Dental Journal
Majalah Kedokteran Gigi

Dental Journal
(Majalah Kedokteran Gigi)
2024 December; 57(4): 259–266

Original article

Influence of implant number on the retention and support of mandibular overdentures

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ABSTRACT

Background: *There are two distinct categories of attachments—magnetic attachments and positioner attachments—currently in use for dental implants. Many implants required for implant-retained overdentures need support from implant-retained overdentures.* ***Purpose:*** *The aim of this study is to evaluate the effect of different implant numbers and attachment types on the retention and support of implant-retained overdentures.* ***Methods:*** *This experimental work involved the utilization of a model that replicated a mandibular edentulous arch, a total of five models. Within this model, seven dental implant analogues were implanted to mimic the tooth positioning observed in the natural dentition. Thirty-five titanium dental implant analogues (Dentium, South Korea) were employed in this study. A total of ten overdenture housings were fabricated using 3D printer acrylic resin, with each housing including a specific type of attachment (magnetic and positioner attachment). These attachments were equipped with three loops that were affixed to the occlusal surface of the housing. Subsequently, three chains were connected between the loops and a force gauge testing equipment.* ***Results:*** *The positioner was found to be more retentive and supportive than the magnetic one in the three directions of the dislodgement test as well as under unilateral and bilateral load, according to an independent t-test comparing magnetic and positioner attachment ($p<0.05$).* ***Conclusion:*** *Depending on the method of attachment that is used, variations in implant number have varying effects on the retention and support of an implant-held overdenture.*

Keywords: *Exocad program; implant-retained complete overdentures; magnetic attachment; positioner attachment; pressure sensors*
Article history: *Received 24 November 2023; Revised 21 January 2024; Accepted 30 January 2024; Published 1 December 2024*

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INTRODUCTION

Conventional dentures provide limited functional efficiency and comfort, but the use thereof remains a valid treatment option in dental clinics. The use of lower dentures among the elderly has been observed as drastically low, mainly because of the retention. Thus, the provision of lower complete dentures retained by implants (overdentures) is a minimum standard of care and an efficient strategy for the treatment of edentulism among the elderly, who are dependent on the public healthcare system.[1] Tooth loss is multifactorial, often a complex interaction of multiple problems, including trauma, caries, iatrogenic treatment, congenital defect, periodontal disease, which, if not resolved, may lead to complete edentulism. Edentulism is the state of losing all-natural teeth. The traditional treatment for edentulism is the fabrication of removable dentures, tissue-supported complete dentures.[2–4] The main factors of optimal denture treatment are retention, stability, and support. Denture and overdenture function, comfort, and patient appearance all depend on these factors. Retention is an important factor for denture treatment, while support is provided by the tissue surface of the edentulous ridge, and stability is defined as resistance to horizontal force.[5]

The greatest challenge facing dentists in this regard is the need for the adequate retention, stability, and support of dentures. The difficulties involved in ensuring the adequate retention, stability, and support of dentures are encountered more during the fabrication of mandibular dentures than upper dentures because of the resorption of the mandibular residual ridge, which adversely affects the denture-bearing area.[6] Implant-retained overdenture is considered a substitute for complete denture in the mandibular arch, as it provides adequate retention, stability,

DOI: 10.20473/j.djmkg.v57.i4.p259–266

and support of the denture as well as the benefits of improved function, chewing efficiency, comfort, sensation, and bone preservation, thus maintaining the health of the residual ridge.[7]

The majority of the patients reported that their implant-retained overdentures are better than dentures without implants in terms of increase in biting force, chewing efficiency and pattern with little soft tissue adverse effect (improved function).[8] Each mandibular implant-retained overdenture consists of an implant, an abutment with an attachment system, and overdenture prosthesis. There are different types of attachments (bar, stud, magnetic, ball, telescope, precision, semi-precision, and resilient) used to increase the retention of overdentures. Therefore, because of the potential advantage of increasing the retention of overdentures using adding attachments, many reports recommend abutment selection, distribution, and support criteria for overdentures.[9]

The treatment of an edentulous mandibular arch with two implants is well accepted; has long-term successful outcomes in relation to prosthesis and implants; more cost effective than other treatment options (like full-mouth rehabilitation with fixed prosthesis by dental implant); results in better stress distribution; and enhances patient satisfaction.[10] Many studies focus on the measurement of retention, stability, and support using different forms of attachments, comparing them, and studying the function of attachments depending on the number, position, and distribution of implants. The recommended number of implants for implant-retained overdentures is between one and four implants, depending on the financial circumstances of each patient.[11] The aim of this study is to evaluate the effects of different implant numbers and attachment types on the retention and support of implant-retained overdentures.

