# ASSESSMENT OF RETENTION OF OT EQUATOR SMART BOX ATTACHMENT SYSTEM IN MANDIBULAR IMPLANT-RETAINED OVERDENTURE WITH ANGULATED IMPLANT VERSUS STRAIGHT ANGLED IMPLANT. (AN-IN VITRO STUDY)

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## Abstract

**Aim:** To Compare the changes of retention between three different implant analog angulations of OT equator smart box attachment for a two implant-retained mandibular overdenture when subjected to chewing cycles of 75 000 and 150 000 equivalent to 6 months and 12 months).

**Methodology:** A completely edentulous mandibular stone model was scanned using an extra-oral lab scanner to produce an STL file. The STL file was then used to virtually plan for two-implant analogs in the canine area bilaterally. Three groups were planned; In group I (straight); two implants analog were installed parallel to each other with a zero-degree difference in implant analog angulations, in group II (Buccal inclination) the left implant analog socket (A) was straight, and right implant analog socket (B) hole was installed with a 25degrees buccal angulation and group III (Distally inclined) the left implant analog socket (A) straight and right implant analog socket (B) with a 25degrees distal angulation. Simulation of the oral mucosa was carried out by preparing a 2mm cutback on the residual alveolar ridge extending between the retromolar pads bilaterally. The overdenture was then designed and a space for the attachments housing of the three different angulations were designed to be included in the fitting surface of the overdenture to facilitate the pickup procedure. Nine models and nine overdentures were 3D-printed to be used in the present study. For all groups, the implants were installed in the prepared sockets by using self-cure acrylic resin, and then the smart box OT equator attachment was screwed to the implant analogs and then picked up in the fitting surface of the denture.

The geometric center was identified and then the initial retention (baseline values) was recorded for all groups using the universal testing machine. Then all groups were subjected to 75000 cycles and 150000 cycles using the chewing simulator and retention values were recorded after each cycle. The mean retention of both implants in each group was then tabulated and statistically analyzed. Shapiro Wilk and Kolmogorov test was used for normality exploration. One Way ANOVA was used for multiple comparisons followed by Tukey`s Post Hoc test. Repetitive One-Way ANOVA for different intervals followed by Tukey`s Post Hoc test. Paired -t-test was used to measure changes in retention before and after the different cycles. The significant level (P-value) was determined to be significant as P-value > 0.05.

**Results:** There was a statistically significant decrease in retention between the three groups after being subjected to 75 000 cycles (equivalent to 6 months) and 150 000(equivalent to 12 months). After 75000 Cycles (equivalent 6 months) the greatest decrease in retention was recorded for group I (straight) -13.32 ±0.27N, followed by -9.96±0.98N, and the least decrease in retention was reported by group III 1.54±0.59 N (P=0.0001). While after 150 000 cycles (equivalent to 12 months) group I showed the greatest decrease in retention -12.28 ±0.31N, followed by group III -8.44±0.26N, and the least decrease in retention was reported by group II -3.31±0.26N (P=0.0001).

**Conclusions:** Smart box OT equator attachment showed the greatest significant retention loss with straight parallel implants after chewing cycles equivalent to 6- and 12 months. The Smart box OT equator with 25 degrees distally inclined implant showed the least loss of retention after chewing cycles equivalent to 6 months. While after chewing cycles equivalent to 12-month the 25-degree buccally inclined implants showed the least retention loss.

## INTRODUCTION

An implant-supported removable prosthesis is a reliable treatment option that offers comfort, prosthesis stability, good chewing performance, cost effectiveness, and increased patient satisfaction to overcome the limitations of the conventional complete denture **(Doornewaard** 2019)**.**

Different attachment systems can be utilized with mandibular implant overdentures to improve stability and retention. The most common types of attachment used are studs, bars, and magnet type. Implant overdentures can be retained by a single, two, three, and four implants. Two implant retained mandibular overdenture is the standard of care for completely edentulous mandible.

The OT Equator Smart Box, it is a novel attachment that would enable passive insertion even in extreme divergences of up to 50° thanks to a tilting mechanism with a rotation fulcrum. This would ensure passive insertion. The OT Equator Smart Box with the newly designed is considered to be a cost-effective treatment option in cases of extreme implant divergence.

Stresses directed to the underlying implants is of major importance as it has an impact on successful osseointegration. To achieve structural stability and a precise fit of the prosthesis, it is therefore preferable to place implants as parallel as possible. The inclination of the implant would affect the insertion and removal of the prosthesis, which affects the retention of the attachment system and its durability.

Retention is an important factor that will improve the patient quality of life and satisfaction. Therefore, it is always important to test the retention of the different attachments through invitro studies before carrying out randomized clinical trials. Several methods have been used to evaluate retention mainly through objective and subjective methods Objective methods proved to be more reliable and has been used commonly in several invitro studies.

Therefore, the purpose of this study is to compare the changes in retention of the OT equator smart box attachment between three different implant analog angulations for a two-implant mandibular-retained overdenture after being subjected to chewing cycles of 6- and 12-months equivalent.

# MATERIAL AND METHODS

**PICOT elements:**

**P:** edentulous resin model with two mandibular bilateral inter foraminal implant analogue

**C:** edentulous mandible with inter foraminal 2 implants retained overdenture, Both straight angle implant analogue.

**O:** Retention.

**T:** time interval at day 0, after 6 months, and after 1 year.

**. Description of study sample**

1- **Data collection for fabrication of a 3D-printed model**

An ideal stone model of a completely edentulous mandible simulating a clinical condition. The model was selected with the interforaminal area having adequate width and length. The model was scanned using an extra-oral lab scanner[1] to obtain an STL file. The 3D model for the completely edentulous patient was analyzed using Mesh mixer. **(Figure 1)**

1 DOF lab scanner, Mauchly, USA

Figure (1): the scanned model

## 2- Implant analogue planning

A virtual setup of the teeth was made using Blue-sky Bio[2] software by arranging the teeth over the crest of the ridge as a first step. This virtual setup of the teeth will be locked (fixed) to avoid any change in their position and to be later on used in the overdenture preparation. **(Figure 2)**

