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THE EFFECT OF IMPLANT NUMBER, DISTRIBUTION WITH DIFFERENT ATTACHMENTS ON THE RETENTION AND STABILITY OF IMPLANT SUPPORTED OVERDENTURE

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Abstract: -

Background: *It was stated that the "PREVENTION IS BETTER THAN CURE"*
Today, with the more attention on preventive measures in prosthodontics, the use of implant supported overdenture has increased to the point where it is now a feasible alternative to most treatment plan outlines in the construction of prosthesis for patients (Sheldon Winkler, 2009).
Objective: *Evaluate the effect of number and distribution of an implant upon in vitro retention and stability of a simulated implant-supported overdenture.*
Methods: *In this in-vitro experimental study a model simulating a mandibular edentulous ridge with 7 dental implants analogs inserted in the model approximating the tooth position in the natural dentition was constructed. A two overdenture housing for each type of attachment made of acrylic resin with three hooks attach to occlusal surface of it which connected to three chains attached to a force gauge testing machine was used to measure peak load (N) required to disconnect (dislodge) an attachment in three directions vertical, rotational and oblique. Two different type of attachments have been studied (Ball, Locator). This study was aimed to evaluate retention and stability of implant-retained overdentures based upon implant number and distribution.*
Result: *One way ANOVA analysis of variance test indicated that there were significant differences at P<0.05, using Duncan`s Multiple Range Test for comparison among the groups of Ball and Locator attachment indicated that groups of multi-implants recorded the significantly higher measured peak load*
(N) in the three directions of dislodgement
Conclusion: *variation in implant`s number and distribution affect the retention and stability of implant supported overdenture according to type of attachment utilized.*

Key word: *Overedentur retention, Ball attachment, Implant number*

INTRODUCTION

Teeth may be lost because of trauma, caries, periodontal disease, congenital defects, and iatrogenic treatment. Tooth loss has a negative impact on masticatory function, aesthetics, and self-image. Fixed partial dentures, removable partial dentures, complete dentures, and implant-supported dentures can replace missing teeth comfortably and aesthetically [1]. Loss of natural teeth and subsequent alveolar resorption has a significant impact on appearance [2]. Bone resorption in the maxilla occurs mostly on the buccal aspect and this leads to a decrease in lip support. [3] Anterior tooth position influences retention and stability of the denture with speech pattern [2,4]

Overdentures help to partly overcome several problems posed by conventional complete dentures like progressive bone loss, poor stability and retention, loss of periodontal proprioception, low masticatory efficiency [5]

With implant supported Overdenture's problems related to retention and stability were solved, patients feel more secure, their chewing ability improves and thus their nutrition [6] various numbers of implants (typically one, two, or four) have been recommended for mandibular implant overdentures. Four implants have been suggested as one of the treatment options for edentulous patients seeking mandibular implant overdentures. However, in terms of prosthetic maintenance and complications, and patient satisfaction, two and four implant groups do not appear to be significantly different [7]

The prosthetic and attachment system factors involved with treatment planning successful mandibular implant overdentures have been the subject of extensive investigations. [8]. This study evaluated the effect of implant positions and number with two type of attachments on retention and stability of overdenture through determine whether there were any differences in the peak load measurement, a measure of retention and stability (maximum forces developed before complete separation of attachment components) for vertically, obliquely, and anteriorposteriorly directed dislodging forces and took a step towards selecting the locations of implants for overdenture according to evidence-based dentistry (EBD) guidelines.

Materials and Methods

Seven implant analogs made of titanium cylindrical with diameter (3.75 mm) and length (13 mm);

(internal hex) used in this study. Two types of attachments were used, Ball Attachment: consisted of a titanium ball abutment, screwed into the test model implant analogues with a teflon cap embbeded in the fitting surface of the overdenture. Locator Attachment: consisted of a titanium abutment TIN coated, screwed into the test model implant analogues with a resin replaceable pink retainers were incorporated into the overdenture. An edentulous mandibular test model made of acrylic resin (Figure 1) was constructed which had no undercut on it all the test were performed

Figure 1: Acrylic resin mandibular test model

To determine the locations of points F1, A, B, C, D, E and F2 have been identified to simulate natural tooth positions, first a denture base was fabricated on the mandibular model cast using light cure acrylic resin. Then, normal size artificial teeth were arranged on the acrylic base. The locations of points F1, A, B, C, D, E and F2 were determined. Point C, was the location of midline (symphysis) the contact between the central incisors, point B was the location of mandibular canine tooth at right quadrant, point D was the location of mandibular canine tooth at the left quadrant, point A was the contact point of mandibular premolar teeth of the right quadrant, point E was the contact point of premolar teeth of the left quadrant, the point F1 was the location of the mandibular first molar in the right quadrant and point F2 was the location of mandibular first molar in the left quadrant. Implant holes were drilled using ITI drill series and milling machine in order to achieve parallel holes. After making sure of the correct distance and direction of the holes, drilling was performed. Analogs of implant were eventually inserted in their respective locations and secured by using cold cure acrylic resin (Figure 2).

