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Comparative Evaluation Of Alteration In Retention Force Values Of Different Attachment Systems For Implant Overdenture Over Various Time Intervals: An In Vitro Study

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Abstract:

Aim: To compare the retention force value alterations of four different types of implant overdenture attachments over various time intervals.

Materials And Methods: 28 cuboidal blocks were fabricated using autopolymerising acrylic resin. Four of these were used as master blocks, one for each group. Master blocks for Group A and B contained an implant analog with ball abutment, for Group C contained a single piece implant with ball abutment and for Group D contained an implant analog with Locator abutment. Six blocks for each group were used as prosthetic blocks, which included the overdenture attachment to be studied. Prosthetic blocks for Group A contained nylon cap - clear attachments, Group B contained nylon cap - pink attachments, Group C contained O-ring attachments and Group D contained Locator - clear attachments. The retention force was tested at four time intervals - baseline, after 1 month (after 90 cycles of insertion-removal), after 6 months (540 cycles) and after 1 year of simulated clinical use (1080 cycles), using Universal testing machine. These values were compared and statistical analysis was performed on the data obtained.

Results: Locator attachments were found to be the most retentive among all the stud attachments. The attachments showed significant retention loss over a period of 1 year except for nylon cap- pink. Maximum retention loss occurred for O-ring attachments (76.6%). Nylon cap - pink was found to require least force for removal but showed more consistency over a period of 1 year of use.

Conclusion: It was concluded that all overdenture attachments lose retention over time. However, the Locator attachment showed maximum retention values after 1080 cycles of insertion-removal.

Keywords: Implant, overdenture, attachments, retention, ball attachment, wear

I. INTRODUCTION

Epidemiologic and demographic studies performed lately have anticipated an expansion in the quantity of maturing edentulous patients in most countries. The prosthetic therapy of the edentulous patient, since long, has been a noteworthy challenge for dentists. The compulsion of suffering misery from uncomfortable dentures was countered by the advent of dental implants in the field of dentistry in the mid 1980s. Specifically, the issues of stability and retention of lower prostheses have been improved by creating a fixed prosthesis or fabrication of an overdenture (OVD) to implants when the number is constrained in light of anatomical or social complexities. With the inclusion of implants in overdentures, there is a decrease in displacement of prosthesis due to lateral forces, leading to better stability and a repeatable centric occlusion. It also improves the masticatory function, quality of life, speech and even nutrition.

In the course of recent years, mandibular two-implant supported overdentures (opposing conventional maxillary

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dentures) have become the standard of care for edentulous patients. A definitive objective would be the smallest intervention that offers an enhancement in the support, stability and retention of complete dentures. Henceforth, with the alternative of less intrusive implant surgery in the anterior region of the mandible, with decreased implant components and prosthodontic expenditure, the idea of the mandibular single-implant retained overdentures (opposing the conventional complete maxillary prostheses) is a reality for elderly edentulous patients.

Currently, numerous attachment systems are available for utilisation with implant - tissue - supported overdentures. Attachments can be classified on basis of their variability in flexibility, geometrical shape and cross section, casting precision and process of manufacture. Frequently used implant overdenture attachments comprise bar - clip attachments, stud attachments and magnetic attachments. The utility of stud attachments has been classically restricted to implants with divergence of less than 10 degrees. They are relatively economical, less technique sensitive, easy to use and easy to repair. Stud attachments could be nylon cap attachments, O-rings, ERA (extracoronal resilient attachments), Sterngold attachments or Locator attachment systems.

O-rings are doughnut shaped attachments which offer several advantages, including easy insertion/ removal by the patient, better hygiene, ease of maintenance, low cost and exclusion of the superstructure bar. The Locator attachment system, which was introduced in 2000, has dual retention (inner and outer), is self-aligning and has the least profile height of all the attachment systems available.

However, stud attachments tend to wear over time of clinical use and thus, lose retention. Wear occurs primarily during insertion and removal of the prosthesis and during functional as well as parafunctional activities. Thus, an alteration in the retention force of the attachment systems is expected with time, which leads to more maintenance visits and reduced patient satisfaction. A controversy exists regarding the comparison of retention loss over time with these attachment systems. Therefore, this in vitro study was conducted to compare the retention values of locator attachment, ball/O-ring and ball/nylon-cap, over a specified simulated period of time of use.