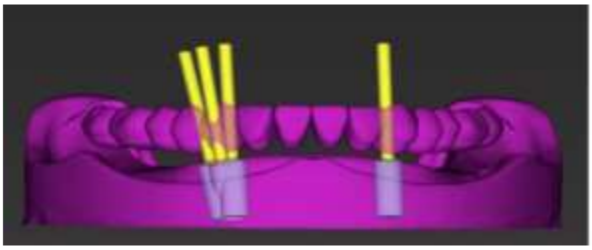
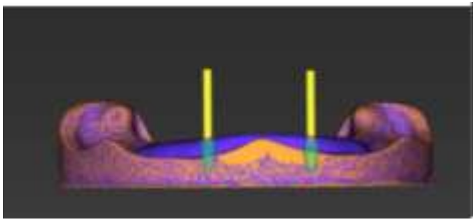


Figure (2): demonstrate the virtual setup of the teeth

Based on the setup of the teeth, two implants analogue[3] were selected and were planned to be installed in the canine area bilaterally.

In the present study, three models were used;

In group I (straight); two implants analogue were installed parallel to each other with a zero-degree difference in implant analogue angulations, in the canine lateral region bilaterally. **(Figure 3 and 4)**



**Figure(3): represent group I (straight) frontal view**

Figure (4): represent group I (straight) occlusal view

2 Blue-Sky Plan® software; USA

3 JDentalCare, Italian company

In group II a 25 degrees difference in implant angulations was achieved by preparing the left implant analogue socket (A) straight and the right implant analogue socket (B) hole with a 25-degree buccal angulation. **(Figure 5)**

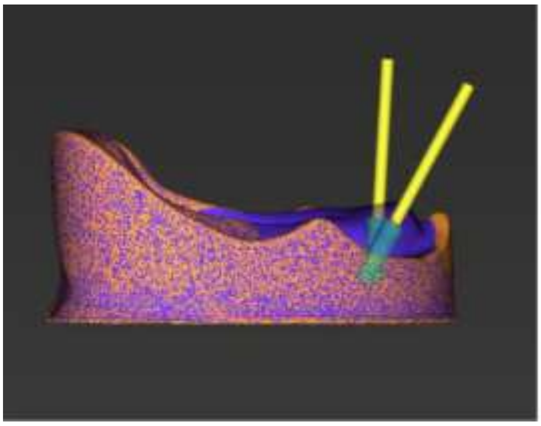


Figure (5): represent group II (buccal)

In group III a 25 degrees difference in implant angulations was achieved by preparing the left implant analogue socket (A) straight and right implant analogue socket (B) with a 25-degree distal angulation

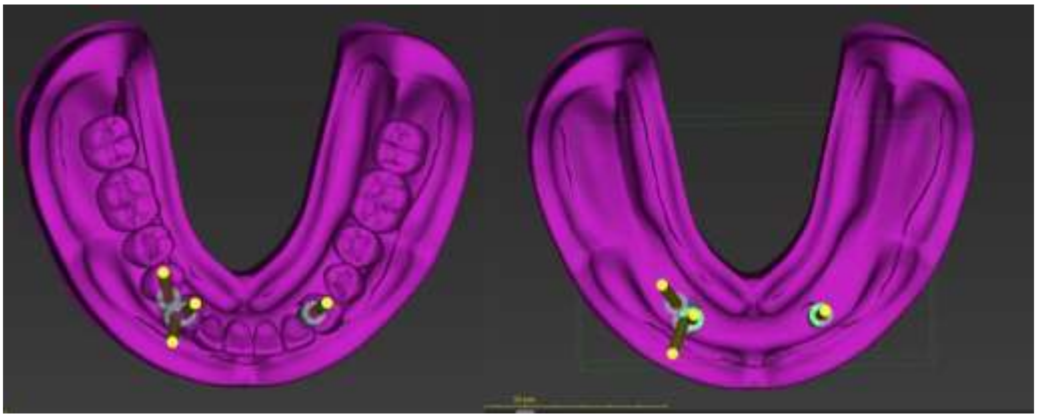


***Figure (6): show the angulation of the implant analogue socket (B) in the 3 groups together.***

For each implant a virtual attachment with its housing was selected from the library to try to simulate the space that would be occupied by the real attachment, using the Boolean difference operation in Blue-Sky bio, every implant analogue was cut off from the model leaving a planned socket with the exact position and angulation that would be present in the printed model for each group. The same procedure was repeated for each group. **(Figure 7)**

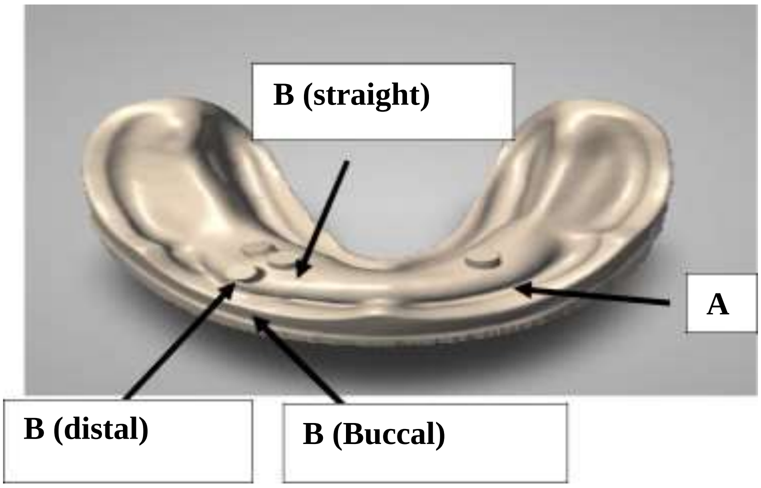



***Figure (7): Represent the model with the planed housing in different direction***

3- **Overdenture construction**

A mandibular overdenture was planned using the Blue-sky Bio denture module, by determining the outline of the mandibular cast. The denture was designed to extend to the full depth of the buccal and lingual vestibule.

The overdenture for all three groups was designed to cover the implant analogue and the virtual attachment with its selected housing with the different angulations in each group.

