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Retention and support of implant retained 3D printed overdentures with different attachments types and implant positions

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Abstract

Objectives: This study aims to evaluate the effect of different implant position (2 implant in lateral position, 2 implant in canine position and 2 implant in first premolar position), and attachment types on the retention and support of implant retained overdentures.

Methods: Throughout this experimental effort, a total of five mandibular edentulous arch replicas were used. Seven dental implant analogues were placed in this model in order to replicate the tooth location seen in the normal dentition. In this investigation, 35 titanium dental implant analogues from Dentium (South Korea) were used. Ten overdenture housings in all, each with a different kind of connection (magnetic and positioner attachment), were created using acrylic resin from 3D printers. These attachments had three loops on them, which were fastened to the housing's occlusal surface. Three chains were then attached to the loops and a force gauge testing apparatus. This setup was designed to calculate the peak stress, given in Newtons, required to separate or loosen the connection. Pressure sensors were utilised to measure the amount of strain placed on the ridge as a result of unilateral and bilateral application of a vertical load (50 n). The research has looked at two different types of attachments: positioner attachments and magnetic attaches. The study looks at how implant placement affects implant-retained overdenture support and retention. Research is to evaluate the support and retention offered by overdentures held in place by implants, with an emphasis on the impact of different attachment methods. Support was measured unilaterally and bilaterally in the research, whereas retention was examined in three force directions: vertical, oblique, and anterior-posterior.

Results: An independent t-test comparing positioner and magnetic attachment revealed that positioner was more retentive and supportive than magnetic in the three dislodgement test directions as well as under unilateral and bilateral stress ($p<.05$).

Conclusion: Changes in implant location affect an implant-held overdenture's retention and support differently, depending on the attachment technique used.

Keywords: OHRQoL, pressure sensors, magnetic attachment, positioner attachment, 3D printer, blender program

Introduction

Components of the prosthesis are subjected to stress and, at the same time, can produce stresses in the supporting structures as well [1]. Supporting and retaining structures to the prosthesis, are subjected to stress during function, insertion, and removal of the prosthesis. If this stress exceeded their natural resistance, this may result in resorption in the supporting alveolar bone, loss of the abutment, and, eventually failure of the prosthesis [2]. Denture retention has been defined as 'resistance of a denture to vertical movement away from the tissues' It is clear then that ordinarily retention is regarded as a property of the denture rather than of the patient [3]. In an actual oral cavity, the ridge morphology and the elasticity and thickness of the mucosa differs, which affects the retentive force of the denture. [4]. However, mandibular dentures will stand helpless in resisting dislodging forces due to their smaller support area, unfavorable distribution of occlusal forces, and an increased rate of bone resorption. The use of endosseous implants can certainly assist in the support and stabilization of complete dentures [5]. Implant retained overdentures offer various benefits that are not provided with conventional dentures. Patients with implant overdentures often report improved appearances, oral health-related quality of life (OHRQoL), and satisfaction [6].

