



Impact of Ball and Magnetic Attachments and Inter-Implant Distance on Retention of Mandibular Overdenture (An in Vitro Study)

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ABSTRACT

Purpose: To evaluate the influence of the attachment type and inter-implant distance on the retention of 2-implant retained mandibular overdenture during 12 months of simulated function. **Material and Methods:** Three transparent acrylic resin casts simulating a completely edentulous mandible were fabricated. The retentive forces (N) of two implant-retained mandibular overdentures were estimated by a universal testing machine. Six groups were computed on three casts; two ball attachments with inter-implant distances (IIDs) 23mm were placed in the canine, 31mm were placed in the premolar and 40mm were placed in the first molar regions respectively and two magnetic attachments were placed on the same 3 IIDs. Mean value and differences between and within groups were calculated were performed using a one-way ANOVA, repeated measure ANOVA, and independent student's t-test, $P \leq 0.05$. **Results:** Significant differences were detected between ball attachments at all IIDs after 12 months of simulated function, $P \leq 0.05$, but no significant differences with magnetic attachments, $P > 0.05$. Statistically significant differences were observed between the ball and magnetic attachments at different IIDs, $P = 0.001$. The correlation between the attachment type, IIDs and time for both ball and magnetic attachments were significant, $P = 0.001$. **Conclusions:** The retention of the ball was more than the magnetic attachment. Inter-implant distance influences the retention of both the ball and magnetic attachments. The retention of ball attachment has been influenced by 12 months of simulated function.

INTRODUCTION

The retention, function, aesthetics, and stability of dentures are enhanced and the residual alveolar bone is preserved by dental implants. Also, the masticatory efficiency and patients' occlusal force are enhanced by implant-retained overdenture; patients' satisfaction and standard of life are improved^(1,2).

KEYWORDS

Overdenture, Implant, Retention,
Precision Attachment.

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Attachment is “a specific category of retentive system utilizing suited matrix and patrix comparable parts”. The receptacle part of the attachment system is the matrix, and the part frictionally fitted and engages the matrix is the patrix. Attachments used with implant-retained overdenture can either bar attachments or stud-type attachments. Stud attachments systems involve ball and socket, magnetic, and locator attachments^(3,4).

Currently, there are several attachments’ designs: ball, magnetic, and locator attachments connected to implants. Different shapes, elements, and retentive qualities are now available. The choice of a specific attachment type to be used with implant-retained mandibular overdenture persists challenging^(5,6).

The ball attachment is the simplest and most commonly used attachment’ type in two implant-retained mandibular overdentures. It offers good retentive properties, decrease occlusal forces on the implants, help in correction of misaligned implants, lower cost, more straight forward design, and easier maintenance. However, the bulk of the attachments limit its application where there is limited inter-arch space and minimal residual ridge resorption. Retention loss after a few months is due to wear of the nylon insert⁽⁷⁻⁹⁾.

The retention of a complete denture is improved by the repulsive force of magnetic attachments. Advantages of magnets are: retention was maintained by time, decrease the amount of horizontal stresses transmitted to the alveolar ridge, prevents implant damage during lateral force, proper distribution of loading forces, simplicity in positioning, instinctive reseating, and simplicity of cleaning. Intraoral corrosion remains a main drawback, it leads to rapid retention loss and the replacement of the attachments becomes inevitable. Plaque tends to accumulate more around magnets, thus meticulous hygiene measures are required⁽¹⁰⁻¹²⁾.

The primary concern in the selection of the type of attachments is its retentive force which is associated with the sufficient retention and the

stability of the implant overdentures and patients’ satisfaction⁽¹³⁾.

Wear of attachments, after its frequent insertion and removal, due to cyclic dislodging forces, fracture of attachment’s parts and deformation causes loss of retention which is considered the most common problem of attachments^(7,14).