MATERIALS AND METHODS

This experimental work involved the utilization of an in vitro model that replicated a mandibular edentulous arch. Within this in vitro model (fabricated by a 3D printer [Shenzhen, China]), seven dental implant analogues were implanted in mid-symphysis, with the lateral incisors on both sides, canines on both sides, and first premolars on both sides of the 3D printed model to mimic the tooth positioning observed in the natural dentition. Thirty-five titanium dental implant analogues (Dentium, South Korea) were employed in this study. A total of ten overdenture housings were fabricated using 3D printer acrylic resin (FL351823, Elegoo, China), with each housing including a specific type of attachment (magnetic and positioner attachments). These attachments were equipped with three loops that were affixed to the occlusal surface of the housing. Subsequently, three chains were connected between the loops and a force gauge. The purpose of this setup was to determine the necessary peak load (expressed in newtons) to separate or dislodge the attachment.

Pressure sensors were employed to quantify the magnitude of stress exerted on the ridge where the vertical load (50N) was applied unilaterally and bilaterally. The study examined two distinct categories of attachments: magnetic and positioner attachments. Its goal was to determine the effects of the number of implants on the retention and support of implant-retained overdentures. The specific focus of the study is the influence of the attachment types. The study assessed the support provided by means of both unilateral and bilateral measurements, whereas retention was evaluated across three force directions: vertical, oblique, and anterior-posterior.

A mandibular model devoid of any natural teeth was fabricated using stone material (Zahndent, China). The acquisition of the 3D shape of the visible portion of the cast was accomplished by the utilization of a 3D scanner. The procedure was conducted by utilizing an intraoral scanner (Medit I 700, Korea). The edentulous lower stone cast was scanned following the manufacturer's instructions for scanning the lower dental arch (Figure 1A and B).[12]

The determination of the hole sites was based on the utilization of blender software (Blender 4.1) that accurately reproduces the positioning of genuine teeth. The hole sizes were designed in the blender program according to the dimensions of the implant analogue (width 4.5 mm and length 12 mm) (Figure 1C).[13]

The utilization of a 3D printer was employed in the production of the models in Halot (Shenzhen, China). The sculptures were sequentially produced using thin layers of liquid photopolymer (LCD 3D printer model resin from China) that undergo curing with UV light following each deposition. The spaces beneath the overhangs are typically occupied by an additional substance known as support material. The cavities were deliberately incorporated into the model to simulate the positioning of teeth that remained unfilled with the aforementioned material. A total of five models were produced (Figure 1D and E).[14]

Thirty-five titanium dental implant analogues (Dentium, South Korea) were employed in this study. The analogues are cylindrical, with an internal hex and 4.5mm in diameter and 12mm in length. Cold-cure acrylic resin (FL351823, Elegoo, China) was used for fixing them in the holes to prevent their dislodgement from the model while performing the tests (Figure 1F).[15]

The models were covered by a 2mm-thick layer of auto-polymerized silicone (CAD/CAM gum material [Alphadent, Korea]) to simulate the ridged mucosa.[16] The overdenture was designed using CAD software (Exocad model creator 3.0 [Exocad GmbH, Bochum, Germany]). Individual standard tessellation language files were used to construct the 3D-printed overdenture. Exocad is used for various dental prosthetics designs (Figure 1G and H).[17]

Two types of attachment were used in this study. The magnetic attachment comprised an implant keeper (Dentium, South Korea), a titanium magnetic abutment with a diameter of 4.5mm and a gingival height G/H of 1mm (Figure 2A). The positioner attachment comprised a