II. MATERIALS AND METHOD

A cuboidal wooden block of dimensions 40*25*8mm was constructed. A silicone mould was obtained using polyvinyl siloxane impression material and twenty eight acrylic cuboidal blocks of the same dimension were thus obtained in autopolymerising acrylic resin. These were divided into four groups; each group containing seven blocks - one block being the master block and six blocks used as prosthetic blocks which would incorporate the attachments. The samples were grouped according to the attachment systems to be used as:

Group A: Ball/Nylon Cap Attachment
Group B: Ball/Nylon Cap Attachment
Group C : Ball/O-ring Attachment
Group D: Locator Attachment

A. PREPARATION OF MASTER BLOCKS

Using an acrylic trimming bur, one recess was prepared exactly in the centre of the master block. The block was placed on the surveying table such that its upper and lower surfaces were parallel to the horizontal plate of the surveyor. For group A, B and D, the implant analogues were attached to the impression transfer and autopolymerising acrylic resin was used to secure the impression transfer to the analysing rod of the surveyor. For group C, the single piece implant was vertically attached to the analysing rod. The implant/analogue was placed exactly vertically into the prepared recess such that the implant abutment junction would correspond to the level of the horizontal upper surface. Autopolymerising acrylic resin was used to fill the space between the master block and the implant/analogue to rigidly fix it, simulating osseointegration. The abutments were tightened using torque ratchet to 25 Ncm.

The cylindrical metal posts were incorporated using autopolymerising resin into the recesses prepared 2mm away from each end such that 4mm of the height was exposed out of the acrylic block. This shall allow exact vertical insertion and removal of the prosthetic blocks from the master blocks in a single pathway.

B. CONNECTING THE ATTACHMENTS TO THE PROSTHETIC BLOCKS

Three recesses were prepared in the prosthetic block such that the prosthetic block would passively seat on the master blocks. A small circular piece of glove was placed on the abutment to prevent the flow of acrylic resin into the areas with undercuts, during pick up procedure. The attachment system was assembled and placed on the implant abutment. The attachments were incorporated into the centre of these blocks using autopolymerising acrylic resin, using direct pick up technique. After polymerisation, excess acrylic around the attachments was cleaned with a small round bur. (Fig 1)

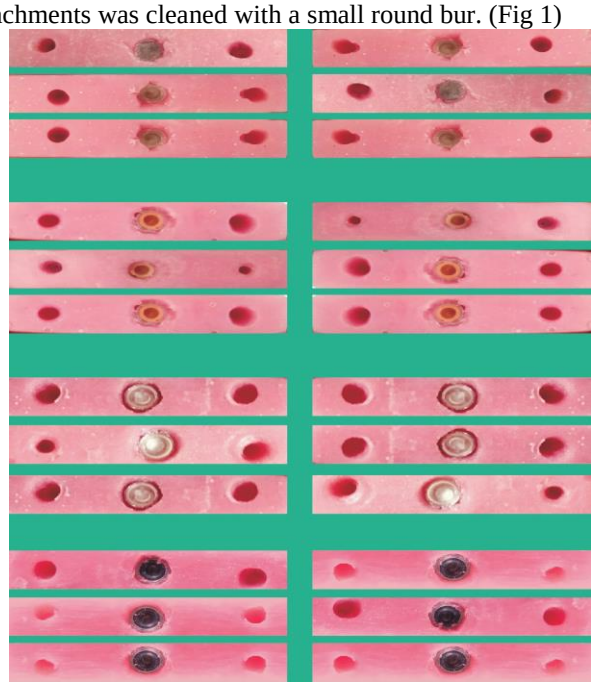

Figure 1: Prosthetic Blocks for each group

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Hooks were prepared using 19 gauge wire and secured on the upper surface in the centre of the blocks, using autopolymerising acrylic resin. The prosthetic blocks were pulled away from the master block during retention force measurement by these hooks. The samples were stored in artificial saliva at room temperature to simulate oral conditions.