Furthermore, implant retained overdentures offer increased biting forces over conventional dentures, enabling patients to eat a larger selection of foods, as well as preventing bone loss and muscle atrophy, common in edentulous patients [7]. The overdenture experiences diverse forces in many directions. The arrangement of implant attachments within the dental arch aids in the distribution of these forces, hence mitigating mechanical difficulties [8]. The support of mandibular detachable prostheses is influenced by the diminished surface area of the mandible as well as the mobility of the tongue and the floor of the oral cavity [9]. The utilisation of a limited number (2 implants) in different position of mandibular overdenture for the purpose of supporting and retaining an overdenture is more effective when there is an adequate residual ridge present to distribute the load. However, in cases when more than two implants are intended for placement, it is crucial to carefully consider the distribution of the implants in order to ensure restorability, aesthetics, and ease of maintenance [10]. The utilisation of implant-retained overdentures has emerged as the most efficacious approach for rehabilitating individuals with full loss of teeth in the dental arch. In a general sense, overdenture attachment systems can be classified into four primary groups. There are various types of attachments commonly used in the field, including ball or stud, bar and clip, magnet type, and telescopic attachments [11]. The attachment system comprises a retainer that is composed of a metal receptacle, referred to as the female or matrix, and a closely fitting counterpart, known as the male or patrix. In this method, one of these components is embedded within the underside of the prosthesis, while the other is linked to the implant [12]. Moreover, the degree of retention offered by different overdenture attachment techniques exhibits variability. Excessive prosthesis retention can potentially lead to difficulties during the insertion and removal processes of the prosthesis. Various attachment mechanisms have been found to have notable implications for peri-implant tissue conditions, including the deposition of plaque and calculus, the development of gingivitis, increased probing depth, and marginal bone loss. The satisfaction of patients is a crucial factor that can be influenced by various aspects, including the maintenance of prostheses, the stability and retention of the prosthesis, and the prosthesis's functional capabilities. The success of prosthesis is determined by a combination of various factors [13]. The types of attachments available in the include non-splinted attachments (ball, magnet, locator, and double crown attachment) and splinted attachments bar and clip attachment [14]. Attachments can also be characterised as hard or robust. Theoretically, rigid attachments prohibit any movement of their components during operation, which encompasses bars as well. In practical application, it is observed that minor motions can indeed transpire, which can be attributed to the gradual deterioration of components. Resilient attachments encompass various mechanisms such as clips, ball attachments, and locators, which are designed to allow a predetermined degree of movement. The purpose of this movement is to disperse forces that have the potential to cause harm [15]

Materials and Methods

Throughout this experimental effort, a total of five mandibular edentulous arch replicas were used. Seven dental implant analogues were placed in this model in order to replicate the tooth location seen in the normal dentition. In this investigation, 35 titanium dental implant analogues from Dentium (South Korea) were used. Ten overdenture housings in all, each with a different kind of connection (magnetic and positioner attachment), were created using acrylic resin from 3D printers. These attachments had three loops on them, which were fastened to the housing's occlusal surface. Three chains were then attached to the loops and a force gauge testing apparatus. This setup was designed to calculate the peak stress, given in Newtons, required to separate or loosen the connection. Pressure sensors were utilised to measure the amount of strain placed on the ridge as a result of unilateral and bilateral application of a vertical load (50 n). The research has looked at two different types of attachments: positioner attachments and magnetic attaches. The study looks at how implant placement affects implant-retained overdenture support and retention. research is to evaluate the support and retention offered by overdentures held in place by implants, with an emphasis on the impact of different attachment methods. Support was measured unilaterally and bilaterally in the research, whereas retention was examined in three force directions: vertical, oblique, and anterior-posterior

Making the test model: The edentulous lower stone cast was scanned using a Medit I 700 intraoral scanner from Korea, following the manufacturer's instructions for scanning the lower dental arch. The recommended scanning path consists of three swipes, namely occlusal, buccal, and lingual, in order to achieve comprehensive data coverage of all required surfaces. The outcome is a digital depiction of the obtained surface presented as a collection of three-dimensional dots [16-17] (Figure 1A, B).

Determination of implant position: Analog positions were selected on laterals, Canines and first premolars area, a complete denture were fabricated based on the printed mandibular model and holes were drilled through left and right laterals, canine and first premolar teeth and extended to the printed model to mark the exact locations [18] (Figure 1C).

Creation of models and placement of an analog implant: 3D printer was employed in the production of the models in Halot, China. This research used 35 titanium dental implant analogs from Dentium, South Korea. The analogs have a cylinder-shaped internal hex, a diameter of 4.5 mm, and a length of 12 mm. To keep them from coming loose from the model while the tests were being conducted, cold-cure acrylic glue was employed to put them in the holes. [19] (Figure 1D, E).