The fitting surface of the designed overdenture will have a preplanned socket corresponding to the position of the attachment housing in the different 3 angulations (straight, buccal, distal) For each model, three overdentures were designed. **(Figure 8)**

***Figure (8): Represent fitting surface of the overdenture with housing sockets***

After the overdenture design was completed, it was exported as an STL file from Blue-Sky Bio, and this STL file was imported into Mesh Mixer software in order to design a T-shaped bar extending bilaterally from the lingual right distal area of the second premolar and right first molar to the lingual left second premolar and left first molar and to the midline between the two central incisors to form a T shaped bar that will be later on used to determine the geometric center. **(Figure 9)**

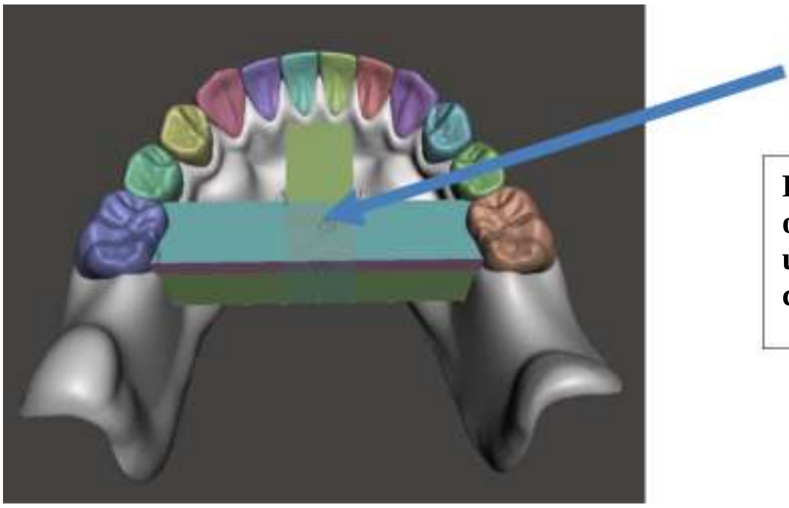



**Figure (9): T Bar designed in the overdenture, that was later on used to determine the geometric center**

The three different angulation positions of the housing sockets of the implant analogue (B)(straight, buccal, distal) and implant analogue (A)(straight) housing sockets were designed together in each overdenture fitting surface to accommodate placement of the housing in all 3 groups. A total of nine overdentures were printed with Savoy dental model resin[4] using 3D printer EPAX[5]

**4- Planning for oral mucosa simulation**

The edentulous mandibular model was exported from Blue-Sky Bio to obtain STL file, that was imported to Mesh Mixer software**,** using the select tool and the extrude tool of the Mesh mixer software, a 2mm cut back on the residual alveolar ridge extending between the retromolar pads bilaterally, which will be later replaced with a soft tissue mimic material after 3d printing of the model. The STL files of each models of the study groups were exported for 3d printing.

**5- Pick-up**

Two implant analogs (4 mm in diameter) were inserted and fixed in the preplanned sockets in each model for all 3 groups with soft mix of self-cured acrylic resin, after complete setting of the soft mix of acrylic resin[6], the implants analogue were checked for complete seating. **(Figure 10 and 11)**

[4] Savoy resin; China

[5] EPAX 3D is dedicated to EPAX brand 3D Printers; Morrisville, USA

[6] Acrostone, Acrostone is the lead company in Egypt and Africa.

***Figure (10): insertion of implant analogue and OT equator screwed to it checked for complete seating, implant analogue flushed with the reduced crest of the ridge***

***Figure (11): placement of OT housing and pickup in the overdenture***

The OT Smart Box equator[7] attachment with a 2mm cuff size was screwed to the 2 installed implants analogue for each group utilizing a hand torque ratchet.

The OT Smart Box equator is in a shape of a ball attachment, the novel Smart box is a titanium housing for retentive caps. Its creative design, which utilizes a tilting mechanism with a pivoting fulcrum, enables passive cap insertion even in conditions of high divergence up to 50 degrees.

[7] Rhein83 company, Italy

**6- Oral mucosa simulation**

After the pick-up of the metal housing was carried out, the fitting surface of the dentures were painted with a separating medium and filled with Bredent tissue mimic material[8] and allowed for complete setting, while dentures were seated over the models. Rubber bands were used to ensure full denture seating until complete polymerization of the tissue mimic material attached to the 3D model. After the complete setting, excess material was removed using a sharp scalpel before removing the dentures from the model. This was carried out for all groups. **(Figure 12)**