C. RETENTION FORCE TEST

The master and prosthetic blocks were positioned on the machine table to ensure that all abutments and inserts were fully and accurately engaged. Engagement and disengagement of the attachments were carried out at right angles to the horizontal level of the blocks. Assuming that a patient removes and inserts his prosthesis thrice daily for hygiene purpose (three meals a day), retention force values were measured at baseline, after 90 cycles of insertion - removal (after 1 month of simulated clinical usage), after 540 cycles (after 6 months) and after 1080 cycles (after 1 year). A time interval of 10 seconds was given between each removal insertion cycle to allow elastic recovery of the attachments system.

The Universal Testing Machine was used to measure the force which is required to separate the prosthetic block from the master block. The samples were kept moist with artificial saliva as it acts as a lubricant to simulate potential in-vivo conditions. The maximum vertical dislodging force required to separate the two blocks was recorded (in Newtons) at a crosshead speed of 50mm/min, using a load cell of 20 kN. This speed approximates the actual speed of movement of an overdenture away from its retentive elements in the mouth under a vertical dislodging force. Only vertical uniaxial insertion and removal movements were performed during testing. (Fig 2)

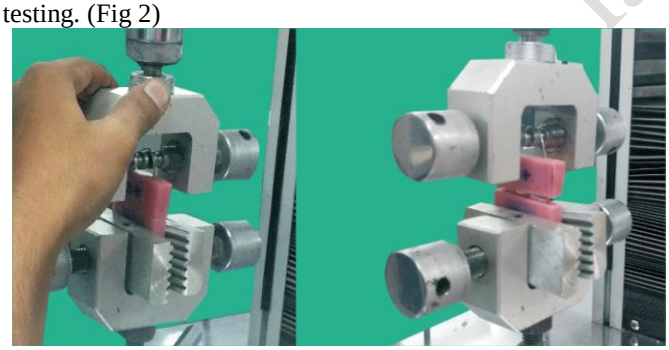

Figure 2: Retention force Measurement Using Universal Testing Machine

D. STATISTICAL ANALYSIS

The data was compared the data using one-way ANOVA, keeping the significance at $p \leq 0.05$, followed by POST HOC test with Tukey HSD analysis

III. RESULTS

The retention force measurements at baseline showed highest retention for Locator attachment system followed by O-ring, nylon cap - clear and nylon cap - pink attachments. The nylon cap-pink and O-ring attachment systems showed significant decrease in their retention over 1 year of simulated clinical use (Table 1). Most of the attachments showed significant retention loss over the first month of use and the Locator attachment showed insignificant retention loss over time (Figure 3 and 4).

GROUPS	AT BASELINE	90 CYCLES	540 CYCLES	1080 CYCLES
GROUP A (NYLON CAP CLEAR)				
SAMPLE 1	6.8	4	3.6	0.8
SAMPLE 2	5.8	4.8	4.2	3.2
SAMPLE 3	6.8	4.4	3.2	4.2
SAMPLE 4	6.2	3.8	2	2.2
SAMPLE 5	5.4	4.6	4.2	2.6
SAMPLE 6	4.8	3.2	3.8	3.2
MEAN	5.967	4.133	3.5	2.7
PERCENTAGE DECREASE		30.7%	41.3%	54.7%
GROUP B (NYLON CAP PINK)				
SAMPLE 1	3	3.4	3.8	2.4
SAMPLE 2	2.8	2.8	2.6	2.8
SAMPLE 3	3.6	3.6	2.8	3.6
SAMPLE 4	4.2	3.6	4	3.8
SAMPLE 5	3.8	5	3.6	2.6
SAMPLE 6	3.2	3.8	3.2	1.6
MEAN	3.433	3.7	3.33	2.8
PERCENTAGE DECREASE		-7.7%	3%	18.4%
GROUP C (O-RING)				
SAMPLE 1	18.4	7.2	4.8	3.2
SAMPLE 2	15.2	5.4	3.4	4.4
SAMPLE 3	18.6	7.4	2.8	4.8
SAMPLE 4	12.4	3.4	3	3.6
SAMPLE 5	13.2	6.8	4.6	2.8
SAMPLE 6	16.2	6.2	3.2	3.2
MEAN	15.667	6.667	3.633	3.667
PERCENTAGE DECREASE		57.4%	76.8%	76.6%
GROUP D (LOCATOR)				
SAMPLE 1	32.2	20.2	32	22.4
SAMPLE 2	25.2	23.4	30.4	26
SAMPLE 3	35.2	17.2	22.8	20.8
SAMPLE 4	28.8	28.6	32.2	30.2
SAMPLE 5	31.2	23.6	26.4	28.2
SAMPLE 6	35.8	32.2	30.8	22.8
MEAN	31.4	24.2	29.1	25.067
PERCENTAGE DECREASE		22.9%	7.3%	20.2%