The rate of wear and loss of retention of attachments’ parts are affected by the attachment type and inter-implant distance (IID). Therefore, evaluation of the retentive behaviour of the attachment is important at insertion and after one year of use. Furthermore, the effects of attachment type, inter-implant distance, and time on the retention loss still unclear^(15,16).

The aim of this study was to estimate the effect of two different types of attachment; ball and magnetic and IID on the retention of 2-implant retained mandibular overdentures during 12 months of simulated function; cyclic insertion–removal procedures. The null hypotheses were; there were no differences in the retentive force: between the ball and magnetic attachment systems, in each attachment system at different IIDs, and at each attachment system during 12 months of function; cyclic insertion–removal procedures.

MATERIAL AND METHODS

The experimental design of this in-vitro study included using a standardized stone cast to represent severely resorbed mandibular ridge so that retention was achieved with only the implant-abutment assembly. The stone cast was duplicated to produce three transparent heat-cured acrylic casts (Acrostone, industrial area El Salam City, Egypt), according to manufacturer instruction, for 3 IIDs (23, 31, and 40 mm) and 2 types of attachments (n = 12). Based on results from previous studies, it was found that using a standardized cast with 2 implants and those 3 IIDs are enough for conducting the research at power 0.80, confidence interval 0.95 and alpha level. 0.05^(15,16).

According to the implant position, inter-implant distance and type of attachment the three casts were used and divided into six groups. Two groups were performed on the first cast as follows; group Ball C: two implants placed in the canine region at inter-implant distance 23mm with 2 ball and socket attachments and group Mag C: two implants placed in the canine region at inter-implant distance 23 mm with 2 magnetic attachments.

While on the second cast 2 groups were performed as follows; group Ball P: two implants placed in premolar region at inter-implant distance 31 mm with 2 ball and socket attachments and group Mag P: two implants placed in premolar region at inter-implant distance 31mm with 2 magnetic attachments.

On the third cast 2 groups were performed as follows; group Ball M: 2-implants positioned in 1st molar region at inter-implant distance 40mm with 2 ball and socket attachments and group Mag M: 2-implants positioned in 1st molar region at inter-implant distance 40mm with 2 magnetic attachments.

The mandibular complete denture was constructed according to the conventional manner. The denture was connected to Y shaped metallic rods and a vertical rod perpendicular to the meeting point of the Y shaped rod. The Y-shape was made of two rods at the first molar region and rod between the two incisors, to facilitate engaging the denture base to the load cell. For group Ball C, on the first cast, a mark was done on the midline of the cast. An inter-canine distance line of length 23mm was drawn perpendicular to the midline, and a mark was carried out on both sides of the midline at a distance of 11.5mm. Two holes were drilled on these marks for two implants using a special drilling machine to ensure that the implant holes were prepared parallel to each other. In the drilled holes, few drops of monomer were added. A small amount of mixed transparent self-cured acrylic (Acrostone, industrial area El Salam City, Egypt) was then placed in the holes. Two implants (Dyna push-in titanium HA-

coated implant, 13 mm height and 3.6 mm diameter; Dyna Dental Engineering BV, Netherlands) were pushed into the holes and the excess acrylic resin was removed. The ball abutments (Dyna titanium ball and socket attachment, 3 mm height and 3.6 mm diameter; Dyna Dental Engineering, Netherlands) were inserted into the implant using an appropriate driver. The female part of the attachment was fit over the ball abutment. A shallow hole was made at the basal surface of the denture where attachment to be positioned. A fluid mix of self-cure acrylic resin was applied into the hole, then the denture was re-seated on the cast. After complete curing, the denture was removed from the cast and excess was removed. For group Mag C, on the first cast, the same steps as for group Ball C were followed except, 2 magnetic abutments of magnetic attachments (Dyna magnetic abutment of 3mm height and 3.6mm diameter, Magnet of 500 g and height 2.5mm; Dyna Dental Engineering, Netherlands) were placed into the implant using an appropriate driver. Then the magnet part placed on the magnetic abutment, figure 1.