Manufacturing of gingiva substitutes: The model was scanned using the same protocol that was used for scanning dental stone cast previously then the artificial gingiva's thickness was standardized to a thickness of 2mm.The blender program was used for fabricating the design of artificial gingiva guide with thickness of (2mm). The design shape and thickness determined based on a blender software as same method in determining the hole of analogs as mentioned previously [20] (Figure 1F).

Making the overdenture base: Exocad was used to create an overdenture bases with attachments holes that precisely match the placement of analogs from the 3D printed acrylic resin model and three points on the occlusal surface of the dentu re base to establish the position of hooks connections to ensure the standard positions of hooks in all overdenture bases (Figure 1G, H) [21].

Attachments: Two types of attachment had been used in this study.

1. Magnetic attachment: comprised an implant keeper (Dentium, South Korea) titanium magnetic abutment with a diameter of (4.5 mm) and gingival height G/H of (1 mm) screwed into the test model [22].
2. Positioner attachment: A titanium positioner abutment (Dentium – South Korea) with a diameter of (3.5mm) and a G/H of (1 mm) was screwed into an analogous test model [23].

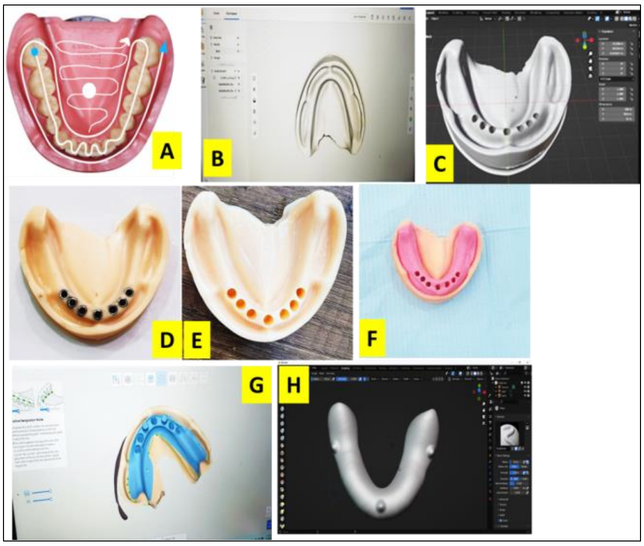

Fig. 1: A representative images for the used model Scanning the cast (A,B), Blender program (C), 3D printer acrylic resin model (D,E), artificial gingiva (F), Exocad program (G,H).

Fixation of attachments: all the attachments have the same torque and fitting in insertion. The method of fixing the attachments parts in denture base was by placing the female part of attachment on the male part that was screwerd into the implant analog while placing cold cure acrylic resin in the holes prepared in denture base, then pressing the denture base on the model for fixing the female part in the prepared holes of denture base (Figure 2) [24].

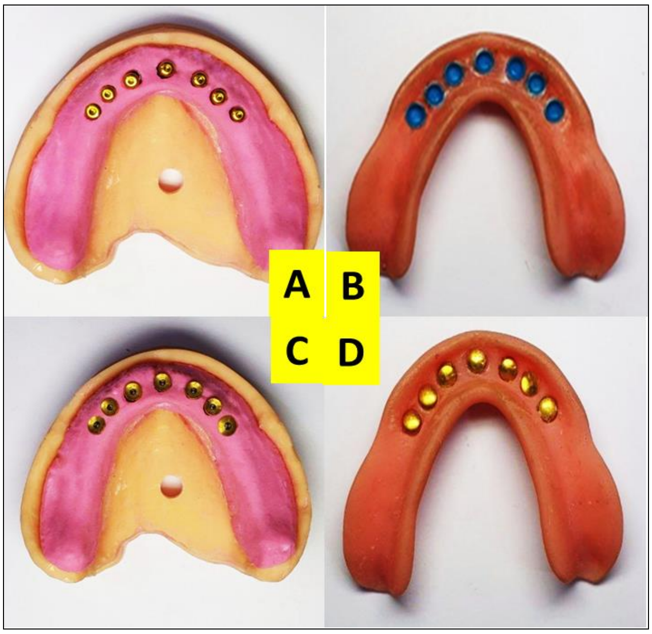

Fig. 2: Fixing the attachment parts.