Table 1: Retention Force Values (in Newtons) obtained Using Universal Testing Machine for 6 samples of each group

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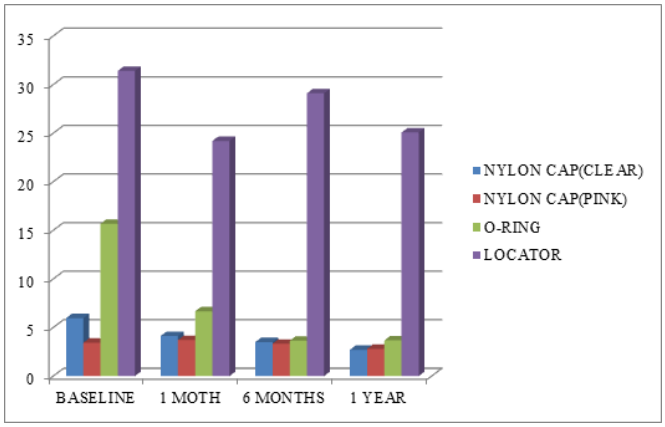

Figure 3: Comparison of Retention Force Values (in Newtons) of Different Implant Overdenture Attachment Systems Over Various Simulated Time Periods of Clinical Use

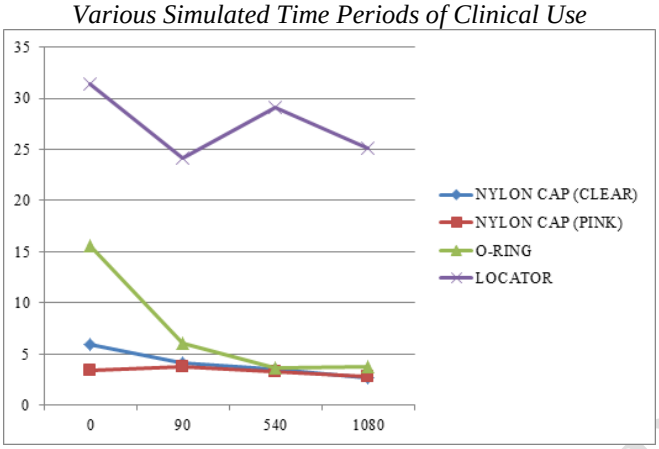

Figure 4: Graph showing Variation in Retention Values (In Newtons) of Different Implant Overdenture Attachment Systems Over Simulated Time Periods of Clinical Use

IV. DISCUSSION

For nylon cap - clear attachment, the retention decreases significantly over the first month of simulated overdenture use and then becomes more or less constant while in case of nylon cap - pink, the retention force value alterations are insignificant throughout the period of the study. A loss of retention for nylon cap attachments was also observed by Cohen et al and Tabatabaian et al, which can be attributed to distortions of plastic component due to wear on repeated insertion and removal. Lehmann stated in his study that "forces from 5 to 7 N would be enough for a set of attachment to retain an overdenture during function". Pink nylon cap was the only attachment to show insufficient initial retention value, which can be because it is slightly oversized in comparison to the clear nylon cap. Such a loose attachment may be used in patients with manual dexterity problems or at initial delivery of immediately loaded prosthesis to ensure easy adaptability of the patient and it would decrease chances of screw loosening during the first few months. This can be replaced later by a higher retentive attachment.

For O-ring matrices, the retention decreases significantly over first 90 cycles (15.667N to 6.667N), then shows an insignificant reduction to a value of 3.667N at 6 month interval (540 cycles) and then remains constant. A similar pattern was observed by Branchi et al, where 50% retention loss occurred over first 500 cycles and then value reduced very gradually uptil 5500 cycles. The retentive force of O-ring attachments is an outcome of the undercut structure of the patrix, elasticity of its rubber matrix and the frictional resistance between the matrix and patrix. The frictional resistance produces a contact force between the contacting surfaces, leading to deformation of the rubber component. When subject to wear, metal housing and plastic inserts generate scratches parallel to the direction of wear. However, rubber generates a rigid pattern perpendicular to the wear direction. The wear and tear caused may elicit a slight increase in diameter of the matrix, leading to loss of retention. Previous studies also found a significant reduction in retention force values over time for O-ring attachment. After 540 cycles, retention force tested was below the theoretical limit of 5N required to achieve an acceptable retention of a removable prosthesis, as also seen by Branchi et al.