Figure 2: the implant analogs were inserted

Two experimental overdenture housing were fabricated for each type of attachment systems 3 hooks were fixed in the positions coressponding to the midline, left and right molars. (Figure 3),

Figure 3: 3 hooks was fixed in the positions coressponding to the midline, left and right molars

The two attachment systems (Ball, Locator) were activated by screwing the key component of the abutments (depending on which system was used) into the implant analogs (Figure 4) and by positioning its counterpart attachment on fitting surface of the overdenture (Figure 5).
Each sample overdenture attachment system had one part (matrix) contained with overdenture housing and primary

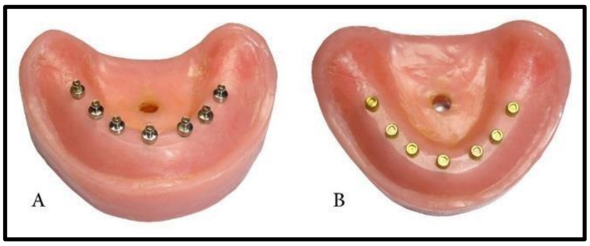

Figure 4: the key component of the abutments (A: Ball abutments, B: Locator abutments) screwed into the implant analogs

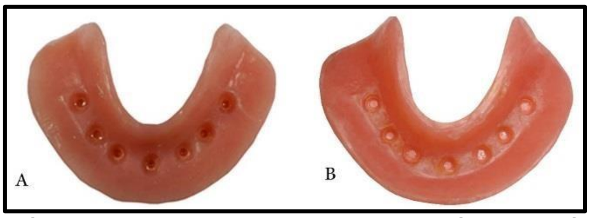

Figure 5: counterpart of attachment (A: Ball, B: Locator) on fitting surface of the overdenture

copying (patrix) attach to test model implants. [9]
Overdenture dislodgement were performed using the device or machine in the (Figure 6). The device had two components: A: Force Gauge (FG-5100): consisting of the load cell and a force sensor which read the value of the dislodging or tensile forces in newton unit (N) and a hardware component in which the model is placed and tensile forces are applied to the model. B: Test Stand for Force Gauge

Three directions of dislodgement were performed: A 3-point vertical pull was used to determine retention against a strictly vertically directed dislodging force parallel to the path of insertion and withdrawal (Figure 7) with three chains attached to the hooks in the mid-anterior and bilateral molar

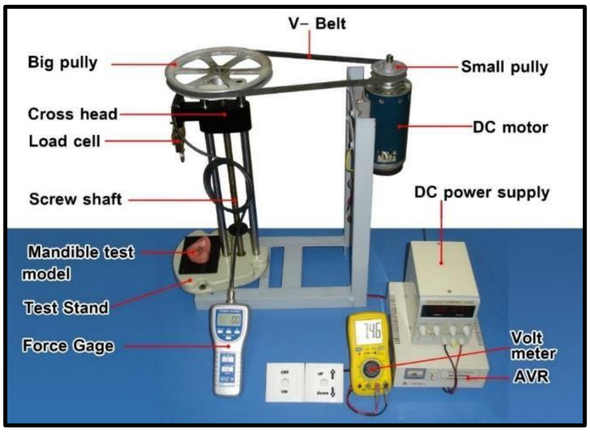

Figure 6: the device for the dislodgement test

regions; Following this, the chain located in the right molar area was disconnected, and the 2 legs of the chain were attached to the 2 hooks corresponding to the left molar and central incisors areas. This resulted was an oblique lifting force simulating function (Figure 8); Following that, the chains in the left and right molar region remained, while the chain in the anterior region was removed. This resulted in a rotational pull, an anterior-posterior lifting force (lifting forces applied to the distal extension bases) simulating function (Figure 9), this type of pull was a measure of denture stability.