Retention test: According to the points that were set on the occlusal surface of the denture bases following fabrication from denture base resin using a 3D printer, the three hooks were fixed in the places corresponding to the middle anterior, right, and left first molars areas. Ten denture bases were made, five for each style of connection and three chains attached to the hooks to perform the retention test by 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 (14.5 cm). The main chain is connected to the hook of the universal testing machine as shown in figure [7, 25].

Support test: A tactile sensor system (strain Sensor, Sunspot, USA) was used for the construction of the measuring system. This sensor sheet comprised two (0.05 mm) resin film sheets. Special link was formed into a film over the electrode. Adhesive tape was applied on areas of the film to attach the sheets to overdenture base, so the thickness of this sensor sheet was almost 0.1 mm. The electrical resistance of the sensor cells under no load was almost infinite, while it decreased inversely proportional to applied force I-shaped sensor sheet with six measuring points (3.0 mm in diameter) was designed based on this studies (Figure 3) [26].

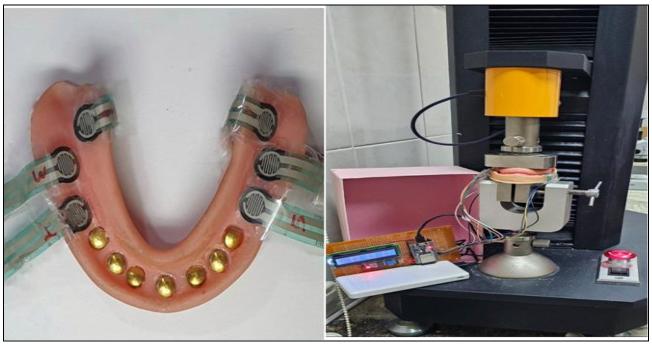

Fig. 3: Channel sensors

Statistical analysis: All measurements were tabulated in 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, minimum, and maximum values, were employed to analyses the data and provide a concise summary of the information in a relevant manner. One way analysis of variance (ANOVA) test: was used to determine whether there are many statistically significant differences between the means of groups. and duncans multiple range tests used for comparison the larger pairs of means among groups. Independent t-test: compares the means between two related groups (magnetic and positioner) on the same dependent variable.

Results

The Influence of Implant Positioning on the Retention of Implant-Retained Overdentures with Magnetic Attachments and positioner attachments under Three Different Force Direction

The selected implants positions were: 2C, 2P, 2L.

The analysis of variance (ANOVA) was conducted to examine the relationship between the positions of different implants with magnetic attachment. The results of the study indicated that there were statistically significant differences at a significance level of $P \leq 0.05$ (Table 1). The analysis of variance (ANOVA) test was conducted to examine the relationship between the location of different implants with positioner attachment. The results of the test revealed significant differences at a significance level of $P \leq 0.05$ (Table 1).

Table 1: The comparison of retention between 2C, 2P and 2L implant in three different force directions of magnetic attachment/ positioner attachment.

Implant position	Direction of force	Magnetic attachment (Mean±SD)	Positioner attachment (Mean±SD)
2 c (canine location)	Vertical	2.92±0.12	14.34±0.88
	Oblique	2.82±0.01	11.34±0.77
	Rotation	2.42±0.03	5.99±0.46
2 p (premolar location)	Vertical	2.65±0.14	20.26±1.57
	Oblique	2.48±0.02	19.3±1.71
	Rotation	2.75±0.12	7±0.47
2l (lateral location)	Vertical	2.69±0.38	9.84±1.14
	Oblique	2.51±0.08	7.26±1.23
	Rotation	2.27±0.34	5±0.32

Effect of type of attachments on retention of implant retained overdenture according to implant`s position:

The selected positions were: 2C, 2P, 2L.