DOI: 10.20473/j.djmkg.v57.i4.p259–266

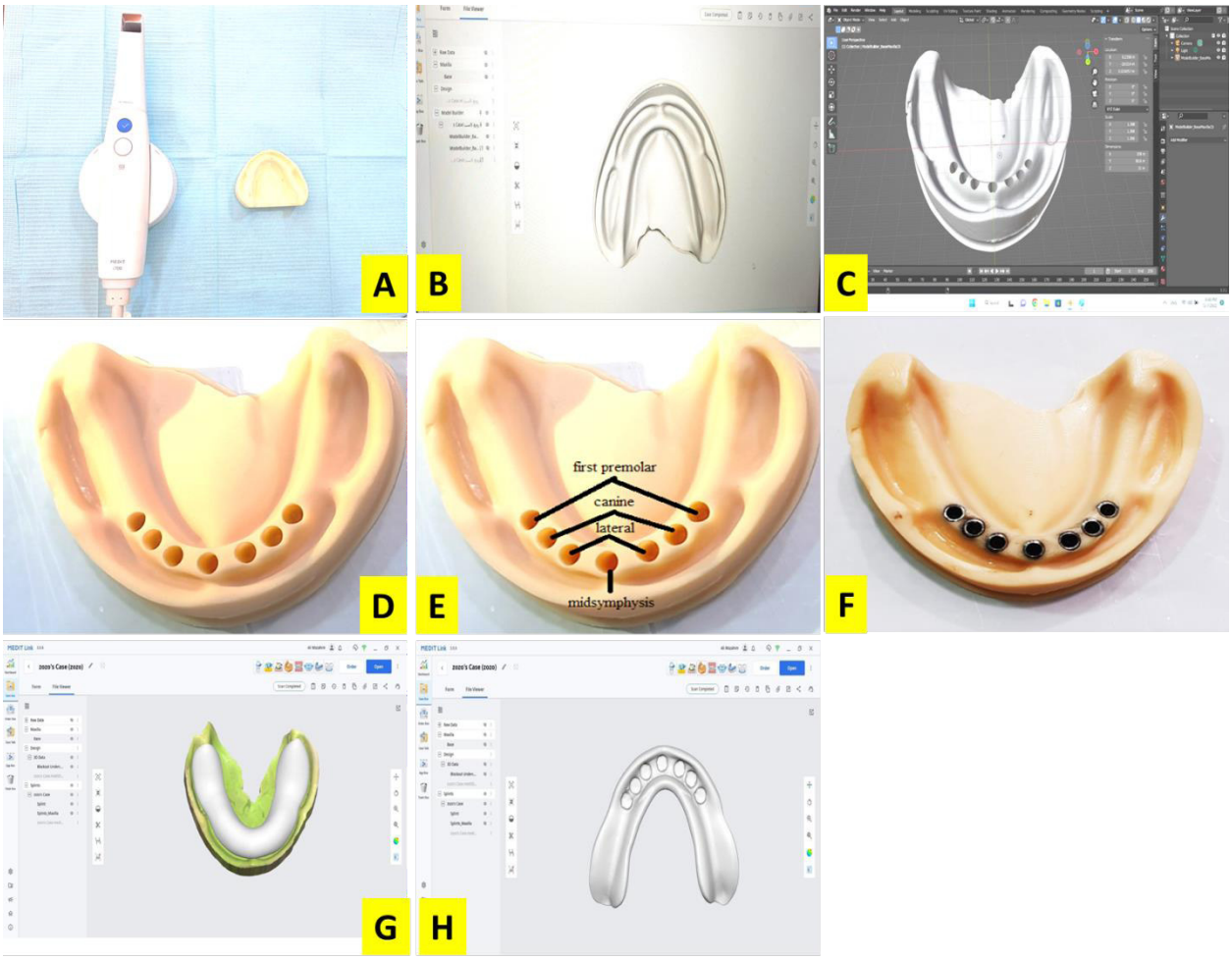

Figure 1. A representative image of the prepared model: scanning the cast (A, B), the blender program (C), the 3D printer acrylic resin model, holes' locations (D, E), insertion of the implant analogues (F), positioned using the Exocad program (G, H).