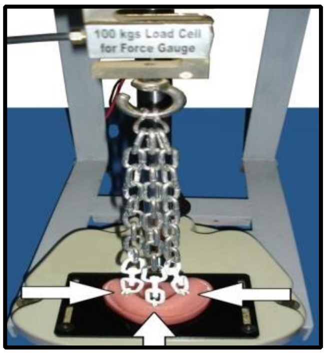

Figure 7: vertical dislodgement

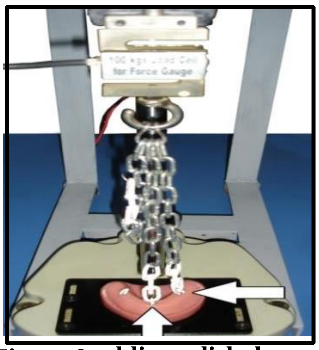

Figure 8: oblique dislodgement

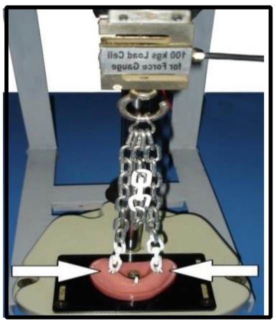

Figure 9: rotational dislodgement

The implant's abutments of the Ball and Locator attachment systems were distributed to the areas that divided or designed as groups number which represent natural tooth positions (Table 1), (Figure 10, 11) represent the groups of different number and distribution of Ball, Locator attachment system respectively.

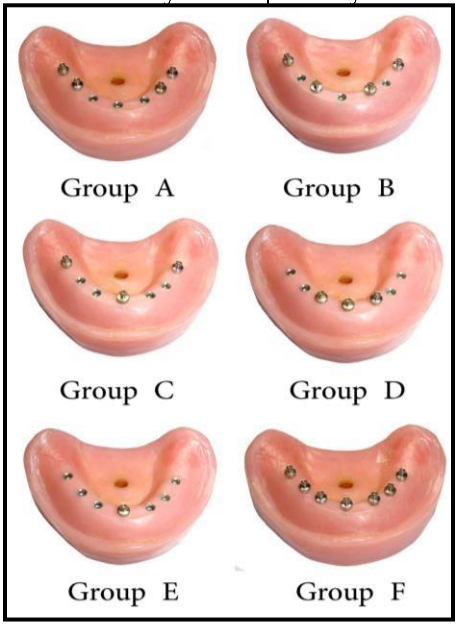

Figure 10: groups of different number and distribution (Ball attachment)

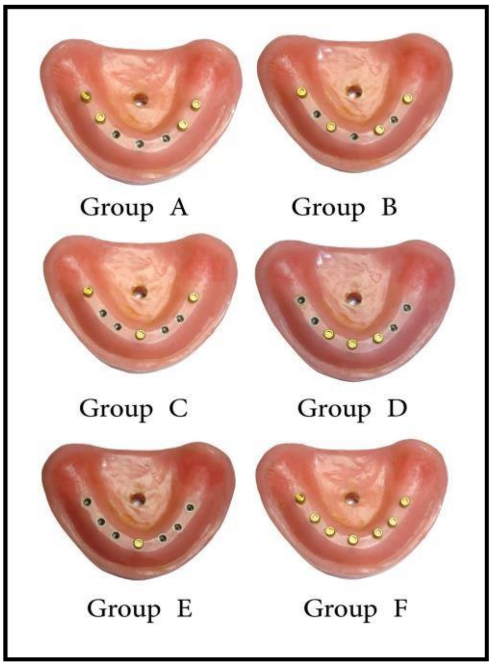

Figure 11: groups of different number and distribution (Locator attachment)

Table 1: classification of groups

groups	Number of Implants	Distribution of implants	Type of attachments	
Group A	four implants	F1, A, E, F2	Ball	Locator
Group B	four implants	F1, B, D, F2	Ball	Locator
Group C	three implants	C, F1, F2	Ball	Locator
Group D	three implants	C, B, D	Ball	Locator
Group E	one implant	C	Ball	Locator
Group F	seven implants	F1, A, B, C, D, E,F2	Ball	Locator

Results

1-Mean retentive force measured in newton`s unit (N) and standard deviation standard error for the six groups of both attachment systems (Ball, Locator) were calculated by SPSS statistical program (version 19) and listed at (Table 2,3). Then groups have been analyzed using one-way ANOVA there were significant differences among different groups at ($p \leq 0.05$) as shown in (Table 4,5) followed by Duncan multiple range test to compare means among groups of Ball and Locator attachment respectively, indicated that In vertical, rotational and oblique dislodging test. Group F (seven implants at molars, premolars, canines and mid symhyseal regions F1, A, B, C, D, E, F2 positions) had a significantly higher measured peak load (N) than all other groups when compared with all other sets. Group E (single implant model at mid symphyseal region C position) had the lowest measured peak load (N) when compared with all other sets groups (Figures 12, 13).