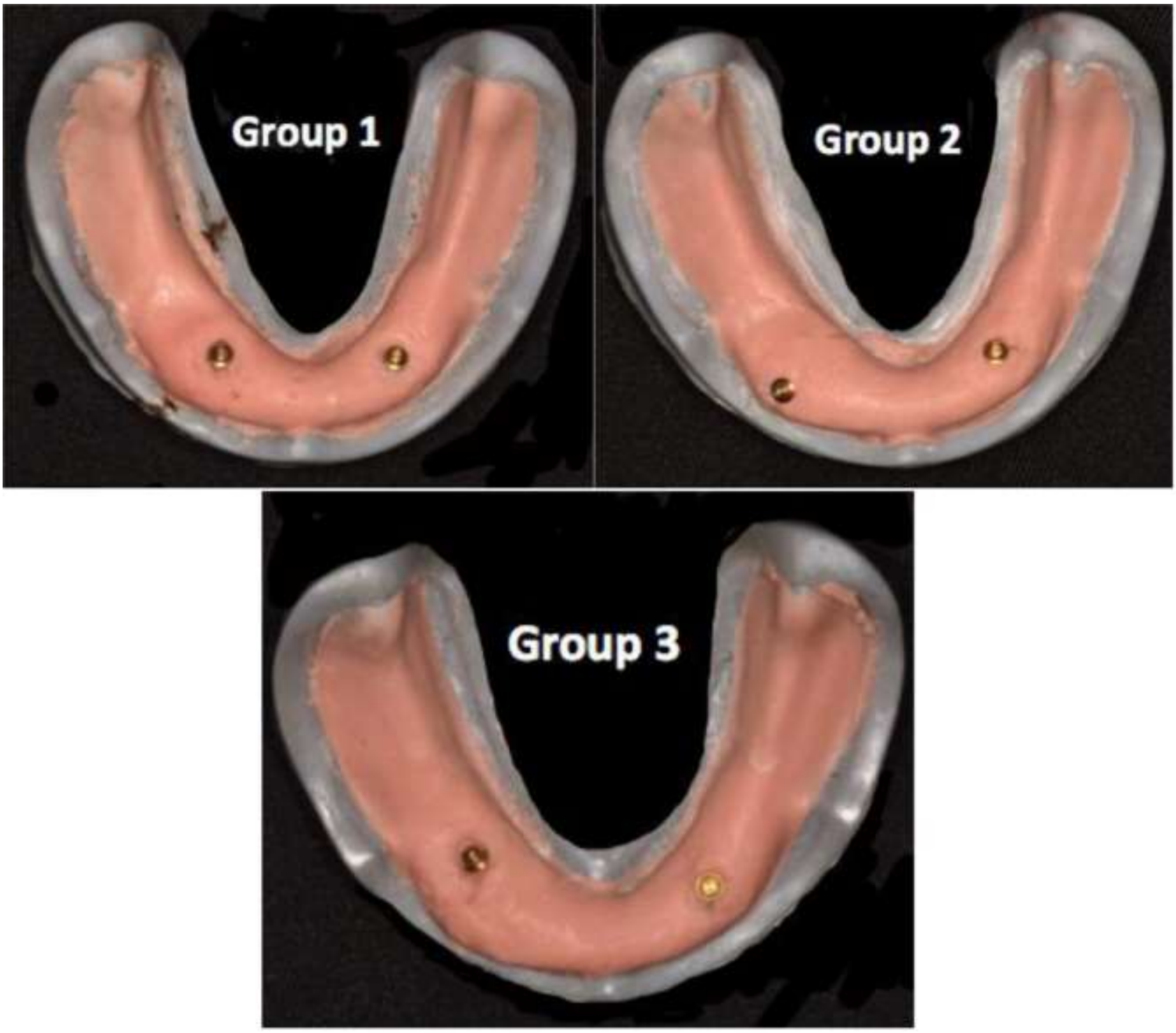



**Figure (12): demonstrate all 3 groups (straight, Buccal, distal) with tissue mimic simulation.**

[8] Bredent Multisil-Mask soft 50 ml cartridges, Germany.

**7- Determination of denture geometric center:**

In the following Invitro study all models were initially tested for retention in all groups then were subjected to chewing cycles using a chewing simulator.

The geometric center for a mandibular denture was determined to standardize the point from which all dentures will be pulled out for retention measurement and the point that the chewing simulator will be applied. (**Figure 13)**

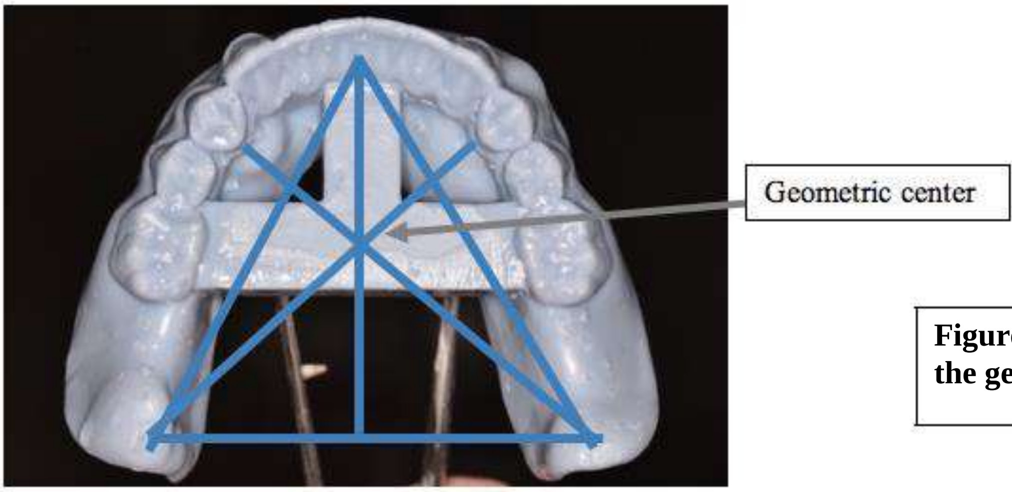



**Figure 13: demonstrate the geometric center**

## 8- Measurement of retention:

The measurement of retention of the nylon cap will be done using universal testing machine, after applying simultaneously the chewing cycles with the insertion and removal cycles in a pattern.

The number of mastication cycles used in this study (0, 75 000 and 150 000) which will be done simultaneously with the insertion and removal cycles of (0, 720 and 1440 ) which correspond approximately to day 0 , 6 months and 1 year in vivo , respectively and a comparison between the groups throughout the cycles .

A T-form support bar was incorporated in the geometric center of all the overdentures connecting the first molars bilaterally, which will be used when subjected to chewing cycles using the chewing simulator and then later retention will be measured.

Then a hole was drilled in the center (in the point of intersection between the 3 lines) of the T Bar and a circular metal hook of 3 mm in diameter was then screwed

## 9- Insertion-Removal test

Retention was first measured at baseline using the universal testing machine[9], the overdenture of all groups was placed at the predetermined position and the circular hook will be further connected to a metal hook that is attached to the universal testing machine **(Figure 14)**


**Figure 14: demonstrate the universal testing machine attached to the model**

The model of each group was subjected to insertion and removal of the overdenture of 0, 720, and 1440 times, which is equivalent to baseline, 6 months, and 12 months. This was done simultaneously with cycles of the chewing simulator.

