaning and easier to construct than the splinted attachments [11,12].

Ball and socket attachment is the most well-known non-splinted attachment to retain a mandibular overdenture, because of its simplicity, low cost, less technique sensitive, less dependent on implant position, easier to clean and to replace, easier to adjust and to control the amount of retention, may require less interarch space and are better able to distribute functional forces [13].

Bar attachment is used to splint implants with the lowest complications in the prosthetic superstructure and maximum patient satisfaction. It allows occlusal forces to be shared between the abutments but requires sufficient interarch space and it may cause mucosal hyperplasia underneath the bar if insufficient relief is present [14,15].

In vitro stress analysis studies have been widely used to provide good understanding of the nature of stresses and strains acting on dental structures, even more than *In vivo* studies. This can be explained by the fact that any valid *in vivo* test has to be repeated under the same conditions every time standardizing all the variables except the one under investigation which is clinically impossible. Thus comparative studies would be more accurate and practical if they were laboratory performed [16].

Many experimental stress analysis methods have been employed to evaluate biomechanical loads. These techniques comprise brittle coating technique, photoelastic stress analysis, strain gauge stress analysis, holographic interferrometry and finite element stress analysis [17-20]. The electrical resistance strain gauge is one of the most common methods of measurement used in experimental stress analysis of dental studies both *in vivo* and *in vitro* [21]. The strain gauge method has some limitations as sensitivity to electrical noise and high temperature which may alter the analysis readings [22].

Materials and Methods

This *In vitro* study was conducted on an acrylic completely edentulous mandibular model.

Acrylic model construction and implant insertion

An impression of an educational stone model was made using silicone impression material (Speedex colton A. G, Alsatten, Switzerland). Molten base plate wax (Cavex Set up Regular modeling wax, Holland B V, Haarlem, The Netherlands) was poured into the silicone impression using a mechanical vibrator and was left to harden. After complete hardening, the wax model was removed. The wax model was processed into pink heat cured acrylic model (Acrostone heat cure acrylic resin, Egypt).

Waxed up denture was made on the model for correct placement of the two implants in the canine regions. A single mix condensation silicon impression of the waxed-up trail denture was made to produce a mold for fabrication of duplicate dentures. Waxing up, flasking, packing and curing was then performed in a conventional manner followed by de-flasking and finishing and polishing of the acrylic mandibular denture. The mandibular denture was then duplicated into a clear acrylic resin stent after being checked for proper fit and seating on the acrylic model. Drilling was carried out in right and left canine areas aided by the clear acrylic resin stent. Two implants (Legacy, Implant Direct LLC, USA) were then mounted on the right and left canine areas using a surveyor milling machine to ensure parallelism of the two implants and then were fixed in place using self cure acrylic resin.

Construction of the curved bar attachment

Plastic bar (OT Bar Multi-use attachments, RHEIN, Italy) was bend to follow the arch curvature then was connected to two plastic bar abutments which is 10 mm length (Bar castable abutment, Implant direct LLC, USA) that were placed and screwed to the implants (Figure 1). Spruing, investing, burn out and casting using chrome cobalt alloy (Bego, Bego Dental alloys, Germany) were performed for the curved bar (Figure 2). Casted bar abutments connected with curved bar were tried on the acrylic model to ensure their accurate fit on the implants then the bar abutments were reduced to 3 mm in height and then the bar and abutments were finished and polished (Figure 3).

Construction of the overdentures

Rubber base impression was made for the model while the ball abutments (ball abutment, Implant direct LLC, USA) were screwed to the implants and then the ball abutments was removed and replaced by the curved bar and another rubber base impression was then taken. The impressions were poured in hard dental stone to produce two stone casts. Two identical experimental overdentures were constructed one on each stone cast aided by condensation silicon impression of the waxed up trail denture that was made on the model. The upper piece of the mold was the negative of the denture polished surfaces and artificial teeth. Molten base plate wax was poured into the intervening space between artificial teeth in the mould and the master casts. Heat cured acrylic overdentures were constructed following the conventional technique.

For picking up clip attachment (OT Retentive clip attachments, RHEIN, Italy), the curved bar was screwed to the implants and a space was created in the fitting surface of its overdenture opposite to the attachment site. Auto-polymerizing acrylic resin was applied in the space created in the fitting surface of the overdenture then overdenture was placed on the model. Firm steady pressure was applied on the overdenture bilaterally until complete curing of the resin take place then the overdenture was removed from the model. The curved bar was then replaced by the ball abutments and the same procedure is carried out for picking up ball housing (Ball abutment housing, Implant direct LLC, USA) to its overdenture (Figure 4 and 5).