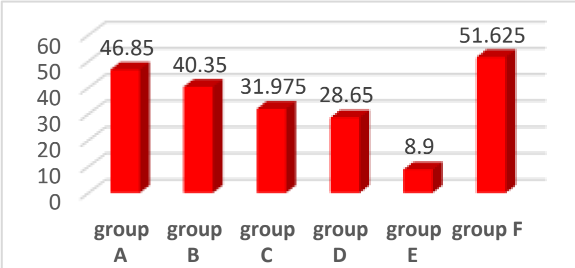

Figure 12: Duncan's multiple range test of the six implant groups (Ball attachment) for the vertically directed dislodging forces.

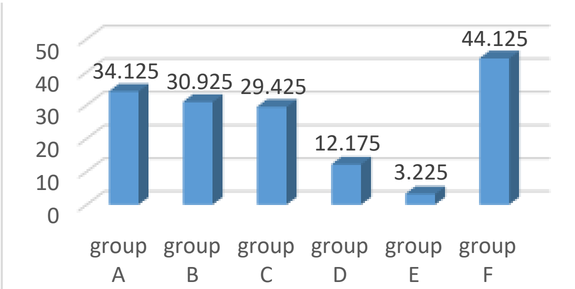

Figure 13: Duncan's multiple range test of the six implant groups (Locator attachment) for the vertically directed dislodging forces.

2-for comparison between two attachments the statistical analysis of independent t-test were significant at the ($P<0.05$) level indicating that statistically significant differences existed between the Ball and Locator The mean retentive force measured in newton`s unit (N), standard deviation indicated that the Ball attachment system had the significant higher mean retentive value than Locator attachment system. With each of the performance measurements (peak load with vertically directed dislodging forces, peak load with anteriorposteriorly directed dislodging forces, peak load with obliquely directed dislodging forces) as shown in (Tables 6, 7, 8)

groups	N	Mean (N)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A	8	46.8500	.73872	.26118	46.2324	47.4676	45.80	47.80
B	8	40.3500	.88641	.31339	39.6089	41.0911	39.40	41.60
C	8	31.9750	1.61842	.57220	30.6220	33.3280	29.20	35.00
D	8	28.6500	.77644	.27451	28.0009	29.2991	27.60	29.80
E	8	8.9000	.56569	.20000	8.4271	9.3729	8.00	9.60
F	8	51.6250	1.86222	.65839	50.0681	53.1819	48.60	53.80
Total	48	34.7250	14.18998	2.04815	30.6047	38.8453	8.00	53.80

Table 2: mean, standard deviation and standard error of vertical dislodgement test of Ball attachment (six implant groups)

groups	N	Mean (N)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A	8	34.1250	.68400	.24183	33.5532	34.6968	33.20	35.00
B	8	30.9250	.80490	.28457	30.2521	31.5979	29.60	32.00
C	8	29.4250	.78876	.27887	28.7656	30.0844	28.60	30.40
D	8	12.1750	.73630	.26032	11.5594	12.7906	11.20	13.40
E	8	3.2250	.42003	.14850	2.8738	3.5762	2.40	3.60
F	8	44.1250	.42678	.15089	43.7682	44.4818	43.60	44.60
Total	48	25.6667	13.94207	2.01236	21.6183	29.7150	2.40	44.60

Table 3: mean, standard deviation and standard error of vertical dislodgement test of Locator attachment (six implant groups)

SOV	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9405.320	5	1881.064	1353.052	*.000
Within Groups	58.390	42	1.390		
Total	9463.710	47			

* Significant difference at p≤ 0.05. df: Degree of freedom. SOV: Source of Variance.

Table 4: One way ANOVA of vertical directed dislodging test of Ball attachment groups

SOV	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9117.457	5	1823.491	4146.542	*.000
Within Groups	18.470	42	.440		
Total	9135.927	47			

* Significant difference at p≤ 0.05. df: Degree of freedom. SOV: Source of Variance.