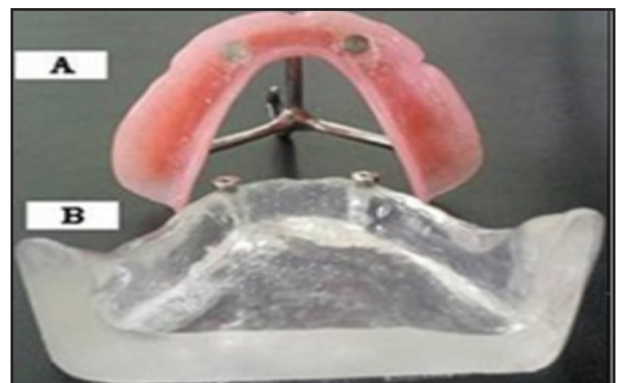


Figure (1): Magnet and magnet abutment placement in group Mag C. A: Magnet placed in the denture B: Magnet abutment placed in the cast.

For group Ball P and Mag P, on the second cast, the same steps as for group Ball C and Mag C were followed except, the two implants were placed in the premolar regions with 31 mm inter- implant distance. Also for group Ball M and Mag M, on the third cast, the same steps as for group Ball C and Mag C were followed except, 2-implants positioned in the 1st molar region with 40 mm inter- implant distance.

Casts of all groups were measured for retentive force after 0, 720 and 1440 cycles representing 0, 6 and 12 months of simulated overdenture insertion and removal. All casts were separately mounted on the lower fixed part of computer-guided materials advanced universal testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with 5KN load cell. Vertical rod of overdenture was hanged with a custom-made S-shape steel hook (allowing self-adjustment of load line) was fixed to the upper movable part of the universal testing machine (fig. 2).

Then the overdentures lifted upward at 5 mm/min crosshead speed. Values for these properties were carried out throughout during linear dislodgement slide, which was perpendicular to the occlusal plane. 10 pulls were applied for each overdenture of each group. The load required to lift up each overdenture as a function of vertical deflection was registered with a computer software (Nexygen-MT; Lloyd Instruments Ltd., Fareham, UK).

Statistical analysis:

For statistical analysis, SPSS 20 was used to analyze the computerized data. Shapiro-Wilk normality tests were carried out for constant variables and normally distributed data was disclosed. A mean and standard deviation were used to represent the quantitative data. To clarify the significance



Figure (2): Suspension -Retention test for group Ball M.

of differences between two continuous variables, the independent student's t-test was utilized and between more than 2 groups, one-way ANOVA was used. A repeated measure ANOVA was utilized to clarify the effects of attachment type, IIDs, time and the relations between them. The results were found to be significant when $p\text{-value} \leq 0.05$.

RESULTS

The results of the present study were shown in tables (1-3) and figure 3.

Table 1: Retentive forces (N) for each group at different time intervals.

Attachment type & IID	Time intervals (Mean $\pm$ SD)			F	P-value
	0 month	6 months	12 months		
Ball C(23mm)	8.13 $\pm$ 0.60	6.11 $\pm$ 0.55	5.08 $\pm$ 0.47	9.45	0.05*
Ball P(31mm)	13.7 $\pm$ 0.38	11.97 $\pm$ 0.35	10.64 $\pm$ 0.50	25.31	0.04*
Ball M(40mm)	17.44 $\pm$ 0.80	15.36 $\pm$ 0.92	14.22 $\pm$ 0.87	4.94	0.05*
Mag C(23mm)	2.02 $\pm$ 0.21	1.97 $\pm$ 0.20	1.93 $\pm$ 0.19	0.23	0.89
Mag P(31mm)	3.14 $\pm$ 0.33	3.09 $\pm$ 0.48	3.03 $\pm$ 0.47	0.002	0.97
Mag M(40mm)	4.66 $\pm$ 0.46	4.60 $\pm$ 0.45	4.55 $\pm$ 0.48	0.01	0.94

SD, Standard deviation.