[9] Instron Instruments' Bluehill® Lite (Model 3345; Instron Instruments Ltd., USA)

## 10- Simulation of the masticatory process:

The newly developed four stations multimodal ROBOTA chewing simulator in conjunction with thermo-cyclic protocol driven on servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., Germany) was used to perform the cycle loading test under programmed logic control. **(Figure 15)**


**Figure 15: Represent chewing simulator machine (Robota)**

The specimens were placed inside a Teflon holder in the simulator's lower section. 49 N of chewing force, or a weight of 5 kg, was applied. According to previous studies, the test was performed 75 000 and 150 000 times which is equivalent to 6 and 12 months **(Fayad et al., 2018).**

The test settings were kept wet with distilled water and at room temperature (20±2 °C). The test was performed at specific parameters summarized in **table (1).**

**Table (1): chewing simulator parameters**

| Chewing simulation parameters | |
|---|---|
| Vertical movement: 3 mm | Horizontal movement: 1 mm |
| Rising speed: 90 mm/s | Forward speed: 90 mm/s |
| Descending speed: 40 mm/s | Backward speed: 40 mm/s |
| Cycle frequency 1.6 Hz | Weight per sample: 3 kg |
| Torque; 2.4 N.m | |

The model of each group was subjected to different chewing cycles of 75000, and 150 000 which is equivalent to 6 months, and 12 months, which was done in conjunction with the number pull out of the overdenture of 720, and 1440 times which is equivalent to 6 months, and 12 months.

After each cycle of insertion and removal, the hook was unscrewed for simulation of the chewing cycle and then screwed again for retention measurement. The mean retention of the right and left implants of all groups were tabulated and statistically analyzed.

## Results

***Table (2): Mean and standard deviation of retention in newtons after 75,000 cycles (equivalent to 6 months) cycle and after 150,000 cycles (equivalent to 12 months)***

| | | Min | Max | M | SD | P value |
|---|---|---|---|---|---|---|
| Group I | Base line (initial) | 20.07 | 21.54 | 20.61[a] | 0.81 | 0.01* |
| | After 6 months (75,000cycle) | 6.71 | 7.79 | 7.29[b] | 0.54 | |
| | After 12 months (150,000cycle) | 4.30 | 13.05 | 8.33[b] | 4.41 | |

***M:** Mean **SD:** standard deviation **NS:** non-significant difference as P>0.05.*

Means with the same superscript letters were insignificantly different as P>0.05.

There was a statistically significant decrease in retention from initial retention (baseline) and after 75,000 cycles (equivalent to 6 months). The initial retention recorded was 20.61 ± 0.81N, and after75,000 cycles (equivalent to 6 months) decreased to 7.29 ± 0.54N, while after 150,000 cycles (equivalent to 12 months), there was a decrease in retention values to 8.33 ± 4.41N but this decrease was not statistically significant (P = 0.01) **(Table 2) (Figure 16)**

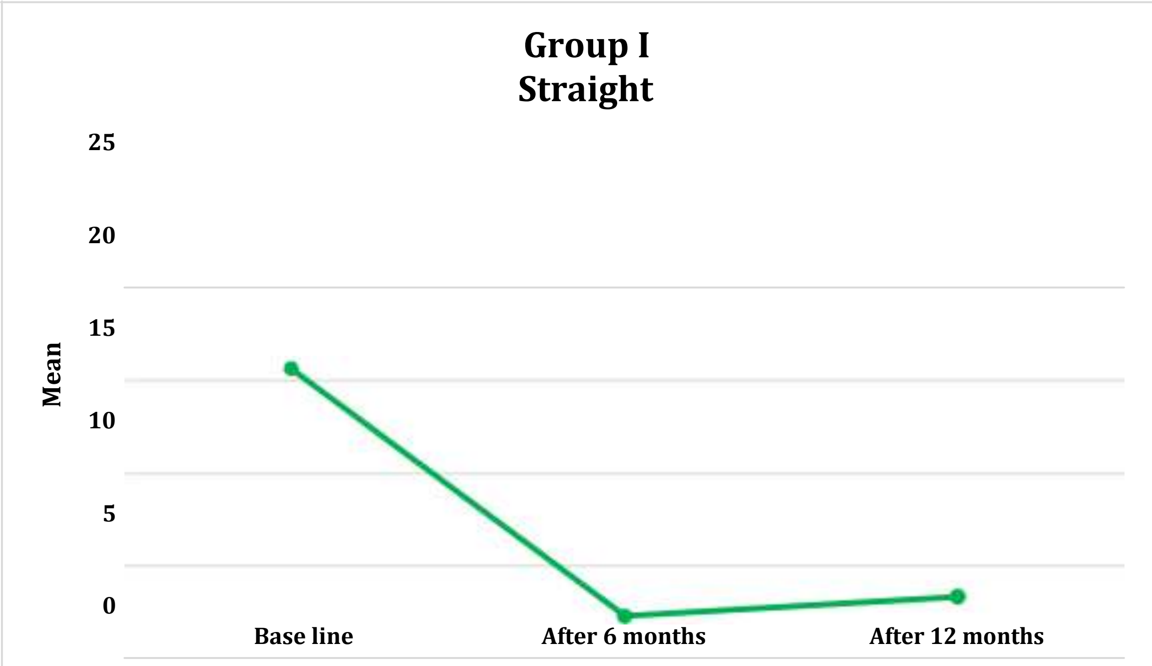



**Figure 15: Line chart representing retention of group I at baseline, after 6 months (75,000 cycles) and after 12 months (150,000 cycles).**

**The retention values in newtons recorded by group II ( Buccal) after 75,000 cycles ( equivalent to 6 month) cycle and after 150,000 cycles (equivalent to 12 months)**

***Table (3): Mean and standard deviation of retention in newtons after 75,000 cycles (equivalent to 6 months) cycle and after 150,000 cycles (equivalent to 12 months)***

| | | Min | Max | M | SD | P value |
|---|---|---|---|---|---|---|
| Group II | Base line Initial | 23.39 | 25.61 | 24.43 [a] | 1.12 | 0.23 ns |
| | After 6 months (75,000 cycle) | 11.82 | 19.11 | 14.47 [a] | 4.03 | |
| | After 12 months (150,000 cycle) | 12.19 | 28.56 | 21.12 [a] | 8.29 | |

**M:** Mean **SD:** standard deviation **NS:** non-significant difference as P>0.05. Means with the same superscript letters were insignificantly different as P>0.05.