Table 5: One way ANOVA of vertical directed dislodging test of Locator attachment groups

	attachment	N	Mean (N)	Std. Deviation	Std. Error Mean
Vertical dislodgement	Ball	48	34.7250	14.18998	2.04815
	Locator	48	25.6667	13.94207	2.01236

Table 6: Descriptive statistics of vertically directed dislodging test in relation to implant`s number and distribution

	attachment	N	Mean (N)	Std. Deviation	Std. Error Mean
Rotational dislodgement	Ball	48	28.7854	11.82493	1.70678
	Locator	48	23.1667	12.57314	1.81478

Table 7: Descriptive statistics of rotational directed dislodging test in relation to implant`s number and distribution

	attachment	N	Mean (N)	Std. Deviation	Std. Error Mean
Oblique dislodgement	Ball	48	32.0875	14.14388	2.04149
	Locator	48	15.1896	8.38388	1.21011

Table 8: Descriptive statistics of oblique directed dislodging test in relation to implant`s number and distribution

Discussion

An overdenture, once placed in the mouth, is subjected to a variety of forces applied in different directions, there are two aspects of retention: (1) the perspective of the patient, the feeling of how secure the prosthesis is in place as the overdenture is removed and separated from the implant abutments (break load or breakaway force); and (2) the perspective of the clinician, the measurement of the peak load (maximum dislodging force) as the overdenture is resisting removal from the patient’s abutments [9]

The design of removable overdenture for good retention & stability is difficult. It is seen that many treatment concepts involving mandibular overdenture design are based on empirical experiences of individual. Clinicians often base their selection of implant location and attachment systems empirically on expected retentive quality [10] Various approaches have been used for the retention and stability of implant-supported overdentures. This study examined the effect of different implant`s number, distribution with two attachment systems (Ball, Locator) on retention and stability of implant-supported overdenture. Retention can be considered as the force that resists withdrawal along the path of insertion, while the resistance to dislodgment of the overdenture base to anterior-posterior forces was refer to as the stability [11]

This in vitro study revealed that as the number of implant increase retention and stability of implant supported overdenture have increased in turn the effort required to exact a dislodging force would be higher. (Figure 14) demonstrate the real dimensions among implants.

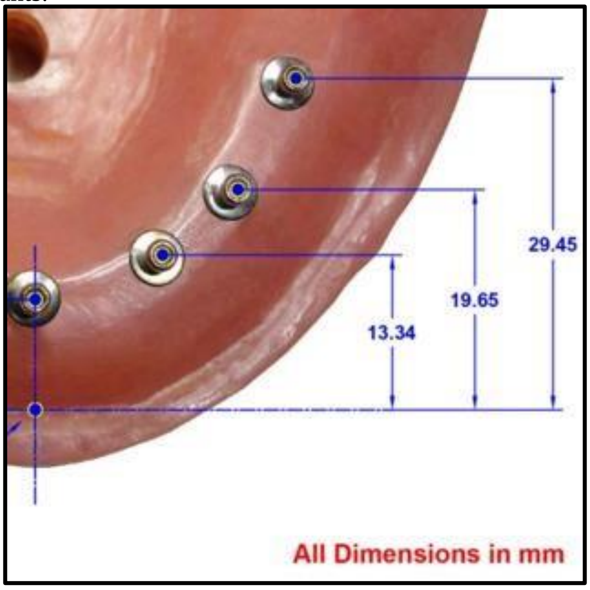

Figure 14: actual dimensions among implants

Statistical analysis showed the highest significant retention values (N) in the vertical dislodgement test (A 3-point vertical pull) was for group F (seven implants at molars, premolars, canines and mid symhyseal regions F1, A, B, C, D, E, F2) positions with both attachment systems, according to Duncan`s Multiple Range Test this means as the number of implant increase the resistance to dislodgement would increase in turn the effort required to exact a dislodging force would be higher as it obvious in the equilibrium equation and free body diagram (Figure 15).