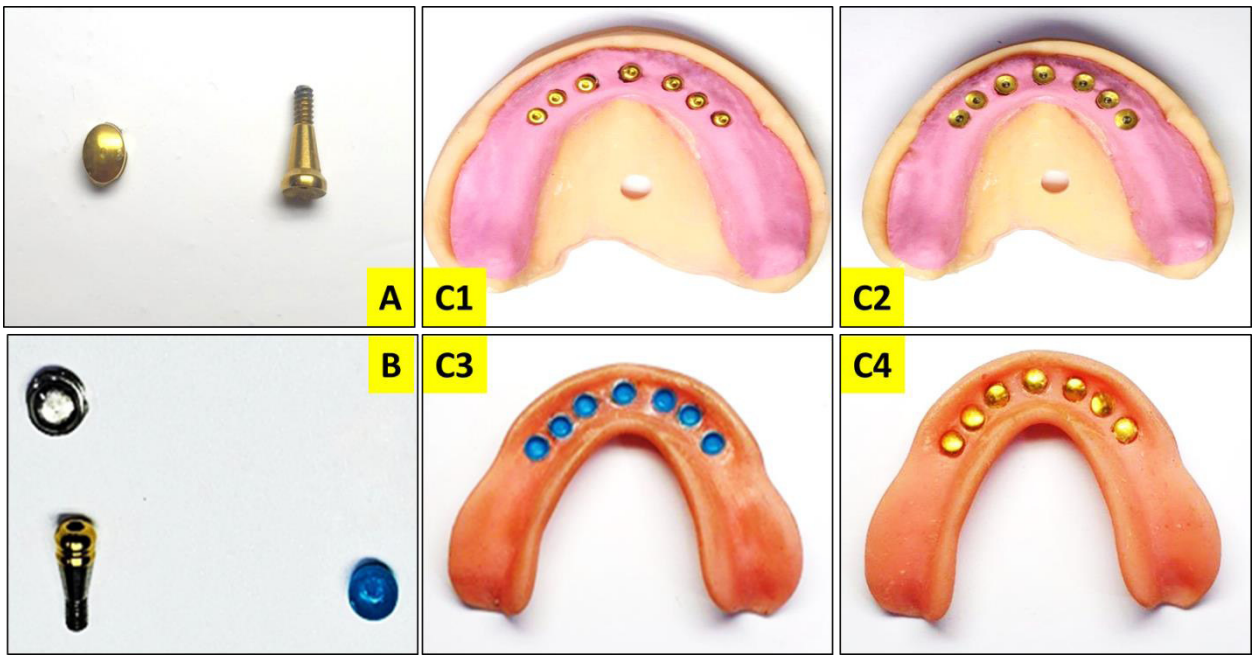

Figure 2. A representative image of the attachments of the model used: magnetic attachment (A), positioner attachment (B), fixing the attachment parts (C1–4).

DOI: 10.20473/j.djmkg.v57.i4.p259–266

titanium positioner abutment (Dentium, South Korea) with a diameter of 3.5mm and a G/H of 1mm (Figure 2B).

The attachment system comprised two parts. The female part was attached to the denture base fixed in the prepared hole by means of the self-curing acrylic resin. The other part was screwed into implant analogues by means of a screwdriver and dental implant ratchet with a torque fixed at 30cm to ensure that all the attachments have the same torque and fit in insertion (Figure 2 C1-4).[18]

Ten denture bases were made (five for each style of connection), and three chains were attached to the hooks in order to perform the retention test by means of a universal testing machine. Three steel chains measuring 13cm in length were attached to the overdenture. The three steel chains were connected to the main chain, which measured 14.5cm. The main chain was connected to the hook of the universal testing machine. A vertical force was exerted. By disengaging either the right or left chains, an oblique force could be exerted. The application of a rotating force in order to release the anterior chain was implemented (Figure 3A).[19] Using electric pressure sensors, six measuring points were placed. Vertical bilateral and vertical unilateral forces were applied to the denture base by using pressure sensors (Figure 3B1 and B2).[20]

All measurements were tabulated according to groups, and the statistical analysis was performed using the SPSS software program (version 20, SPSS Inc., Chicago, IL, USA). Descriptive statistics, such as the mean, standard deviation, standard error, and the minimum and maximum values were employed to analyze the data and provide a concise summary of the information in a relevant manner.

An ANOVA test was undertaken to determine whether there were many statistically significant differences between the means of the groups. Duncan's multiple range tests were used for comparing the larger pairs of means among groups. Independent t-test was applied in order to compare the means of two related groups (magnetic and positioner attachments) in relation to the same dependent variable.

RESULTS

The impact of the number of implants on the retention of implant-retained overdentures with magnetic and positioner attachments in three different force directions. Figure 4A show the results in relation to the magnetic attachment

Figure 3. Retention test: universal testing machine (A) and channel sensors (B1 and B2).