*, Significant ≤ 0.05 .

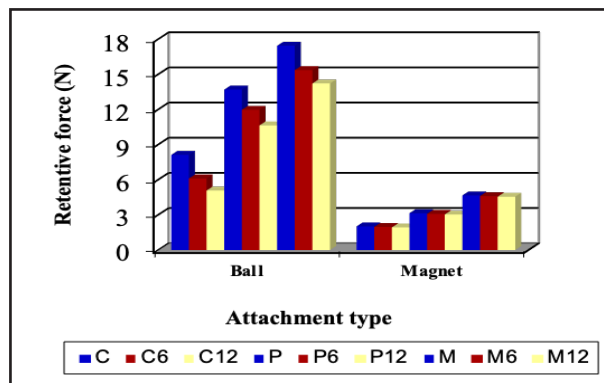


Figure (3): Retentive force (mean values) for different groups as a function of attachment type, IID and time.

Table 1 and figure 3 showed; retentive force at the initial insertion of ball attachment at the canine region, Ball C-0, was the highest followed by 6 months than 12 months. Group Ball C-0 > Ball C-6 > Ball C-12. The difference within studied groups was statistically significant, $p \leq 0.05$. Also, retentive forces at the initial insertion of ball attachment at premolar and first molar regions, Ball P-0 and Ball M-0, were the highest. Group Ball P-0 > Ball P-6 > Ball P-12 and group Ball M-0 > Ball M-6 > Ball M-12. The differences within groups were statistically significant, $p \leq 0.05$. Moreover, retentive forces at the initial insertion of magnetic attachments at canine, premolar, and molar (Mag C-0, Mag P-0, and Mag M-0) were the highest.

Group MagC-0 > MagC-6 > MagC-12, MagP-0 > MagP-6 > MagP-12 and MagM-0 > MagM-6 > MagM-12. The differences within groups were statistically non-significant, $p > 0.05$.

Table 2 showed; the initial retentive forces for ball attachment in the canine region with inter-implant distance 23mm, Ball C-0, was the lowest followed by the premolar region with inter-implant distance 31mm, group Ball P-0, then the first molar region with inter-implant distance 40mm, group Ball M-0. Group Ball C-0 < Ball P-0 < Ball M-0. The difference within groups was statistically non-significant, $p > 0.05$ except between Ball C-0 and ball M-0, $p = 0.03$. Also, the retentive forces after 6 months and 12 months were the lowest values in Ball C-6 and Ball C-12; group Ball C-6 < Ball P-6 < Ball M-6 and Ball C-12 < Ball P-12 < Ball M-12. The differences within groups were statistically significant, $p \leq 0.05$ except between (Ball C-6 and Ball P-6) and (Ball C-12 and Ball P-12), $p = 0.16$ and $p = 0.44$ respectively. The initial retentive forces for magnetic attachment in the canine region, group Mag C-0, showed the lowest followed by the premolar region, group Mag P-0, then the first molar region, group Mag M-0. Group MagC-0 < MagP-0 < MagM-0. The difference within groups was statistically significant, $p \leq 0.05$ except between Mag P-0 and Mag M-0, $p = 0.75$. Moreover, the retentive forces after 6 months and

Table (2) Retentive forces (N) for each group at different inter-implant distances.

Attachment type & time intervals	IID (Mean $\pm$ SD)			F	P-value
	Canine (C) (23mm)	Premolar (P) (31mm)	Molar (M) (40mm)		
Ball 0	8.13 $\pm$ 0.60	13.7 $\pm$ 0.38	17.44 $\pm$ 0.80	2.47	0.13
Ball 6	6.11 $\pm$ 0.55	11.97 $\pm$ 0.35	15.36 $\pm$ 0.92	4.48	0.05*
Ball 12	5.08 $\pm$ 0.47	10.64 $\pm$ 0.50	14.22 $\pm$ 0.87	4.92	0.04*
Mag 0	2.02 $\pm$ 0.21	3.14 $\pm$ 0.33	4.66 $\pm$ 0.46	5.74	0.03*
Mag 6	1.97 $\pm$ 0.20	3.09 $\pm$ 0.48	4.60 $\pm$ 0.45	6.04	0.02*
Mag 12	1.93 $\pm$ 0.19	3.03 $\pm$ 0.47	4.55 $\pm$ 0.48	6.12	0.02*

SD, Standard deviation.