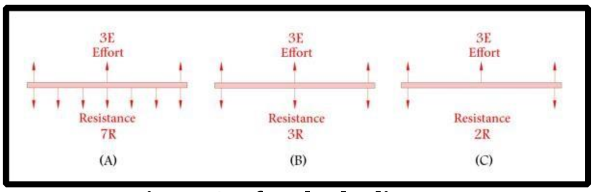

Figure 15: free body diagram

Group F (seven implants)
$\sum F=0$
$3E = 7R \Longrightarrow E = 7/3\ R$
$E = 2.33\ R$

The next highest mean retentive value (N) was recorded for group A (four implants model at molars F1, F2 and premolars A, E position) then followed by group B (four implant model at molars F1, F2 and canines B, D positions) in which the equation would be as
$3E = 4R \Longrightarrow E = 4/3\ R$
$E = 1.33\ R$

Then group C (three implants model at mid symphyseal C and molars F1, F2 positions), group D (three implants model at mid symphyseal C and canines B, D)
$3E = 3R \Longrightarrow E = 3/3\ R$
$E = R$

While group E (single implant model at mid symphyseal C region) recorded the lowest mean retentive value (N).
$3E = R \Longrightarrow E = 1/3\ R$
$E = 0.33\ R$

The results of anterior-posterior dislodgement (rotational dislodgement) can be explain by principles of the mechanics of leverage, [12] The implant overdenture in rotational dislodgement would function as a class II lever. Assuming the example of an implant-retained overdenture prosthesis that is intimately fitting the soft tissue support, the fulcrum is the anterior alveolar ridge (mid symphyseal region), the resistance is the attachment system, and the effort (E) is the posterior dislodging force lifting the denture base away from the ridge [13]

- In group F (seven implants group at molars, premolars, canines and mid symhyseal regions F1, A, B, C, D, E, F2) where the fulcrum axis was at the labial flange border seal in the mid symphyseal region as in the (Figure 16), the resistance (R) was between the fulcrum and the effort (E) {dislodging force (N)} so the overdenture function as class II lever. To achieve the equilibrium.

$$\sum \overset{+}{\mathbf{M}}_o = 0$$

2E*29.45 - 2R*29.45 - 2R*19.65 - 2R*13.34 - R*9.7 = 0
58.9E = 58.9R + 39.3R + 26.68R +
9.7R
58.9E = 134.58R
E = 2.28R

- In group A (four implants model at molars F1, F2 and premolars A, E position) here the position of fulcrum axis was similar to group F as in the

(Figure 17)
E = 1.66R

- In group B (four implant model at molars F1, F2 and canines B, D positions) as in (Figure 18) Although in group B we had the same number of implants as in group A but they vary in distribution, in group A implants were narrowly spaced and behave as single unit giving significantly higher dislodging force value so effort (E) {dislodging force (N)} value was less than group A, due to the resistance arm was longer in group A. Higher forces were required to dislodge the prosthesis when implants were positioned in molar and premolar region on the test model.

E = 1.45 R

- in group C (three implants model at mid symphyseal C and molars F1, F2 positions) as in (Figure 19) As the number of implants decrease the effort (E) {dislodging force (N)} required to exact a similar dislodging force would be lesser, in comparison to group D higher forces were required to dislodge the prosthesis when implants were widely distributed on the test model By lengthening the resistance arm in this group

E = 1.16 R

- in group D (three implants model at mid symphyseal C and canines B, D) as in (Figure 20) Less effort (E) {dislodging force (N)} due to less resistance, the same aforementioned explanation

E = 0.61 R

- in group E (single implant model at mid symphyseal C position) as in (Figure 21) We have noticed that effort (E) {dislodging force (N)} value was the lesser among all because one implant was used in the mid symphyseal region which is closest to the fulcrum axis so resistance arm was the shortest in this group.
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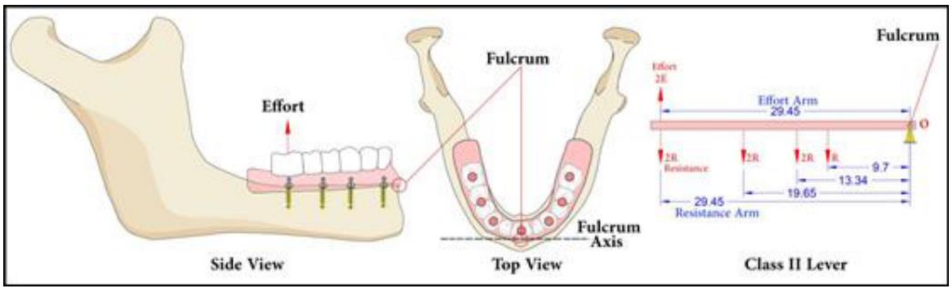