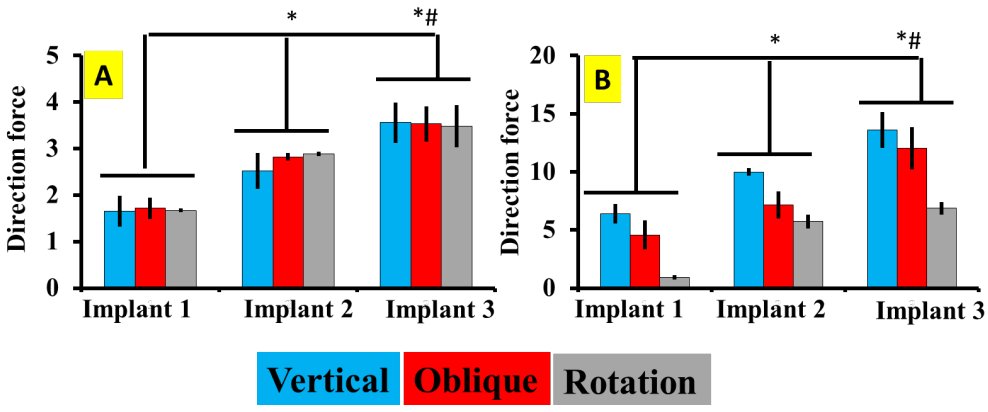

Figure 4. A comparison of the retention performance levels in relation to the number of implants (one, two, or three) in three different force directions: magnetic attachment (A) and positioner attachment (B). Data are expressed as mean±SD, *# indicates significant differences at P<0.05, * indicates significant differences when compared to implant 1 and # indicates significant differences when compared to implant 1 or implant 2.

DOI: 10.20473/j.djmkg.v57.i4.p259–266

reveal that among the three implant configurations, the group with three implants exhibited the highest peak load (measured in newtons). The results in relation to the positioner attachment revealed that among the three implant configurations, the group with three implants exhibited the highest peak load (measured in newtons), followed by the group with two implants. The group with just one implant demonstrated the lowest peak load among all three force directions (vertical, oblique, and rotational) (Figure 4B).

The experiments were conducted at a significance level of <0.05, revealing that the positioner attachments provide greater retention than magnetic attachments in three types of dislodgements: vertical, oblique, and rotational. The independent t-test was conducted to examine the differences between the different numbers of implants. The results indicated significant differences, at a significance level of P≤0.05, as shown in Table 1.

In comparing the differences among the groups, the results indicated that one implant subjected to bilateral pressure was found to have the highest measured peak load (N) followed by two implants with bilateral pressure. The three implants subjected to bilateral pressure showed the lowest measured peak load in all the locations of the pressure sensors. A significant difference between a single implant and three implants was found in this regard—three implants showed more support and decreased pressure on the ridge (Figure 5).

Table 1. Comparison of the magnetic and positioner attachments in relation to vertical, oblique, and rotational dislodgment.

Vertical	T	df	Sig.(2-tailed)	Mean difference	Std. error
1 implant	11.492	8	0.0001	4.73000	0.41158
2 implants	33.761	8	0.0001	7. 47200	0.22132
3 implants	13.894	8	0.0001	10.03400	0.72219
Oblique	T	df	Sig.(2-tailed)	Mean difference	Std. error
1 implant	4.947	8	0.0001	2.83200	0.57248
2 implants	8.238	8	0.0001	4.31400	0.52366
3 implants	10.245	8	0.0001	8.51000	0.83066
Rotational	T	df	Sig.(2-tailed)	Mean difference	Std. error
1 implant	8.496	8	0.0001	.75400	0.08875
2 implants	10.130	8	0.0001	2.83000	0.27936
3 implants	10.733	8	0.0001	3.39400	0.31622