The results of the independent t-test conducted to examine the effects of different implant positions revealed statistically significant differences at a significance level of P≤0.05 (Table 2).

Table 2: Comparison between magnetic and positioner attachment in vertical. Oblique and rotational dislodgment

		T	df	Sig. (2-tailed)	Mean difference	Std. error difference
Vertical	2C	33.761	8	0.0001	7.47200	22132
	2 L	24.819	8	0.0001	17.56400	0.70768
	2 P	29.216	8	0.0001	11.68400	0.39992
Oblique	2C	8.238	8	0.0001	4.31400	0.52366
	2 L	21.853	8	0.0001	16.78600	0.76813
	2 P	25.380	8	0.0001	8.85400	0.34886
Rotational	2C	10.130	8	0.0001	2.83000	0.27936
	2 L	16.962	8	0.0001	3.54400	0.20894
	2 P	9.546	8	0.0001	1.50000	0.15713

The analysis of variance (ANOVA) was conducted to examine the relationship between various positions of implants with magnetic attachments. The results of the research revealed statistically significant differences at a significance level of P≤0.05 (Table 3).

Table 3: Comparison of support between 2C,2P and 2L implant with bilateral pressure of magnetic attachment.

Implant position	Direction of force	Bilateral (Mean±SD)	Unilateral (Mean±SD)
Canine	RBM	49.4±1.14	54.4±1.14
	RBP	31±0.83	36.2±0.83
	RLM	61±1.58	66.6±1.14
	LLM	61.8±1.78	36.2±1.92
	LBP	34.8±0.83	19.4±1.14
	LBM	49±1.58	27.8±1.92
Premolar	RBM	43.4±1.14	49±1.58
	RBP	26.8±0.83	31±0.70
	RLM	54.2±0.83	60.4±1.14
	LLM	53.8±1.30	30.8±1.30
	LBP	29.2±1.30	16±1.00
	LBM	41.6±1.14	20.8±0.83
Lateral	RBM	56.2±0.83	59.6±1.14
	RBP	37.8±0.83	42.6±1.14
	RLM	62.8±1.48	73.2±1.30
	LLM	64±1.22	43.2±1.92
	LBP	39.8±0.83	24.8±0.83
	LBM	55.6±1.14	36±0.70
RBM=Right buccal molar, RBP=Right buccal premolar, RLM=Right lingual molar, LLM=Left lingual molar, LBP=Left buccal premolar, LBM=Left buccal molar.			

The analysis of variance (ANOVA) was conducted to examine the relationship between various implant positions and the use of positioner attachment. The results of the analysis revealed significant differences at a significance level of P≤0.05 (Table 4). In this *in vitro* study, the retention was quantified in Newton's unit (N), and the standard deviation was determined using an independent T-test to compare the magnetic and positioner attachments. The experiments were conducted at a significance level of ≤0.05, revealing that positioner attachments offer greater support than magnetic attachments in bilateral and unilateral pressure.

Table 4: The comparison of support between 2C, 2P and 2L implant with bilateral/unilateral pressure of positioner attachment.

Implant position	Direction of force	Bilateral (Mean±SD)	Unilateral (Mean±SD)
Canine	RBM	39.6±1.14	53.8±1.30
	RBP	22.8±2.28	29.2±1.48
	RLM	42.4±2.07	51.6±1.81
	LLM	43.6±2.30	22±1.58
	LBP	25±1.58	19.4±1.14
	LBM	40.4±1.14	19.2±0.83
Premolar	RBM	36.4±1.14	47.8±1.48
	RBP	22.6±2.07	22.4±1.14
	RLM	38.2±1.30	47±1.58
	LLM	36.8±2.38	15.8±2.04
	LBP	19.8±1.30	14.6±1.14
	LBM	33.6±1.14	15±1.58
Lateral	RBM	45.2±0.83	60.4±1.14
	RBP	30.4±1.14	35.4±2.07
	RLM	48.4±2.07	57.4±1.67
	LLM	49.4±2.07	27±1.58
	LBP	32±1.58	25.6±1.14
	LBM	45.4±1.14	24.8±1.1
RBM=Right buccal molar, RBP=Right buccal premolar, RLM=Right lingual molar, LLM=Left lingual molar, LBP=Left buccal premolar, LBM=Left buccal molar.			