Figure 16: number and distribution of implants in group F

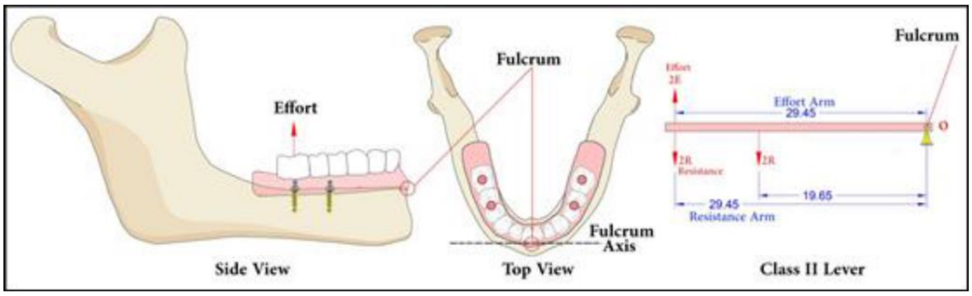

Figure 17: number and distribution of implants in group A

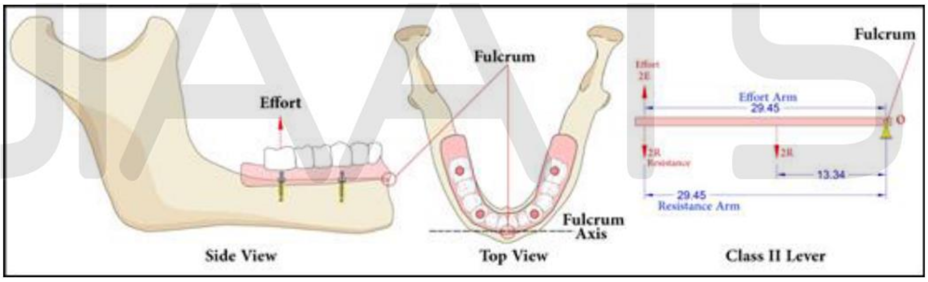

Figure 18: number and distribution of implants in group B

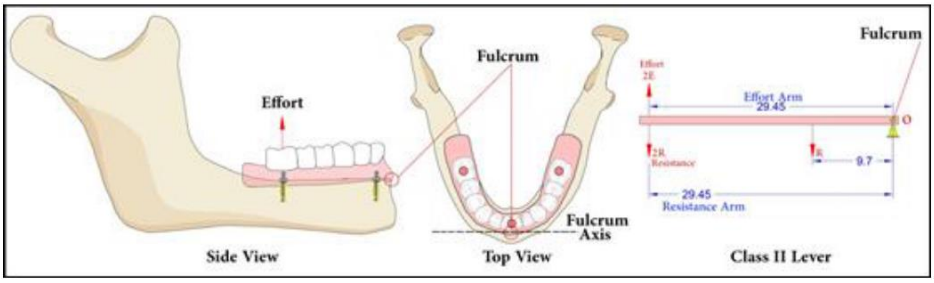

Figure 19: number and distribution of implants in group C

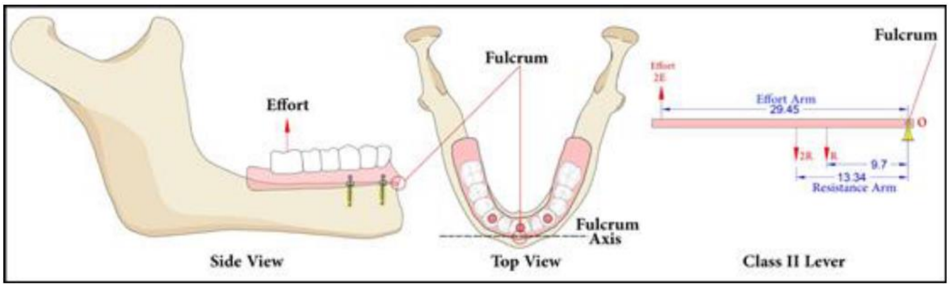

Figure 20: number and distribution of implants in group D

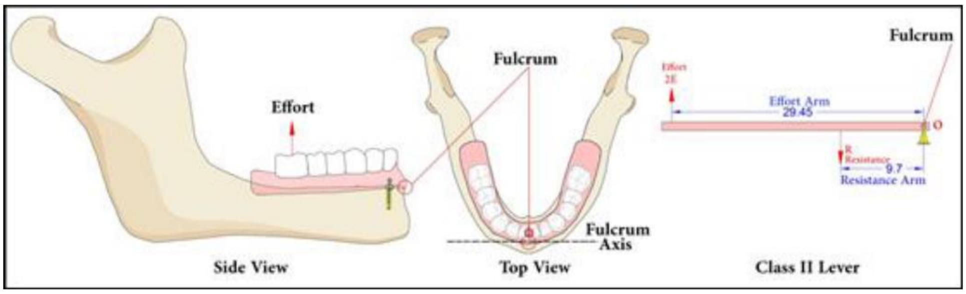

Figure 21: number and distribution of implants in group E

Also during the oblique dislodgement, the results have been identified that as the number of implants increase the dislodgement force (N) would be higher. However, inconsistent results have been obtained among groups according to type of attachment used.