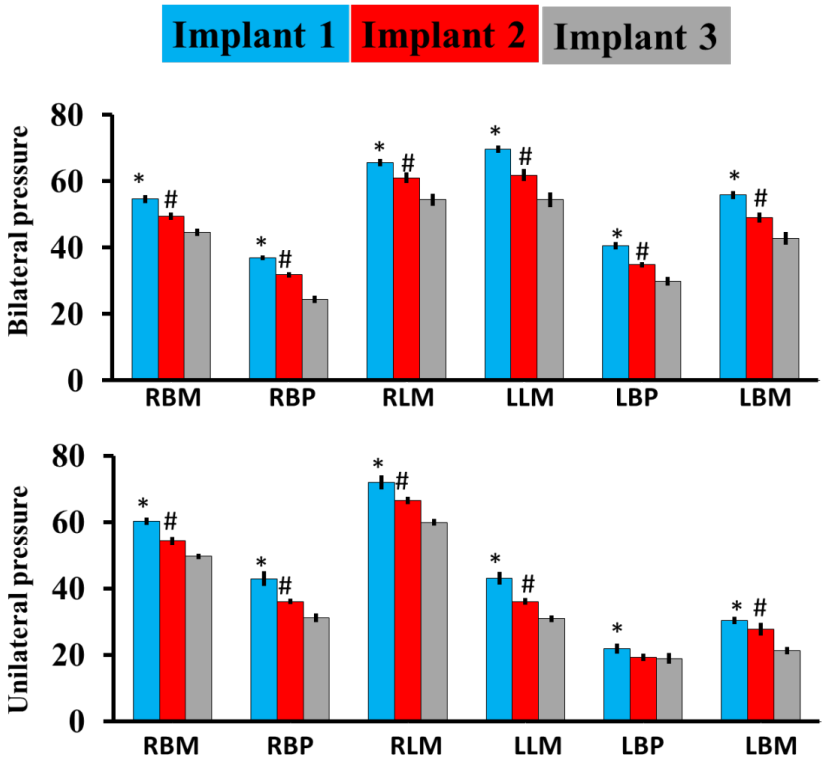

Figure 5. A comparison of the support levels of implants 1, 2, and 3 under the bilateral and unilateral pressure of a magnetic attachment. RBM=right buccal molar, RBP=right buccal premolar, RLM=right lingual molar, LLM=left lingual molar, LBP=left buccal premolar, LBM=left buccal molar. Data are expressed as mean±SD, *# indicates significant differences at P<0.05, * indicates significant differences when compared to implant 2 or implant 3, and # indicates significant differences when compared to implant 3.

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Comparing the differences among the groups, the results indicated that one implant bilaterally had the highest measured peak load (N) followed by two implants. The three implants bilaterally had the lowest measured peak load in all the locations of the pressure sensors. A significant difference was found between a single implant and three implants in this regard—three implants showed more support and decreased pressure on the ridge (Figure 6).

In this in vitro study, the retention was quantified in newtons (N), and the standard deviation was determined by means of an independent t-test, with the goal of comparing the magnetic and positioner attachments. The experiments were conducted at a significance level of $P \leq 0.05$, revealing that the positioner attachments offer greater support than magnetic attachments under bilateral pressure.

DISCUSSION

The present in vitro study investigated the effects of the number of implants and attachment types on the retention and support of a simulated prosthesis. The results of this study found that implant distribution and number affect the retention and support of an implant overdenture.[21] Retention is a major concern for patients, and one of the greatest challenges facing clinicians is the need to provide prosthetic treatment that has the patients' desired retention. While retention and its effects on overdenture prosthetic factors are related, studies have not yet reached a consensus regarding what is considered sufficient retention.[22] The desire for appropriate stress distribution is present when using implants to support a detachable overdenture in order to minimize both forces exerted on the implants and the movement of the denture.[23]

To optimize the long-term outcomes of prosthetic therapy by utilizing immediate occlusal loading (IOD), it is imperative to effectively manage the forces exerted on both the implants and the oral mucosa of the remaining ridge. In particular, it is important to take into account the placement of the implants and the configuration of the denture on its superstructure.[24] Pressure sensors were employed to gain a deeper understanding of the effects of attachments on the oral mucosa of residual ridges.[25]

Numerous tests have been conducted in which synthetic 1, 2, and 3-IOD models were applied and various designs for incorporating implants were examined. These investigations are primarily concerned with evaluating the impact of pressure exerted on the bone in the distal extension base.[26] The utilization of three implants resulted in greater retention compared to the use of two implants, whereas the use of a single implant yielded the lowest retention. Significant statistical differences were found in relation to the magnitude of the dislodging force applied in different orientations.[27]