Preparation for mucosa simulation

A stone index (Type IV dental stone material, Syna-Rock, DFS-DIAMON, Germany) was made covering the denture bearing area, labial, buccal and lingual vestibules and tongue space of the acrylic resin model. A round bur of 2 mm thickness was used to make pitting on the edentulous area and then a uniform reduction to the denture bearing area and the limiting borders was done.

Installation of the Strain Gauges

The strain gauges (Kyowa electronic instrument co., Tokyo, Japan) used in this study were supplied with fully encapsulated grid and attached wires. The gauge length was 2 mm, the gauge resistance was 120.4 ohm and the gauge factor was 2.09%. The wire used for the strain gauges was insulated by a packing material. A fissure bur was used to create a groove 1 mm on the distal side of each implant in the model, where a flat plane parallel to the long axis of the implant was created to receive the strain gauges, while the labial side of each implant is prepared with a flat surface. Four holes were done in the labial vestibule to allow the strain gauge wires to pass through. Two strain gauges were installed, on the labial and distal sides of each implant. The wires of the strain gauges were oriented vertically in their grooves and fixed in position using an adhesive (Strain gauge cement, Kyowa electronic instrument co., Tokyo, Japan) recommended by the manufacturer (Figure 6).

Simulation of the oral mucosal layer

The reduced denture bearing area was painted by rubber base adhesive (Zetaplus adhesive, Zhermack., Italy). Medium body rubber base (Speedex, medium, colton A. G, Alsatten, Switzerlan) was placed over the reduced edentulous area and stone index was repositioned in its previous position after its painting with a separating medium to produce an even thickness of the medium body, until setting of impression material.

Load application and recording measurement

A four channel strain meter was used to assess the strains induced by the load applied.

The ball abutments were screwed to the implants and its overdenture was fitted on the model. The acrylic model with the overdenture was placed on the lower metal plate of the universal testing machine. The T-shaped load applicator bar of the testing machine was allowed to touch the denture teeth bilaterally at the central fosse of first molars. Simultaneous and even contacts between the bar and the artificial teeth on both sides at the previously mentioned position were achieved by spot grinding using articulating paper markings. Load was applied using the universal testing machine at central fosse of first molar bilaterally (Figure 7). The applied load started from zero up to 60N. The microstrains of the four strain gauges were recorded to measure the strains developed at the distal and labial sides of each implant for each load application. Once the load was completely applied, the microstrain readings were transferred to microstrain units from the four channel strain meter.

After fifteen minutes another load was applied. The T-shaped load applicator bar of the universal testing machine was replaced with I-shaped load applicator bar which was allowed to touch lower central incisors to apply load at lower central incisors. The applied load started from zero up to 60 N. The macrostrain's of the four strain gauges were recorded to measure the strains developed at the distal and labial side of each implant (Figure 8).

The same steps were followed with the curved bar attachment to measure the strains developed at the distal and labial side of each implant.

The obtained data was inspected, to detect the sudden drop of the measured microstrains. The mean of the last ten readings obtained from each channel before the incidence of the sudden drop of the measured microstrains were tabulated for statistical analysis to compare between strains obtained from the two attachments when bilaterally and incisally loaded.

Figure 1: Curved bar connecting plastic bar abutments.

Figure 2: Spruing of curved bar and plastic abutments.

Figure 3: Cast curved bar and abutments screwed to their implants.

Figure 4: The clip attachment picked up in the fitting surface of its overdenture.

Figure 5: Ball housings picked up in the fitting surface of its overdenture.

Figure 6: Strain gauge wire fixed in their position.

Figure 7: Bilateral load application.

Figure 8: Incisal load application.

Results

Microstrain data were presented as mean and standard deviation (SD) values. Student t-test was used to compare between the two types of attachments. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS Version 20.

Comparison between recorded microstrains measured with bilateral load application

The mean values of the recorded microstrains at the distal and labial sides of the two implants when bilateral load was applied on the two types of attachments are shown in table 1.