*, Significant ≤ 0.05 .

12 months were the lowest values in, MagC-6 and Mag C-12. Group Mag C-6<MagP-6< MagM-6 and Mag C-12<MagP-12< MagM-12. The differences within groups were statistically significant, $p \leq 0.05$ except between (MagP-6 and Mag M-6) and (MagP-12 and Mag M-12), $p=0.74$ and $p=0.80$ respectively.

The retentive forces for ball attachment in the canine region in all time intervals, Ball C-0, Ball C-6, and Ball C-12, were higher than that for magnetic attachment, Mag C-0, Mag C-6, and Mag

C-12, respectively. The difference within groups was statistically significant, $p= 0.0001$. Also, the retentive forces for ball attachment in the premolar and the first molar region in all time intervals (Ball P-0, Ball P-6, and Ball P-12) and (Ball M-0, Ball M-6, and Ball M-12) were higher than that for magnetic attachment (Mag P-0, Mag P-6, and Mag P-12) and (Mag M-0, Mag M-6, and Mag M-12) respectively. The difference within groups was statistically significant, $p= 0.0001$.

Table (3) Repeated-measures ANOVA for retentive forces.

Effect	Sum of squares	Mean square	Degree of freedom.	F	P-value
Attachment type	3201.29	3201.29	1	E34.1	0.001*
IID	934.80	467.40	2	600.04	0.001*
Time	61.68	61.68	1	E31.16	0.001*
Attachment type $\times$ IID $\times$ Time	2.34	1.17	2	21.978	0.001*

*, Significant ≤ 0.05 .

Table 3 showed; there was a statistically significant influence of the attachment type, the inter-implant distance and time respectively on the retentive force mean values, $p \leq 0.05$. The interaction of these three factors was statistically significant, $p \leq 0.05$.

DISCUSSION

Using a ball and socket and magnet were the most commonly used abutment types for connections between overdentures and inter foraminal implants. Ball and magnetic attachments, with 3 mm height and 3.6 mm diameter, were indicated in limited inter-arch space, found to induce less stress concentration, provide broad load distribution than those of higher values, and discovered to induce lower bending movements than bars, simpler to apply and less costly^(8, 11).

The design of this study was in vitro, which allowed isolated evaluation of the retention of the attachment system. Intra-orally, there are many factors providing retention of overdentures. Exactly reproduction of intraoral dislodgement manners is impossible.

This study measured the retentive forces of the ball and magnetic attachment systems at 3 different IIDs in relation to 12 months of simulated function in the form of insertion-removal cycles. The inter-implant distances of choice were 23 mm, 31mm and 40 mm represented the canine, premolar, and the first molar region. In group Ball C and Mag C, implants were placed at canine regions with inter-implant distance 23mm. This value was very close to 22.88 mm recorded for mature untreated Angle class I dentition⁽¹⁷⁾.

In groups Ball P, Ball M, Mag P, and Mag M, implants were placed at premolar and molar regions with inter-implant distance 31mm and 40 respectively. It was reported that implants placed posterior to the mental foramen significantly improve support, function, comfort and can help with the preservation of bone⁽¹⁸⁾.

Generally, all patients place and/or remove their overdentures before sleep and after each meal (4 cycles a day). In this study, the retentive force of each attachment was assessed after 0, 720 and 1440 cycles of insertion and removal, which is equivalent to 0, 6 and 12 months of simulated function.