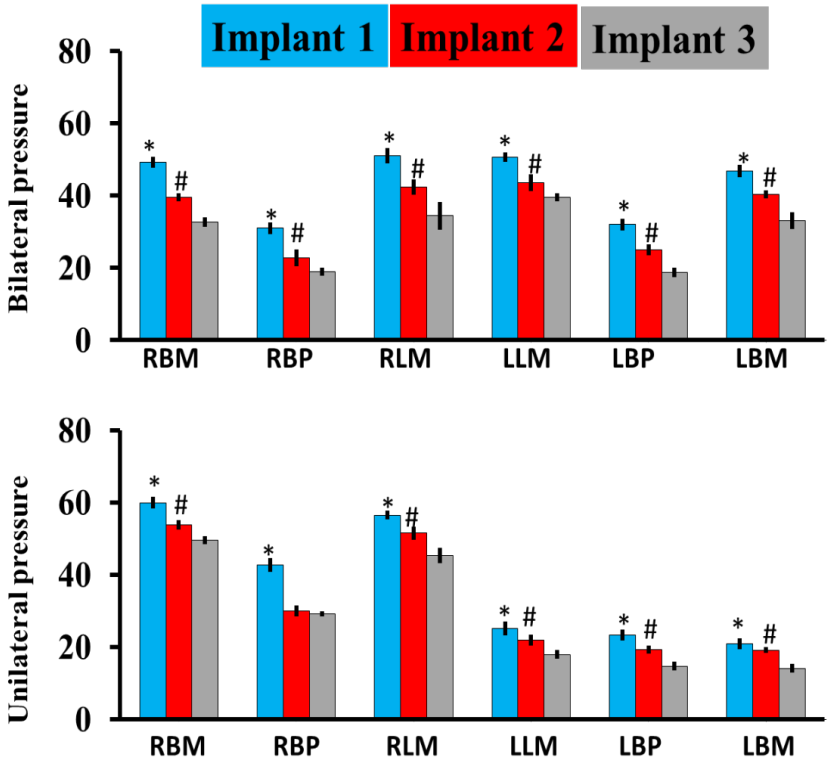

Figure 6. A comparison of the support levels of implants 1, 2, and 3 under the bilateral and unilateral pressure of a positioner attachment. RBM=right buccal molar, RBP=right buccal premolar, RLM=right lingual molar, LLM=left lingual molar, LBP=left buccal premolar, LBM=left buccal molar. Data are expressed as mean±SD, *# indicates significant differences at $P<0.05$, * indicates significant differences when compared to implant 2 or implant 3, and # indicates significant differences when compared to implant 3.

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The statistical analysis in the present study revealed that the retention values were highest and statistically significant for three implants utilizing both magnetic and positioner attachment systems, as indicated by Duncan's multiple range test. This trend was observed across all three force directions (vertical, oblique, and rotational). Two implants exhibited intermediate retention values, while the single implant demonstrated the lowest level of retention. This implies that there is a positive correlation between the number of implants and resistance to dislodgement.[28]

The statistical findings obtained from the independent t-test revealed a significant correlation between the level of retention of implant-retained overdentures and the specific attachment mechanism employed as well as the quantity and arrangement of these attachments. In terms of the three directions of the dislodgement test (vertical, rotational, and oblique), the statistical analysis revealed that the results obtained with the positioner attachment were significantly higher than those obtained with the magnetic attachment.[29]

It is also important to assess the alteration in mucosa pressure resulting from the insertion of implants in the supporting and bracing areas of an overdenture. In order to evaluate the pressure distribution across the entire denture region, it is most appropriate to position a sheet sensor over the complete mucosal surface of the denture base.[30] The oral mucosa pressure value at the supportive regions or bracing regions was found to be reduced depending on the geometry of the attachments, resulting in different types of occlusal load on implants and attachments.[31] The findings of this research provide evidence in favor of the proposed hypothesis that the quantity of implants affects the denture base pressure of a mandibular implant overdenture when subjected to loading, regardless of the kind of attachment used. The results indicate that the 1-IOD exhibited considerably greater displacements at the distal edge compared to the 2-IOD and 3-IOD.[32] The pressure value of each location on the oral mucosa may be influenced by factors such as the type of attachment and the quantity and position of the implants.[33]

In conclusion, the number and distribution of implants have a substantial impact on the retention and support of implant-supported overdentures. The improvement in the quantity of dental implants correlates with an enhancement in the durability and stability of implant-supported overdentures. This study provided evidence to support the notion that there is a positive correlation between the type of attachment and the increased levels of retention and support observed in implant-supported overdentures. The forces associated with vertical retention and rotational dislodgement exhibit an upward trend as the number and distribution of implants grow, as observed in this study's results in relation to the two distinct attachment types. The decrease in bilateral and unilateral pressure was found to be inversely proportional to the increasing number of implants.

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