In group II the retention values decreased from baseline (initial, 24.43±1.12N), and after being subjected to 75,000 cycles (equivalent to 6 months) (14.47 4.03N) this decrease wasn't statically significant (P=0.23)

While after 150,000 cycles (equivalent to 12 months) the retention value increased to 21.12 8.29N which was not statistically significant (P=0.23) **(Table 3) (figure 16)**

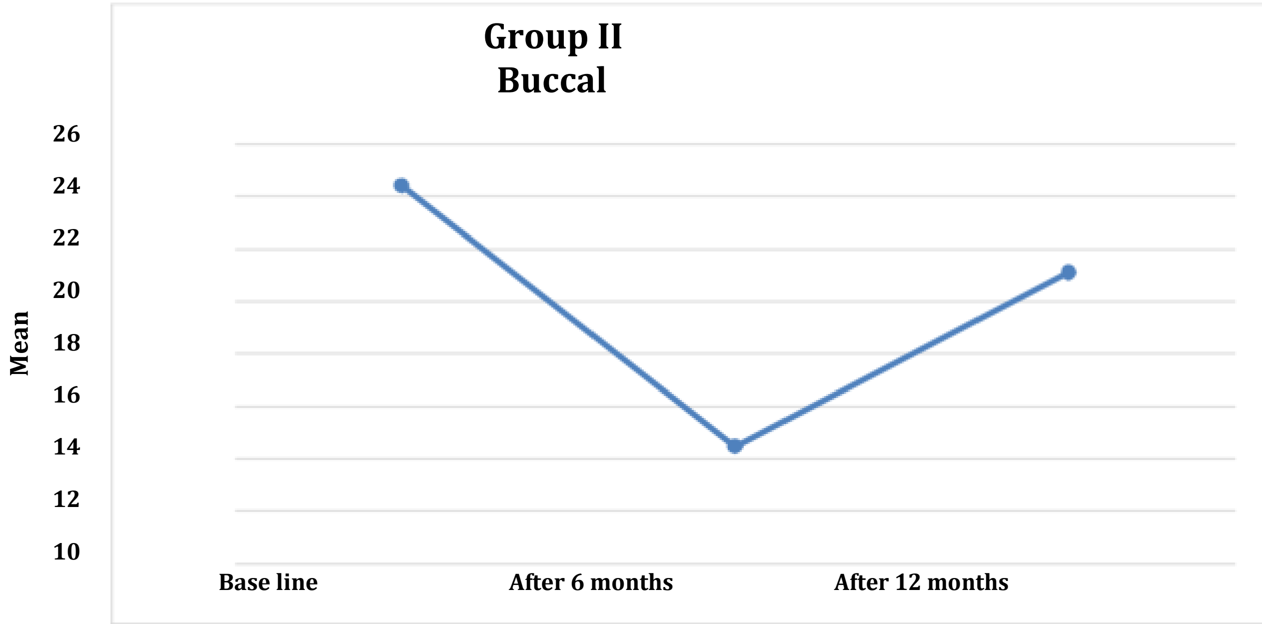



***Figure 16: Line chart representing retention of group II; baseline, 75,000cycles (equivalent to 6 months) and 150,000cycle (equivalent to 12 months)***

**The retention values in newtons recorded by group III ( Distal) after 75,000 cycles (equivalent to 6 months) cycle and after 150,000 cycles ( equivalent to 12 months)**

***Table (4): Mean and standard deviation of retention in newtons after 75,000 cycles (equivalent to 6 months) cycle and after 150,000 cycles (equivalent to 12 months)***

| | | Min | Max | M | SD | P value |
|---|---|---|---|---|---|---|
| Group III | Base line Initial | 20.71 | 32.10 | 25.54 [a] | 5.89 | 0.24 ns |
| | After 6 months (75,000cycle) | 17.68 | 30.62 | 24.00 [a] | 6.48 | |
| | After 12 months (150,000 cycle) | 12.56 | 24.13 | 17.10 [b] | 6.17 | |

**M:** Mean **SD:** standard deviation **NS:** non-significant difference as P>0.05. Means with the same superscript letters were insignificantly different as P>0.05.

There was a decrease in retention value from baseline (initial 25.54 5.89N), after 75,000 cycles (equivalent to 6 months) (24.00 6.48N), and after 150,000 cycles (equivalent to 12 months) (17.10 6.17N) which was not statistically significant (P=0.24) **(Table 4) (figure 17)**

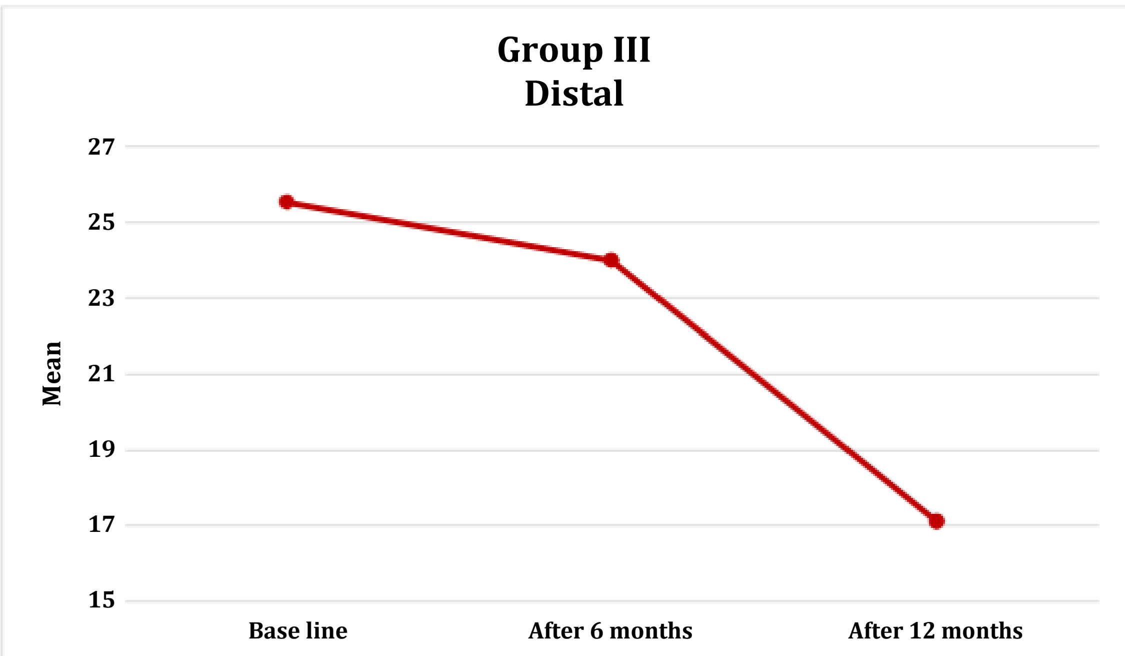


**Figure 17: Line chart representing retention of group III; baseline, 75,000cycles (equivalent to 6 months) and 150,000cycle (equivalent to 12 months)**