Attachment Site	Ball Attachment		Curved Bar attachment		P-value
	Mean	SD	Mean	SD	
Right distal	37.31	5.43	51.19	3.22	<0.001*
Right labial	31.57	2.47	36.84	3.22	0.007*
Left labial	33.97	1.51	74.16	5.16	<0.001*
Left distal	35.88	5.16	69.37	6.07	<0.001*

Table 1: Means, standard deviation (SD) values and results of student t-test for comparison between recorded microstrains with bilateral loading.

***:** Significant at $P \leq 0.05$.

At the right distal side, the right labial side, the left labial side and the left distal side, the mean recorded microstrains with curved bar attachment showed statistically significant higher value than that with ball attachments.

Comparison between recorded microstrains measured with incisal load application.

The mean values of the recorded microstrains at the distal and labial sides of the two implants when incisal load was applied on the two types of attachments are shown in table 2.

Attachment Site	Ball attachment		Curved Bar attachment		*P*-value
	Mean	SD	Mean	SD	
Right distal	104.3	7.41	157.88	7.13	<0.001*
Right labial	92.34	5.06	171.76	7.29	<0.001*
Left labial	78.94	2.52	137.31	16.58	<0.001*
Left distal	108.61	8.45	184.68	6.45	<0.001*

Table 2: Means, standard deviation (SD) values and results of student t-test for comparison between recorded microstrains with incisal loading.

***:** Significant at $P \leq 0.05$.

At the right distal side, the right labial side, the left labial side and the left distal side, the mean recorded microstrains with curved bar attachment showed statistically significant higher value than that with ball attachments.

Discussion

This study was carried out *in vitro* to evaluate the effect of ball attachment versus curved bar attachment on stress distribution in implant retained mandibular overdenture.

In vitro study was carried out as it seemed beneficial in providing valid comparative data excluding the effect of variation among individual. In addition, variation of oral hygiene, strength of masticatory muscle, age and sex are factors representing further difficulties to reach definite result in the clinical evaluation [16]. Accordingly, this study was carried out in- vitro to omit human variation and to produce more realistic results.

Lower model was used in this study instead of upper model because the mandible exhibited a decrease in the size of the denture bearing area which associated with problems in denture stability, support and retention [23].

The strain gauge system was used in this study as it was reported to be a stable and accurate system with few problems. The strain gauge assesses strains induced into a loaded structure by converting the change in resistance of an electric wire into strain measurement [24]. The wire used for the strain gauges was insulated by a packing material as a protection from humidity which was reported to be essential for obtaining reliable recordings [21,25]. In an attempt to eliminate the occurrence of inaccurate incremental strains, the sites where strain gauges were mounted were prepared and made flat to avoid mounting strain gauges on curved surfaces [25]. The strain gauges were bonded to the surfaces to standardize their location when the test was executed. The thickness of the layer of cement used as a bonding agent was the minimum required to avoid the effect of thick cement layer on the obtained data. The cement used was reported by the manufacturer to exhibit efficiency when used in minimum thickness [24].

For standardization, identical overdentures were fabricated. In order to provide a stable non movable model surface an adhesive was used for bonding between the silicon layer and the underlying acrylic model [26].

The load application sites were adjusted using articulating paper to provide even and simultaneous loading on both sides of the denture. Incisal and bilateral loading applications were performed to simulate the clinical situation. The occlusal surfaces of the first molars were preferred as loading points as they represent the masticatory area where most of masticatory load are concentrated [27]. The load applied to first molar was 60 N in order to correspond with the average chewing force required for implant overdenture patients [28].

The idea in this study to use curved bar instead of using straight bar splinting the two implants is that the use of the straight bar cannot follow the anterior curvature of the alveolar ridge, so the bar may occupy too much tongue space with the resultant difficulties with speech [14,29]. Depending on the shape of the ridge, the implants distance may interfere with the straight bar design and a slight bending of the bar in harmony with the anterior curvature avoids a bulky denture body. The use of the curved bar that follows the anterior curve of the arch result in improved lingual contour of the restoration [29].

This study showed that the stresses induced by curved bar attachment are higher than that induced by ball attachments. The curved bar corresponds to an increased length and even greater flexibility of the superstructure together with the fact that the curved bar is anterior to the implants causing a greater moment of force. This long lever arm of the superstructure increase force which may result in mobility of the implants and possible fracture of an implant component [29]. To overcome the problems of the curved arches, two options exist. The first is to place at least one additional implant in the central incisors region while the second option is to leave the implants independent with O-ring attachment [29].

Conclusion

Stresses transmitted to the implants using curved bar attachment were much higher than that transmitted by the use of ball attachments.

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