Discussion

Overdenture retention is necessary for patients' satisfaction with their prosthesis. However, adequate overdenture retention is debatable, and many studies reported different values of adequate retention. The retentive force should be high enough to prevent displacement of overdenture during functioning to provide comfort [27]. Mandibular two-implant-retained overdenture that provide sufficient retention to the lower complete denture from the attachment system is considered a reliable treatment option. To achieve patient satisfaction, the minimum acceptable retention has been about (8 to 20 N). The attachment system's materials, designs, and dimensions can impact on the retention force [28]. Typically, the retention of an implant-retained overdenture is influenced by the outcomes associated with altering the placement of the implants [29]. The findings from the vertical dislodging test of the magnetic attachment system indicate that the vertical retention of implants was observed to be higher in the canines areas, followed by the laterals areas, and finally the premolars areas. This can be attributed to the lower non-axial force exerted in the canine position as compared to the lateral and premolar areas while the vertical dislodging test at positioner attachment showed an increased retention at premolar areas were increase the distance between implant when moving distally [30]. the placement of implants in the lateral incisor area is a more favourable approach compared to the placement in the canine area. This conclusion was based on the evaluation of frontal plane trauma and fracture risk in patients with an atrophic edentulous mandible who were undergoing rehabilitation with an overdenture supported by two implants. Implants that are placed in the canine region experience heightened exposure to force and consequently amplify the force delivered to the mandible, in contrast to implants inserted in the lateral incisor region [31]. the retention and stability of an implant-retained overdenture are comparable between implants placed at the Mandibular canine position and those placed at the Mandibular 1st premolar location [32]. the outcomes are influenced by the type of attachments, with the positioner attachment resulting in a higher vertically applied force compared to the magnetic attachment [33]. This study aimed to compare the retention forces of two distinct attachments, namely the positioner and magnetic attachments, in the lower arch. The researchers indicated that the positioner exhibited a higher level of retention force compared to magnetic attachments, which demonstrated a lower level of retention. The aforementioned findings align with the outcomes of the present investigation [34]. The manipulation of attachments resulted in alterations to the mucosa pressure values observed in the molar and premolar areas during both unilateral and bilateral situations. Nevertheless, the scope of measurements conducted in this investigation was restricted to the molar and premolar regions exclusively, with no comprehensive examination of the entire residual ridge being undertaken in any of the studies [35]. In the present study, it was observed that physical activity (PA) was associated with the lowest oral mucosa pressure value across all load circumstances and in all areas. The limited mobility and rotation of dentures can be attributed to the presence of metal housings surrounding the male part, which effectively eliminates any free space between the components [36]. The study revealed that the presence of resilient attachments facilitated a reduction in the transmission of stress. Additionally, they observed a reduction in the bone loads during the process of mastication loading. Therefore, it can be inferred that the implementation of resilient attachments facilitates a more equitable distribution of forces over both the denture carrying surfaces and the dental implants [37]. The pressure value of each location on the oral mucosa may be influenced by factors such as the kind of attachment, as well as the quantity and position of the implants [38].

Conclusion

The impact of attachment style on retention and support is influenced by both the quantity and geographical context. The positioner attachments demonstrated superior retention levels in comparison to magnetic attachments, as seen by the results of three dislodging tests conducted in various directions. Additionally, the positioner attachments provided greater support. Vertical retention and support of a simulated overdenture prosthesis increased with distal implant location to the premolar. Retention and support of a 2-implant simulated overdenture prosthesis is significantly affected by implant location.

Conflict of Interest

Not available

Financial Support

Not available

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