***<u>Comparison of retention in newtons between group I, II, III after 75,000 cycles ( equivalent to 6 month) cycle and after 150,000 cycles ( equivalent to 12 months)</u>***

***Table (5): Mean and standard deviation of retention in newtons for all groups after 75,000 cycles (equivalent to 6 months) and after 150,000 cycles (equivalent to 12 months)***

| | | Min | Max | M | SD | P value |
|---|---|---|---|---|---|---|
| Base line Initial | Group I | 20.07 | 21.54 | $20.61^{a}$ | 0.81 | 0.27 |
| | Group II | 23.39 | 25.61 | $24.43^{a}$ | 1.12 | |
| | Group III | 20.71 | 32.10 | $25.54^{a}$ | 5.89 | |
| After 6 months (75,000 cycle) | Group I | 6.71 | 7.79 | $7.29^{b}$ | 0.54 | 0.01* |
| | Group II | 11.82 | 19.11 | $14.47^{ab}$ | 4.03 | |
| | Group III | 17.68 | 30.62 | $24.00^{b}$ | 6.48 | |
| After 12 months (150,000 cycle) | Group I | 4.30 | 13.05 | $8.33^{a}$ | 4.41 | 0.12 |
| | Group II | 12.19 | 28.56 | $21.12^{a}$ | 8.29 | |
| | Group III | 12.56 | 24.13 | $17.10^{a}$ | 6.17 | |

**M:** Mean **SD:** standard deviation **NS:** non-significant difference as P>0.05. Means with the same superscript letters were insignificantly different as P>0.05.

There was no statistically significant difference in the initial retention between the three groups, group III (Distal) recorded the highest retention value (25.54±5.89N) (P=0.27) **(Table 6) (Figure 24).** While after 75,000 cycles (equivalent to 6 months) there were a statistically significant difference between the three groups, with group III (Distal) showing the highest retention value (24.00±6.48N) (P=0.01) **(Table 6) (Figure 24).**

After 150,000 cycles (equivalent to 12 months) there were no statistically significant differences between the three groups, with group II (Buccal) recording the highest retention (21.12±8.29) (P=0.12) **(Table 5) (Figure 18)**

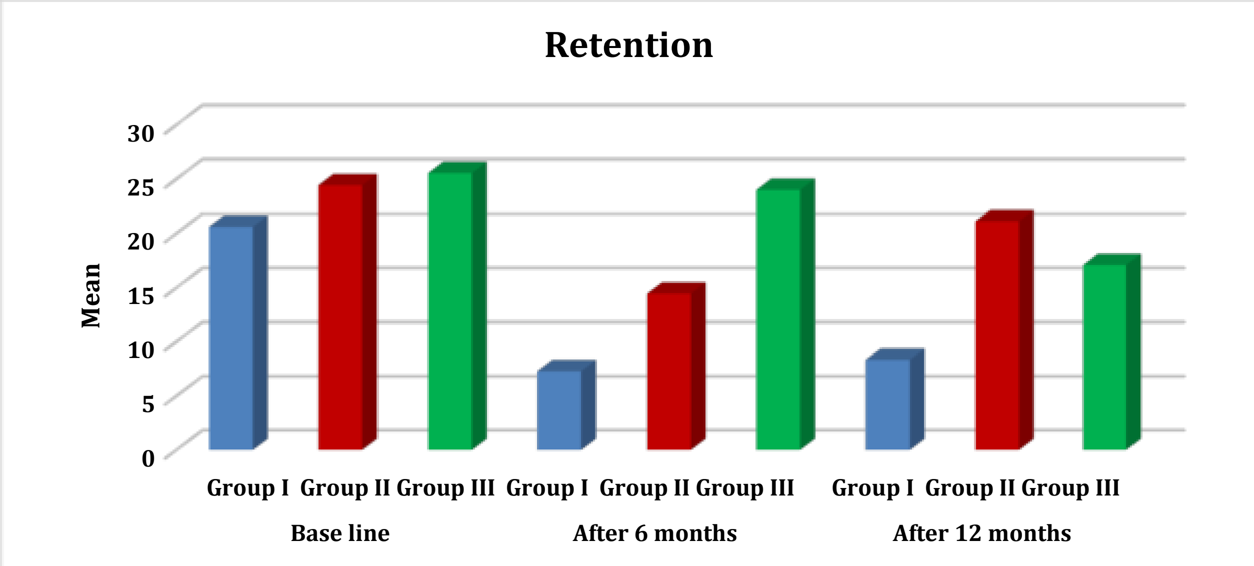



**Figure (18): Bar chart representing retention of all groups before, after 75,000 cycles (equivalent to 6 months) after 150,000 cycles (equivalent to 12 months)**

## Discussion

Mandibular implant overdentures retained by two implants is a reliable and cost-effective treatment option modality for the completely edentulous patients (**Feine, J.S. et al. 2002**). This treatment option would improve the stability and retention of the mandibular complete denture which will have an impact on the patient's masticatory performance with major improvement in patient satisfaction and quality of life compared with conventional complete dentures (**Awad MA, et al. 2003**)

Several attachments have improved the retention and stability of implant retained overdentures, whether splinted or unsplinted systems**.** The selection of any attachment would depend on several factors such as the proper alignment of the installed implants, the retention required, and the available prosthetic space **(Sadowsky, S.J et al. 2007)**. The aim of this invitro study was to compare the retention of OT Smart Box equator attachment of three different implant analog angulations for a two-implant retained mandibular overdenture after being subjected to chewing cycles 75,000 and 150,000 equivalent to 6 and 12 months.