The retention force was evaluated using a 5 mm/min slow crosshead speed. Magnetic attachment showed low retentive force when measured at fast crosshead speed, which is considered to be imprecise. In contrast, it was reported that 50, 50.8, and 60 mm/min fast crosshead speeds were used to evaluate the retentive force of other attachments.^(19–21)

Based on the results of the current study, the first null hypothesis of no difference in the retentive force between the ball and magnetic attachments at different IIDs was rejected. Significant differences were detected in the retentive force between ball attachment and magnetic attachments at different IIDs during 12 months of simulated function.

This was consistent with findings from previous studies; which showed that magnets were the least retentive attachment type as compared with ball/socket attachments which were the most retentive attachment type^(18–20).

In contrast, it was reported that at initial insertion, ball attachments showed more retentive forces than magnetic attachments in a vertical direction. After simulated wear, the retentive forces had reduced to nearly half of its value for some of the ball attachments and had considered being equal to that of magnetic attachments⁽²²⁾.

The second null hypothesis of no difference in the retentive force of each attachment at different IIDs

was rejected. Statistically significant differences were found in the retentive force of the ball attachment with different IIDs. The retentive force of the ball attachment at 40 mm IID, molar region, was significantly higher than that at 23mm and 31 mm IIDs, canine and premolar region, respectively at 6 and 12 months of function. Also, the retentive force of the magnetic attachment in at 31mm and 40 mm IID was significantly higher than that at 23mm at 0, 6 and 12 months of function.

These results are in accordance with studies revealed that the retention of ball attachment connected to two implant-retained overdenture is significantly affected by the location of the implant and the IID and increased from canine to second premolar region. Moreover, it was found that the magnitude of force values measured with ball attachments steadily increased from lateral incisor to molar region in anteroposterior and vertical tests. It was indicated that inter-implant spacing had a significant effect on ball and magnetic attachment systems, with generally higher retention with greater inter-implant spacing^(16–18).

It was reported in previous studies that, the effect of inter-implant distance on the retention of ball and socket attachment with a gold matrix was evaluated and there was not any significant effect of inter-implant distance on the retention. This could indicate that results from different studies should be compared and interpreted carefully according to the materials used⁽²³⁾.

The third null hypothesis of no difference in the retentive force of each attachment during 12 months of simulated function; cyclic insertion–removal procedures was rejected for ball attachment and accepted for magnetic attachment.

A significant reduction of the retentive force of ball attachment after 6 and 12 months of function were found. The wear and deformation of the nylon inserts of ball attachment could be causing loss of retention^(24,25).

However, no significant decrease in the retentive force of magnetic attachment after 6 and 12 months of function was discovered. This was consistent with results from other studies which revealed that the magnetic attachments showed the lowest retentive force, but the most persistent retentive force with time^(11,26).

It was reported in a previous clinical study that, the retentive force of each of the ball and magnetic attachments was compared after six months after insertion and the retention wasn't affected. Perhaps, three or six months after insertion are not sufficient for retention's loss to be measurable. However, loss of retention of ball, magnet, and bar attachments after 5 years were noticed.^(10,11,23)

The retentive forces of the ball and magnetic attachments after 6 and 12 months of simulated function interacted with the type of attachment at the three selected IIDs.

In the present study, only the vertical dislodgement which was perpendicular to the occlusal plane was evaluated, the movement of the implant-supported overdenture, in relation to a complex and variable biomechanical environment, such as occlusal and mastication forces could not be precisely simulated, the manner of retention loss of attachments could be affected by the presence of saliva around the attachments and the thermal variations of the oral cavity, and the study period was rather short. Clinical studies with longer duration are needed to reinforce the results of the current study.

CONCLUSION

Within the parameters of this study design: the retention of the ball and socket was more than the magnetic attachment, inter-implant distance influences the retention of both the ball magnetic attachments and the retention of ball and socket attachment has been influenced by 12 months of simulated function.

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