Results of this study in regards to implant distribution and number are in agreement with previous studies, Fatalla AA *et al.*, (2012) they said that the four overdenture support designs with flexible acrylic attachments improved the retention force and reduced the fatigue retention than the three overdenture support designs.
[14]

A study by (Scherer M.D *et al.*, 2013) revealed that retention increases with increasing implant number and distribution. The vertical dislodging tests performed in this study simulate retentive force of a mandibular overdenture analog when pulling on three chains simultaneously. The greatest increase occurred when comparing single implants versus two; retention doubled for most systems. This increase in retention was statistically significant and could potentially be clinically significant as well. The lowest mean values were reported in the single implant groups and increased at the two- and threeimplant groups this is On Consensus with the result of this study. [13] In the three-implant-supported overdenture, the most anteriorly positioned implant may provide indirect retention for the denture by preventing the intrusion of the anterior portion of the denture towards the tissues. (Ben-Ur Z *et al*., 1996) so this study supports the fact that increasing the number of implants is useful in clinical practice. [15]

In 2002, the McGill Consensus Statement on Overdentures asserted that mandibular two implant overdentures have been shown not only to be superior to conventional complete dentures, but also to improve the quality of life for these patients regardless of the attachment system used (bar, ball, magnet). [16]. However, in general, the use of mandibular overdentures supported by more than two implants does not lead to greater patient satisfaction in terms of denture and social function. Meijer *et al*. found no clear difference in either clinical or radiographic outcomes between two-implantretained and four-implant-supported mandibular overdentures over a 10year evaluation period. [17]. The use of more than 2 implants has been recommended to support a mandibular overdenture in clinical scenarios that will require increased retention such as high muscle attachments, prominent mylohyoid ridges, or extreme gaggers. [18] Statistical results by Independent ttest indicated that the degree of retention and stability of implant supported overdenture was directly linked to the type of attachment system used and their number and distribution. Whereas the results were statistically higher with Ball attachment than the Locator attachment with the three directions of dislodgement test (vertical, rotational, oblique).

According to study of Meghea D.M *et al*., (2014) said that type of attachments affect the results whereas vertically applied force was higher with Ball attachment than the Locator attachment [19]. Alsabeeha *et al*. compared retention forces of six different attachments (four types of Ball attachment and two types of Locator attachment) in the lower arch. They indicated that Ball had more retention force and Locator attachments demonstrated less retention. These are in agreement with the results of this study. [20,21]. However, Krennmair G, *et al.*, (2012) show that there were no differences between Ball or Locator attachment for any items of satisfaction evaluated and neither attachment had a significant patient preference. No differences for peri-implant parameters or for patient satisfaction were noted between the definitive attachments (Ball; Locator) after one year. Although the overall incidence rate of prosthodontic maintenance did not significantly differ between both retention modalities, the Locator attachment required more post insertion aftercare (activation of retention) than the Ball anchors [22].

But at the same time there were researchs found adverse results as Sadig W. A. (2009) evaluated the effect of connector type and implant number and location on the retention and stability of implant-supported overdentures by measuring retentive forces during vertical and 2 types of rotational dislodgment. He found that
Locator connectors provide significantly higher retention and stability of implant-supported overdentures, followed by Ball connectors and then magnets. The 2implant design offers less retention and stability than the 4-implant model. [23] The obvious limitation in this study is that the retentive force was evaluated only during simulated overdenture removal. Movement of overdentures in oral environment typically occurs in six directions: occlusal, gingival, mesial, distal, facial, and lingual. While true unidirectional dislodging forces rarely occur in clinical scenarios. These multidirectional movements are difficult to simulate in vitro.

Conclusion

1. Retention and stability of implant supported overdenture is significantly affected by implant number and distribution as the number of implant increase retention and stability of implant supported overdenture have increased.
2. Attachment type affects retention and stability differently by number and location. Ball attachments reported the highest levels of retention and stability with three directions of disloging tests.

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