In the present invitro study there was no significant difference between the initial retention values of the OT smart Box equator for all the three groups, with group III (distally inclined) recorded the highest initial retention values (25.54±5.89N). An explanation for this would be that the OT smart box equator would allow for a tilting mechanism with a rotation fulcrum , and it is designed for extreme implant divergence up to 50 degree , in group III has the right implant was installed with a 25 degree distal angulation and the left implant was installed with a zero degree ( parallel) so the OT smart box equator through the tilting mechanism of the rotational core, titanium anodized housing and the titanium liner would engage the 25 degree distally inclined implant which would act as an undercut and would probably be the reason for the increased initial retention.

This comes in agreement with **(Elsonbaty et al., n.d.)** Who concluded that retention forces increased with the 30-degree implant divergence and decreased with the 60-degree group divergence. In the 30-degree group, the distal side of the patrix abutment exhibited more undercut than the mesial side, which formed a challenging path of removal from which the matrices had to be simultaneously withdrawn. Interestingly, the 60-degree group did not demonstrate significantly greater retention, possibly because the vertically oriented titanium matrix caps did not engage the most inferior undercuts on the distal sides. This finding was consistent with that of **Yang et al**, **2011** who observed that retention forces of attachment systems decreased as the angle between the matrix withdrawal path and the patrix increased.

When all of the groups in this study were subjected to 75,000 cycles (equivalent to 6 months) there was a statistically significant decrease in retention for all of the three groups, which would mainly be due to the frictional wear between the male and female part of the attachment that will result in loss of retention (**Aroso C et al. 2016**) (**Yilmaz B et al. 2019**). In addition to that **Uludag et al.** reported that all attachment systems demonstrated a decrease in retention over time. This may be due to wear simulation effects as postulated by **Rutkunas et al** who concluded that mechanism of retention loss of resilient overdenture attachments can be explained by dimensional changes and surface alterations with advance of time. According to **passia et al 2016** and **Wolf et al, 2009** all attachment systems exhibit some wear or deformation under functional loading or after many cycles of insertion and removal, which may be due to friction between the retaining abutment and its counterpart .Similar findings were reported by **choi et al. 2017** These results in concurred with **Evtimovska et al 2009** who explained that the reduction of the retentive capacity of the attachments attributed to the strain energy that absorbed during insertion and removal that may be divided into elastic (recoverable) and plastic (permanent) components. If permanent deformation occurs, a rapid loss of retention will be observed.

The greatest decrease in retention was recorded by Group I (parallel implant), followed by Group II (buccally inclined implant), and the least decrease in retention was recorded for Group III (distally inclined implant). In the literature, the mode of action of the OT smart box equator is not fully explained as there are very few studies regarding the performance of this attachment **(Doaa Rostom & Ragheb, 2021)**.

The OT smart box equator is designed for extreme implant divergence, in group I the two installed implants were parallel to each with no implant divergence. Several authors reported that implants should be installed parallel to one another in order to improve the maintenance and decrease the loss of retention of the attachment **(Jins John et al., 2012)** as non-parallel implants would interfere with the insertion and removal of the attachment causing wear of the retention **(Nayrouz A. Metwally,et al. 2020) ,** But actually, this was not the case with the OT smart box equator as during the insertion and removal of the retentive cap for the installed parallel implants with the special feature of the tilting motion of the attachment this has increased the friction between the retentive cap and the female portion of the attachment and resulted in a significant amount of wear that eventually resulted in the greatest loss of retention. Concerning group II, the right implant was installed at 25 degrees to the buccal, and the left implant was installed at zero, the buccal inclination of one implant have interfered with the path of insertion and removal of the attachment and resulted in greater friction between the retentive cap and the female portion **(Atashrazm et al 2014)** of the attachment when compared to group III which has one implant installed at 25-degree distal inclination, insertion and removal in this case with the special titling mechanism with a rotational core didn't result in significant amount of wear as the rotational core and the titling mechanism have resulted in a passive insertion mesiodistally that probably have decreased the friction between the retentive cap and the female part of the attachment which explains the least retention loss for group III.

While after all groups were subjected to 150,000 cycles (equivalent to 12 months) there was a statistically significant decrease in retention for all groups, with Group I (parallel implants) still showing the greatest loss of retention followed by Group III, and Group II showing the least decrease in retention.

When having a closer look at the retention values concerning group II after being subjected to 75,000 cycles (equivalent to 6 months) the mean retention values recorded increased from 14.47 4.03N to 21.12 8.29N at 150,000 cycles (equivalent to 12 months) as this increase could be attributed to an increased surface roughness of the nylon retentive cap resulting from the early wear that resulted after the 75,000 cycles (equivalent to 6 months), ( **Al-Ghafli SA et al. 2009**) with an increase in surface roughness and the insertion and removal of the OT smart box equator with the 25-degree buccally inclined implant has resulted in less friction with greater engagement of the buccally inclined implant which resulted in an increase in retention, matrix degradation may not always result in a corresponding decrease in retention because it might increase surface roughness and enhance retention via micromechanical friction. **(Choi et al 2017)**.

The increase in retention for Group II has resulted in the least retention loss compared to Group I and Group III. In group III, after 75,000 cycles (equivalent to 6 months the retention value recorded was 24.00 6.48N which decreased to 17.10 6.17N after 150,000 cycles (equivalent to 12 months), the decrease in retention resulted due to the frictional wear that resulted in the sides of the retentive cap which resulted in easier dislodgment of the attachment.

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusion

It can be concluded from the present study that Smart box OT equator attachment would show better performance with extreme angle deviations. The Smart box OT equator attachment showed the greatest significant retention loss with straight parallel implants after chewing cycles equivalent to 6- and 12-month. The Smart box OT equator with 25 degree distally inclined implant showed the least loss of retention after chewing cycles equivalent to 6 months. While after chewing cycles equivalent to 12-month the 25-degree buccally inclined implants showed the least retention loss.

**Recommendations**

Within limitations of the present in-vitro study that the Smart box OT equator attachment is not recommended to be used with straight parallel implants. Implants with extreme angle deviations would require further randomized clinical trials to be carried out with a long follow-up period to conclude whether this attachment would show better clinical performance with extreme distally or buccally inclined implants.

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