For the Locator attachments, a significant decrease was observed from baseline to 1 month of use, then remained relatively constant. An overall 20.2% retention loss was observed till 1 year of simulated use. Previous studies have also reported a decrease in retention force values of locator attachments. This decrease is attributed to the wear and deformation of the nylon insert. Scanning electron microscopy in study conducted by Rutkunas et al revealed that the plastic core remained relatively stable while the inner surface of the outer ring, which is in contact with the metal undercuts of the locator abutment, showed significant wear. The initial retention value of Locator attachment system (31.4 N) was seen to be similar with findings by Kobayashi et al (33.5N).

The retention values increased slightly from 1 month to six months of usage and then decreased till 1 year of use. An increase in retention values followed by a decrease for Locators was also observed in previous studies. There is an increase in hardness and surface roughness due to change in surface charge on repetitive insertion-removal cycles. This leads to fine mechanical friction, consequently causing increase in the retention force values. This may also occur due to thermal expansion and water absorption of nylon inserts.

The dissimilar behaviour found among the four groups on undergoing 1080 cycles of insertion removal can be explained by varying geometrical design and material properties of the attachments. The nylon cap and Locator attachments are made of plastic/nylon and O-ring attachments are made of silicone rubber. The high retention capability of the Locator system can be attributed to the dual retention characteristic of the Locator attachment system, which comprises of inner and outer aspect of the patrix, and titanium matrix linked to the implant. The mode of retention for these attachments is "frictional" and the "dimensional misfit between the slightly oversized nylon male insert and smaller diameter inner ring of the abutment". The greater cross section of the locator abutment increases surface area available for frictional contact between its components. Furthermore, the cylindrical profile of the component provides supplementary retention as the retentive areas are adjacent to parallel surfaces. The nylon cap attachment is an analog to the ball abutment and engages it from the undercut, while the O-ring is a doughnut shaped attachment. According to Petropolous et al, "the strain energy

absorbed during insertion may be divided into elastic (recoverable) and plastic (permanent) components. If the deformation is elastic, no loss of retention is expected. If permanent deformation occurs, incomplete recovery occurs leading to rapid loss of retention." According to Craig, "a material that is momentarily submitted to stress below its yield strength returns to its original form without any internal or structural change. However, if this stress is repetitive as in a fatigue process, the material can suffer definitive deformations."

The initial and final retention values were in the order - Locator (31.4N to 25.1N) > O-ring (15.667N to 3.67N) > Nylon cap - clear (5.97N to 2.8N) > Nylon cap - pink (3.43N to 2.7N). Maximum retention loss was observed for O-ring(76.6%) and minimum for nylon cap (pink) and Locator attachment system (20.2%) after 1 year of simulated clinical use.

V. LIMITATIONS

To simplify the experimental study, a homogenous rectangular model made of acrylic with an attachment linked to the implant was used which may have caused limitations in this study. Thus, overdenture samples fabricated on edentulous models or in vivo studies can provide more realistic results. In this study, only vertical dislodgement forces were simulated. Clinically, a combination of vertical, horizontal and oblique and rotational forces act on the prosthesis during masticatory function and parafunctional habits.

VI. CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

- ✓ The retention for all attachments seemed to decrease with time.
- ✓ Retention loss was maximum for O-ring. The least retention loss was seen for nylon cap (pink) and Locator attachment system.
- ✓ Initial and final retention of Locator attachment system is maximum among all groups, followed by O-ring > nylon cap (clear) > nylon cap (pink).
- ✓ Retention loss was maximum within the first month of simulated clinical use for nylon cap (clear), O-ring and Locator attachments.

Retention force value for nylon cap (pink) was found to be insufficient for removable prostheses, even at baseline. The retention force for O-ring and nylon cap (clear) decreased to below 4N after six months of clinical use simulation.

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